IoT TECHNICIAN (SMART HEALTHCARE)

NSQF LEVEL - 3

Volume I of II

TRADE THEORY

SECTOR: IT & ITES

(As per revised syllabus July 2022 - 1200 hrs)

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 : IT & ITES

Duration : 1 Year

Trade : IoT Technician (Smart Healthcare) - Trade Theory - Volume I of II - NSQF level - 3 (Revised 2022)

Developed & Published by

National Instructional Media Institute
Post Box No.3142
Guindy, Chennai - 600 032
INDIA
Email: chennai-nimi@nic.in
Website: www.nimi.gov.in

First Edition: January 2023 Copies : 500

Rs.360/-

FOREWORD

The Government of India has set an ambitious target of imparting skills one out of every four Indians, 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 Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **IoT Technician (Smart Healthcare) - Trade Theory - Volume I of II - NSQF Level - 3 (Revised 2022) in IT & ITES Sector under** Annual pattern. The NSQF Level - 3 (Revised 2022) 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 - 3 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 3 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

Director General (Training)
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

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

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

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

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

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

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

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

Chennai - 600 032 **EXECUTIVE DIRECTOR**

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisation to bring out this IMP **(Trade Theory)** for the trade of **IoT Technician (Smart Healthcare) - Volume I of II - NSQF Level - 3** (Revised 2022) under the **IT & ITES** Sector for ITIs.

MEDIA DEVELOPMENT COMMITTEE MEMBERS

Shri. N. P. Bannibagi	-	Deputy Director, NIMI, Chennai - 32.
Shri. A. Jayaraman	-	Training Officer (Rtd) MDC Member, NIMI, Chennai - 32.

NIMI COORDINATORS

Shri. Nirmalya Nath	-	Deputy Director, NIMI, Chennai - 32.
Shri. S. Gopalakrishnan	-	Assistant Manager NIMI, Chennai - 32.

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

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

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

INTRODUCTION

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **IoT Technician (Smart Healthcare) Volume I of II -** Trade Theory NSQF Level - 3 (Revised 2022) in **IT & ITES**. The contents are sequenced according to the practical exercise contained in NSQF LEVEL -3 syllabus on Trade Theory attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

Module 1 - **Trade and Orientation**

Module 2 - **Basics of AC and Electrical Cables**

Module 3 - **Components and AC & DC Measurements**

Module 4 - **Soldering / Desoldering, SMD Components**

Module 5 - **Diodes and Trasnsistors**

Module 6 - **Basic Gates and Digital Circuits**

Module 7 - **Computer Hardware and Networking**

Module 8 - **Electronic Circuit Simulation**

Module 9 - **Sensors, Transducers and Applications**

Module 10 - **Microcontroller 8051**

Module 11 - **Test and connect Components/parts of IoT system and Arduino board**

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

It will be preferable to teach/learn trade theory connected to each exercise at least 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 for the purpose of self-learning and should be considered as supplementary to class room instruction.

TRADE PRACTICAL

The trade practical manual is intended to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the course. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 3 (Revised 2022) syllabus are covered.

The manual is divided into Eleven modules.

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

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

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

Sl.No	Learning Outcome	Exercise No
1	Perform electrical / electronic measurement of meters and instruments following safety precautions.	1.1.01 - 1.2.12
2	Test various electronic components using proper measuring instruments and compare the data using standard parameter.	1.3.13 - 1.3.26
3	Identify, place, solder and de-solder and test different SMD discrete components and IC packages with due care and following safety norms using proper tools/setup.	1.4.27 - 1.4.40
4	Construct, test and verify the input/ output characteristics of various analog circuits.	1.5.41 - 1.5.46
5	Assemble, test and troubleshoot various digital circuits.	1.6.47 - 1.6.54
6	Install, configure, interconnect given computer system(s) and networking to demonstrate & utilize application packages for different applications.	1.7.55 - 1.7.61
7	Develop troubleshooting skills in various standard electronic circuits using Electronic simulation software.	1.8.62 - 1.8.66
8	Apply the principle of sensors and transducers for various IoT applications.	1.9.67 - 1.9.70
9	Identify, select and test different signal conditioning and converter circuits. Check the specifications, connections, configuration and measurement of various types of sensor inputs as well as control outputs.	1.9.71 - 1.9.84
10	Identify, Test and troubleshoot the various families of Microcontroller. Plan and Interface input and output devices to evaluate performance with Microcontroller.	1.10.85 - 1.10.89
11	Identify different IoT Applications with IoT architecture. Identify, test and interconnect components/parts of IoT system.	1.11.90 - 1.11.100

SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 30Hrs.; Professional Knowledge 12 Hrs.	Select and perform electrical/ electronic measurement of meters and instruments following safety precautions. (MAPPED NOS: ELE/N9401)	1 Visit to various sections of the institute and identify location of various installations. (02hrs.) 2 Identify safety signs for danger, warning, caution & personal safety message. (02hrs.) 3 Use of personal protective equipment (PPE). (03hrs.) 4 Practice elementary first aid. (02hrs.) 5 Preventive measures for electrical accidents & steps to be taken in such accidents. (03 hrs.) 6 Use of Fire extinguishers. (02hrs.)	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. (06 hrs.)
		Basics of AC and Electrical Cables 7 Identify the Phase, Neutral and Earth on power socket, use a tester to monitor AC power. (02hrs.) 8 Construct a test lamp and use it to check mains healthiness. Measure the voltage between phase and ground and rectify earthing. (02hrs.) 9 Prepare terminations, skin the electrical wires /cables using wire stripper and cutter. (02hrs.) 10 Measure the gauge of the wire using SWG and outside micrometer. (02hrs.) 11 Demonstrate various test and measuring instruments (02hrs.) 12 Measure voltage and current using clamp meter. (02hrs.)	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. Different type of electrical cables and their Specifications. Types of wires & cables, standard wire gauge (SWG). Classification of cables according to gauge (core size), number of conductors, material, insulation strength, flexibility etc. Introduction to electrical and electronic measuring instruments. (06hrs.)
Professional Skill 30Hrs.; Professional Knowledge 12 Hrs.	Test various electronic components using proper measuring instruments and compare the data using standard parameter. (MAPPED NOS: ELE/N7001 Identify, place,	**Active and Passive Components** 13 Identify the different types of active and passive electronic components. (02 hrs.) 14 Measure the resistor value by colour code, SMD Code and verify the same by measuring with multimeter. (02 hrs.) 15 Identify resistors by their appearance and check physical defects. (02 hrs.)	Ohm's law. Resistors; types of resistors, their construction & specific use, color-coding, 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 energy storage concept.

		16 Practice on measurement of parameters in combinational electrical circuit by applying Ohm's Law for different resistor values and voltage sources. (02hrs.) 17 Measurement of current and voltage in electrical circuits to verify Kirchhoff's Law. (02hrs.) 18 Verify laws of series and parallel circuits with voltage source in different combinations. (02hrs.) 19 Identify different inductors and measure the values using LCR meter.Identify the different capacitors and measure capacitance of various capacitors using LCR meter. (03 hrs.) 20 Identify and test the circuit breaker and other protecting devices (Fuse). (03 hrs.) 21 Test Step-up, Stepdown, Isolation Transformer. (02hrs.) **AC & DC measurements** 22 Use the multi meter to measure the various functions (AC V, DC V, DC I, AC I, R). (02 hrs.) 23 Identify the different controls on the Digital Storage Oscilloscope front panel and observe the function of each control. (02hrs.) 24 Measure DC voltage, AC voltage, time period, sine wave parameters using DSO. (02 hrs.) 25 Identify and use different mathematical functions +,-,X, diff, intg, AND, OR of DSO on the observed signal. (03 hrs.) 26 Identify and use different acquisition modes of normal, average, persistence mode. (03 hrs.)	Capacitance and Capacitive Reactance, Impedance. Types of capacitors, construction, specifications and applications. Dielectric constant. Significance of Series parallel connection of capacitors. Properties of magnets and their materials, preparation of artificial magnets, significance of electro Magnetism, types of cores. Relays, types, construction and specifications etc. Multi meter, use of meters in different circuits. Use of DSO, Function generator, Arbitrary Waveform Generator, LCR meter (12 hrs.)
Professional Skill 50Hrs.; Professional Knowledge 12 Hrs.	solder and desolder and test different SMD discrete components and ICs package with due care and following safety norms using proper tools/setup. (MAPPED NOS: ELE/N7812)	**Soldering/ Desoldering** 27 Practice soldering on different electronic components, small transformer and lugs. (03 hrs.) 28 Practice soldering on IC bases and PCBs. (03 hrs.) 29 Practice Soldering on various SMD Components including SMD IC packages. (04hrs.) 30 Practice desoldering using pump and wick. (02 hrs.) 31 Practice Desoldering of SMD Components using SMD Hot Air Gun. (03 hrs.) 32 Join the broken PCB track and test. (03 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. Introduction to SMD technology Identification of 2, 3, 4 terminal SMD components.

		Basic SMD (2, 3, 4 terminal components) 33 Identification of 2, 3, 4 terminal SMD components. Desolder the SMD components from the given PCB. (05hrs.) 34 Solder the SMD components in the same PCB. Check for cold continuity of PCB. (05 hrs.) 35 Identification of loose /dry solder, broken tracks on printed wired assemblies. (04hrs.) **SMD Soldering and Desoldering** 36 Identify various connections and setup required for SMD Soldering station. (05hrs.) 37 Identify crimping tools for various IC packages. (03hrs.) 38 Make the necessary settings on SMD soldering station to desolder various ICs of different packages (at least four) by choosing proper crimping tools (03hrs.) 39 Make the necessary settings on SMD soldering station to solder various ICs of different packages (at least four) by choosing proper crimping tools (03hrs.) 40 Make the necessary setting rework of defective surface mount component used soldering / desoldering method. (04hrs.)	Advantages of SMD components over conventional lead components. Introduction to Surface Mount Technology (SMT). Advantages, Surface Mount components and packages. Cold/ Continuity check of PCBs. Identification of lose / dry solders, broken tracks on printed wiring assemblies. (12 hrs.)
Professional Skill 18Hrs.; Professional Knowledge 06 Hrs.	Construct, test and verify the input/ output characteristics of various analog circuits. (MAPPED NOS: ELE/N5804)	41 Identify and test different types of diodes, diode modules using multi meter and determine forward to reverse resistance ratio. Compare it with specifications. (03hrs.) 42 Measure the voltage and current through a diode in a circuit and verify its forward/Reverse characteristic. (02hrs.) 43 Identify and test Zener diode and construct peak clipper. (02hrs.) 44 Identify different types of transistors and test them using digital multimeter. (02hrs.) 45 Measure and plot input and output characteristics of a CE amplifier. (03hrs.) 46 Construct and test a transistorbased switching circuit to control a relay. (03hrs.)	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. 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. Construction, working of a PNP and NPN Transistors, purpose of E, B & C Terminals. Significance of a, ß and relationship of a Transistor.

			Transistor applications as switch and CEamplifier. Transistor input and output characteristics. Transistor power ratings & packaging styles and use of different heat sinks.(06hrs.)
Professional Skill 17Hrs.; Professional Knowledge 12 Hrs.	Assemble, test and troubleshoot various digital circuits. (MAPPED NOS: ELE/N7812)	47 Identify different Logic Gates (AND, OR, NAND, NOR, EX OR, EX-NOR, NOT ICs) by the number printed on them. (02hrs.) 48 Verify the truth tables of all Logic Gate ICs by connecting switches and LEDs. (02hrs.) 49 Use digital IC tester to test the various digital ICs (TTL and CMOS). (03hrs.) 50 Construct and Test a 2 to 4 Decoder. (02hrs.) 51 Construct and Test a 4 to 2 Encoder. (02hrs.) 52 Construct and Test a 4 to 1 Multiplexer. (02hrs.) 53 Construct and Test a 1 to 4 De Multiplexer. (02hrs.) 54 Identify and test common anode and common cathode seven segment LED display using multi meter. (04 hrs.)	Introduction to Digital Electronics. Difference between analog and digital signals. Logic families and their comparison, logic levels of TTL and CMOS. Number systems (Decimal, binary, octal, Hexadecimal). BCD code, ASCII code and code conversions. Various Logic Gates and their truth tables. Combinational logic circuits such as Half Adder, Full adder, Parallel Binary adders, 2-bit and four bit full adders. Magnitude comparators. Half adder, full adder ICs and their applications for implementing arithmetic operations. Concept of encoder and decoder. Basic Binary Decoder and four bit binary decoders. Need for multiplexing of data. 1:4 line Multiplexer / De-multiplexer. Introduction to Flip-Flop. S-R Latch, Gated S-R Latch, D- Latch. Flip-Flop: Basic RS Flip Flop, edge triggered D Flip Flop, JK Flip Flop, T Flip Flop. Master-Slave flip flops and Timing diagrams. Basic flip flop applications like data storage, data transfer and frequency division. Types of seven segment display. BCD display and BCD to decimal decoder. BCD to 7 segment display circuits. Basics of Register, types and application of Registers. (12 hrs.)
Professional Skill 24Hrs.; Professional Knowledge 12 Hrs.	Install, configure, interconnect given computer system(s) and networking to demonstrate & utilize application packages for different applications.(MAPPED NOS:SSC/N9408)	55 Identify various indicators, cables, connectors and ports on the computer cabinet. (02hrs.) 56 Demonstrate various parts of the system unit and motherboard components. (03hrs.) 57 Identify various computer peripherals and connect it to the system. (02hrs.)	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. Working principle of SMPS, its specification. Windows OS MS widows: Starting windows and its operation, file

		58 Boot the system from Different options and install OS in a desktop computer. (05 hrs.) 59 Browse search engines, create email accounts, practice sending and receiving of mails and configuration of email clients. (04 hrs.) 60 Identify different types of cables and network components e.g. Hub, switch, router, modem etc. (04hrs.) 61 Configure a wireless Wi-Fi network. (03 hrs.)	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. (12 hrs.)
Professional Skill 30 Hrs.; Professional Knowledge 06 Hrs.	Develop troubleshooting skills in various standard electronic circuits using Electronic simulation software. (MAPPED NOS: ELE/N1201)	62 Prepare simple digital and electronic circuits using the software. (06 hrs.) 63 Simulate and test the prepared digital and analog circuits. (06 hrs.) 64 Create fault in particular component and simulate the circuit for it's performance. (06 hrs.) 65 Convert the prepared circuit into a layout diagram. (06 hrs.) 66 Prepare simple, power electronic and domestic electronic circuit using simulation software. (06 hrs.)	Study the library components available in the circuit simulation software. Various resources of the software. (06 hrs.)
Professional Skill 17Hrs.; Professional Knowledge 06 Hrs.	Apply the principle of sensors and transducers for various IoT applications. (MAPPED NOS: SSC/N9444)	67 Identify and test RTDs, Temperature ICs and Thermo couples. (03hrs.) 68 Identify and test proximity switches (inductive, capacitive and photoelectric). (04hrs.) 69 Identify and test, load cells, strain gauge, LVDT, PT 100 (platinum resistance sensor). (04hrs.) 70 Detect different objectives using capacitive, Inductive and photo electric proximity sensors. (06 hours)	Basics of passive and active transducers. Role, selection and characteristics. Sensor voltage and current formats. Thermistors/ Thermocouples - Basic principle, salient features, operating range, composition, advantages and disadvantages. Strain gauges/ Load cell – principle, gauge factor, types of strain gauges. Inductive/ capacitive transducers - Principle of operation, advantages and disadvantages. Principle of operation of LVDT, advantages and disadvantages. Proximity sensors – applications, working principles of eddy current, capacitive and inductive proximity sensors.(06 hrs.)
Professional Skill 32Hrs.; Professional Knowledge 18 Hrs.	Identify, select and test different signal conditioning and converter circuits. Check the	**Integration of Analog sensors** 71 Identify various Analog sensors. (02 hrs.) 72 Identify Roles and Characteristics of each sensor. (02 hrs.)	Working principle of different types of control circuits and their applications for sensors.

	specifications, connections, configuration and measurement of various types of sensor inputs as well as control outputs. (MAPPED NOS: SSC/N9444)	73 Select appropriate Analog sensor. (02 hrs.) 74 Connect & measure AC/DC Analog Input such as voltage / current / RTD two-three-four wire AC mV signal etc. (02 hrs.) 75 Configure Engineering & Electrical zero/span configuration mV, 0-10VDC, 4-20mA, 0-20mA. (02 hrs.) 76 Understand various units and zero span configuration as per sensor datasheet such as temperature, pressure, flow, level, lux level, environment, soil, moisture etc. (02 hrs.) 77 Measure the Analog Input as per configuration and sensor selection. (02 hrs.) 78 Generate and measure Analog Output to operatecontrol valves and actuators. (02 hrs.) **Integration of Digital sensors** 79 Identify various Digital sensors.(02 hrs.) 80 Identify Roles and Characteristics of each sensor.(02 hrs.) 81 Select appropriate Digital sensor. (03hrs.) 82 Connect and Measure Digital Inputs of various voltage level such as TTL (0-5V), 24VDC (0-24 VDC) signals. (03hrs.) 83 Connect Pulse Inputs of various frequency ranging from 10 Hz to 1 KHz and configure the filters. (03hrs.) 84 Select, Configure and ascertain of Digital Outputs and Relay Outputs to take On and Off action for actuators. (03hrs.)	Principle of operation of signal generator, distinguish between voltage and power amplifier. Working principle of different converters. Demonstrate different types of filter circuits and their applications. The specification and working of Analog sensor inputs as well as Analog control outputs. The specifications and working of Digital sensor inputs, Pulse Input as well as Digital control outputs. (18hrs.)
Professional Skill 30 Hrs.; Professional Knowledge 12 Hrs.	Identify, Test and troubleshoot the various families of Microcontroller. (MAPPED NOS: SSC/N9445) Plan and Interface input and output devices to evaluate performance with Microcontroller. (MAPPED NOS: SSC/N9445)	85 Explore different microcontroller families' architecture like 8051, AVR, PIC, ARM, Raspberry pi and Arduino. (06 hrs.) 86 Explore the different Software IDE used for microcontroller. (06 hrs.) 87 Explore ICs & their functions on the given Microcontroller Kit. (06 hrs.) 88 Identify the port pins of the controller & configure the ports for Input & Output operation. (06 hrs.) 89 Explore Universal IC programmer to program burn output file on different ICs. (06 hrs.)	Introduction Microprocessor & 8051 Microcontroller, architecture, pin details & the bus system. Function of different ICs used in the Microcontroller Kit. Differentiate microcontroller with microprocessor. Interfacing of memory to the microcontroller. Internal hardware resources of microcontroller. I/O port pin configuration. Different variants of 8051 & their resources. Register banks & their functioning. SFRs & their configuration for different applications.

			Comparative study of 8051 with 8052. Introduction to PIC Architecture. Introduction to ADC and DAC, schematic diagram, features and characteristic with the applications. (12 hrs.)
Professional Skill 30 Hrs.; Professional Knowledge 12 Hrs.	Identify different IoT Applications with IoT architecture. (MAPPED NOS: SSC/N9462) Identify, test and interconnect components/parts of IoT system. (MAPPED NOS: SSC/N9446)	90 Connect and test Arduino board to computer and execute sample programs from the example list. (04hrs.) 91 Upload computer code to the physical board (Microcontroller) to blink a simple LED. (02hrs.) 92 Write and upload computer code to the physical Arduino board Micro controller to sound buzzer. (02hrs.) 93 Circuit and program to Interface light sensor – LDR with arduino to switch ON/OFF LED based on light intensity. (03hrs.) 94 Set up & test circuit to interface potentiometer with Arduino board and map to digital values for e.g. 0-1023. (03hrs.) 95 Interface Pushbuttons or switches; connect two points in a circuit while pressing them. This turns on the built-in LED on pin 13 in Arduino, while pressing the button. (03hrs.) 96 Rig up the Circuit and upload a program to Control a relay and switch on/off LED light using Arduino. (02hrs.) 97 Make Circuit and upload a program to Interface of LCD display with a microcontroller to display characters. (03hrs.) 98 Rig up the circuit and upload a program to interface temperature sensor – LM35 36 IoT Technician (Smart City) with a controller to display temperature on the LCD. (02hrs.) 99 Set up Circuit and upload program to Interface DC motor (actuator) with microcontroller to control on/off/forward/re verse operations. (03hrs.) 100 Rig up Circuit and upload program micro-controller to switch on/off two lights using relay. (03hrs.)	Arduino development board, Pin diagram, Functional diagram, Hardware familiarization and operating instructions. Integrated development Environ-ment, Running Programs on IDE, simple Programming concepts.(10 Hours) (06 hrs.)

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.

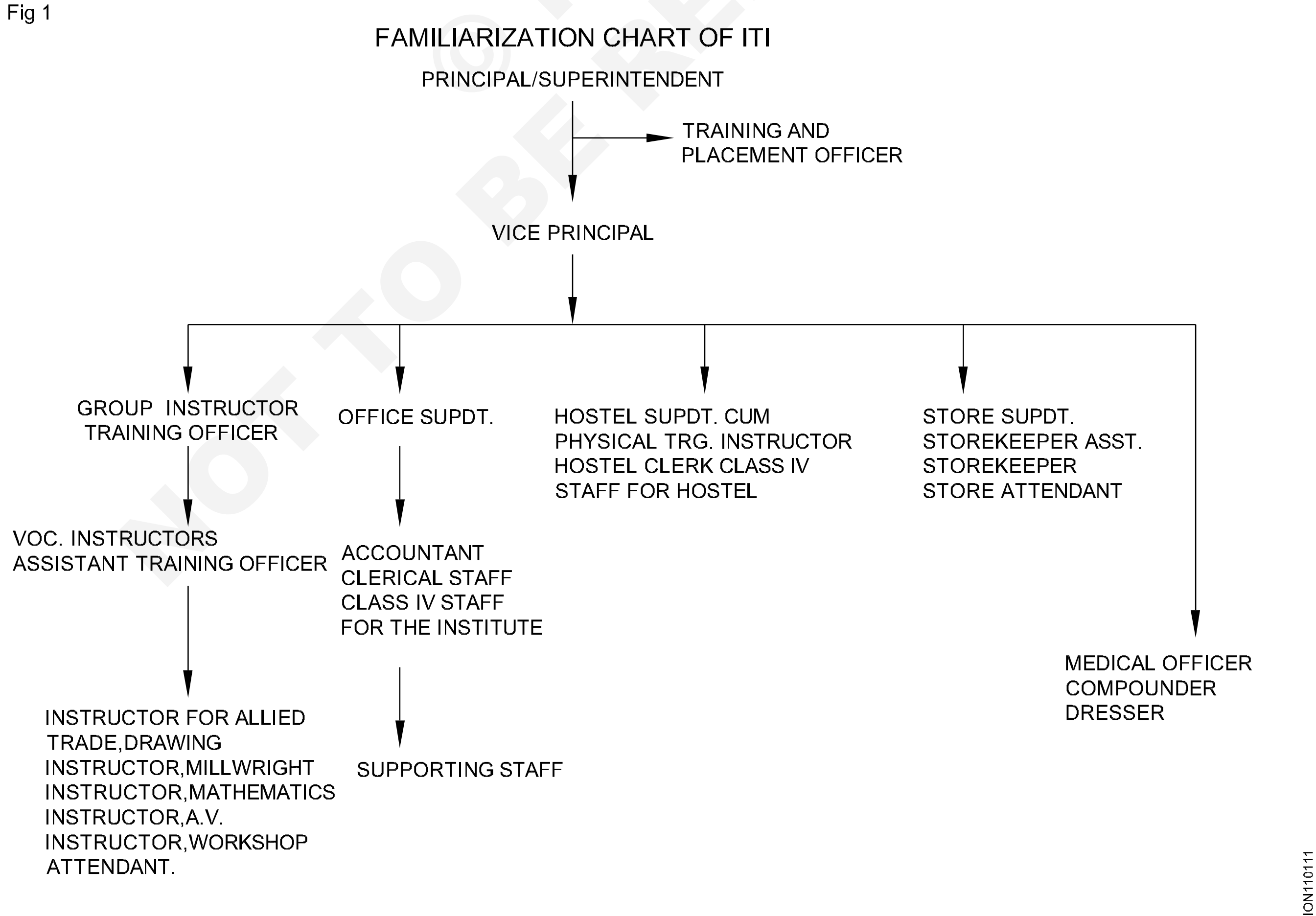
In India there are about 2293 Govt. ITIs and 10872 Private ITIs. (Based on the Govt.of India, Ministry of Labour Annual report of 2016-2017). The Govt. ITIs in each state functioning under the Directorate of Employment and Training Dept (DET) under the state Govts.

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



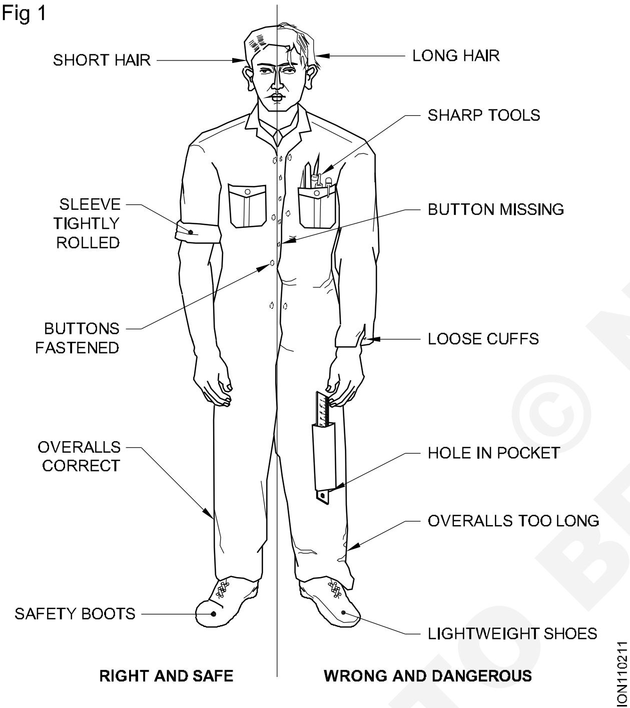
Importance of safety and precautions to be taken in the industry/ shop floor

Objectives: At the end of this lesson you shall be able to
- **state the importance of safety and safety signs**
- **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

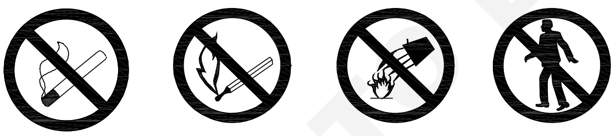
Indicating a warning such tht suitable precatution is taken. Refer to chart 1 for examples.

d Information signs

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

Chart 1

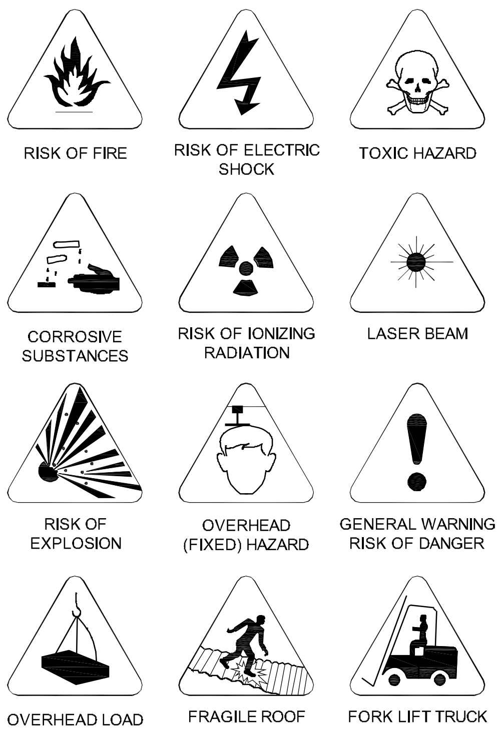
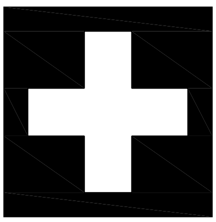
a Prohibition signs



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

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

c Warning signs  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 KIT	**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.

Occupational health, safety & PPE

Objectives: At the end of this lesson you shall be able to
- **what is occupational safety and health**
- **explain how to maintain health and safety in workplace**
- **state regulation and legislations.**

What is Occupational Health and Safety?

Occupational health and safety (OHS) relates to health, safety and welfare issues in the workplace. OHS includes the laws, standards and programs that are aimed at making the workplace better for workers, along with co-workers, family members, customers, and other stakeholders.

The purpose of Occupational Health and Safe:

The goal of an occupational safety and health program is to foster a safe and healthy occupational environment. OSH also protects all the general public who may be affected by the occupational environment.

What are the examples of Occupational Health and Safety?

Occupational Health and Safety Tips

- Be Aware.
- Maintain Correct Posture.
- Take Breaks Regularly.
- Use Equipment Properly.
- Locate Emergency Exits.
- Report Safety Concerns.
- Practice Effective Housekeeping.
- Make Use of Mechanical Aids.

How do you maintain health and safety in the workplace?

Maintaining Your Health and Safety in the Workplace

- Correct Your Posture.
- Be Aware of Your Surroundings.
- Take Regular Breaks.
- Report Unsafe Conditions.
- Wear the Correct Safety Equipment.
- Reduce Workplace Stress.

The legislation for labour welfare, known as the Factories Act, 1948, was enacted with the prime objective of protecting workmen employed in factories against industrial and occupational hazards. The Act provides for the health, safety, welfare and other aspects of OHS for workers in factories. What are occupational health and safety regulations?

OHS is particularly relevant to employees and volunteers. The purpose of the Work Health and Safety laws (WHS laws) are to protect the health, safety and welfare of employees, volunteers and other persons who are at, or come in to contact with a workplace.

Which one is legislation in the-area of occupational safety and health?

The 13 Acts are: Factories Act, 1948; Mines Act, 1952; Dock Workers (Safety, Health and Welfare) Act, 1986; Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996; Plantations Labour Act, 1951; Contract Labour (Regulation and Abolition) Act, 1970; Inter-State Migrant ...

What is the main legislation for health and safety?

The Health and Safety at Work Act 1974 states employers are responsible for protecting the safety of their employees at work, by preventing potential dangers in the workplace. It places general duties on employers to ensure the health, safety and welfare of all persons while at work.

What are four of the aims of health and safety legislation?

secure the health, safety and welfare of employees and other people at work; protect the public from the health and safety risks of business activities; eliminate workplace risks at the source; and.

What are legislation and regulations?

1 Legislation is a directive proposed by a legislative body while a regulation is a specific requirement within legislation.

2 Legislation is broader and more general while regulation is specific and details how legislation is enforced.

The difference between legislation and regulation is that legislation is the act or process of making certain laws while regulation is maintaining the law or set of rules that govern the people. It is a government-driven or ministerial order having the force of law.

Why are regulations and legislations important?

Legislation makes a positive contribution to employee relationships and increases employees' sense of fairness and trust in their employer. Ultimately it can also have a positive impact in supporting strategic HR and business goals.

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

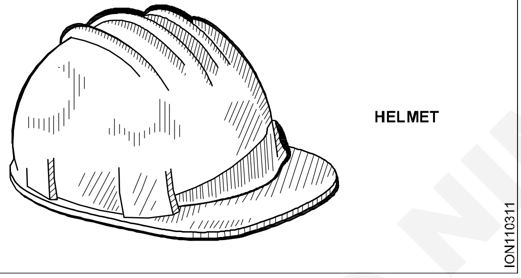


Fig 2

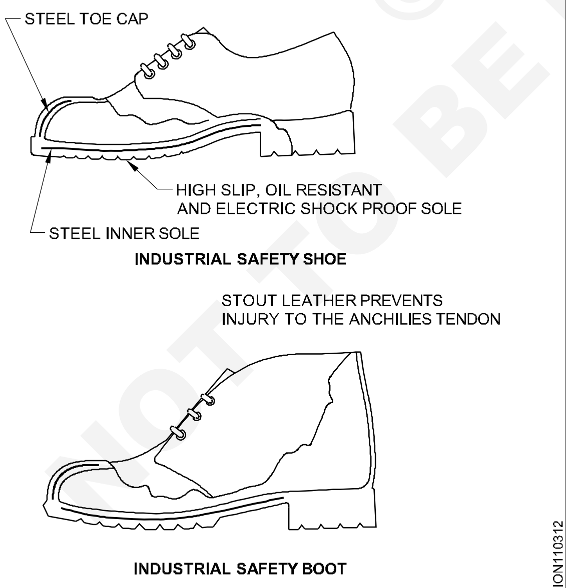


Fig 3

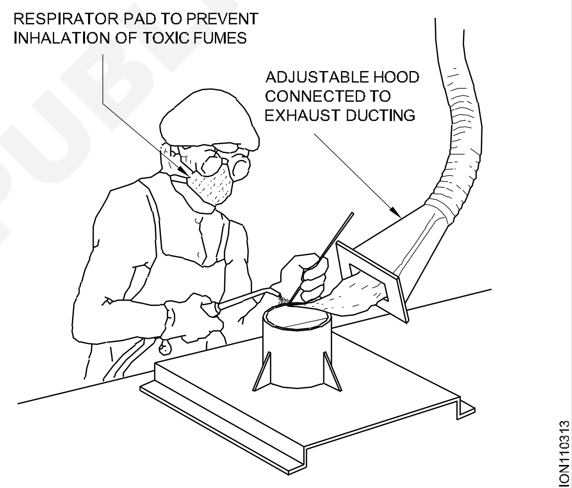


Fig 4

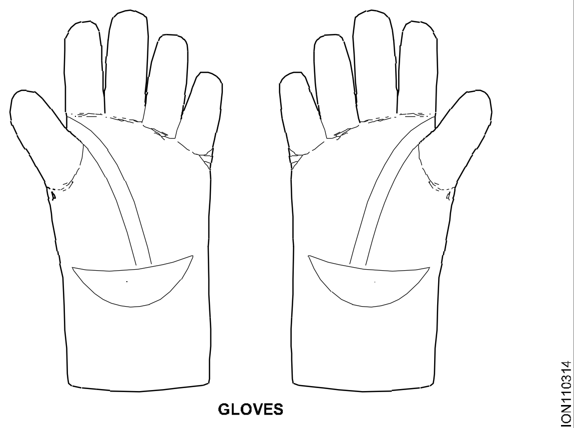
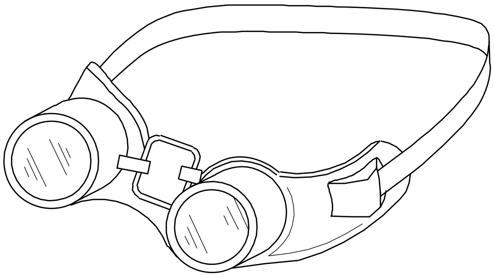
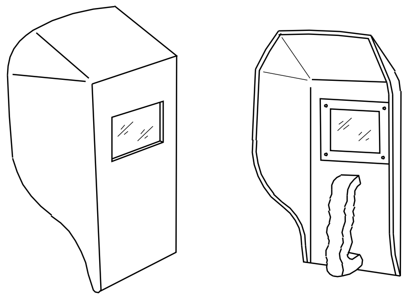


Fig 5



ION110315

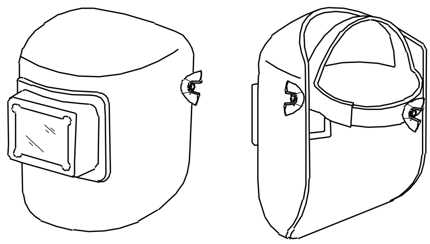
Fig 6



HAND SCREEN

ION110316

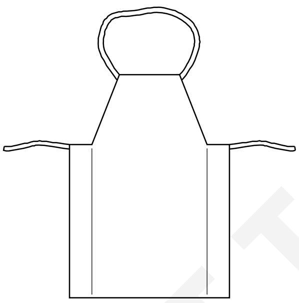
Fig 7



WELDING HELMET

ION110317

Fig 8



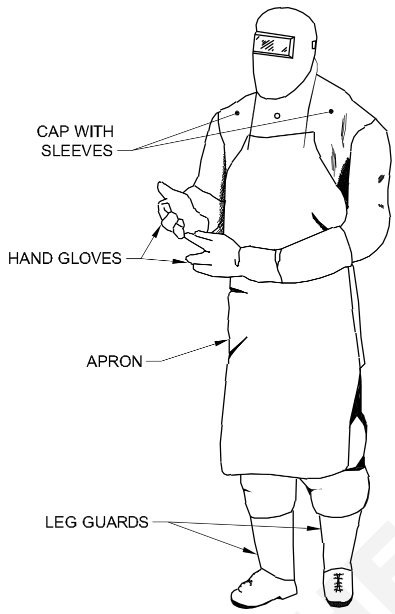
APRON

ION110318

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.

Fig 9



LEG GUARDS

ION110319

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 occupational safety**
- **state legislation and regulations.**

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.

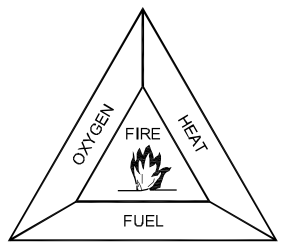
Fire extinguishers

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°C - 25°C) 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 (Fig 1), 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.

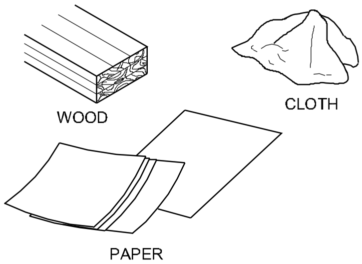
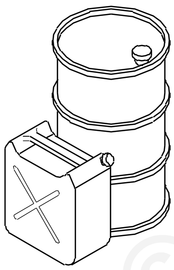
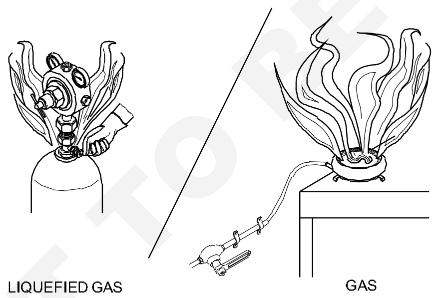
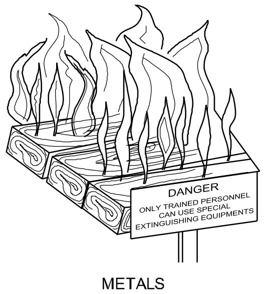
3 **Cooling**

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.

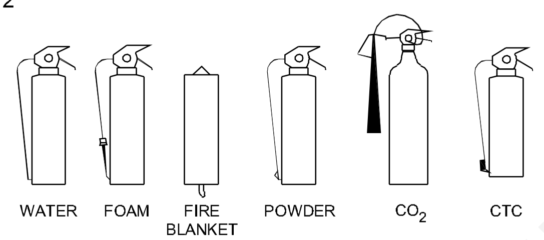
A fire extinguishing agent is the material or substance used to put out the fire. These extinguishing materials are usually (but not always) contained in a container called the 'fire extinguisher' with a mechanism for spraying into the fire when needed.

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



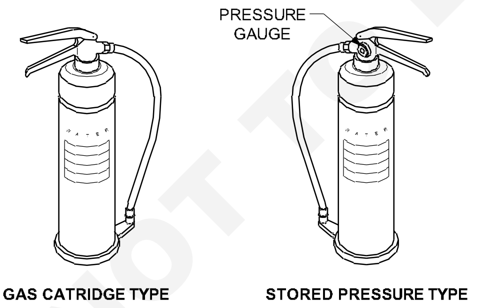
i Water-filled extinguishers

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

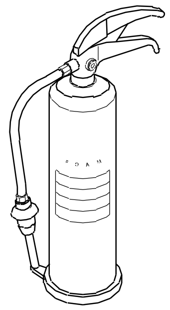
These may be stored pressure or gas cartridge types as shown in (Fig 4).

Most suitable for:

- flammable liquid fires
- running liquid fires.

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

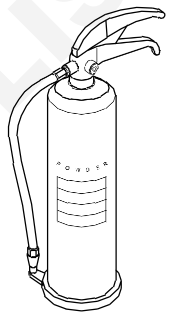
Fig 4



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.

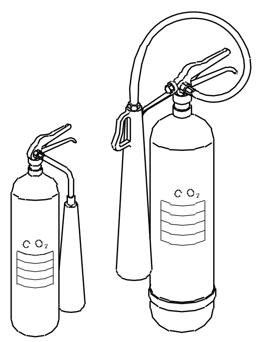
Fig 5



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

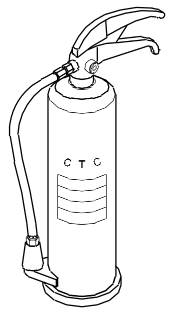


v Halon Extinguishers (Fig 7)

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



ION110517

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, hand drilling machine and files.**

Basic Hand tools

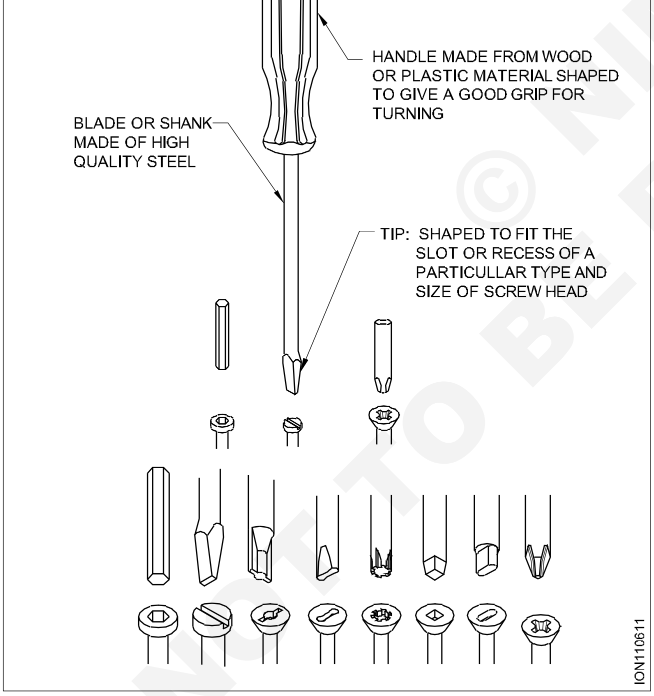
There are innumerable types of hand tools used for different types of work. Some of the basic tools which are a must for a mechanic electronics are dealing in are :

- 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.

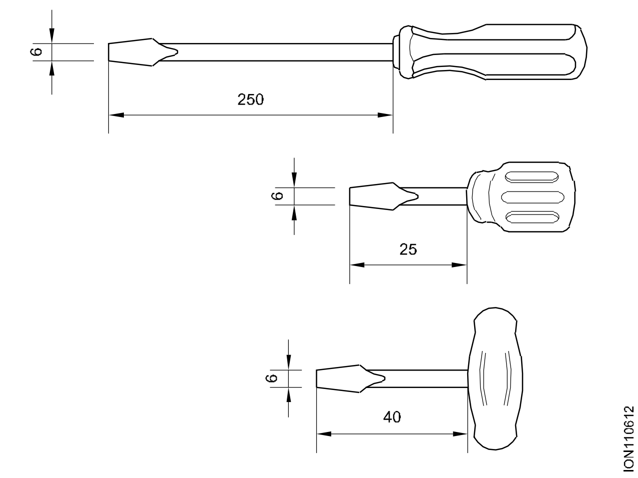
Screwdrivers with flat tips are specified in size by the length of their blade and by the width of their tip. These dimensions are given in millimetres (mm).

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.

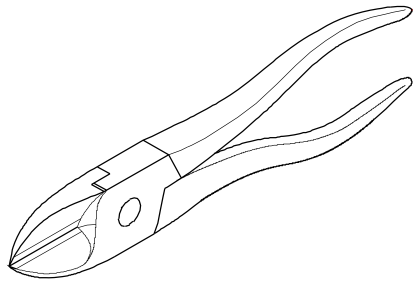
To keep pliers in good working condition, they should be kept clean, the metal parts should be wiped with an oily piece of cloth and, from time to time, a drop of oil should be applied to the pivots and joints.

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.

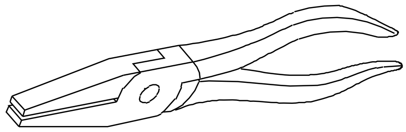
They are used to form and shape wires and small pieces of metal.

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.

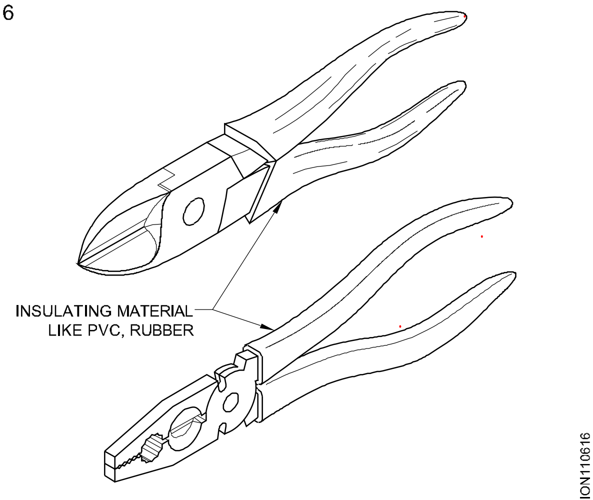
Fig 5



FLAT NOSE PLIERS

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 6.

Fig 6

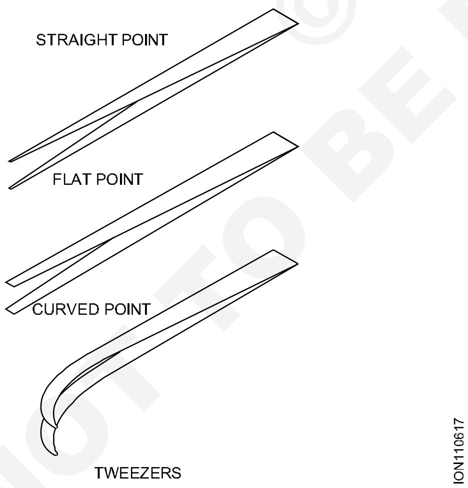


Before you work with electrical installations or electrical appliances, they have to be disconnected from the electrical supply. Working with live parts of an electrical installation or appliance can INJURE or KILL you, and it might seriously damage the installation and equipment.

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 7 shows different types of tweezers.

Fig 7



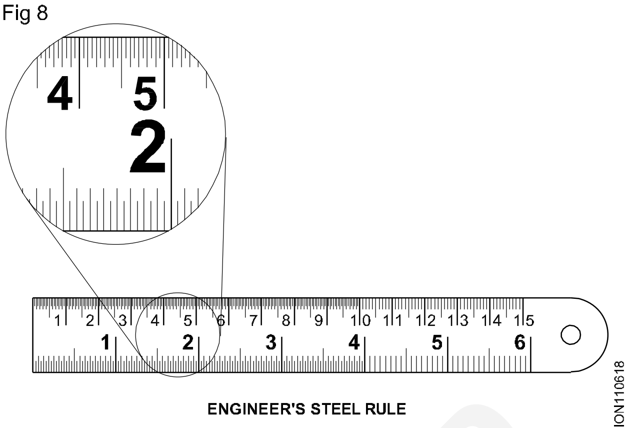
The thin structure of the tweezers permits easy access to places where fingers cannot reach. Tweezers are very useful during soldering of wires, components and placing of small screws in interior places.

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 8.

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.

Fig 8



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 8. 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

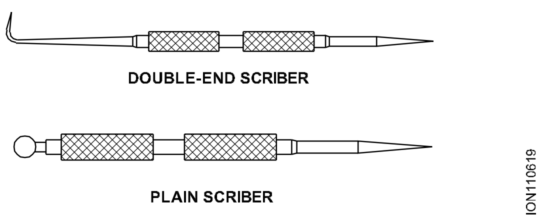
Steel rules are available in different lengths. The common sizes are 150 mm/6inches, 300 mm/12 inches and 600 mm/24 inches.

Scriber

A scriber is a pointed, sharp tool made of steel or carbon steel as shown in Fig 91There are two types of scribers, namely,

- Plain scribers
- Double end scribers

Fig 9



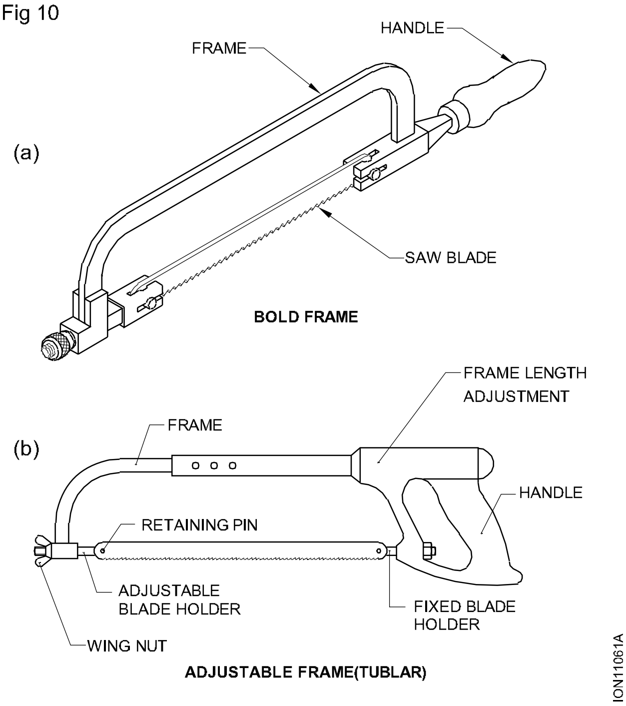
Uses of scribers

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 10 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 10



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

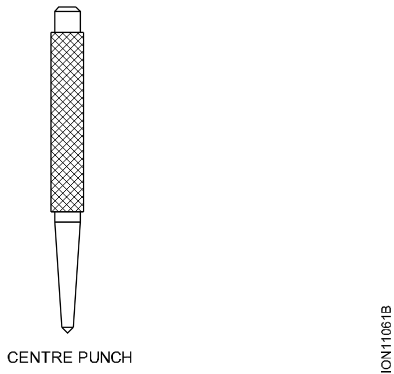
A hacksaw blade is a thin, narrow, steel band with teeth and two pin holes at the ends. These blades are made of either low alloy steel (la) or high speed steel (hs). Hacksaw blades are available in standard lengths of 250 mm and 300 mm.

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 11. 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.

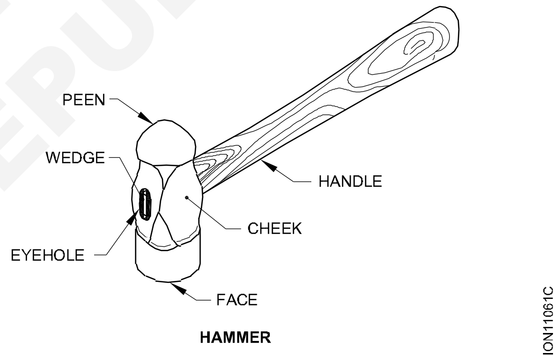
Hammer

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 12 shows a typical hammer with the parts labeled.

Fig 12



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

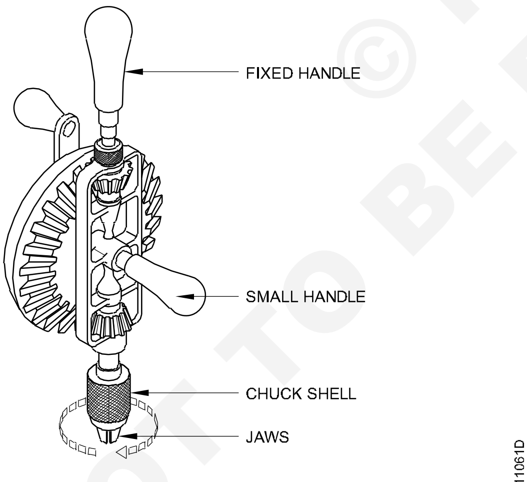
– ensure that the face of the hammer is free from oil or grease.

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 13. Fig 14 illustrates a portable power drilling machine.

Fig 13



HAND DRILLING MACHINE

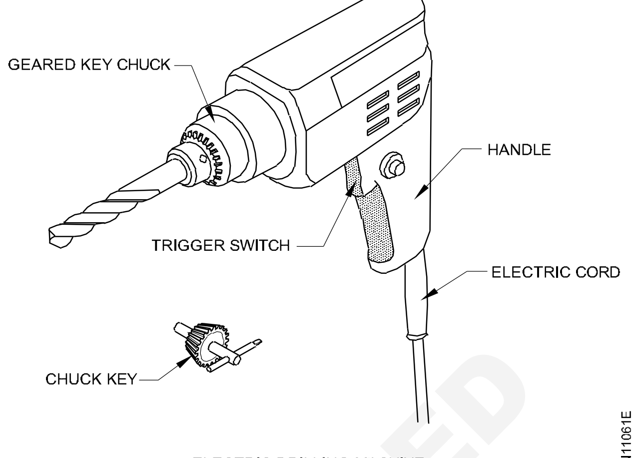
The hand drill is used for drilling holes up to 6.5 mm diameter.

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.

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'.

Fig 14

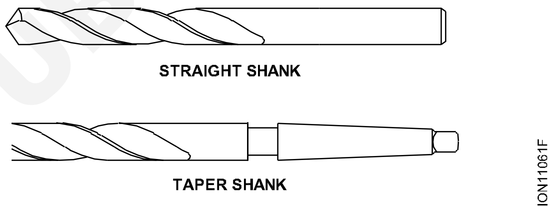


ELECTRIC DRILLING MACHINE

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 15.

Fig 15



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.

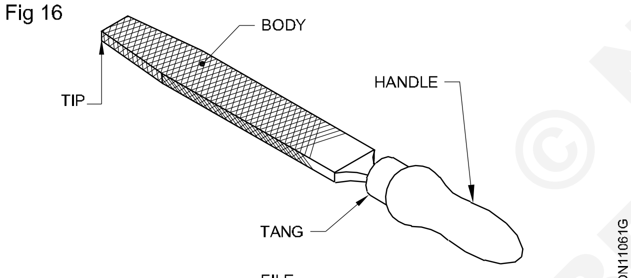
Files

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 16 illustrates the main parts of a typical file.

Fig 16



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.

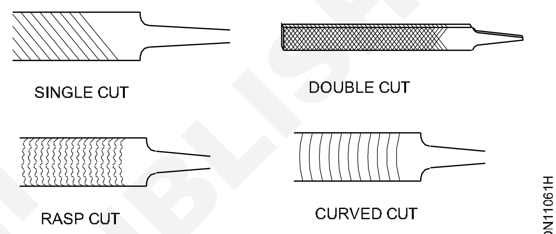
Smooth file is used for removing less metal and for giving good surface finish.

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 17, it is called 'single cut file.'

Fig 17



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.

Electrical terms

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

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.

The symbol for electric charge is Q or q. A charge of 6.25 x 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.

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

In terms of electrons and protons, they tend to be attracted to each other by the force of attraction between opposite charges.

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

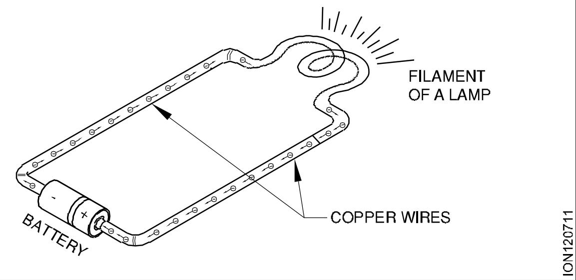
In order to produce an electric current, the free electrons in a copper wire must be made to move in the same direction. This can be done by putting electrical charges at the ends of the copper wire more precisely, a negative charge at one end and a positive charge at the other end of a copper wire.

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

A complete or closed circuit is shown in (Fig 1) with a battery, a lamp and copper wire to connect them in a closed circuit.

Fig 1



In order to have continuous electric current, the free electrons must continue to flow. Battery is the electrical energy source used to keep applying opposite charges at the ends of the wire. The negative charge would repel the electrons through the wire. At the positive side, electrons is attracted into the source; but for each electron attracted into the source, an electron is 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.

Electrical Unitsof Measurements

Electromotive force (voltage)

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

Potential difference

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

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

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

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.
- 220/440/240 volts from hydro/hydel or thermal generating stations for homes and industrial purposes.

Voltage

The Voltage is defined 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. Voltage is represented in equations and schematics by the letter “V”.

Milli Volt, Kilo Volt, Mega Volt

Larger quantities of voltage are measured in kiloVolt (kV) and MegaVolt (MV).

1kV = 1000 Volt

1mV = 1000 kilo Volt

Smallest quantites less than a volt are measured in milli volt (mV) and micro Volt (μV).

$$\frac{1}{1000}\ \mathrm{V} = 1\mathrm{mV}$$

$$\frac{1}{1000000}\ \mathrm{V} = 1\mu\mathrm{V}$$

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.

A quantity of current smaller than one ampere is measured in milliampere (mA) and micro-ampere (μA).

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

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

Resistance

Resistance is the measure of opposition to current flow in an electrial circuit (also known as Ohmic resistance). It is measured in Ohms, symbolized by the greek letter Omega (Ω). Higher values are measured in kilo ohms and mega ohms (1000Ω = 1 kΩ, 1000kΩ = 1MΩ).

Types of electricity

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

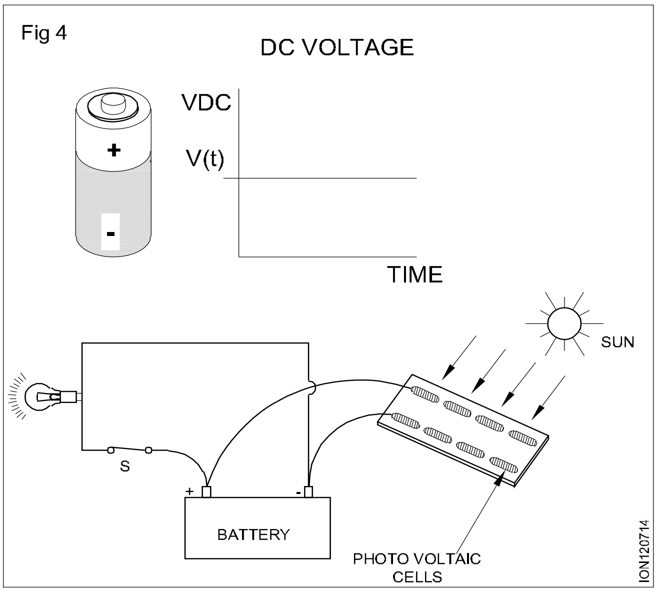
1 Direct current supply, generally known as **DC supply.**

2 Alternating current supply, generally known as **AC supply.**

DC supply

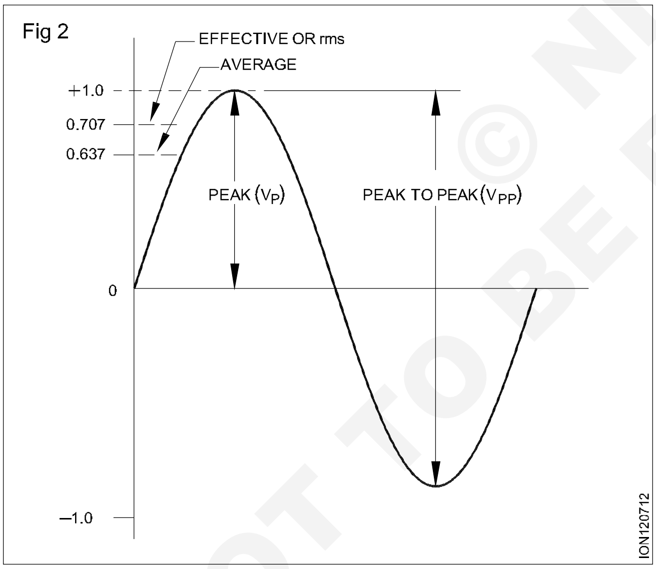
The term DC supply is given to a supply source that makes current to flow through a circuit in one direction only. This is in contrast to the alternating current supply.

Batteries and some types of generators give DC supply of constant voltage. Solar cells are also used to produce DC supply as shown in (Fig 4).



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 cycles that the current alternates in a period of one second is shown in (Fig 2).



A.C. Waveform:

It is known as sinusoidal waveform (Sine wave). Details of the AC waveform is explained below

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 or voltage in a half cycle.

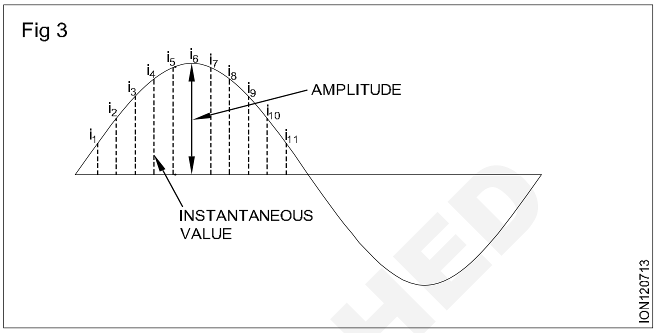
Frequency: It is defined as the number of cycles per second (c/s) measured in Hertz (Hz). Larger quantities are measured in kilo Hertz (kHz) and Mega Hertz (MHz)

1kHz = 1000Hz

1MHz = 1000kHz

In India we use 50Hz frequency for AC mains supply. IN Europe also 50Hz AC is used, while in USA it is standardized as 60Hz.

Instantaneous value: It is the value of an alternating quantity at a praticular instant of time in the cycle within 360 degrees as shown in (Fig 3) (it may be AC voltage or AC current or AC power).



Peak value (V_p): The maximum value attained by the alternating quantity during one cycle. It is also known as amplitude or crest value. This peak value is reached at 90^0 and 270^0 during each cycle as shown in (Fig 2).

R.M.S. Value (V_{rms}): 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 ammeters read r.m.s. value of voltage and current.

Average Value (V_{av}): Average value of a sinusoidal waveform is also known as mean value determined by multiplying the peak value by the constant 0.637. It is the average value of any one half cycle of the waveform (63.7% of V_p) as shown in (Fig 2).

AC supply has the following advantages over dc supply:

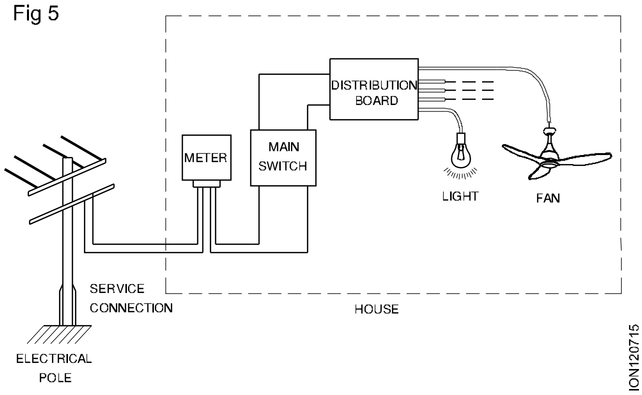
- Reduced transmission loss over very long distances.
- Voltage levels can be changed using simple devices called transformers.
- Reduced severity of electrical shock.
- Generating equipments are simple and cheaper.
- Can be easily converted to dc supply.

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

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 240 volts, 50Hz, AC. For industrial user three-phase, 440 volts, 50Hz, AC supply is made available.

The domestic voltage of **240 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 5).

Fig 5

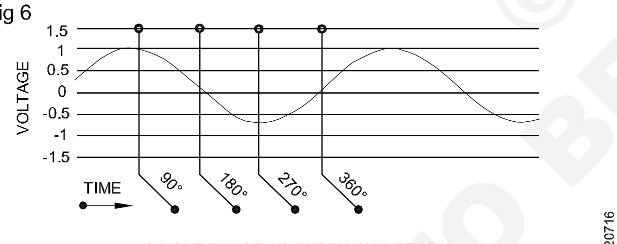


Single Phase and Three Phase AC supply system

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°, within a complete cycle of 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 live wire with current flowing between them. The cyclical changes in magnitude and direction usually change in current and voltage about 50 times per second as shown in (Fig 6).

Fig 6



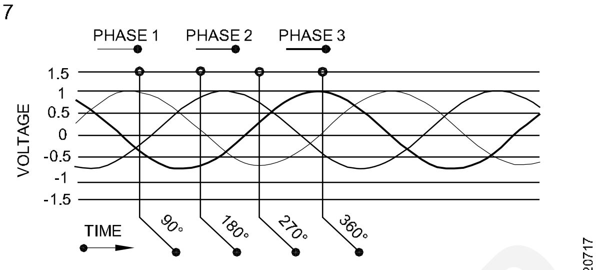
SINGLE PHASE AC SUPPLY WAVEFORM

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. Also lesser design cost and complexity

3 - Phase AC supply system

In a 3 phase system there are three live wires, each 120° out of phase with each other. Delta and Star are star (Y) the two types of circuits used to maintain equal load across a three phase system, each resulting in different wiring configurations. In the delta configuration, no neutral wire is used. The star (Y) 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 7). With a three phase power supply, a steady stream of power is delivered at a constant rate, making it possible to carry more load. Three phase power supplies offer a superior carrying capacity for higher load systems greater than 1000 watts. It also offer a reduction of copper consumption, fewer safety risks for workers and greater conductor efficiency.

Fig 7



THREE PHASE AC SUPPLY WAVEFORM

Line voltage and phase voltage

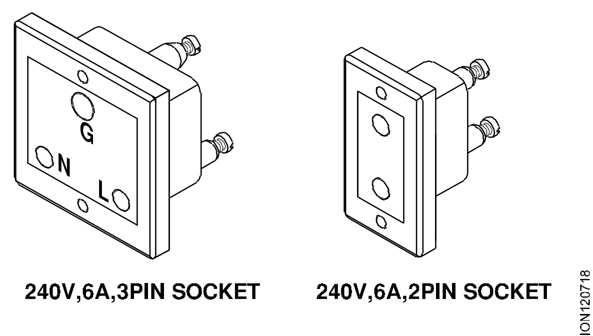
Line voltage is the voltage measured between any two lines in a three-phase circuit. Phase voltage is the voltage measured across a single phase and neutral in a three-phase source or load.

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 240 volts is used to light up the lamps, fans etc., in homes. To connect electrical appliances at home, 240V AC is available in either two-pin or three-pin sockets as shown in (Fig 8).

Fig 8



All the 3 pin outlets are generally connected through a single pole ON/OFF switch-as shown in (Fig 9). 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 9). This is as per I.S & I.E rules.

Referring to the (Fig 9), when the switch is put ON, the voltages across the three points in a 3 pin socket should be as shown in (Fig 10).

Fig 9

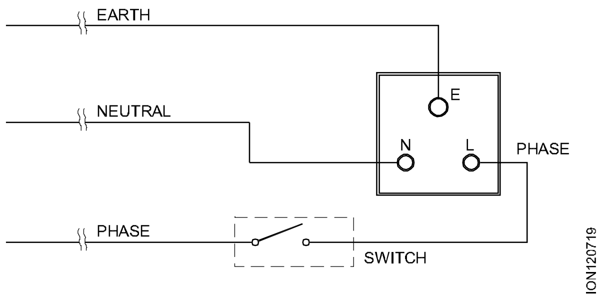
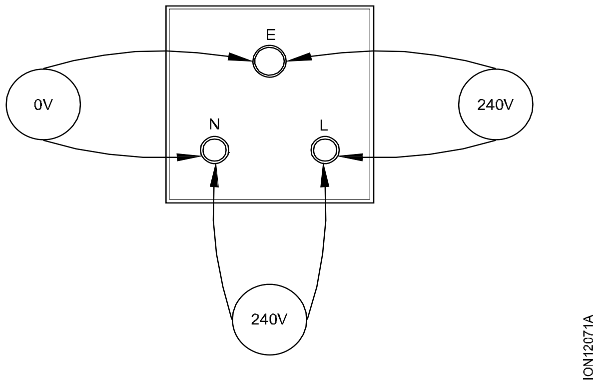


Fig 10



TESTING A 3 PIN SOCKET OUTLET

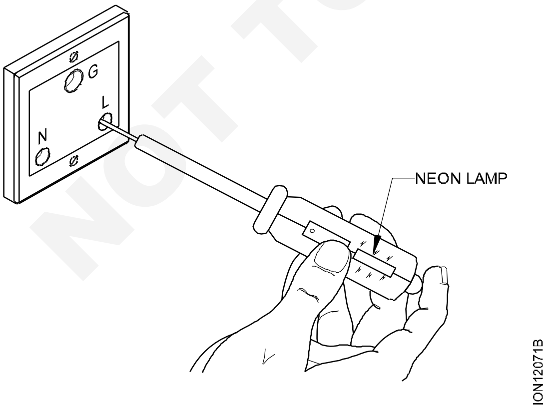
Testing a mains outlet can be done using any one or more of the following test instruments;

1 Neon tester

A neon tester is a simple 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 11), if voltage exists at the phase point of the socket, the neon lamp inside the tester glows indicating presence of voltage.

Fig 11

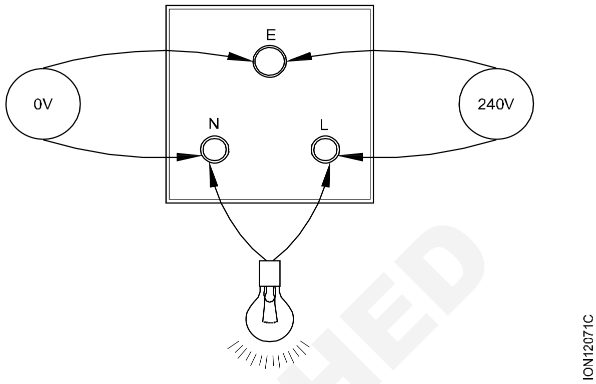


The neon lamp should not glow for the neutral or ground points are tested.

2 Test lamp

It is test circuit consisting of an incandescent lamp with two lengthy wires connected across the holder 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 (Fig 12).

Fig 12



3 AC voltmeter/multimeter

Using AC voltmeter or a multimeter set to AC 300V range, the voltage across all the 3 terminals of the socket as in (Fig 10) 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, phase-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.

4 If the voltage across neutral – ground is higher than 10 volts or high, this indicates defective earthing connection and it must be immediately rectified.

Electrical Earthing: Earthing system is used to protect the user from electrical shock. A set of conductors, pipe or plate are connected with the electrical system to the ground for safety and functional purpose. It provides a low resistance path for the leakage/fault current pass immediately into the earth. It also causes the protective device (ELCB) to switch OFF AC mains power in case of leakage current.

The defective earthing connection must be immediately attended to and rectified; otherwise, the electrical system is not safe for using sensitive and delicate equipments/ instruments like computers, CRO etc.

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.

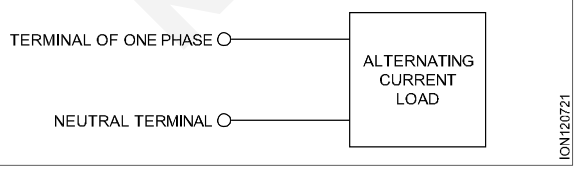
3-Phase AC fundamentals

Objectives: At the end of this lesson you shall be able to
- **state and describe the generation of 3-phase system with single loops**
- **state the advantages of the 3-phase system over a single phase system**
- **state and explain the 3-phase, 3-wire, and 4-wire system**
- **state and explain the relation between phase and line voltage.**

Introduction

When a piece of electrical equipment is plugged into the socket of a normal alternating current supply (e.g. a ring main circuit), it is connected between the terminal of one phase and the neutral wire. (Fig 1)

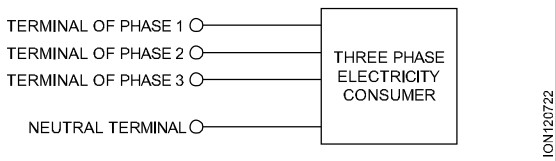
Fig 1



Thus a normal domestic alternating current circuit may also be described as a single-phase circuit.

Similarly, a three-phase power consumer is provided with the terminals of three phases. (Fig 2)

Fig 2



One great advantage of a three-phase AC supply is that it can produce a rotating magnetic field when a set of stationary three-phase coils is energized from the supply. This is the basic operating principle for most modern rotating machines and, in particular, the three-phase induction motor.

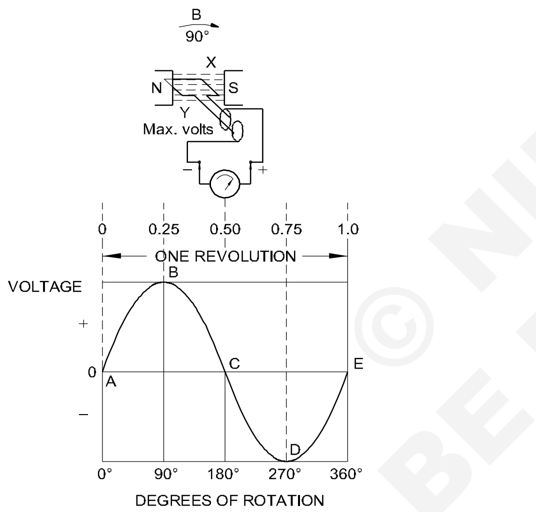
Further, lighting loads can be connected between any one of the three phases and neutral.

Review: Further to the above two advantages the following are the advantages of polyphase system over single phase system.

- 3-phase motors develop uniform torque whereas single phase motors produce pulsating torque only
- Most of the 3-phase motors are self starting whereas single phase motors are not
- Power factor of 3-phase motors are reasonably high when compared to single phase motors
- For a given size the power out put is high in 3-phase motors whereas in single phase motors the power output is low.
- Copper required for 3-phase transmission for a given power and distance is low when compared to single phase system.
- 3-phase motor like squirrel cage induction motor is robust in construction and more are less maintenance free.

The basic principle used in generating an alternating voltage is that of rotating a wire loop at a constant angular speed in a uniform magnetic field. (Fig 3) The alternating voltage thus produced varies sinusoidally with time.

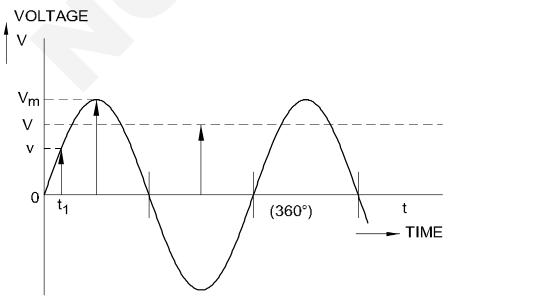
Fig 3



(AS THE LOOP ROTATES THROUGH THE MAGNETIC FIELD, THE MAGNITUDE AND DIRECTION OF THE VOLTAGE CHANGES.)
GENERATION OF AN ALTERNATING VOLTAGE

The effective (RMS) value is the same as that of a direct current that would produce the same heating effect, RMS voltage and frequency are usually quoted for a sinusoidal alternating voltage (Fig 4).

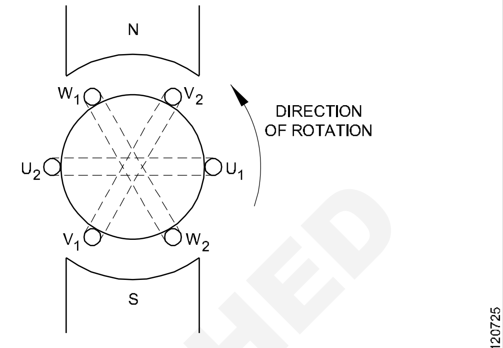
Fig 4



V_m = PEAK VOLTAGE
V = RMS VALUE
v = INSTANTANEOUS VOLTAGE AT TIME t_1

Three-phase generation: To generate three-phase voltages, a similar method to that used for generating single-phase voltages is employed but with the difference that, this time, three wire loops U_1, U_2, V_1, V_2 and W_1, W_2 rotate at a constant angular speed about the same axis in the uniform magnetic field. U_1, U_2, V_1, V_2 and W_1 , W_2, are displaced 120° in position with respect to each other, permanently. (Fig 5)

Fig 5

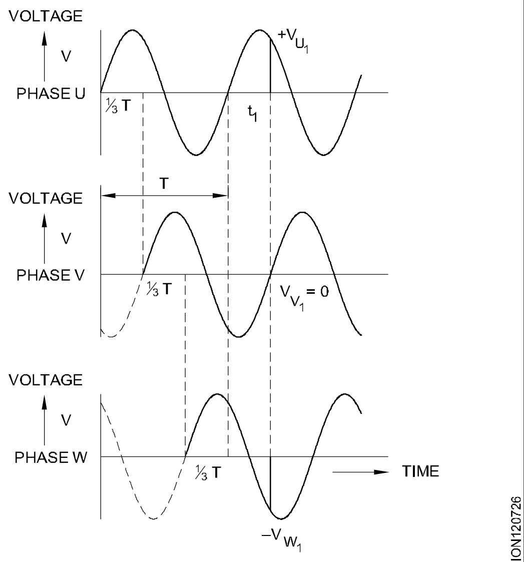


SIMPLIFIED THREE – PHASE ALTERNATOR

For each wire loop, the same result is obtained as for the alternating voltage generator. This means that an alternating voltage is induced in each wire loop. However, since the wire loops are displaced by 120° from each other, and a complete revolution (360°), takes one period, the three induced alternating voltages are delayed in time by a third of a period with respect to each other.

Because of the spatial displacement of the three wire loops by 120°, three alternating phase voltages result, which are displaced by one third of a period, T, with respect to each other. (Fig 6)

Fig 6



To distinguish between the three phases, it is a common practice in (heavy current) electrical engineering to designate them by the capital letters U,V and W or by a colour code red, yellow and blue. At a time 0, U is passing through zero volts with positively increasing voltage. (Fig 6a) V follows with its zero crossing 1/3 of the period later (Fig 6b), and the same applies to W with respect to V. (Fig 6c)

In three-phase networks, the following statements can be made about the three-phase voltages.

- The three-phase voltages have the same frequency.
- The three-phase voltages have the same peak value.
- The three-phase voltages are displaced by one third of a period in time with respect to each other.
- At every instant in time, the instantaneous sum of the three voltages

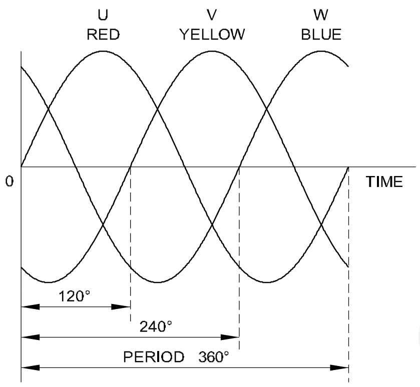
$$V_U + V_V + V_W = 0.$$

The fact that the sum of the instantaneous voltages is zero is illustrated in Fig 6. At time t_1, U has the instantaneous value V_U. At the same time, $V_V = 0$, and the instantaneous value for W is $-V_W$. Because V_U and V_W have the same value but are opposite in sign, it follows that,

$$V_{U1} + V_{V1} + V_{W1} = 0.$$

The three voltages of the same amplitude and frequency are shown together in Fig 7.

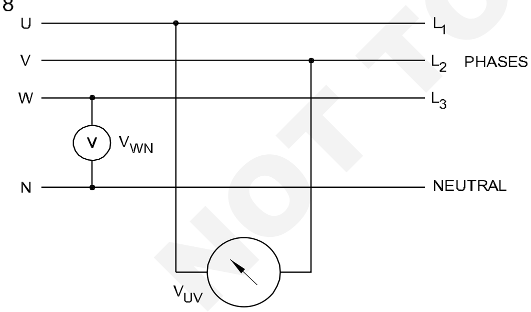
Fig 7



COMBINED WAVE - FORMS OF THREE PHASE SUPPLY

Three-phase network: A three-phase network consists of three lines or phases. In Fig 8, these are indicated by the capital letters U, V and W.

Fig 8



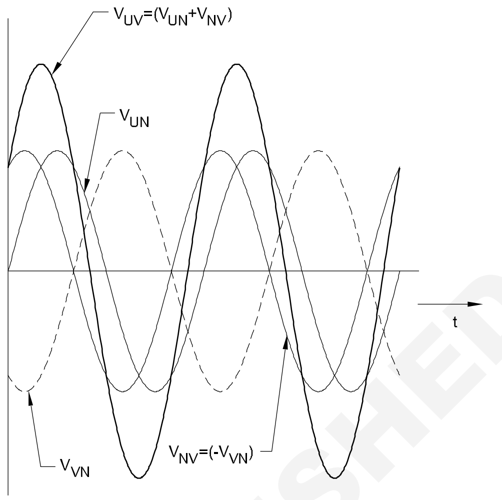
The return lead of the individual phases consists of a common neutral conductor N, which is described later in more detail. Voltmeters are connected between each of the lines U, V and W, and the neutral line N. They indicate the RMS (effective) values of the voltages between each of the three phases and neutral.

> **These voltages are designated as phase voltages V_{UN}, V_{VN} and V_{WN}.**

The individual, phase voltages all have the same magnitude. They are simply displaced from each other by one third of a period in time. (Fig 9)

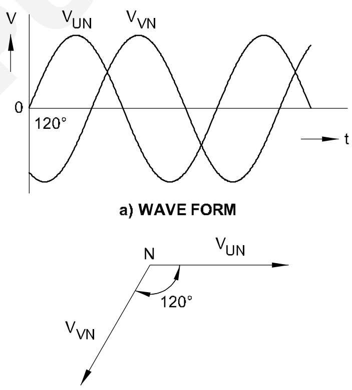
The individual instantaneous, peak and RMS values are the same as for a single-phase alternating voltage.

Fig 9



Line and phase voltage: If a voltmeter is connected directly between line U and line V (Fig 10), the RMS value of the voltage V_{UV} is measured, and this is different from any of the three phase voltages.

Fig 10



a) WAVE FORM

b) VECTORS

Its magnitude is directly proportional to the phase voltage. The relationship is shown in Fig 9, where the time-variation wave- forms of V_{UV} and the phase voltages V_{UN} and V_{VN} are drawn.

V_{UV} has a sinusoidal wave-form and the same frequency as the phase voltages. However, V_{uv} has a higher peak value since it is computed from the phase voltages V_{UN} and V_{VN}. The varying positive and negative instantaneous values of V_{UN} and V_{VN} at a particular time produce the instantaneous value of V_{UV}. V_{UV} is the phasor sum of the two phase voltages V_{UN} and V_{NV}.

This combination of phase-displaced alternating voltages is called phasor addition.

> **The voltage across phase-to-phase is called the line voltage.**

Relationship between line and phase voltage: The possibility of combining pairs of phases in a generator is a basic property of three-phase electricity. The understanding of this relationship will be enhanced by studying the following illustrative example which explains the concept of phase difference in a very simple way.

The phase voltages V_{UN} and V_{VN} are separated in phase by one third of a period, or 120^o between the two phasors. (Fig 10)

The phasor sum of the two phase voltages V_{UN} and V_{NV} can be obtained geometrically, and the resultant phasor so obtained is the line voltage V_{UV} through the relation $V_{UV} = V_{UN} + V_{NV}$.

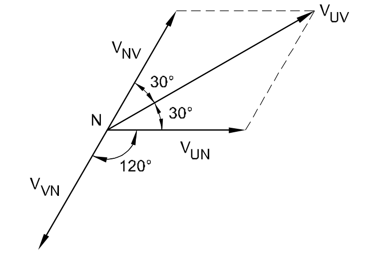
Note that to obtain the line voltage V_{UV} the measurement is made from the U terminal through the common point N to the V terminal, for a star connection.

This fact is illustrated in Fig 11. Starting with the phasors V_{UN} and V_{VN} (Fig 10), the phasor $-V_{VN} = V_{NV}$ is produced from the point N. The diagonal of the parallelogram with sides V_{UN} and V_{NV} is the phasor representing the resulting line voltage V_{UV}.

It can be concluded, therefore, that in a generator the line voltage V_L is related to the phase voltage V_P by a multiplying factor. This factor can be shown to be $\sqrt{3}$, so that

$V_L = \sqrt{3} \times V_P$

Fig 11



In a three-phase generating system, the line voltage is always $\sqrt{3}$ times the phase-to-neutral voltage. The factor relating the line voltage to the phase voltage is $\sqrt{3}$.

It was shown that the line voltage is greater than the phase voltage. Here is a numerical example.

The RMS phase voltage in a three-phase system is 240V. Since the ratio of line voltage to phase voltage is $\sqrt{3}$ the RMS line voltage is

$V_L = \sqrt{3} \times V_P = \sqrt{3} \times 240$

$= 415.68V$

or rounded down, $V_L = 415V$.

Systems of connection in 3-phase AC

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

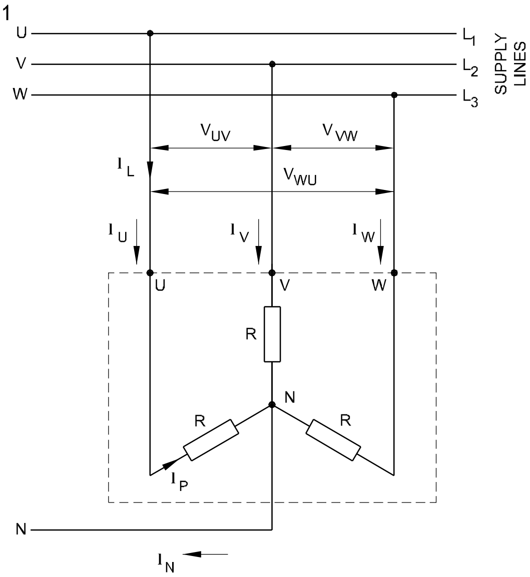
- **explain the star and delta systems of connection**
- **state phase relationship between line and phase voltages and current in a star connection delta connection**
- **state the relationship between phase and the voltage and current in star and delta connection.**

Methods of 3-phase connection: If a three-phase load is connected to a three-phase network, there are two basic possible configurations. One is `star connection' (symbol Y) and the other is `delta connection' (symbol Δ).

Star connection: In Fig 1 the three-phase load is shown as three equal magnitude resistances. From each phase, at any given time, there is a path to the terminal points U, V, W of the equipment, and then through the individual elements of the load resistance. All the elements are connected to one point N: the `star point'. This star point is connected to the neutral conductor N. The phase currents i_U, i_V, and i_W flow through the individual elements, and the same current flows through the supply lines, i.e. in a star connected system, the supply line current (I_L) = phase current (I_P).

The potential difference for each phase, i.e. from a line to the star point, is called the phase voltage and designated as V_P. The potential difference across any two lines is called the line voltage V_L. Therefore, the voltage across each impedance of a star connection is the phase voltage V_P. The line voltage V_L appears across the load terminals U-V, V-W and W-U and designated as V_{UV}, V_{VW} and V_{WU} in the Fig 1. The line voltage in a star-connected system will be equal to the phasor sum of the positive value of one phase voltage and the negative value of the other phase voltage that exist across the two lines (Fig 2).

Fig 1



Thus

$V_L = V_{UV}$ = (phasor V_{UN}) $-$ (phasor V_{VN})

= phasor $V_{UN} + V_{VN}$.

In the phasor diagram (Fig 3)

$V_L = V_{UV} = V_{UN} \text{ Cos } 30^o + V_{NV} \text{ Cos } 30^o$

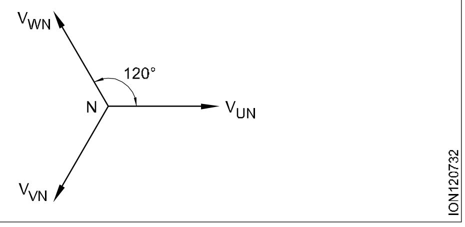
But Cos 30° = $\frac{\sqrt{3}}{2}$.

Thus as $V_{UN} = V_{VN} = V_P$

$V_L = \sqrt{3}\ V_P$.

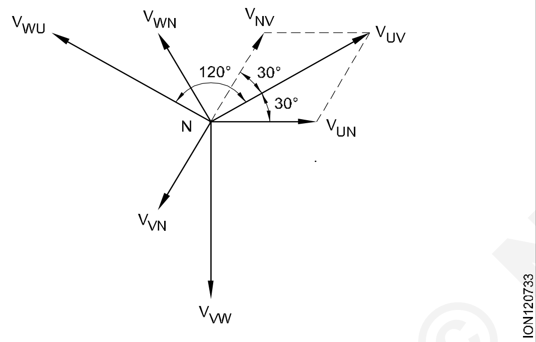
This same relationship is applied to V_{UV}, V_{VW} and V_{WU}.

Fig 2



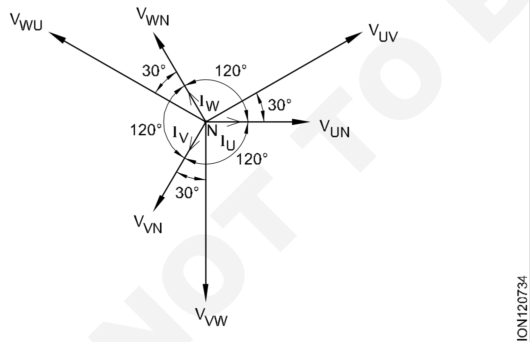
In a three-phase star connection, the line voltage is always $\sqrt{3}$ times the phase-to-neutral voltage. The factor relating the line voltage to the phase voltage is $\sqrt{3}$ (Fig 3).

Fig 3



The voltage and current relationship in a star connection is shown in the phasor diagrams. (Fig 4) The phase voltages are displaced 120° in phase with respect to each other.

Fig 4



Derived from these are the corresponding line voltages. The line voltages are displaced 120° in phase with respect to each other. Since the loads in our example are provided by purely resistive impedances, the phase currents I_P (I_U, I_V, I_W) are in phase with the phase voltages V_P (V_{UN}, V_{VN} and V_{WN}). In a star connection, each phase current is determined by the ratio of the phase voltage to the load resistance R.

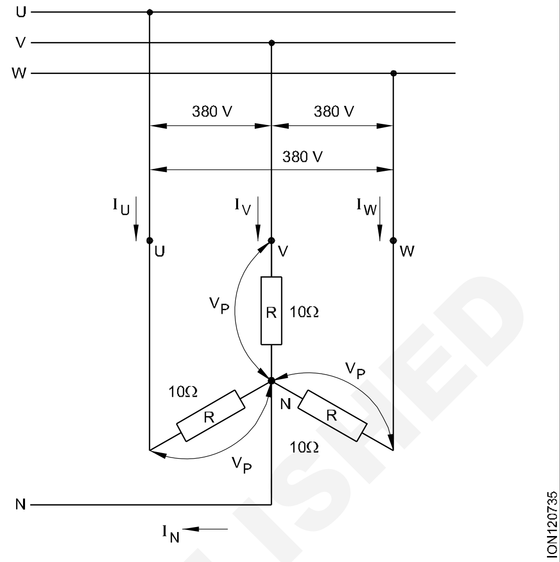
***Example 1**:* What is the line voltage for a three-phase, balanced star-connected system, having a phase voltage of 240V?

$V_L = \sqrt{3} V_P = \sqrt{3} \times 240$

$= 415.7V$

***Example 2**:* What is the magnitude of each of the supply line currents for the circuit shown in Fig 5?

Fig 5



Because of the arrangements of a star connection there is a voltage

$$V_P = \frac{380}{1.73} = 220\ V$$

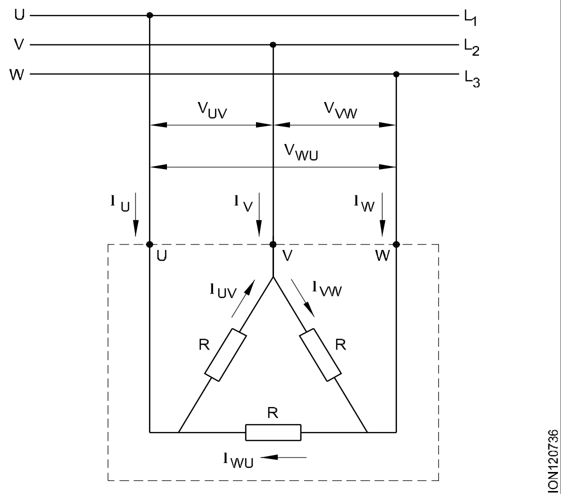
across each of the purely resistive loads R.

The three-supply line currents have the same magnitude since the star-connected load is balanced, and they are given by

$$I_U = I_V = I_W = \frac{V_P}{R} = \frac{220}{10} = 22A = I_L = I_P$$

Delta connection: There is a second possible arrangement for connecting a three-phase load in a three-phase network. This is the delta or mesh connection (Δ).(Fig 6)

Fig 6



The load impedances form the sides of a triangle. The terminals U, V and W are connected to the supply lines of the L_1, L_2 and L_3.

In contrast to a star connection, in a delta connection the line voltage appears across each of the load phases.

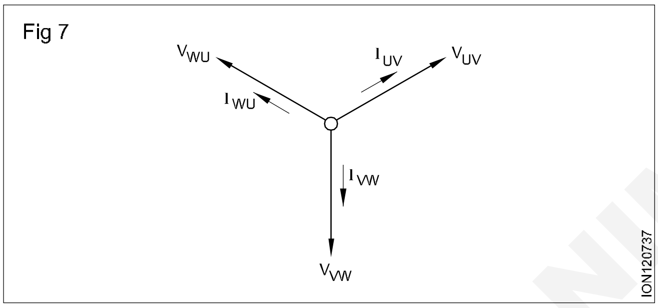
The voltages, with symbols V_{UV}, V_{VW} and V_{WU} are, therefore, the line voltages.

The phase currents through the elements in a delta arrangement are composed of I_{UV}, I_{VW} and I_{WU}. The currents from the supply lines are I_U, I_V and I_W, and one line current divides at the point of connection to produce two phase currents.

The voltage and current relationships of the delta connection can be explained with the aid of an illustration. The line voltages V_{UV}, V_{VW} and V_{WU} are directly across the load resistors, and in this case, the phase voltage is the same as the line voltage. The phasors V_{UV}, V_{VW} and V_{WU} are the line voltages. This arrangement has already been seen in relation to the star connection.

Because of the purely resistive load, the corresponding phase currents are in phase with the line voltages. (Fig 7)

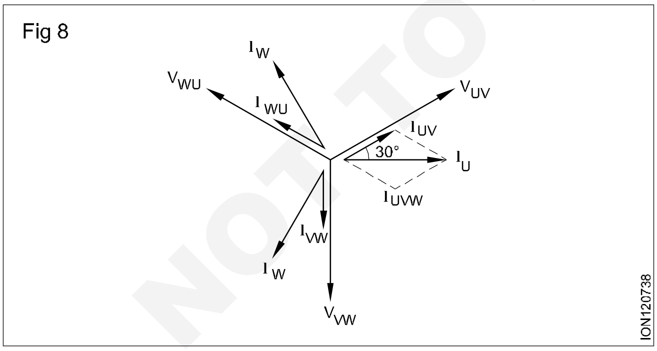
Fig 7



Their magnitudes are determined by the ratio of the line voltage to the resistance R.

On the other hand, the line currents I_U, I_V and I_W are now compounded from the phase currents. A line current is always given by the phasor sum of the appropriate phase currents. This is shown in Fig 8. The line current I_U is the phasor sum of the phase currents I_{UV} and I_{UW}. (See also Fig 8)

Fig 8



Hence, $I_U = I_{UV} \cos 30^\circ + I_{UW} \cos 30^\circ$

But $\cos 30^\circ = \dfrac{\sqrt{3}}{2}$.

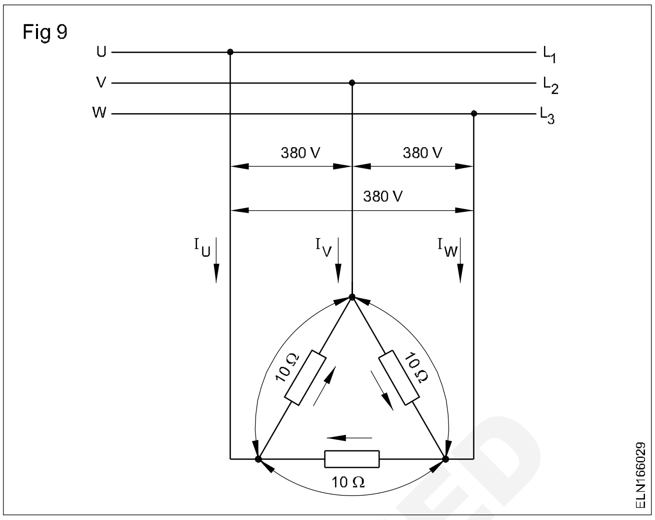
Thus $I_L = \sqrt{3}\, I_{ph}$

Thus, for a balanced delta connection, the ratio of the line current to the phase current is $\sqrt{3}$.

Thus, line current = $\sqrt{3}$ x phase current.

Example 3: What are the values of the line currents, I_U, I_V and I_W in the above example? (Fig 9)

Fig 9



Solution

Since the load is balanced (i.e. the resistance of each phase is the same), the phase currents are of equal magnitude, and are given by the ratio of the line voltage to the load phase resistance,

$$I_{UV} = I_{VW} = I_{WU} = \frac{V_P}{R} = \frac{V_L}{R} = \frac{380}{10} = 38A.$$

Thus, the phase current in the case of delta is 38A. Expressed in words:

$$\text{Phase current} = \frac{\text{line or phase voltage}}{\text{phase resistance}}$$

The line current is $\sqrt{3}$ times the phase current.

Therefore the line current is

$I_U = I_V = I_W = \sqrt{3}$ x 38A = 1.73 x 38A = 66A.

Example 4: Three identical coils, each of resistance 10 ohms and inductance 20mH is delta connected across a 400-V, 50Hz, three-phase supply. Calculate the line current.

For a coil,

reactance $X_L = 2\pi fL = 2 \times 3.142 \times 50 \times \dfrac{20}{1000} = 6.3$ ohms.

Impedance of a coil is thus given by

$$Z = \sqrt{(R^2 + X^2} = \sqrt{(10^2 + 6.3^2)} = 11.8 \text{ ohms.}$$

For a delta connected system, according to equation

$V_L = V_P$.

Thus $V_P = 400V$.

Hence the phase current is given by

$$I_P = \frac{V_P}{Z} = \frac{400}{11.8} = 33.9 \text{ A.}$$

But for a delta connected system, according to equation,

$I_L = \sqrt{3} I_P = \sqrt{3} \times 33.9 = 58.7A$.

Application of star and delta connection with balanced loads

An important application is the `star-delta change over switch' or star-delta starter.

For a particular three-phase load, the line current in a delta connection is three times as great as for a star connection for a given line voltage, i.e. for the same three-phase load (D line current) = 3 (Y - line current).

This fact is used to reduce the high starting current of a 3-phase motor with a star-delta change over switch.

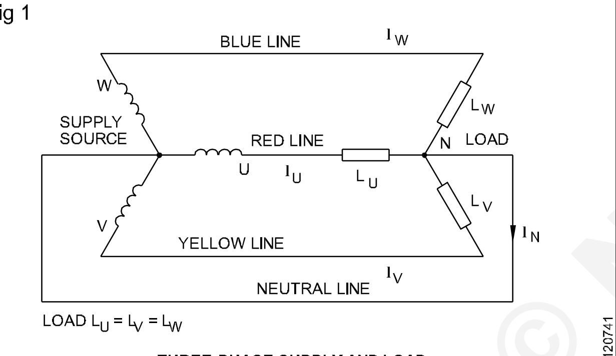
Application of star connection: Alternators and secondoary of distribution transformers, have their three, single-phase coils interconnected in star.

Neutral in 3-phase system

Objectives: At the end of this lesson you shall be able to
- **explain the current in neutral of a 3-phase star connection**
- **state the method of producing artificial neutral in a 3-phase delta connection**
- **state the method of earthing the neutral**
- **explain the behaviour of 3ϕ system when neutral open.**

Neutral: In a three-phase star connection, the star point is known as neutral point, and the conductor connected to the neutral point is referred as neutral conductor. (Fig 1)

Fig 1



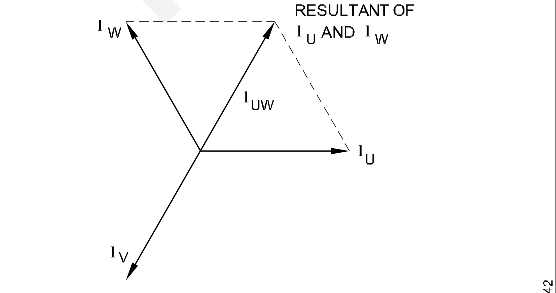
THREE-PHASE SUPPLY AND LOAD

Current in the neutral conductor: In a star-connected, four-wire system, the neutral conductor N must carry the sum of the currents I_U, I_V and I_W. One may, therefore, get the impression that the conductor must have sufficient area to carry a particularly high current. However, this is not the case, because this conductor is required to carry only the phasor sum of the three currents.

I_N = phasor sum of I_U, I_V and I_W

Fig 2 shows this phasor addition for a situation where the loads are balanced and the currents are equal. The result is that the current in the neutral line I_N is zero. This can also be shown for the other instantaneous values.

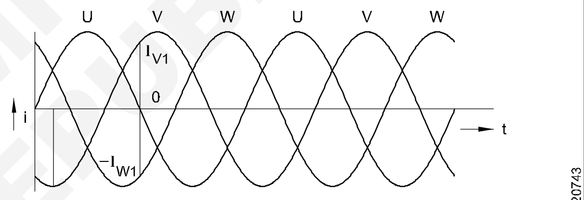
Fig 2



FOR A BALANCED LOAD THE RESULTANT OF I_W AND I_U IS EQUAL IN MAGNITUDE BUT OPPOSITE TO I_V.

At a particular instant in time, t_1, the instantaneous value i_U= 0 (Fig 3), i_V and i_W, have equal magnitudes, but they have opposite signs,i.e. they are in opposition and the phasor sum is zero. Taking the other values of t, it can be seen that the sumof the three phase currents to equal to zero.

Fig 3



RESULTANT OF THREE-PHASE CURRENTS

Therefore, for a balanced load the neutral conductor carries no current.

With unequal value the phase currents are different in magnitude and the neutral current is not zero. Then a `neutral' current I_N does flow in the neutral conductor, but this, however, is less than any of the supply line currents. Thus, neutral conductors, when they are used, have a smaller cross-section than the supply lines.

Effect of imbalance: If the load is not balanced and there is no neutral conductor, there is no return path for the sum of the phase currents which will be zero. The phase voltages will not now be given by the line voltage divided by $\sqrt{3}$, and will have different values.

Earthing of neutral conductor: Supply of electrical energy to commercial and domestic consumers is an important application of three-phase electricity. For `low voltage distribution' - in the simplest case, i.e. supply of light and power to buildings - there are two requirements.

1 It is desirable to use conductors operating at the highest possible voltage but with low current in order to save on expensive conductor material.

2 For safety reasons, the voltage between the conductor and earth must not exceed 250V.

A voltage distribution system according to criterion 2, only possible with a low line voltage below 250 V. However, this is contrary to criterion 1. On the other hand, with a star connection, a line voltage of 415V is available. In this case, there is only 240V between the supply line and the neutral conductor. Criterion 1 is satisfied and, to comply with 2, the neutral conductor is earthed.

Indian Electricity Rules: I.E.Rules insist that the neutral conductor must be earthed by two separate and distinct connections to earth. Rule No.61(1)(a), Rule No.67(1)(a) and Rule No.32 insist on the identification of neutral at the point of commencement of supply at the consumer's premises, and also prevent the use of cut outs or links in the neutral conductor. BIS stipulate the method of earthing the neutral. (Code No.17.4 of IS 3043-1966)

Cross-sectional area of neutral conductor: The neutral conductor in a 3-phase, 4-wire system should have a smaller cross-section. (half of the cross-section of the supply lines).

Artificial neutral: Normally neutral conductors are available with a 3-phase, 4-wire system only. Neutral conductors are not drawn for a 3-phase, 3-wire system. Neutral conductors are also not available with the delta-connected supply system.

A neutral conductor is required for measuring phase voltage, energy, power to connect indicating lamps, etc. An artificial neutral for connecting indicating lamps can be formed by connecting them in star. (Fig 4) Artificial neutral for instruments can be formed by connecting additional resistors in star. (Fig 5)

Fig 4

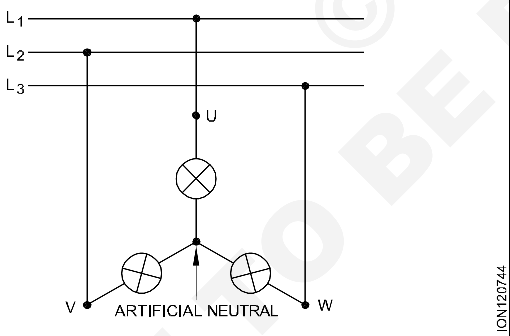
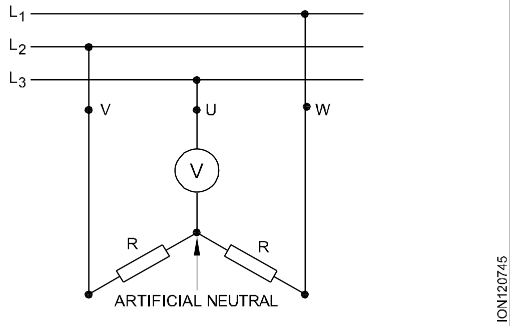


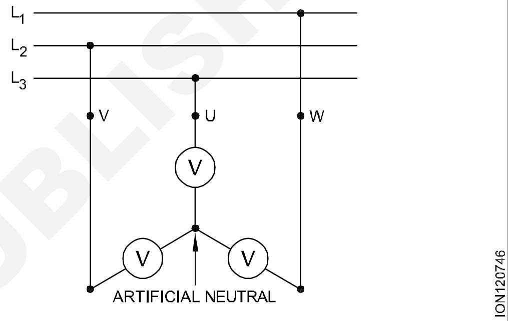
Fig 5



In this method, the value of R must be equal to the resistance of the voltmeter. The same method can be used while measuring power or energy by connecting resistors of equal resistance as of potential coil.

When three instruments of a similar kind are in use, their pressure coils can be connected to form an artificial neutral. (Fig 6)

Fig 6



This type of neutral cannot allow a large current. When earthing of a delta-connected system is required, neutral earthing compensators are used. These can sink or source large currents while keeping neutral to phase voltages constant.

IS 3043 Code No.17, provide a method to obtain neutral for earthing purposes by an earthing compensator.

Power in star and delta connections

Objectives: At the end of this lesson you shall be able to
- **explain active, appparent and reactive power in AC 3 phase ϕ**
- **explain behaviour of unbalanced and balance load**
- **state the method of earthing the neutral**
- **determine the power in 3-phase star and delta connected balanced load.**

Fig 1 shows the load of three resistances in a star connection. So the power must be three times as great as the single phase power.

$$P = 3V_pI_p.$$

If the quantities V_P and I_P in the individual phases are replaced by the corresponding line quantities V_L and I_L respectively, we obtain:

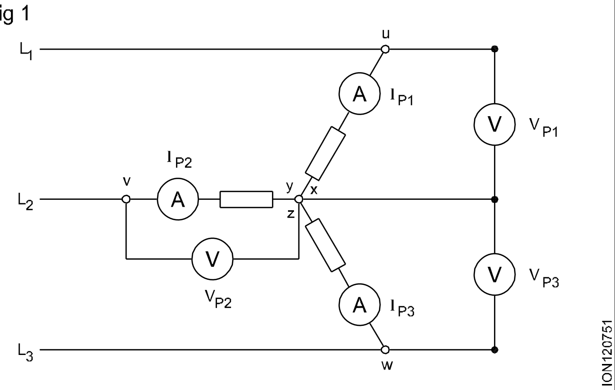
$$P = 3\frac{V_L}{\sqrt{3}}I_L.$$

(Because $V_P = V_L \div \sqrt{3}$ and $I_p = I_L$)

Since $3 = \sqrt{3} \times \sqrt{3}$, this equation can be simplified to the form

$$P = \sqrt{3}\ V_LI_L$$

Fig 1



Note that power factor in resistance circuit is unity. Hence power factor is not taken into account.

Quantity	P	V_L	I_L
Unit	W	V	A

The power in this purely resistive load ($\phi = 0^o$, $\cos\phi = 1$) is entirely active power which is converted into heat. The unit of active power is the watt (W).

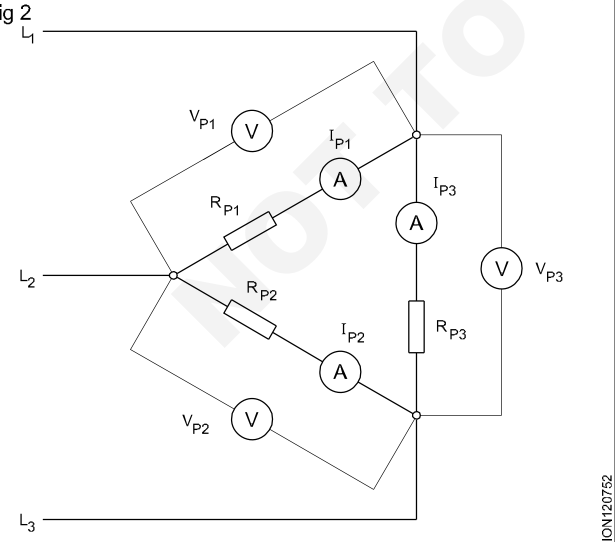
As the last formula shows, three-phase power in a star-connected load circuit can be calculated from the line quantities, and there is no need to measure the phase quantities.

$P = \sqrt{3} \times V \times I$ (Formula holds good for pure resistive load)

It is always possible, in practice, to measure the line quantities but the accessibility of the star point cannot always be guaranteed, and so it is not always possible to measure the phase voltages.

Three-phase power with a delta-connected load: Fig 2 shows the load of three resistances connected in delta. Three times the phase power will be dissipated.

Fig 2



$P = 3P_P = 3V_P I_P$

If the quantities V_P and I_P are replaced by the corresponding line quantities V_L and I_L, we obtain:

Since, $V_L = V_P$

$I_L = \sqrt{3} I_P$ and $I_{P} =$

but since 3 = $\sqrt{3}$ x $\sqrt{3}$, this equation can be simplified to the form:

$P = \sqrt{3} V_L I_L$.(Formula holds good for pure resistive load)

If we compare the two power formulae for the star and delta connections, we see that the same formula applies to both. In other words, the way in which the load is connected has no effect on the formula to be used, assuming that the load is balanced.

Active,reactive and apparent power: As you already know from AC circuit theory, load circuits which contain both resistance and inductance, or both resistance and capacitance, take both active and reactive power because of the phase difference existing between the voltage and current in them. If these two components of power are added geometrically, we obtain the apparent power. Precisely the same happens in each phase of the three-phase systems. Here we have to consider the phase difference between the voltage and current in each phase.

Applying the factor $\sqrt{3}$, the components of power in a three-phase system follow from the formulae derived for single-phase, AC circuits, namely:

Apparent power	S=VI	$S = \sqrt{3} V_L I_L$	VA
Active power	P=VI Cosφ	$P = \sqrt{3} V_L I_L \cos$	W
Reactive power	Q=VI sinφ	$Q = \sqrt{3} V_L I_L \sin$	var

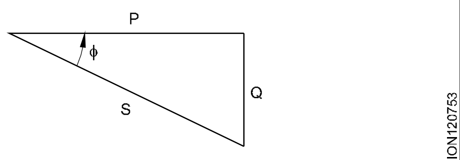
Finally, the well known relationships found in single-phase AC circuits apply also to three-phase circuits.

$$\cos\phi = \frac{\text{activepower}}{\text{apparentpower}} = \frac{P}{S}$$

$$\sin\phi = \frac{\text{reactivepower}}{\text{apparentpower}} = \frac{Q}{S}$$

This can also be seen from Fig 3.

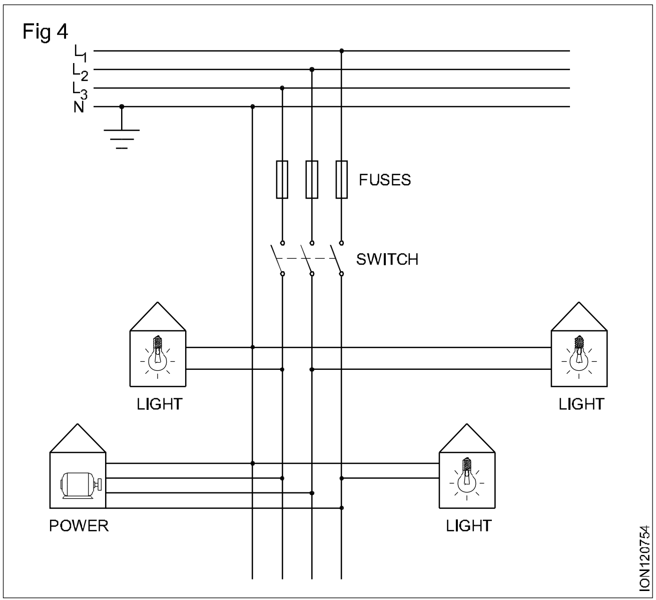
Fig 3



Cos φ is called the power factor, while sin φ is sometimes called the reactive power factor.

Unbalanced load: The most convenient distribution system for electrical energy supply is the 415/240 V four-wire, three-phase AC system.

This offers the possibility of supplying three-phase, as well as single-phase current, to users simultaneously. Supply to buildings can be arranged as in the given example. (Fig 4)



The individual houses utilize one of the phase voltages. L_1, L_2 and L_3 to N are distributed in sequence (light current). However, large loads (eg.three-phase AC motors) may be fed with the line voltage (heavy current).

However, certain equipment which needs single or two phase supply can be connected to the individual phases so that the phases will be differently loaded, and this means that there will be unbalanced loading of the phases of the four-wire, three-phase network.

Balanced load in a star connection: In a star connection, each phase current is determined by the ratio of phase voltage and load impedance `Z'.

This fact will now be confirmed by a numerical example.

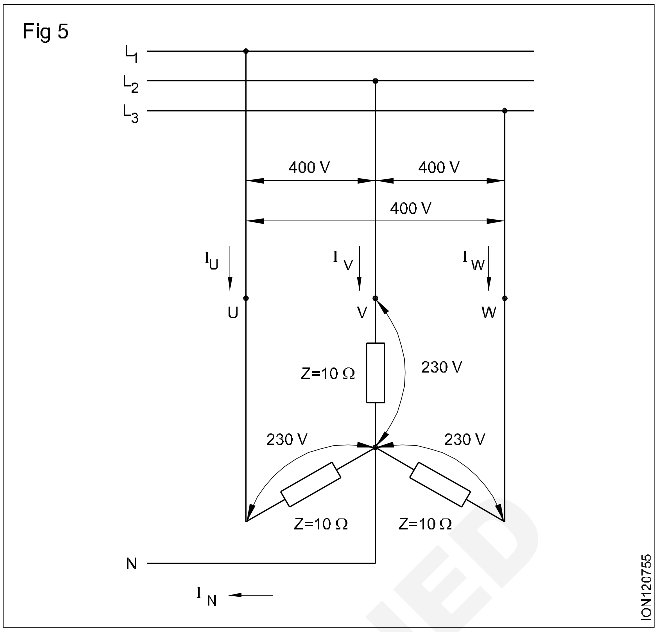
A star-connected load consisting of impedances `Z' each of 10 ohms, is connected to a three-phase network with line voltage V_L = 415V. (Fig 5)

Because of the arrangements of a star connection, the phase voltage is 240V (415/ $\sqrt{3}$).

The three load currents taken froms supply have the same magnitude since the star-connected load is balanced, and they are given by

$$I_U = I_V = I_W = V_P \div Z.$$

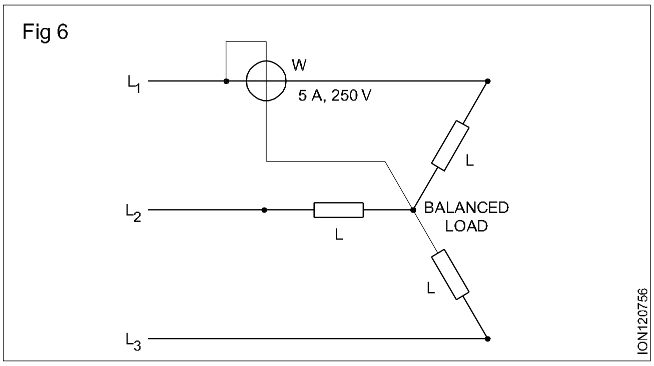
The measurement of power: The number of wattmeters used to obtain power in a three-phase system depends on whether the load is balanced or not, and whether the neutral point, if there is one, is accessible.



- Measurement of power in a a star-connected balanced load with neutral point is possible by a single wattmeter.
- Measurement of power in a star or delta-connected, balanced or unbalanced load (with or without neutral) is possible with two wattmeter method.

Single wattmeter method: Fig 6 shows the circuit diagram to measure the three-phase power of a star-connected, balanced load with the neutral point accessible the current coil of the wattmeter being connected to one line, and the voltage coil between that line and neutral point. The wattmeter reading gives the power per phase. So the total is three times the wattmeter reading.

Power/phase = $3V_P I_P \cos\theta = 3P = 3W$.



The two-wattmeter method of measuring power

Objectives: At the end of this lesson you shall be able to:
- **measure 3-phase power using two single phase wattmeter**
- **calculate power factor from meter reading.**
- **explain the `two-wattmeter' method of measuring power in a three-phase, three-wire system**

Power in a three-phase, three-wire system is normally measured by the `two-wattmeter' method. It may be used with balanced or unbalanced loads, and separate connections to the phases are not required. This method is not, however, used in four-wire systems because current may flow in the fourth wire, if the load is unbalanced and the assumption that $I_U + I_V + I_W = 0$ will not be valid.

The two wattmeters are connected to the supply system as shown in Fig 1. The current coils of the two wattmeters are connected in two of the lines, and the voltage coils are connected from the same two lines to the third line. The total power is then obtained by adding the two readings:

$P_T = P_1 + P_2$.

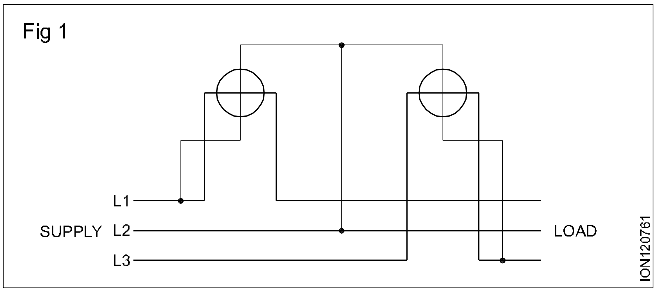


Fig 1

Consider the total instantaneous power in the system $P_T = P_1 + P_2 + P_3$ where P_1, P_2 and P_3 are the instantaneous values of the power in each of the three phases.

$$P_T = V_{UN}\, i_U + V_{VN}\, i_V + V_{WN}\, I_W$$

Since there is no fourth wire, $i_U + i_V + i_W = 0$; $i_V = -(i_U + i_W)$.

$$\begin{aligned} P_T &= V_{UN} i_U - V_{VN}(i_U + i_W) + V_{WN}\, i_W \\ &= i_U(V_{UN} - V_{VN}) + i_W(V_{WN} - V_{UN}) \\ &= i_U V_{UV} + i_W V_{WV} \end{aligned}$$

Now $i_U V_{UV}$ is the instantaneous power in the first wattmeter, and $i_W V_{WV}$ is the instantaneous power in the second wattmeter. Therefore, the total mean power is the sum of the mean powers read by the two wattmeters.

It is possible that with the wattmeters connected correctly, one of them will attempt to read a negative value because of the large phase angle between the voltage and current for that instrument. The current coil or voltage coil must then be reversed and the reading given a negative sign when combined with the other wattmeter readings to obtain the total power.

At unity power factor, the readings of two wattmeter will be equal. Total power = 2 x one wattmeter reading.

When the power factor = 0.5, one of the wattmeter's reading is zero and the other reads total power.

When the power factor is less than 0.5, one of the wattmeters will give negative indication. In order to read the wattmeter, reverse the pressure coil or current coil connection. The wattmeter will then give a positive reading but this must be taken as negative for calculating the total power.

When the power factor is zero, the readings of the two wattmeters are equal but of opposite signs.

Self-evaluation test

- Draw a general wiring diagram for the two-wattmeter method of three-phase power measurement.
- Why is it desirable, in practice, to use the two-wattmeter method? (Fig 2)
- Why can the two-wattmeter method not be used in a three-phase, four-wire system with random loading?
- Which of the above circuits is used for the two-wattmeter method of power measurement?

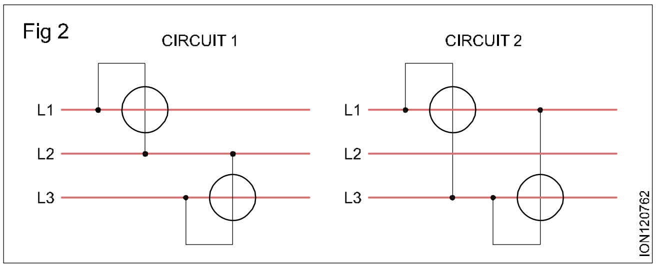


Fig 2

Power factor calculation in the two-watmeter method of measuring power

As you have learnt in the previous lesson, the total power $P_T = P_1 + P_2$ in the two-wattmeter method of measuring power in a 3-phase, 3-wire system.

From the readings obtained from the two wattmeters, the tan f can be calculated from the given formula

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}\,(W_1 - W_2)}{(W_1 + W_2)}$$

from which f and power factor of the load may be found.

Example 1: Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. Find the power factor of the circuit.

Solution

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

$P_1 = 4.5$ KW

$P_2 = 3$ KW

$P_1 + P_2 = 4.5 + 3 = 7.5$ KW

$P_1 - P_2 = 4.5 - 3 = 1.5$ KW

$$\tan\phi = \frac{\sqrt{3} \times 1.5}{7.5} = \frac{\sqrt{3}}{5} = 0.3464$$

$\phi = \tan^{-1} 0.3464 = 19° 6'$

Power factor Cos 19° 6' = 0.95

Example 2: Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. The latter reading is obtained after reversing the connection of the voltage coil of that wattmeter. Find the power factor of the circuit.

Solution

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

$$= \frac{\sqrt{3}(4.5 - (-3))}{(4.5 + (-3))}$$

$$= \frac{\sqrt{3}(4.5 + 3)}{(4.5 - 3)}$$

$$= \frac{\sqrt{3} \times 7.5}{1.5} = \sqrt{3} \text{ x } 5$$

$$= 1.732 \times 5 = 8.66.$$

$\phi = \tan^{-1} 8.66 = 83^\circ 27'$

since power factor (Cos $83^\circ 27'$) = 0.114.

Question 1: The reading on the two wattmeters connected to measure the power input to the three-phase, balanced load are 600W and 300W respectively.

Calculate the total power input and power factor of the load.

Question 2: Two wattmeters connected to measure the power input to a balanced, three-phase load indicate 25KW and 5KW respectively.

Find the power factor of the circuit when (i) both readings are positive and (ii) the latter reading is obtained after reversing the connections of the pressure coil of the wattmeter.

Solution

1 Total power = $P_T = P_1 + P_2$

P_1 = 600W.

P_2 = 300W.

P_T = 600 + 300 = 900 W

$$\tan \phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(600 - 300)}{600 + 300} = \frac{\sqrt{3} \times 300}{900}$$

$$= \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}} = 0.5774$$

$\phi = \tan^{-1} 0.5774 = 30^\circ$

Power factor = Cos 30° = 0.866.

2 a P_1 = 25 KW

P_2 = 5 KW

$$\tan \phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(25 - 5)}{25 + 5}$$

$$= \frac{\sqrt{3} \times 20}{30} = \frac{\sqrt{3} \times 2}{3} = \frac{2}{\sqrt{3}} = 1.1547$$

$\phi = \tan^{-1} 1.1547 = 49^\circ 6'$

Power factor (Cosϕ) = Cos $49^\circ 6'$ = 0.6547

b P_1 = 25 KW

P_2 = –5 KW

$$\tan \phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(25 - (-5))}{25 + (-5)}$$

$$= \frac{\sqrt{3}\ (25 + 5)}{25 - 5} = \frac{\sqrt{3} \times 30}{20}$$

$$= \frac{\sqrt{3} \times 3}{2} = 2.5980$$

$\phi = \tan^{-1} 2.5980 = 68^\circ 57'$

Power factor = Cos $68^\circ 57'$ = 0.3592

Conductors - insulators - wires - types

Objectives: At the end of this lesson you shall be able to
- **differentiate between conducting and insulating materials**
- **state the electrical properties of conducting materials**
- **state the terms used in electrical cables**
- **state the characteristics of copper and aluminium conductors**
- **state the types and propertites of insulating materials**
- **describe the method of measurement of wire size using SWG**
- **explain the method of measure wire size by outside micrometer.**

Conductors and insulators

Material with high electron mobility (many free electrons) are called conductor.

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

Examples - silver, copper, aluminium and most other metals.

Materials with low electron mobility (few (or) no free electron) are called insulators

Materials that have only a few electrons and are incapable of allowing the current to pass through them are known as insulators.

Examples - wood, rubber, PVC, porcelain, mica, dry paper and fibreglass.

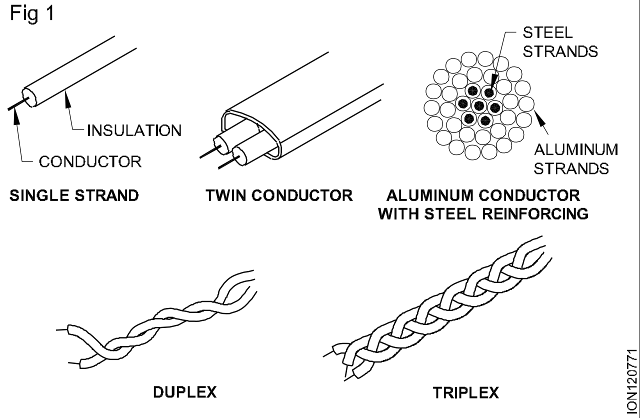
Conductors

The use of conductors and their insulation is regulated by I E regulations and BIS (ISI) code of practice.

The I E regulations and I S cover all 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 are made in a wide variety of forms to suit many different applications. (Fig 1)

Fig 1



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

Current passing through a conductor generates heat. The amount of heat generated depends on the square of the current that passes through the conductor and the resistance of the conductor.

As the heat developed in the conductor depends upon the resistance of 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 upon how much current the conductor can carry without much voltage drop in the line and heat generation in the conductor.

There is a limit to the temperature each kind of insulation can safely withstand and also the type of insulation which can withstand the physical chemical and temperature zones of the surroundings.

BIS (ISI) code specifies 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 in mm or the cross-sectional area. Typical sizes are 1.5 sq.mm, 2.5 sq.mm, 6 sq.mm etc.

Still in India the old method of specifying the diameter by the standard wire gauge number is in use.

Classfication 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 conductors is in overhead electrical transmission and distribution lines. For earthing also bare conductors are used.

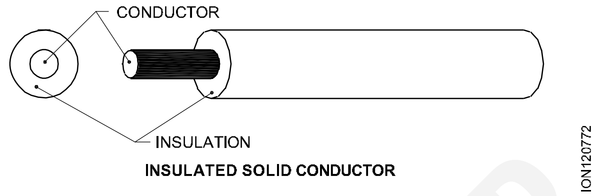
Insulated conductors

They have a coating of insulation. 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.

Solid and stranded conductors

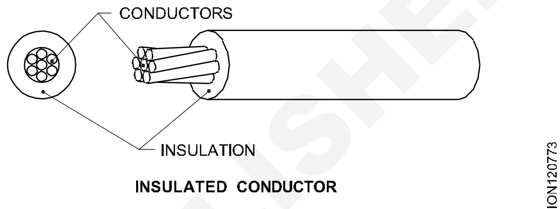
A solid conductor is one in which there will be only one conductor in the core as shown in Fig 2. A stranded conductor is one in which there will be a number of smaller sized conductors twisted to form the core as shown in Fig 3.

Fig 2



INSULATED SOLID CONDUCTOR

Fig 3



INSULATED CONDUCTOR

The number of conductors ranges from 3 to 162 and the conductor size varies from 0.193 mm to 3.75 mm diameter depending upon the current carrying capacity and also upon whether these conductors are used in cables or overhead lines.

Normally stranded conductors are designated as 10 sq. mm cable of size 7/1.40 where 10 sq.mm gives the area of the cross-section, in the size, numerator (7) gives the number of conductors and the denominator 1.40 gives the diameter of the conductor in mm. Alternatively 7/1.40 cable is the same as 7/17 whereas in the latter case the denominator is expressed in Standard Wire Gauge (SWG) number.

Stranded conductors are more flexible and have better mechanical strength. According to recent stipulation, the cable size should be expressed in sq. millimetres or they can be expressed in terms of the number of conductors in the cable and the diameter of the conductor in mm.

Cable

A cable is a length of single, insulated conductor (single or stranded), or two or more such conductors - each provided with its own insulation, and are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

Cable (armoured)

An armoured cable is provided with a wrapping of metal (usually in the form of tape or wire), serving as a mechanical protection.

Cable (flexible)

A flexible cable contains one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.

Core

All cables have one central core or a number of cores of stranded conductors farming high conductivity; generally there are one, two, three, three and half and four cores. Each core is insulated separately and there is overall insulation around the cores.

Wire

A solid substance (conductor) or an insulated conductor (solid or stranded) subjected to tensile stress with or without screen is called a wire.

Copper and aluminium

In electrical work, mostly copper and aluminium are used for conductors. Though silver is a better conductor than copper, it is not used for general work due to higher cost.

Copper used in electrical work is made with a very high degree of purity, say 99.9 percent.

Characteristics of copper

- It has the best conductivity next to silver.
- It has the largest current density per unit area compared to other metals. Hence the volume required to carry a given current is less for a given length.
- It can be drawn into thin wires and sheets.
- It has a high resistance to atmospheric corrosion: hence, it can serve for a long time.
- It can be joined without any special provision to prevent electrolytic action.
- It is durable and has a high scrap value.

Next to copper, aluminium is the metal used for electrical conductors.

Characteristics of aluminium

- It has good conductivity, next to copper. When compared to copper, it has 60.6 percent conductivity. Hence, for the same current capacity, the cross-section for the aluminium wire should be larger than that for the copper wire.
- It is lighter in weight.
- It can be drawn into thin wires and sheets. But loses its tensile strength on reduction of the cross-sectional area.
- A lot of precautions needs to be followed while joining aluminium conductors.
- The melting point of aluminium is low, hence it may get damaged at points of loose connection due to heat developed.
- It is cheaper than copper.

Table 1 shows the properties of copper compared with those of aluminium.

Properties of insulating 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.

Table 1

Chararacteristics of conductor materials

Sl. No.	Properties	Copper (Cu)	Aluminium (Al)
1	Colour	Reddish	White brown
2	Electrical conductivity in MHO/metre	56	35
3	Resistivity at 20°C in ohm/metre (Cross-sectional area in 1 mm^2)	0.01786	0.0287
4	Melting point	1083°C	660°C
5	Density in kg/cm^3	8.93	2.7
6	Temperature coefficient of resistance at 20°C per °C	0.00393	0.00403
7	Coefficient of linear expansion at 20°C per °C	17×10^{-6}	23×10^{-6}
8	Tensile strength in Nw/mm^2	220	70

Insulation resistance

It is the electrical resistance of the insulation against the flow of current. Megohmmeter (Megger) is the instrument used to measure insulation resistance. It measures high resistance values in megohms 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 a breakdown is called the breakdown voltage of the insulation.

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

- high dielectric strength
- resistance to temperature
- flexibility
- mechanical strength.

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

Insulating tapes

Various tapes are used for insulating electrical equipments, conductors and components. Some of these are adhesive. The tapes commonly used include friction, rubber, plastic and varnished cambric tapes.

Rubber tape

Rubber tapes are used for insulating joints. The tape is applied under slight tension. Pressure causes the layers to bend together. Application of this restores insulation but will not be mechanically strong.

Friction tape

This is used over rubber tape insulation. This is made up of cotton cloth impregnated with an adhesive. It does not stretch like the rubber tape. The friction tape does not have insulating qualities of the rubber tape, hence should not be used by itself for insulation.

Plastic tape (PVC tape)

This is used more than the other tapes. PVC tapes have the following advantages.

- High dielectric strength
- Very thin
- Stretches to conform to contours of joints

Varnished cambric tapes

These tapes are made of cloth impregnated with varnish. It usually has no adhesive coating. Available in sheets and rolls and are ideal for insulating motor connecting leads.

Measurement of wire sizes - standard wire gauge - outside micrometer

Objective: At the end of this lesson you shall be able to
- **measure the wire sizes of standard gauge - outside micrometer.**

Necessity of measuring the wire sizes

To execute a wiring job proper planning is necessary. After considering the requirements of the house owner, the electrician prepares a layout plan of the wiring and an estimate of the cost of the wiring materials and labour. A proper estimate involves determination of current in different loads, correct selection of the type of cable, size of the cable and the required quantity. Any error will result in defective wiring, fire accidents and bring unhappiness to both the house owner and the electrician.

While selecting the cable sizes, the electrician has to take into consideration the proposed connected load, future changes in load, the length of the cable run and the permissible voltage drop in the cable.

A sound knowledge about the area of the cross-section of the core, the diameter of the single strand of the conductor and the number of conductors in each core of the stranded conductor is essential for a wireman to be successful in his carreer.

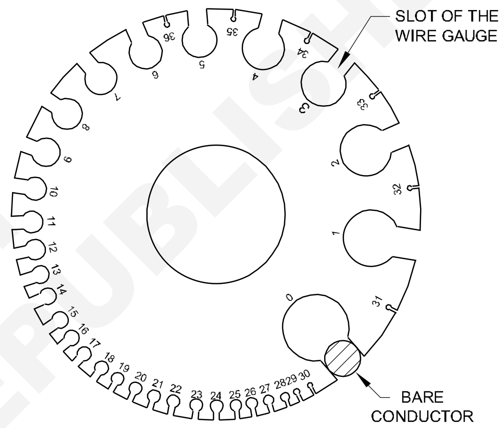
To measure the size of conductors, a electrician can use normally a standard wire gauge or an outside micrometer for more accurate results.

The size of wires are designed more carefully by the manufacturers. Though the Bureau of Indian Standards (BSI) specifies the cables by the area of the cross-section in square millimetres, the manufacturers still produce the cable with the diameter of each wire and number of wires in the stranded cables. Sometimes the indicated size of cable by the manufacturer may not be correct and the electrician has to ascertain the size by measurement.

Standard Wire Gauge (SWG)

The size of the conductor is given by the standard wire gauge number. According to the standards each number has an assigned diameter in inch or mm. This is given in Table 1. The standard wire gauge, shown in Figure 1 could measure the wire size in SWG numbers from 0 to 36. It should be noted that the higher the number of wire gauge the smaller is the diameter of the wire.

Fig 1



STANDARD WIRE GAUGE

For example, SWG No. 0 (zero) is equal to 0.324 inch or 8.23 mm in diameter whereas SWG No.36 is equal to 0.0076 inch or 0.19 mm in diameter.

While measuring the wire, the wire should be cleaned and then inserted into the slot of the wire gauge to determine the SWG number (Fig 2). The slot in which the wire just slides in is the correct slot and the SWG number could be read in the gauge directly. In most of the wire gauges to save the trouble of referring to the table, the wire diameter is inscribed on the reverse of the gauge.

Fig 2

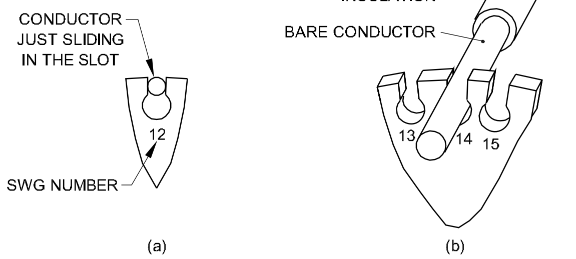


Table 1 - Conversion table SWG to mm/inch

SWG No.	mm	inch
7/0	12.7	0.500
6/0	11.38	0.464
5/0	10.92	0.432
4/0	10.16	0.400
3/0	9.44	0.372
2/0	8.83	0.348
0	8.23	0.324
1	7.62	0.300
2	7.01	0.276
3	6.40	0.252
4	5.89	0.234
5	5.38	0.212
6	4.88	0.192
7	4.47	0.176
8	4.06	0.160
9	3.66	0.144
10	3.25	0.128
11	2.95	0.116
12	2.64	0.104
13	2.34	0.092
14	2.03	0.080
15	1.83	0.072
16	1.63	0.064
17	1.42	0.056
18	1.22	0.048
19	1.02	0.040
20	0.91	0.036
21	0.81	0.032
22	0.71	0.028
23	0.61	0.024
24	0.56	0.022
25	0.51	0.020
26	0.46	0.018
27	0.42	0.0164
28	0.38	0.0148
29	0.34	0.0136
30	0.31	0.0124
31	0.29	0.0116
32	0.27	0.0108
33	0.25	0.0100
34	0.23	0.0092
35	0.21	0.0084
36	0.19	0.0076
37	0.17	0.0068
38	0.15	0.0060
39	0.13	0.0052
40	0.12	0.0048
41	0.11	0.0044
42	0.10	0.0040
43	0.09	0.0036
44	0.08	0.0032
45	0.07	0.0028
46	0.06	0.0024
47	0.05	0.0020
48	0.04	0.0016
49	0.03	0.0012
50	0.02	0.0010

American Wire Gauge (AWG)

The American wire gauge is different from the British standard wire gauge. In an American wire gauge (AWG) the diameter is represented in mils rather than inch or mm. One mil is one thousandth part of an inch. Please note there is no direct conversion from AWG to SWG.

Measurement of wire size by Outside micrometers

A micrometer is a precision instrument used to measure a job, generally within an accuracy of 0.01 mm.

Micrometers used to take the outside measurements are known as outside micrometers. (Fig 3)

The parts of a micrometer

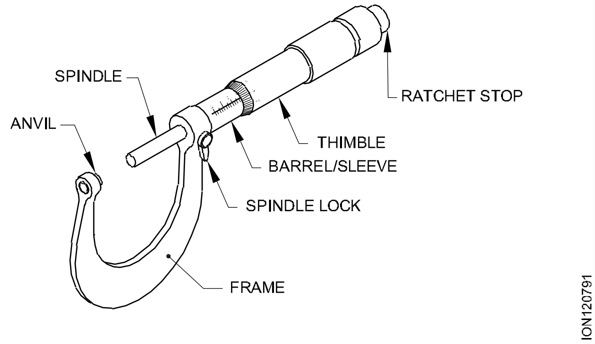
Frame

The frame is made of drop-forged steel or malleable cast iron. All other parts of the micrometer are attached to this.

Barrel/sleeve

The barrel or sleeve is fixed to the frame. The datum line and graduations are marked on this.

Fig 3



Thimble

The thimble is attached to the spindle and on the bevelled surface of the thimble, the graduation is marked.

Spindle

One end of the spindle is the measuring face. The other end is threaded and passes through a nut. The threaded mechanism allows for the forward and backward movement of the spindle.

Anvil

The anvil is one of the measuring faces which is fitted on the micrometer frame. It is made of alloy steel and finished to a perfectly flat surface.

Spindle lock-nut

The spindle lock-nut is used to lock the spindle at a desired position.

Ratchet stop

The ratchet stop ensures a uniform pressure between the measuring surfaces.

Principle of the micrometer

The micrometer works on the principle of screw and nut. The longitudinal movement of the spindle during one rotation is equal to the pitch of the screw. The movement of the spindle to the distance of the pitch or its fractions can be accurately measured on the barrel and thimble.

Graduations

In metric micrometers the pitch of the spindle thread is 0.5 mm.

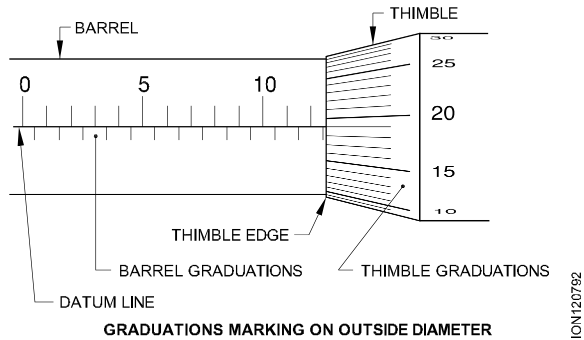
Thereby, in one rotation of the thimble, the spindle advances by 0.5 mm.

In a 0-25 mm outside micrometer, on the barrel a 25 mm long datum line is marked. (Fig 4) This line is further graduated in millimetres and half millimetres (ie. 1 mm & 0.5 mm). The graduations are numbered as 0, 5, 10, 15, 20 & 25 mm on the barrel.

The circumference of the bevel edge of the thimble is graduated into 50 divisions and marked 0-5-10-15... 45-50 in a clockwise direction.

The distance moved by the spindle during one rotation of the thimble is 0.5 mm.

Fig 4



GRADUATIONS MARKING ON OUTSIDE DIAMETER

Movement of one division of the thimble

= 0.5 x 1/50 = 0.01 mm.

This value is called the least count of the micrometer.

The accuracy or least count of a metric outside micrometer is 0.01 mm.

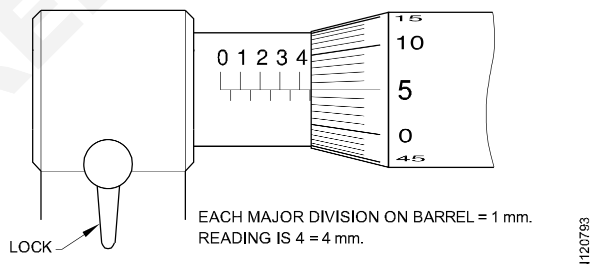
Outside micrometers are available in ranges of 0 to 25 mm, 25 to 50 mm, and so on. For electrician, to read the size of the wire 0 to 25 mm is only suitable.

Reading micrometer measurements

How to read a measurement with an outside micrometer?

a Read on the barrel scale, the number of whole millimetres that are completely visible from the bevel edge of the thimble. It reads 4 mm. (Fig 5)

Fig 5

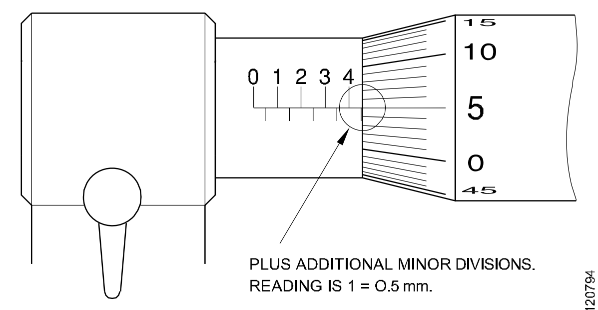


READING MICROMETER MEASUREMENT

b Add to this any half millimetre that is completely visible from the bevel edge of the thimble and away from the whole millimetre reading.

The figure reads one division (Fig 6) mm after the 4 mm mark. Hence 0.5 mm to be added to the previous reading.

Fig 6



THIMBLE READING ON MICROMETER

c Add the thimble reading to the two earlier readings.

The figure shows the 5th division of the thimble is coinciding with the datum line of the barrel. Therefore, the reading of the thimble is 5 x 0.01 mm = 0.05 mm. (Fig 7)

The total reading of the micrometer.

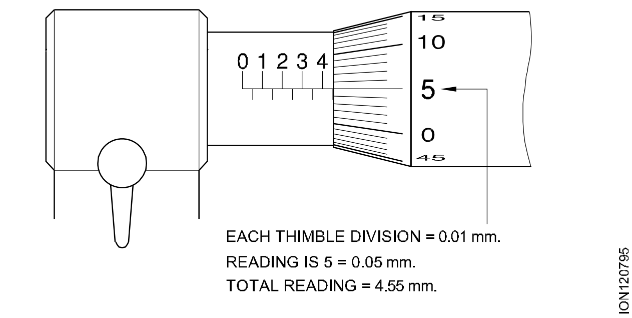
a 4.00 mm

b 0.50 mm

c 0.05 mm.

Total reading = 4.55 mm (Fig 7)

Fig 7



Precautions to be followed while using a micrometer

Before using the micrometer for measurement, it is necessary to ascertain that there is no error in the micrometer. To find the error, close the jaws of the measuring surfaces using the ratchet. Read the micrometer. If the thimble zero is coincident with the datum line of the barrel, error is zero. If it reads higher value, the error is +ve; if it reads lesser value the difference between zero and the read value is -ve error.

If there is minus error it should be added to the total reading and if there is plus error the value should be subtracted from the total reading.

The faces of the anvil and spindle must be free from dust, dirt and grease.

While reading the micrometer, the spindle must be locked with the reading.

Do not drop or handle the micrometer roughly.

Skinning and tinning of wires

Objectives: At the end of this lesson you shall be

- **define a wires and distinguish between single strand and multistrand wires**
- **define skinning**
- **state the meaning of soldering, list two main types and uses of soldering**
- **state the need of soldering in electrical/electronic circuits**
- **state the meaning of solder and types**
- **explain the purpose of using flux while soldering**
- **state the meaning of tinning**
- **explain the need for inspecting a tinned/soldered point.**

Wires

Any metallic conductor drawn (a process of pulling) in the form of a thin solid cylindrical string, is called an electrical wire. Wires are used as a medium for carrying current from one point to another point in an electrical/electronic circuit as shown in Fig 1a.

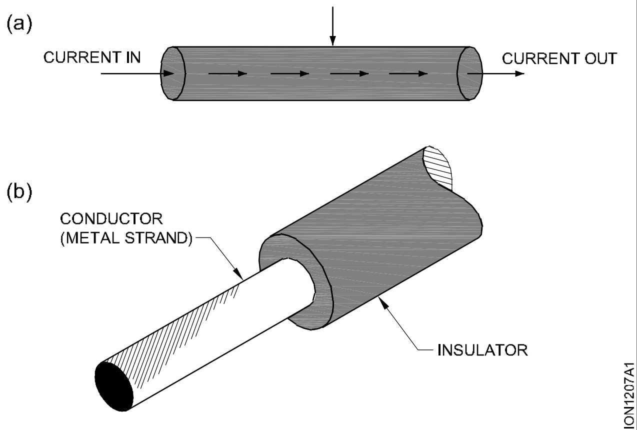
All wires have at least one metal strand which is able to conduct electricity. This is known as the conductor. This conductor is generally surrounded by a material which does not conduct electricity as shown in Fig 1b.

Conductors used in wires are invariably made of good to very good conductor materials like aluminum, copper. This is because electrical wires are intended to carry current with minimum opposition or resistance.

Single Strand Wires

If the conductor of a wire is a single strand of metal, then the wire is known as a **single strand wire**, commonly called **hook-up wire**. These wires are commonly used for jumpering, experimental circuit wiring of electronic circuits.

Fig 1



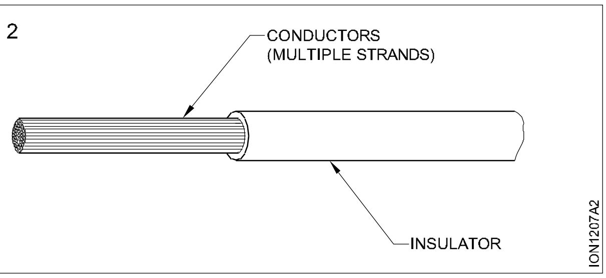
Multistrand wires

If the wire consists of several strands of metal as shown in Fig 2, then the wire is known as **Multi-strand wire**.

Some of the advantages of multistrand wires over single strand wire are listed below;

- More flexible and hence can be routed in any direction more easily.

Fig 2



- More rugged and hence are less likely to cut when bend.
- Can carry more current when compared to a single strand conductor of same dimension.
- More suitable for high frequency application due to reduce skin effect (discussed later)
- Better cooling due to air gap between strands.
- Cancellation of the effect of magnetic field.

Because of the above advantages, multistrand wires are used extensively in electronic circuit connections.

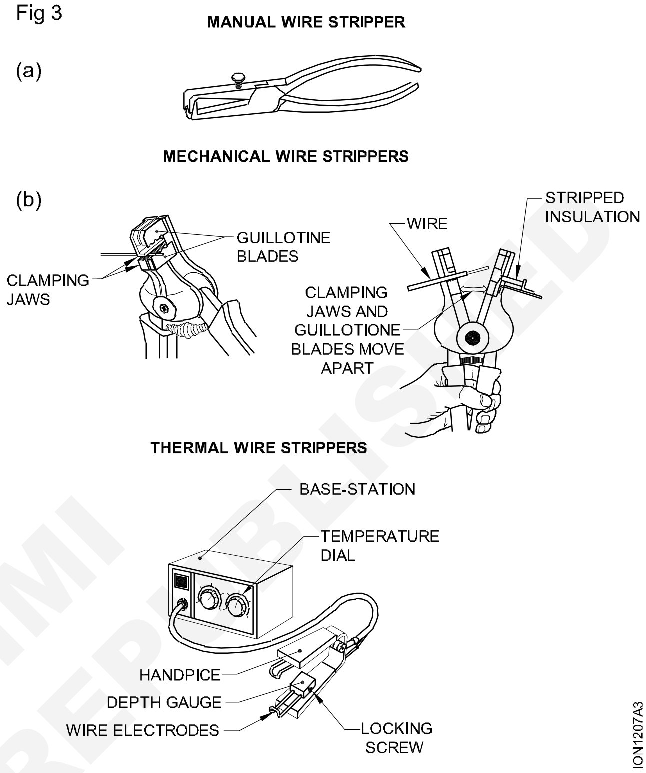
Skinning of wire

To use wires in constructing electrical or electronic circuits, a small portion of insulation at the ends of the wire is to be removed. The process of removing a required length of wire end insulation is called SKINNING of wires. There are several methods and tools to do skinning. The simplest of all these methods is skinning using a knife.

Skinning of wires using a knife is most suitable for single strand wires or multi strand wires with thick strands and thick insulation. This method is not advised to be used for skinning multi-strand wires with thin strands as the strands may get cut while skinning.

Special skinning tools are available for skinning flexible multi-stand wires. The most common of them is the manual wire stripper as shown in Fig 3a. A manual wire stripper is the cheapest of the stripping tools and does good stripping work if one practices with it. A few other types of wire strippers are shown in Fig 3b.

Fig 3



Skinning of cables

Objective: At the end of this lesson you shall be able to
- **state the method of skinning of cable.**

The installation technique for aluminium cables is the same as that for copper cables. Certain additional precautions are necessary as aluminium has low mechanical strength, less current carrying capacity for the same area of cross-section, low melting point, and is quicker in forming oxides on the surface than copper.

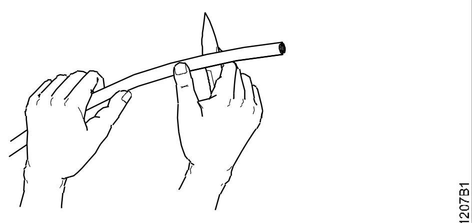
Accordingly, while, using aluminium cables proper care is to be taken regarding the following.

- Handling
- Skinning of the cables
- Connecting the cable ends

Handling: Remember that aluminium conductors when compared to copper conductors have less tensile strength and less resistance to fatigue. As such, bending or twisting of aluminium conductors while laying the cables should be avoided as far as possible.

Skinning of cables: While skinning the insulation from the cables, knicks and scratches should be avoided. As shown in Fig 1, the insulation should not be ringed as there is a danger of nicking the aluminium conductor while ringing the insulation with a knife.

Fig 1



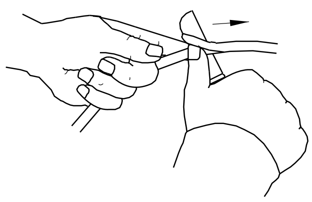
WRONG METHOD

Using the knife as shown in Fig 2 at an angle of 20° to the axis of the core will avoid knicking of the conductor.

Connecting the cable ends

The following problems are encountered while connecting aluminium cables to the accessories.

Fig 2



RIGHT METHOD

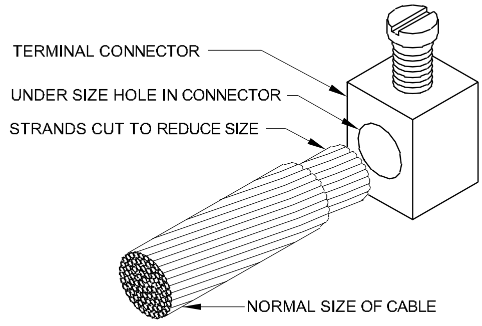
ION1207B2

The termination holes in the accessories may be undersized.

This normally happens in old accessories as they are designed for copper cable ends. Hence, while selecting accessories, a thorough check is necessary of all accessories to ensure whether the holes in the terminating connectors as shown in Fig 4 are suitable to accommodate the specified aluminium conductors. In any case, the strands should not be cut or the conductor filed as shown in Fig 3 to enable insertion in the undersized hole as this operation results in the heating of the cable end on load condition.

Joints in electrical conductors are necessary to extend the cables, overhead lines, and also to tap the electricity to other branch loads wherever required.

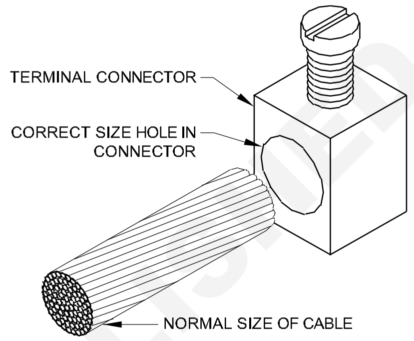
Fig 3



WRONG METHOD

ION1207B3

Fig 4



RIGHT METHOD

ION1207B4

Cable end termination - crimping tool

Objectives: At the end of this lesson you shall be able to:
- **state the necessity of proper termination**
- **list the different types of terminations**
- **describe the parts and their functions of crimping tool**
- **state the advantages of crimping termination.**

Necessity of termination

Cables are terminated at electrical appliances, accessories and equipment etc. for providing electrical connections. All terminations must be made to provide good electrical continuity, and made in such a manner as to prevent contact with other metallic parts and other cables.

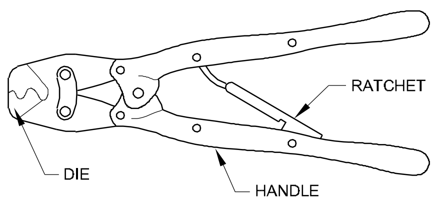
Loose terminations will lead to overheating of cables, plugs and other connecting points due to higher resistance at those terminations. Fires may also be started due to the excess heat. Wrong termination like excess or extended conductor touching metallic part of the equipment may lead to giving shock to the person who comes in contact with the equipment.

Touching of strands projecting from one terminal with other terminal leads to short circuit. To conclude, we can state that wrong termination will lead to overheating of terminating points and cables, short circuits and earth leakage.

Types of termination

Crimp connection: In this type of connection the conductor is inserted into a crimp terminal and is then crimped with a crimping tool (Fig 1).

Fig 1

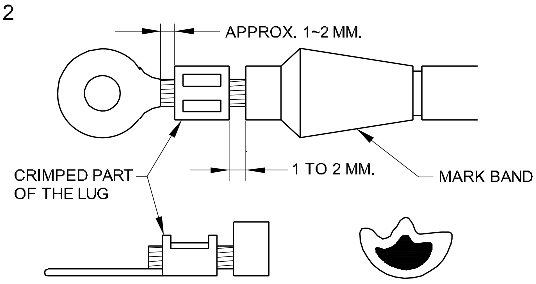


CRIMPING TOOL

ION1207C1

It is important to choose a crimp terminal that matches the conductor diameter and the dimensions of the connecting screw terminal. (Figs 2 and 3)

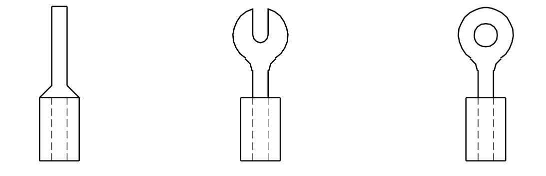
Fig 2



CRIMP TERMINAL CONNECTION

ION1207C2

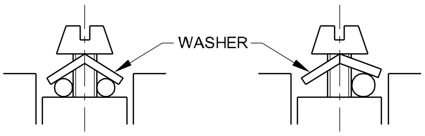
Fig 3



VARIOUS KINDS OF CRIMP TERMINALS

Insert screw setting: The conductor is inserted between the terminal block and the special form of washer (Fig 4), and then the screw is tightened.

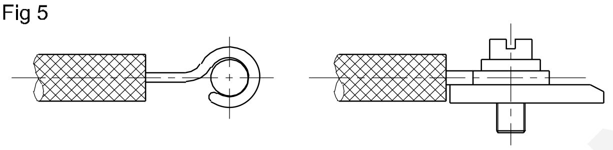
Fig 4



INSERT AND SCREW SETTING

Screw on terminals with loop/ring conductor: A loop is formed clockwise in the bare portion of the conductor to match the size of the screw diameter. Then the loop is inserted to the screw and tightened. (Fig 5) In the case of a stranded conductor, soldering of the loop is essential to prevent strands getting fray.

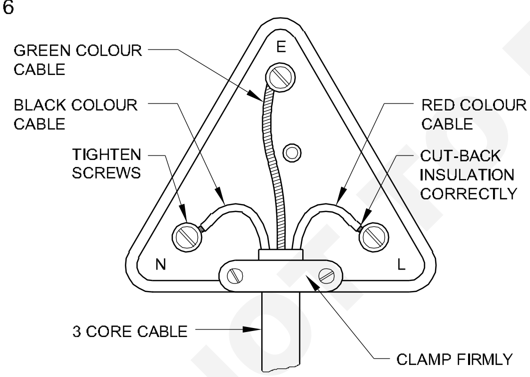
Fig 5



RING MAKE-UP SCREW SETTING

While connecting the plug and socket for extension of the cable, Line (L), the Neutral (N) and Earth (E) terminals must be properly identified by markings on them .(Fig 6)

Fig 6



INSIDE VIEW OF A 3-PIN PLUG

The colour code while connecting 3 core cable must be properly followed. Red wire to L, black/blue to N, green wire or yellow with green line to E terminal. The earth terminal in a 3 pin plug is bigger than the other two.

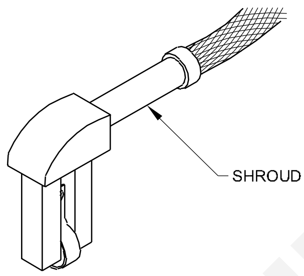
Connections and terminals

There is an electrical fire risk if:

- the current-carrying capacity of the cable is inadequate
- the capacity of the plug is inadequate
- the insulation is cut back too far
- the conductor is damaged while cutting back the insulation
- the connections are not right
- the cable is not adequately supported at the point of entry to the plug or to the appliance.

When a reinforcing rubber shroud is provided, ensure that it is used. (Fig 7)

Fig 7



Crimping and crimping tool

The ends of cables can be prepared for termination with lugs by the soldering process or by mechanical means - compression or crimp fitting.

In crimp compression fitting, a ring-tongued terminal (lug) is to be compressed to the bared end of an insulated multi-strand cable. The process is called crimping and the tool used is called crimping pliers or crimping tool.

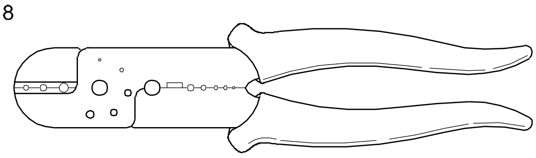
Compression type connectors apply and maintain pressure by compressing the connector around the conductor.

The principal purpose of the pressure is to establish and maintain suitable low contact resistance between the contact surfaces of the conductor. Improper crimping will create increased contact resistance and will cause overheating while carrying electrical load.

Crimping tools

The crimping pliers illustrated in Fig 8 is of a type which crimps from 0.5 to 6 mm cables.

Fig 8



HAND CRIMPING PLIERS

The tool is operated by squeezing the handles. The jaws move together, grip and then crimp the fitting. Using the crimping tool that matches the specific crimp lug will give the correct crimping force for a properly executed crimp. Properly executed crimp will indent the top of the lug and the indentation will hold the conductor securely as shown in Fig 9.

If the terminal has too deep a crimp, the strength of the joint is reduced. With too shallow a crimp, the electrical contact has a high resistance. Selection of the correct crimping tool is essential. A properly crimped terminal is shown in Fig 10.

Fig 9

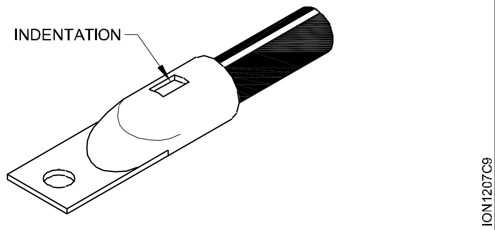
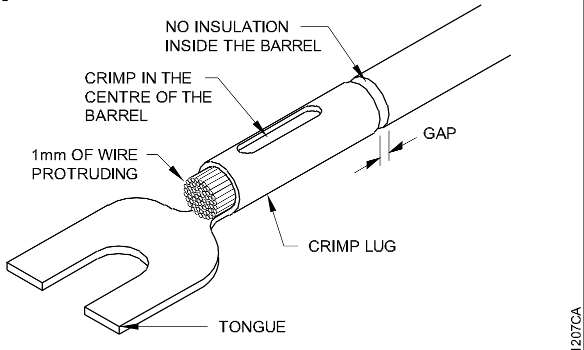


Fig 10

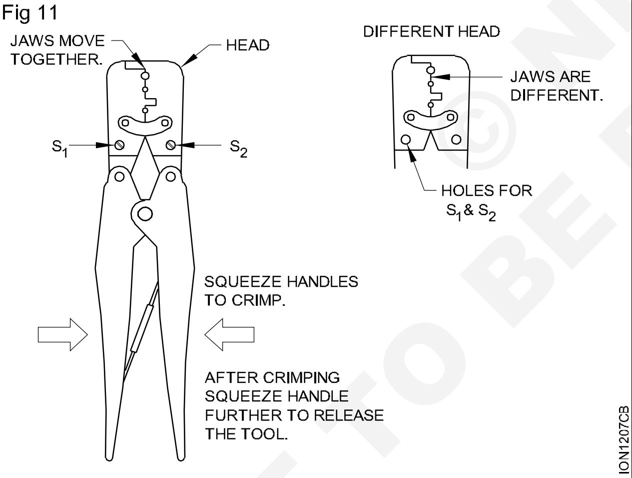


A PROPERLY CRIMPED TERMINAL

Terminal lug crimping pliers are available in lengths ranging from 180 to 300 mm. Crimping tools are available in sets. For higher capacity cables crimping tools are operated by hydraulic force.

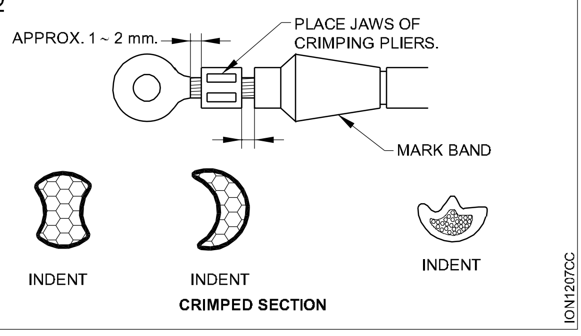
Fig 11 shows another type of crimping tool which crimps from 26 to 10 SWG.

Fig 11



The head and jaws, may be removed, by unscrewing the screws S_1 and S_2. A head with different shaped jaws may then be secured to the tool. The shape of the jaws determines the shape of the crimp (indent). Some crimp sections are shown in Fig 12.

Fig 12



Safety

When using this type of crimping tool care must be taken not to trap the finger, as the operating cycle of the tool is non-reversible i.e. once the handles are squeezed together the jaws can only be released by applying further pressure to the handles as shown in Fig 11.

Terminal types

It is important to consider both the mechanical and electrical requirements when selecting a lug connector.

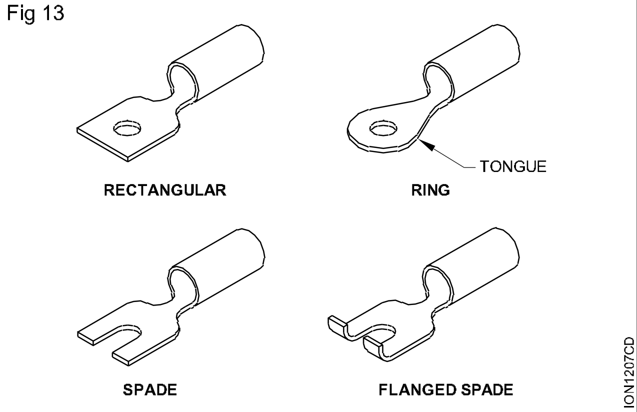
The factors are:

- the type of tongue, i.e. rectangular, ring, spade, etc.
- the mechanical size, i.e. tongue size and thickness, hole size etc. for the cable selected
- the electrical considerations such as the current carrying capacity, that may also determine some of the mechanical dimensions.

The electrical and mechanical requirements for the lug and the base material of the lug are decided by the cable material, and the place of connection will determine the minimum tongue size and the barrel size. The most commonly used base materials are copper and brass. Nickel, aluminium and steel are also used, but less frequently.

Fig 13 shows some lug connectors normally used in practice terminals. They are ring, rectangular, spade, flanged spade etc. Ring and rectangular terminals are not intended for frequent removal to disconnect the terminal whereas in spade and flanged spade lugs (terminals) the screw need not be removed to disconnect.

Fig 13



Precautions for crimping tool application

Do not handle the job/tool roughly e.g. drop, hammer, etc. which may harm the tool.

Do not alter the crimping tool, e.g. alter the shape of the die etc.

Do not let metal chips adhere to the working position of the tool, particularly on the lower surface of replaceable die on the crimping part.

If a pin, spring, etc. is found damaged in the crimping tool, repair it immediately.

Apply oxide inhibiting grease to the aluminium conductor end just before crimping.

Advantages of crimping terminations

- A properly made crimp is better in electrical conductivity and mechanical strength.
- Less costly.
- When the same size cables are to be terminated through lug connectors, the crimping process is faster than soldering.
- The crimping operation surely needs good skill but soldering operation needs advanced skills.
- Heat generated in the conductor sometimes melts the solder and the connection is open circuited. But crimped connection will not open that easily.

Current carrying capacity of copper & aluminium cables - voltage grading

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

- **list out the factors for selection of cables**
- **state the types of protection based on current carrying capacity**
- **state the size and number of strands available in copper and aluminium cables and their current carrying capacity**
- **state the rating factor and determine the current capacity of cables with respect to temperature**
- **differentiate between solid and stranded conductors.**

Selection of cables

The current carrying capacity of a particular area of cross-section cable depends upon the following factors.

- Type of conductors (metal)
- Type of insulation
- Cable run in conduit or in open surface
- Single or three phase circuit
- Type of protection - coarse or close excess current protection
- Ambient temperature
- Number of cables in bunches
- Length of circuit (permissible voltage drop) - this will be discussed at a later stage.

Depending upon the above factors the current rating of cables may vary to a great extent.

Information in this lesson will enable the wireman to select the correct cable under normal working conditions.

Current rating of cables based on type of protection

Cables insulated with PVC, may sustain serious damage when subjected, even for relatively short periods, to higher temperature than the temperature permissible for continuous operation.

Therefore, current ratings of cables insulated with PVC are determined not only by the maximum conductor temperature admissible for continuous rating but also by the temperature likely to be attained under conditions of excess current.

Hence, the current rating of cables are given under two headings:

- cables provided with coarse excess current protection
- cables provided with close excess current protection.

Coarse excess current protection

In this type of protection, circuit protection will not operate within four hours at 1.5 times the designed load current of the circuit which it protects.

The devices affording coarse excess current protection include:

- fuses which are having a fusing factor exceeding 1.5 times the marked rating.
- carriers and bases used in rewirable type electrical fuses.

Close excess current protection

In this type of protection the circuit protection will operate within four hours at 1.5 times the designed load current of the circuit which it protects.

Devices include:

- fuses fitted with fuse links having fusing factor not exceeding 1.5 times the marked rating (H R C & cartridge etc.)
- miniature and moulded case circuit breakers.
- circuit breakers set to operate at an overload not exceeding 1.5 times the designed load current of the circuit.

Electrical inspectors, who are assigned by the Government to test installation and give permission for effecting supply, now recommend close excess current protection devices like MCB and HRC fuses to be included in the circuit for safety to the user and to reduce fire accidents.

Rating factor with respect to protection

For circuits with coarse excess current protection (rewirable fuse unit) current rating of cables is given in Table 1. Though the cables can carry a higher value of current than the current notified in the Table 1, for circuits having coarse excess current protection, the permissible current in cables is obtained by multiplying the normal current capacity by a rating factor of 0.81, whereas for circuits protected by close current protection the normal current capacity is multiplied by a rating factor of 1.23.

The following example will clarify the above information.

Normal current carrying capacity of 1.5 sq mm copper cable = 16 amps (normal rating)

Current capacity of the same cable when protected by coarse excess current protection (Rating factor 0.81)

= Normal capacity x Rating factor

= 16 x 0.81 = 13 amps.

Close excess current protection (Rating factor 1.23)

= Normal capacity x Rating factor

= 16 x 1.23 = 19.7 = 20 amps.

Current capacity for close excess current protection could be obtained by the following formula also.

$$= \frac{\text{Coarse excess current protection rating}}{\text{Rating factor of coarse protection}} \times \text{Rating factor of close excess current protection}$$

Table 1

Current rating for single core PVC insulated sheathed copper and aluminium conductor cables of size 1 to 50 sq. mm at ambient temperature of 40°c (Refer to IS 694 Part I -1964). (Cables provided with coarse excess current protection.)

Nominal cross-sectional area	**Number and diameter of wires**	**Bunched and enclosed in conduit or trunking**			
		2 cables single phase AC or DC		**3 or 4 cables 3-phase AC**	
mm^2	Number of strands/ dia, in mm	Copper Amps.	Aluminium Amps.	Copper Amps.	Aluminium Amps.
1	1/1.12	11	–	9	–
1.5	1/1.40	13	8	11	7
2.5	1/1.80	18	11	16	10
4	1/2.24	24	15	20	13
6	1/2.80	31	19	25	16
10	1/1.40	42	26	35	22
16	7/1.70	57	36	48	30
25	7/2.24	71	45	60	38
35	7/2.50	91	55	77	47
50	19/1.80	120	69	100	59

Rating factor for ambient temperature

Further the current rating of cables is greatly affected by the ambient temperature. As such if the ambient temperature is other than 40°C the current rating shown in the above table should be multiplied by the rating factor given in Table 2.

Table 2

SL. No.	Ambient Temp. °C Rating factor for cables	25	30	35	40	45	50	55	60	65
1	Having coarse excess current protection	1.09	1.06	1.03	1.00	0.97	0.94	0.82	0.67	0.46
2	Having close excess current protection	1.22	1.15	1.08	1.00	0.91	0.82	0.70	0.57	0.40
3	Flexible cords	--	1.09	1.04	1.00	0.95	0.77	0.54	--	–

Example 1

Find the current rating of 2.5 sq mm, aluminium cable at 50°C. The circuit is single phase AC, protected by rewirable fuses and the cable is run in conduit.

Solution

The protection is coarse excess current protection. Hence referring to Table 1 the current rating of 2.5 sq mm aluminium cable at 40°C is = 11 amps.

Rating factor at 50°C referring to Table 2 = 0.94.

The current rating of 2.5 sq.mm aluminium cable protected by coarse excess current protection run in conduit and at ambient temperature of 50°C = 11 x 0.94 = 10 amps.

Example 2

Find the current rating of 4 sq mm copper cable at 60°C, when used in a 3-phase circuit and the circuit is protected by H R C fuses.

Solution

The protection is close excess current protection.

Referring to Table 1, the current rating of 4 sq. mm copper cable for coarse excess current protection (rewirable fuse) at 40°C, when used in 3 phase circuit is = 20 amps

Current rating for closed excess current protection at 40°C when used in 3-phase circuit =(20 x 1.23)/0.81 = 30.37 amps.

The rating factor at 60°C is (Referring to Table 2) = 0.57.

Hence, the current rating of 4 sq. mm copper cable in a circuit protected by close excess current protection at an ambient temperature of 60°C is = 30.37 x 0.57

= 17.31 amps

= say 17 amps.

Current rating of flexible cables is given in Table 3.

Advantages of stranded conductors over solid conductors

As stranded conductors are more flexible, chances of break of conductors and crack of insulation at the bend is less. They can be easily handled and laid.

Table 3

Current ratings for copper conductor flexible cords, insulated with PVC according to BIS No.694

Nominal cross-sectional area of conductor mm^2	Number and diameter of wires Number/mm	Current rating DC, single phase or 3-phase AC (Amperes)
0.50	16/0.20	4
0.75	24/0.20	7
1.00	32/0.20	11
1.50	48/0.20	14
2.50	80/0.20	19
4.00	128/0.20	26

Connections and joints of stranded conductors are stronger and have longer life.

Comparison between solid and stranded conductors

Solid conductor	Stranded conductor
Rigid.	Flexible.
Less mechanical strength. strength	More mechanical
Available in square,round and flat shapes.	Available in round shape having small diameters.
Used for bus-bars and in the winding of large capacity transformers.	Used for cables and wires.

In stranded conductors the insulation has a better grip on the wire.

Solid conductors between supports of overhead lines may break due to vibration. This breakage is less in stranded conductors.

The space between the strands permits flow of oil in U G cables enabling better insulation properties and cooling.

For a given area of cross- section stranded cables carry more current than solid conductors.

Table 4 shows the various types of cables.

Classification of voltage grading

Voltage is classified as

- Low voltage (L.V): Normally not exceeding 250V (i.e.) from 0 to 250 volts.
- Medium voltage (M.V): Exceeding 250V but not exceeding 650V from 250 to 650 volts
- High voltage (H.V): Exceeding 650V but not exceeding 33000V.(650-33000 volts)
- Extra high voltage: All voltages above 33000V comes under this category.

TABLE 4

Various types of electrical cables

Type of code	Voltage grade	Range of cross section in (mm^2)	Application	B.I.S. applicable
A.Wiring cable				
1 PVC insulated a)non-sheathed single core	250/440,650/ 1100	1.5 to 50	Domestic/industrial wiring in conduits. Domestic/industrial wiring in batten.	694 part II
b) PVC sheathed				
i) single core	-do-	-do-	-do-	
ii) flat twin-core	-do-	1.5 to 16	Domestic wiring for power plug.	
iii) flat twin-core ECC and 3-core	250/440	1.5 to 50	Domestic/industrial wiring on batten.	
iv) circular 2,3 or 4 core	650/1100V	1.5 to 300	Sub-main/industrial.	
c)non-sheathed single core and twisted twin flexible copper	250/400 650/1100	4 to 5	Temporary wiring interconnections, household applicances.	694 part I 694 part I&II
d)PVC sheathed circular twin, 3 and 4 core flexible copper	-do-	-do-		
e)Single extrusion	-do-	1.5 to 50	Domestic wiring on batten	694 part I,II
2 Polythene insulated and PVC sheathed with aluminium conductor a) single core flat & circular twin core	250/440	1.5 to 50	Domestic wiring on batten	1596
b) flat twin with ECC & circular	-do-	1.5 to 10	-do-	1596
3 Lead alloy sheathed i) single core ii) 2,3 and 4-core circular iii) twin & 3 core flat (ECC) 250/440	250/440 650/1100	Aluminium Copper 1.5 to 50 1.5 to 50 70 to 625 64.5 to 645 1.5 to 16 1.5 to 16 corrosive atmosphere.	Industrial wiring in damp	434 part I,II

Type of code	Voltage grade	Range of cross section in (mm^2)	Application	B.I.S. applicable
4 TRS sheathed i) single core ii) 2,3 and 4-core circular iii) Twin & 3 core flat (ECC) e) TRS sheathed flexible f) Fire resisting asbestos sheathed g) Poly Phropene sheathed flexible	 -do- -do- 250/440 650/1100 -do- -do-	 1.5 to 50 0.5 to 50 1.5 to 625 64.5 to 645 1.5 to 16 1.5 to 16	 Wiring residential on batten,industrial wiring Residential batten Welding cables in fire hazards. Training cable for lifts and other mobile equipments	 434 part I,II -do- -do- -do-
5 Weather-proof cables a)VIR insulated cotton, braided and treated with weather resistance compound b)PVC insulated PVC sheathed c)Polythene insulated, taped braided and compounded	250/440 650/1100 -do- -do-	1.50 to 50 -do- -do-	 Service connection and other outdoor application.	 434 part I,II 3035 part I 3035 part II
6 Power cables heavy duty 1.1kV grade PVC insulated PVC sheathed cable a)Unarmoured/armoured i) Single core ii) Twin core iii) Three-core iv) Three and a half core v) Four core	 650/1100 650/1100 -do- -do- -do-	 1.5 to 1000 1.5 to 500 1.5 to 400 16 to 400 1.5 to 50	 Armoured cable in singlecore not available. Unarmoured power cables are used only in protected places. Use of copper is banned for such applications	 1554 Part I/76
7 Paper insulated, lead, covered, single core, unarmoured. a) Twin-core, armoured b) Three and three and half, armoured.	1.1kV -do- -do- -do-	6 to 625 6 to 625 -do- -do- -do- -do- -do- -do-	Dry places, heavy duty, hazardous applications underground. Dry places for cotton braided, otherwise metal sheathed.	692-73 693-1965
8 Varnished cambric insulated	-do-			

N.B. 1 Where material of core is not mentioned, it is aluminium.
2 ECC - Earth continuity conductor.

Resistors - Types of resistors, their construction & specific use, color coding, power rating

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

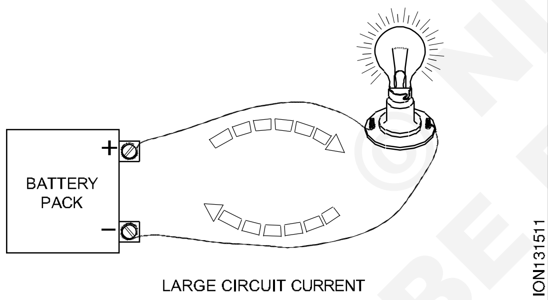
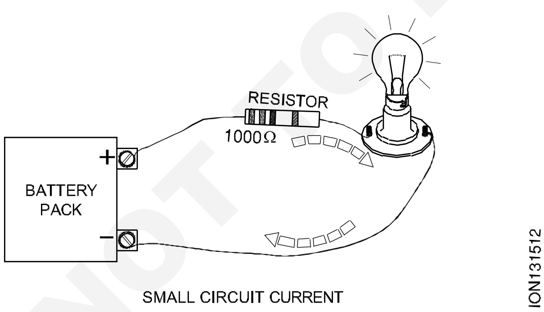


Fig 2



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

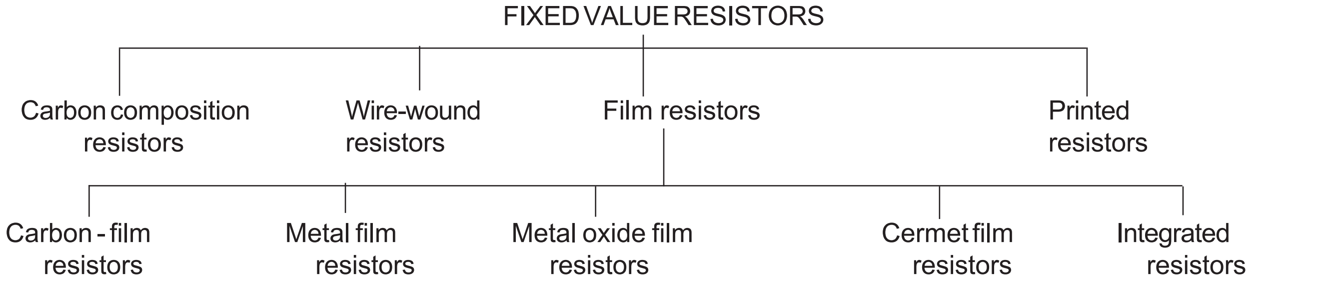
Its ohmic value is fixed. This value cannot be changed by the user. Resistors of standard fixed values are manufactured for use in majority of applications.

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.

Physical appearance of some types of fixed value resistors is shown in Chart 1 at the end of this lesson.

Chart 1

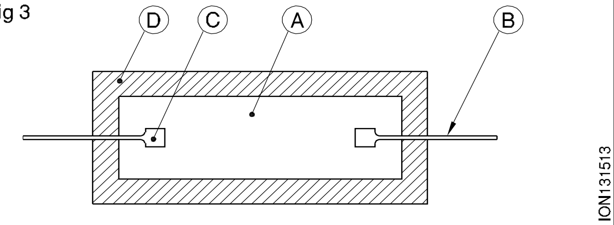


Carbon Composition Resistors

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.

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.

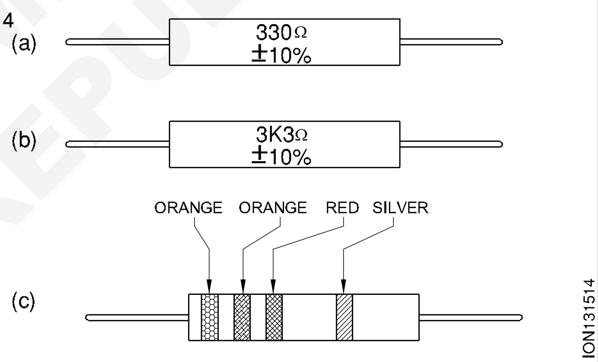
Hence, before using a resistor, in addition to its ohmic value, it is important to choose the correct wattage rating. If in doubt, choose a higher wattage resistor but never on the lower side. The power rating of resistors are generally printed on the body of the resistor.

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.

Fig 4



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.

Typographical 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.

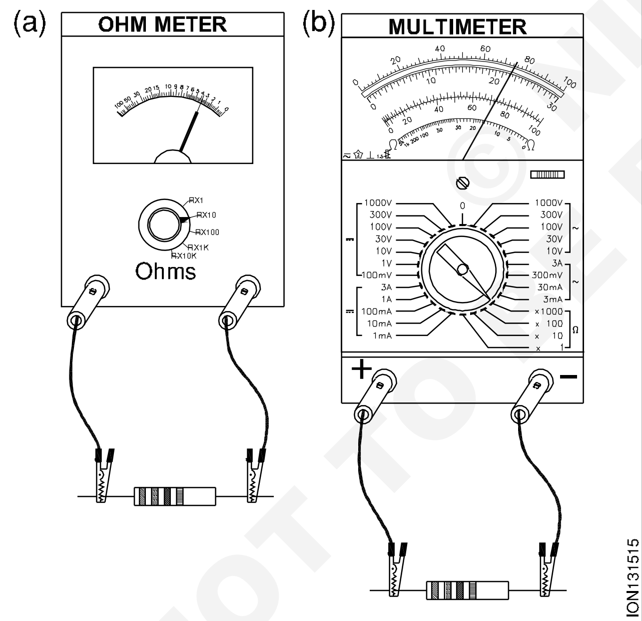
Applications

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.

Fig 5



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.

Wire-wound Resistors

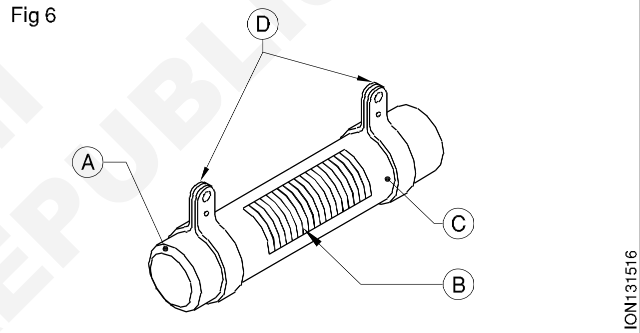
Resistors, in addition to having a required ohmic value, should also be capable of dissipating the heat produced. Carbon by its nature has a limitation in the maximum heat it can dissipate. Carbon resistors become too hot when high current flows through them. This increased heat in carbon resistors changes 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.

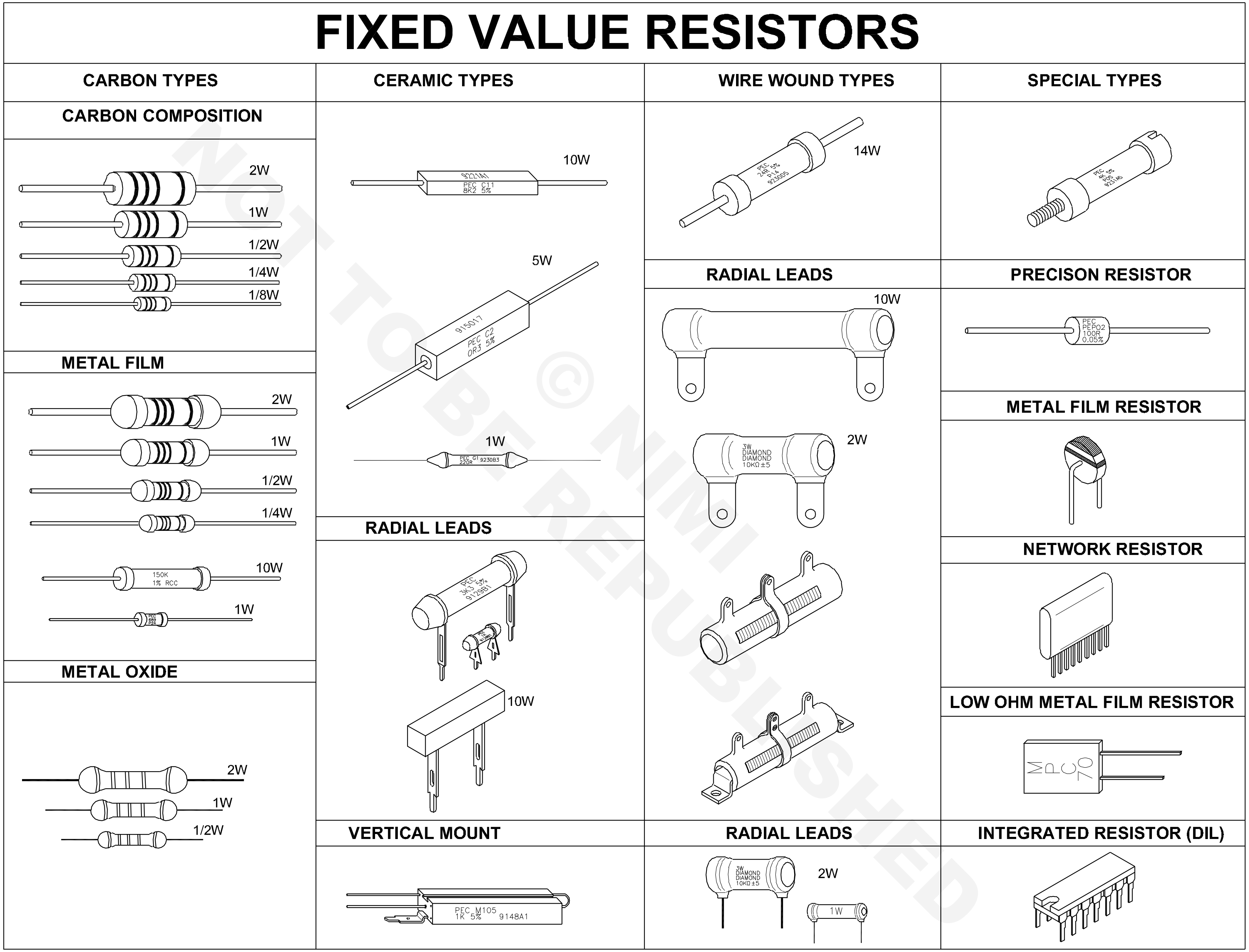
Resistor values

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 1.3.20



Ohm's law

Objectrives: At the end of this lesson you shall be able to
- **state ohm's law**
- **calculate current in a circuit with one resistor**
- **calculate the total resistance of series resistance circuits**
- **calculate the power dissipated across a resistor and circuit**
- **design a simple voltage divider circuit using resistors**
- **calculate the total resistance of parallel resistance circuits**
- **calculate the current flowing through branches of a parallel resistance circuit**
- **calculate the total resistance of series-parallel resistive circuits**
- **calculate the resistance value required to limit current in simple circuits**
- **calculate and connect resistors to obtain non-standard resistance values.**

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.

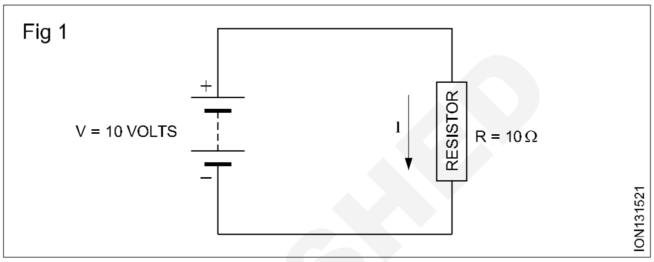
This statement holds good not only for a resistor, but in common to all resistive circuits.

Example 1: Using ohms law, find the current flowing through the resistor in Fig 1.

Solution:

Applied voltage across the resistor is : 10 volts

Fig 1



Resistance value of the resistor is given as 10 ohms.

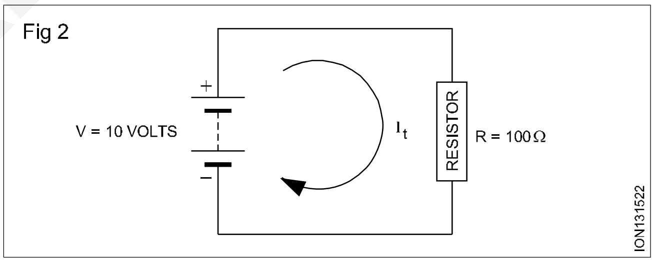
Therefore current (I) through the resistor by Ohm's law is;

$$I = \frac{V}{R} \text{ Amps} = \frac{10 \text{ volts}}{10 \text{ ohms}} = 1 \text{ amp.}$$

Current through the resistor is 1 ampere.

Example 2: Find the current flowing through the circuit in Fig 2.

Fig 2



Solution:

Let the total circuit current be I_t.

From Ohm's law

$$I_t = \frac{\text{Total voltage applied to the circuit (V)}}{\text{Total circuit resistance (R)}}$$

In the given circuit ,

total applied voltage = 10 volts.

Total circuit resistance = resistance of the only resistor = 100W.

> **This is because the given circuit consists of one resistor and that is the only component in the circuit.**

Total current through the circuit I_t is equal to

RESISTORS IN SERIES

$$I_t = \frac{V}{R} = \frac{10\ V}{100\ \Omega} = 0.1 \text{ amps} = 100 \text{ mA.}$$

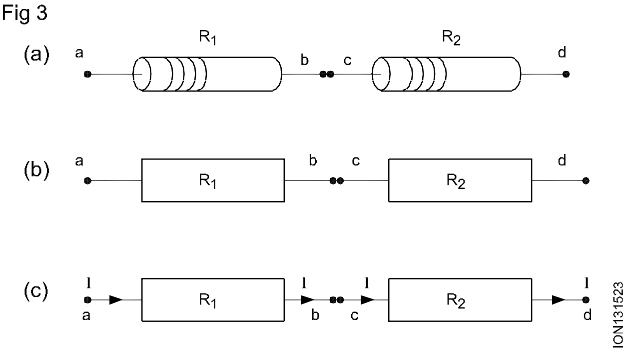
When resistors are connected end to end as shown in Fig 3, the resistors are said to be in series with each other.

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 3, total resistance across points a-d will be equal to $R_1 + R_2$.

Example: In Fig 3, 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,

Fig 3



R_1 and R_2 are connected in series.

Therefore,the effective circuit resistance is

$= R_1 + R_2$

$= 1.0\ K\ \Omega + 2.2\ K\ \Omega = 3.2\ K\ \Omega.$

Current through a series circuit

When resistors are connected in series as shown in Fig 3, 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 as shown in Fig 3c.

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 4.

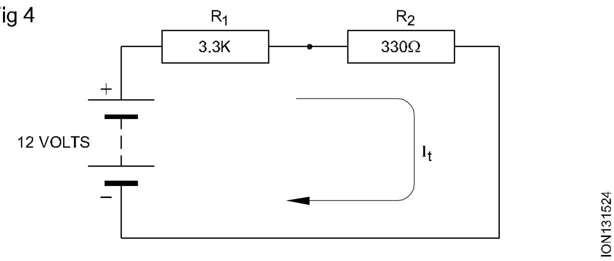
Solution:

Resistors R_1 & R_2 are in series. Therefore, the effective resistance of the circuit = $R_1 + R_2$

= 3.3K ohms + 330 ohms.

= 3300 + 330 = 3630 ohms.

Fig 4



Circuit current I_t

$$= \frac{V}{R} = \frac{12\ V}{3630\ \Omega} = 0.0033 \text{ amps} = 3.3 \text{ mA.}$$

Example: Calculate the voltage drops across R_1 and R_2 for the circuit at Fig 4.

Solution:

In the circuit (Fig 4), 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

$$I = \frac{V}{R} \text{ or } V = I \times R.$$

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 = $I^2 \times R$ 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 $= I^2 \times R = (I \times I) \times R$

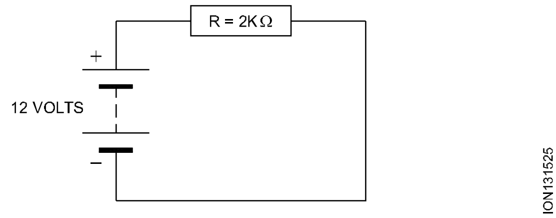
$= (10 \times 10^{-3}) \times (10 \times 10^{-3}) \times (10 \times 10^{3})$

$= 1000 \times 10^{-3} = 1000$ 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 5.

Fig 5



Solution:

Method 1

Current through the circuit is $I_t = V/R$

$= 12V/ 2\ K\Omega = 6$ mA

Power dissipated by the circuit is

= (circuit current)^2 x circuit resistance

$= (36 \times 10^{-6}) \times (2 \times 10^{3})$

$= 72 \times 10^{-3}$ watts

= 72 milli-watts = 0.072 watts.

Method 2

Power dissipated is given by,

$P = I^2 \times R = I \times I \times R$ ....[1]

From Ohm's law $I = \frac{V}{R}$

substituting this in equation ....[1]

Power dissipated $= I \times I \times R = \frac{V}{R} \times I \times R = V \times I$

This formula for the power dissipated is advantageous because, by measuring the total circuit current and the applied circuit voltage, power consumed by the circuit can be found out easily without knowing the value of the resistors.

Using this formula for the circuit as given in Fig 5,

Power dissipated $= (6 \times 10^{-3})$ amps x 12 volts = 72 milli-Watts.

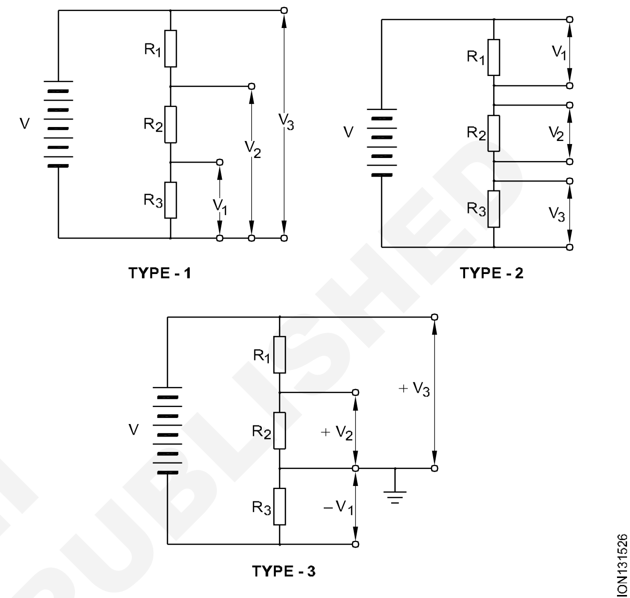
The power dissipated by the circuit found using method 2 is same as that calculated using method 1.

Try to derive alternative formulas for calculating power.

USE OF RESISTORS IN SERIES AS A VOLTAGE DIVIDER

Given a single voltage source, several circuits requiring smaller voltages can be obtained using a set of resistors connected in series. This is called a voltage divider. Some simple voltage divider circuits are shown in Fig 6.

Fig 6



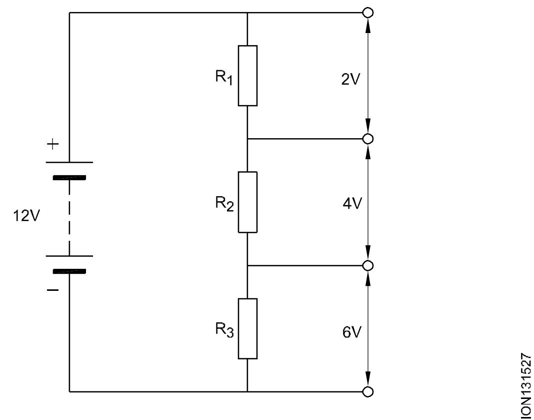
Designing voltage divider circuits using resistors

Example: Given a 12 volts DC power supply, design a voltage divider using resistors to obtain three voltages of 2 volts, 4 volts and 6 volts.

Solution:

Draw the divider diagram as shown in Fig 7. Assume the voltage across resistors as given in Fig 7.

Fig 7



Let the resistor values be R_1, R_2 & R_3.

Assume a value of 1KW will have a drop of 1volt across it.

Therefore to obtain 2 volts we need R_1 = 2K ohms.

Similarly for 4 volts R_2 = 4K ohms

for 6 volts R_3 = 6K ohms

Easier method [Ratio method]

Find the ratio of the three different voltages required:

2V:4V:6V = 1:2:3.

Add up the ratios 1+2+3 = 6.

Divide 12 volts by 6. 12/6 = 2. Fix 2 ohms or 2 K ohms or 2 M ohms as the resistance value of R_1 required to drop 2 volts.

Let us fix R_1 = 2K ohms for the present (reasons in later lessons).

Multiply 2 K ohms by the next ratio value i.e 2.

2x2K ohms = 4 K ohms.This is the value required to drop 4 volts.

Multiply 2 K ohms by the next ratio value i.e 3.

2x3K ohms = 6 K ohms. This is the value required to drop 6 volts.

Values of the resistors of the voltage divider should, therefore, be, R_1 = 2 K ohms, R_2 = 4 K ohms and R_3 = 6 K ohms.

The voltage divider circuit designed above can also be designed in a different way as shown in Fig 8.

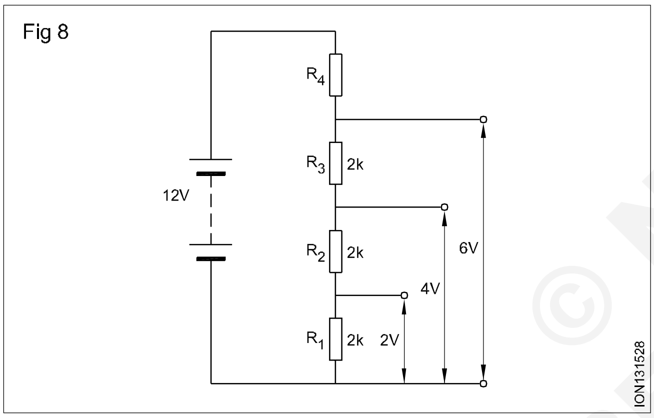


Fig 8

Discuss merits and demerits of the above two designs.

Refer reference books listed at the end of this book for other methods of designing voltage dividers.

RESISTORS IN PARALLEL

Compare the circuits at Fig 9 and Fig 10. Both the circuits are carrying the same current although Fig 9 is having large resistor values than Fig 10.

This means that, the two resistors connected in parallel as shown in Fig 9 has effective or total resistance equal to that of a single resistor that is shown in Fig 10.

Analysing both circuits, it can be concluded that;

when resistors are connected in parallel as shown in Fig 11, the effective resistance(R_T) across the terminals x & y will be equal to,

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

or

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

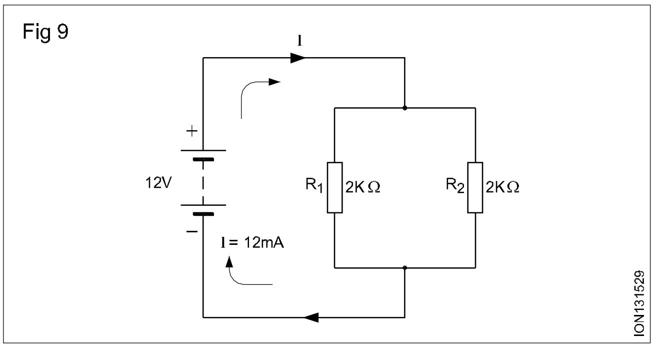


Fig 9

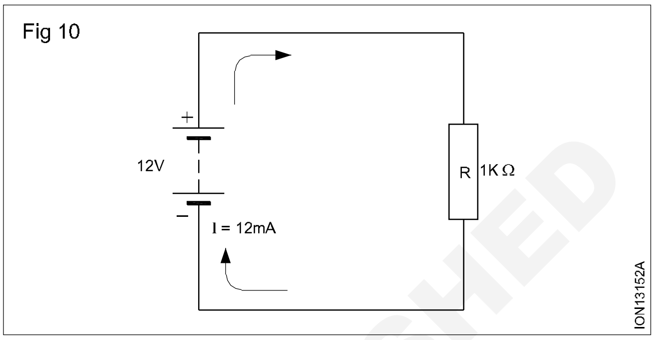


Fig 10

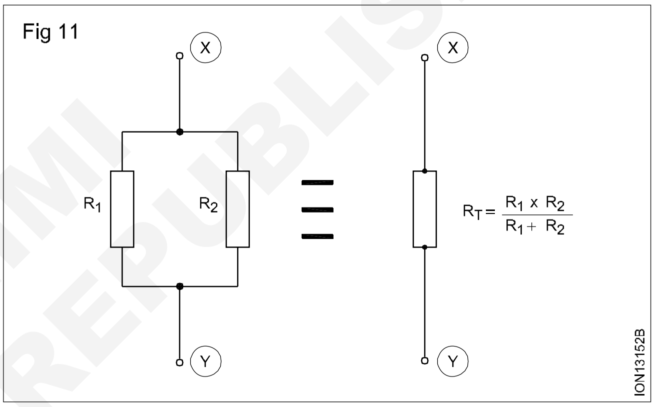


Fig 11

Similarly, if 3 resistors are connected in parallel, the effective resistance R_T will be,

$$R_T = \frac{R_1 \times R_2 \times R_3}{R_1 R_2 + R_2 R_3 + R_1 R_3}$$

As a thumb rule When resistors are connected in parallel, the effective resistance will always be less than the least resistance value of the resistor in the parallel connection.

Example: If two resistors of 1KΩ each are connected in parallel, from the thumb rule, the effective resistance will be less than 1KW.

Verification:

From the formula derived above, $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$

$$= \frac{1K \times 1K}{1K + 1K} = 0.5K\Omega$$

Example: If two resistors of 2 KΩ and 100 Ω each are connected in parallel, from the thumb rule, the effective resistance will less than 100Ω.

Verification

From the formula derived above, $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$

$$= \frac{2K\Omega \times 100\Omega}{2K + 100\Omega} = 95.24\,\Omega$$

Example: In circuit in Fig 11, if the value of the resistors were,

R_1 = 10 ohms , R_2 = 1 K ohm, what is the effective resistance?

Solution:

Using the formula, $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$

$$R_T = \frac{(10)\times(1\times10^3)}{(10)+(1\times10^3)} = \frac{10000}{1010} = 9.9 \text{ Ohms.}$$

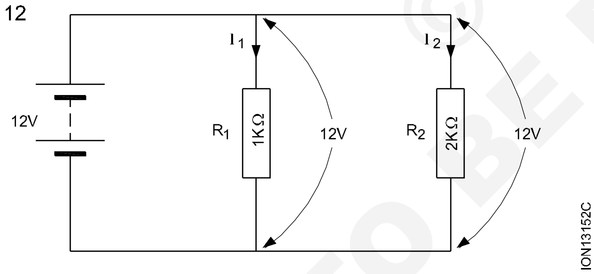
Effective resistance of 10 ohms & 1 K ohm in parallel is 9.9 ohms or approximately 10 ohms. From this, it can be understood when a very small value resistor is connected in parallel with a very large resistor, the effective resistance of the parallel connection will be approximately equal to the values of the very small resistance itself.

The effective value of resistance becoming lower than the lowest value resistor in the parallel connection is called the LOADING effect. This effect is very important in electronic circuits. Effect of loading is discussed in detail in further lessons.

POWER DISSIPATION IN PARALLEL RESISTIVE CIRCUITS

When resistors are connected across a voltage source in parallel as in Fig 12, the voltage across each resistor will be the same and equal to the source/battery voltage.

Fig 12



However the current through the resistors (I_1 & I_2) depends on the value of the independent resistors. Hence, power dissipated/ consumed by each resistor can be calculated separately using the formula $P = I^2R$ or $P = VI$. The sum of the power consumed by each resistors will be the total power consumed by the circuit.

Total power consumed can also be found if the total circuit current and the effective resistance of the circuit are found.

Example: Calculate the power consumed by the circuit in Fig 12.

Solution :

Method 1:

Power consumed by the circuit = $(I_1^2 \times R_1) + (I_2^2 \times R_2)$

$I_1 = V/R_1$ = 12/1K = 12 mA. $I_2 = V/R_2$ = 12/2K = 6 mA.

Power dissipated by R_1 = $(12 \times 12 \times 10^{-6}) \times (1 \times 10^3)$
= 144 mWatts

Power dissipated by R_2 = $6 \times 6 \times 10^{-6} \times 2 \times 10^3$
= 72 mWatts

Total power consumed by the circuit is

= 144 + 72 milli watts = 216 milli-watts.

Method 2:

Total circuit resistance, $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$

$$= \frac{(1\times10^3)\times(2\times10^3)}{1\times10^3 + 2\times10^3} = 666.7\Omega$$

Circuit current $I_t = I_1 + I_2$

$$= \frac{12V}{666.7\,\Omega} = 0.018 \text{ Amps}$$

Power consumed by the circuit = $I_t^2 \times R_T$

= $(0.018)^2 \times (666.7)$

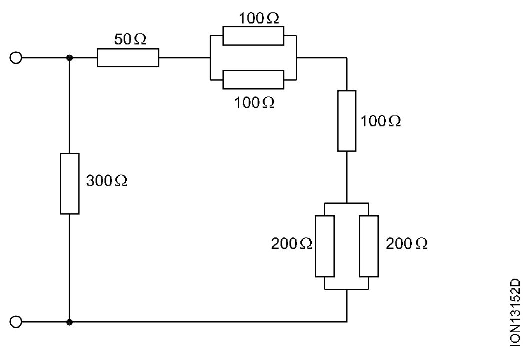
= 0.216 watts

= 216 mwatts

SERIES- PARALLEL RESISTOR CIRCUITS

As shown in Fig 13, when several resistors are connected, in which some resistors are in series and some in parallel, then, such a circuit is called a series-parallel circuit.

Fig 13



To find the effective resistance of such series-parallel circuits.

Once a complex series parallel circuit has been simplified and total circuit resistance is found, it is easy to calculate the circuit current and power consumed by the circuit. Using Ohm's law, it is also easy to calculate the voltage drop and power dissipated by individual resistors.

Some applications of series,parallel and series-parallel connection of resistors in circuit.

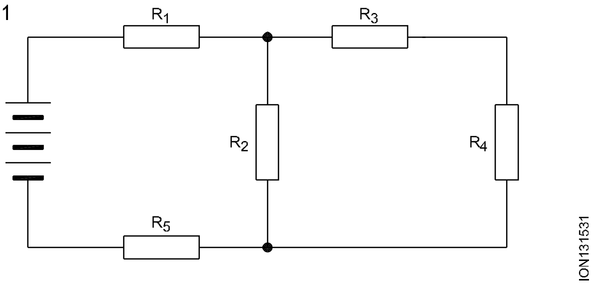
- Series resistor to drop excess voltage.
- Series resistor to obtain non-standard resistor values.
- Parallel resistor used to divert excess circuit current.
- Parallel resistor to obtain non-standard resistor values.
- Resistors in series, parallel to drop voltage and divert current.

Kirchhoff's laws

Objectives: At the end of this lesson you shall be able to
- **state kirchhoff's current law**
- **write kirchhoff's current equation for resistive circuits**
- **state kirchhoff's voltage law**
- **write kirchhoff's loop equation for resistive circuits**
- **calculate voltage and currents at different points in a resistive circuit.**

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,

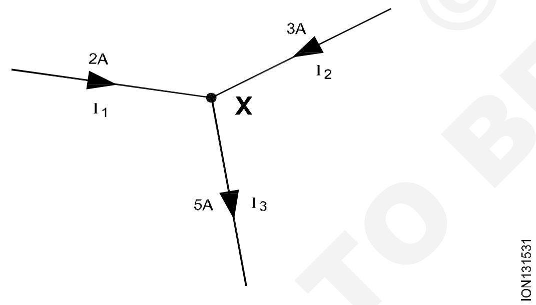
1 Kirchhoff's Current law

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 x 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,

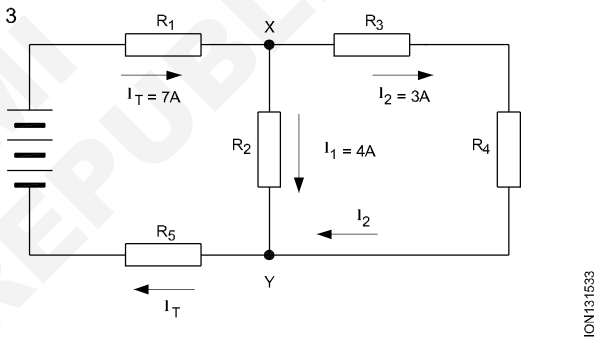
$$(+I_1) + (+I_2) + (–I_3) = 0$$

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 $I_T – I_1 – I_2 = 0$

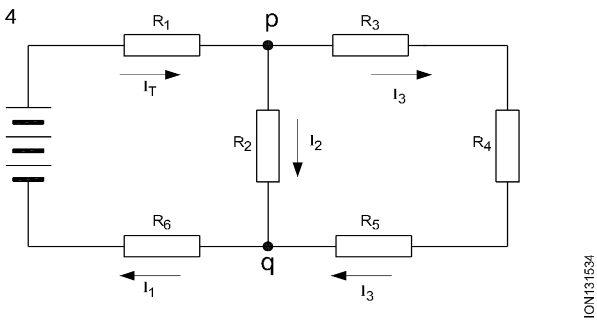
7A – 4A – 3A = 0.

At node Y $I_1 + I_2 – I_T = 0$

4A + 3A - 7A = 0.

Example: Write the current equations at nodes p and q in the circuit at Fig 4.

Fig 4



At node P $I_T – I_2 – I_3 = 0$

or $I_T = I_2 + I_3$

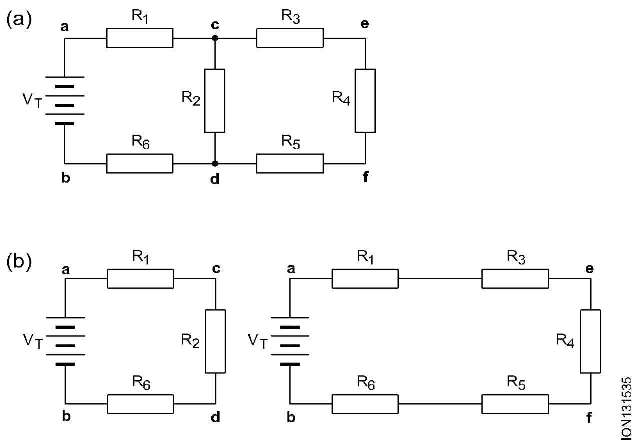
At node Q $I_2 + I_3 – I_1 = 0$

or $I_2 + I_3 = I_1$

KIRCHHOFF's VOLTAGE LAW

In the circuit shown at Fig 5a, consider the two closed paths a-c-d-b-a and a-e-f-b-a as shown in Fig 5b. 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 5



To find the algebraic sum of around a closed path,

- start from any point, go around the path and come back to the same point from where you started.

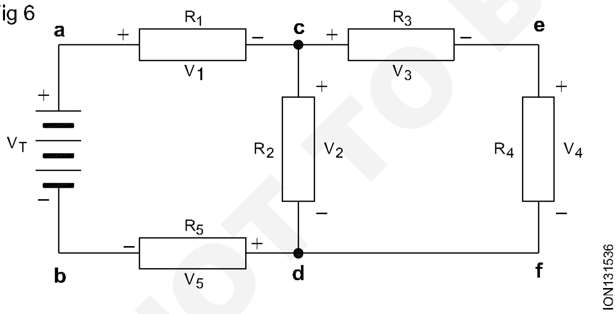
Example: Referring to Fig 5b, the method of going through a closed path is,

- 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 5b,

- mark the polarity of each voltage, based on the polarity of source voltage as shown in Fig 6

Fig 6



- go around the path and give +ve sign for the voltage whose PLUS terminal is reached first or give -ve sign for the voltage whose MINUS 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 6, proceed as follows:

Taking clockwise direction for going through the loop, start from point **a** of Fig 6. 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,

$+ V_1 + V_2 + V_3 + V_4 = V_T.$

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:

$S V_d = V_T$,

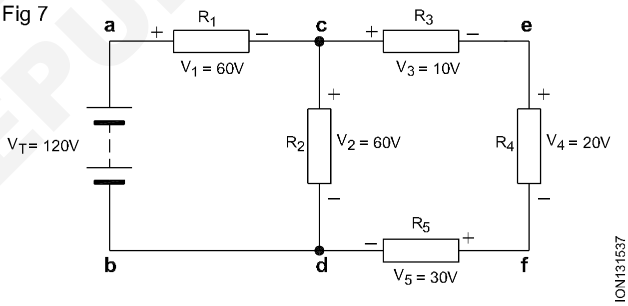
where, $S V_d$ is the sum of voltage drops across resistors V_T is the applied voltage.

For the loop a-c-d-b-a, $+V_1 + V_2 - V_T = 0$

or $V_1 + V = V_T$

Example: Write the loop equations for the circuit given at Fig 7.

Fig 7



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

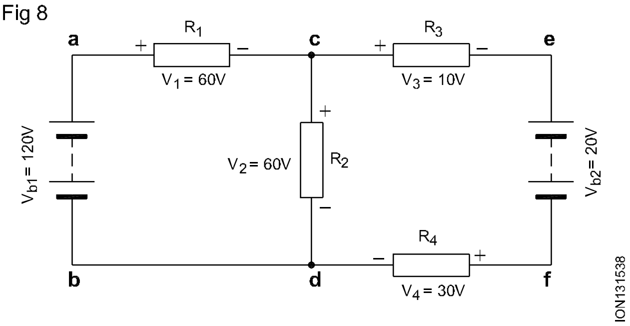
10 + 20 + 30 = 60

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.

Example: Write the loop equations for the circuit shown in Fig 8.

Fig 8



For the loop a-c-d-b-a,

$+V_1 + V_2 - V_{b1} = 0$

$V_1 + V_2 = V_{b1}$

$60 + 60 = 120$

For the loop a-e-f-b-a,

$+V_1 + V_3 + V_{b2} + V_4 - V_{b1} = 0$

$V_1 + V_3 + V_{b2} + V_4 = V_{b1}$

$60 + 10 + 20 + 30 = 120$

For the loop c-e-f-d-c,

$+V_3 + V_{b2} + V_4 - V_2 = 0$

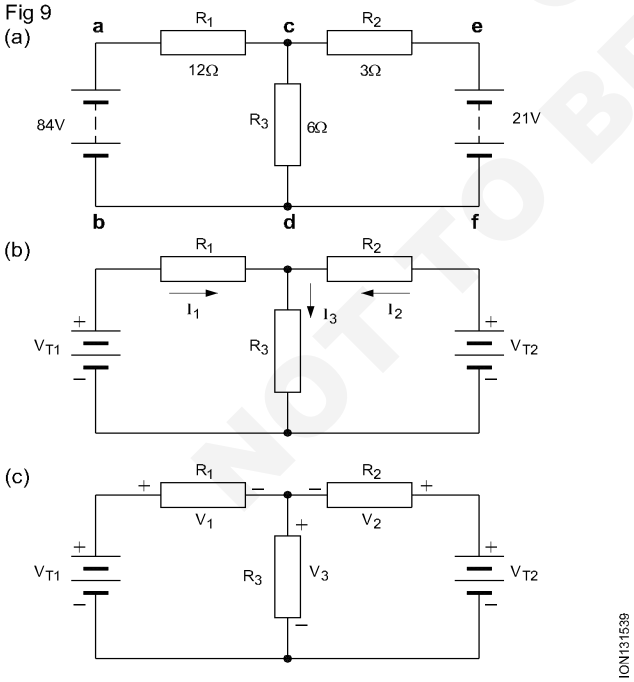
$V_3 + V_{b2} + V_4 = V_2$

$10 + 20 + 30 = 60$

To find current and voltages in a circuit using kirchhoff's law

Example: In the circuit at Fig 9a, find the branch currents and voltage drop across resistors R_1, R_2 and R_3.

Fig 9



Solution :

Step 1: Assume the current flow is from the +ve of the battery to the -ve of the battery (conventional current direction) and write direction of current as shown in Fig 9b.

Step 2: Mark the polarity of voltage across each resistor as shown in Fig 9c consistent with the assumed direction of the current.

Step 3: Write the loop equations which cover the two battery sources as given below;

For the loop a-c-d-b-a,

$+V_1 + V_3 - V_{T1} = 0$

or $V_1 + V_3 = V_{T1}$

$V_1 + V_3 = 84$ ......[1]

For the loop c-e-f-d-c,

$-V_2 + V_{T2} - V_3 = 0$

or $V_2 + V_3 = V_{T2}$

$V_2 + V_3 = 21$ ......[2]

Using the known values of R_1, R_2 & R_3, write I_R drops, V_1, V_2 and V_3.

$V_1 = I_1.R_1 = I_1 \times 12 = 12.I_1$ ......[3]

$V_2 = I_2.R_2 = I_2 \times 3 = 3.I_2$ ......[4]

$V_3 = I_3.R_3 = (I_1+I_2) \times 6 = 6.I_1 + 6.I_2$ ......[5]

Substitute equations 3,4 and 5 in the loop equations 1 and 2, we have,

Substituting for equation 1,

$V_1 + V_3 = 84$

or $(12.I_1) + (6.I_1 + 6.I_2) = 84$

$18.I_1 + 6.I_2 = 84$

(Dividing RHS & LHS by 2)

$9.I_1 + 3.I_2 = 42$ ......[6]

Substituting for equation 2,

$V_2 + V_3 = 21$

$(3.I_2) + (6.I_1 + 6.I_2) = 21$

$6.I_1 + 9.I_2 = 21$

(Divide RHS & LHS by 3)

$2.I_1 + 3.I_2 = 7$ ......[7]

Solving equations ..[6] and ..[7],

$9.I_1 + 3.I_2 = 42$

$2.I_1 + 3.I_2 = 7$

$7.I_1 = 35$

or

Substituting value of I_1 in equation ...[7]

$2 \times 5 + 3.I_2 = 7$

Therefore, $I_2 = -\frac{3}{1} = -$ 1 amp.

> **The Minus sign indicate that, the assumed direction of I_2 in Fig 9b was opposite to that of the actual direction of the current. However the numerical value of I_2 remains unchanged.**

From known value of I_1, I_2 and $I_3 = (I_1 + I_2)$, find the voltage drop across resistors as given below;

$V_1 = R_1.I_1 = 12x5 \quad = 60$ volts

$V_2 = R_2.I_2 = 3x1 \quad = 3$ volts

$V_3 = R_3.I_3 = R_3.(I_1–I_2) = 6x(5-1) = 24$ volts.

- The method used for finding branch currents and voltage drops in the above discussion is called **Branch current method.**
- To solve similar problems, other methods known as, **Node voltage method, Mesh current method** can also be used.

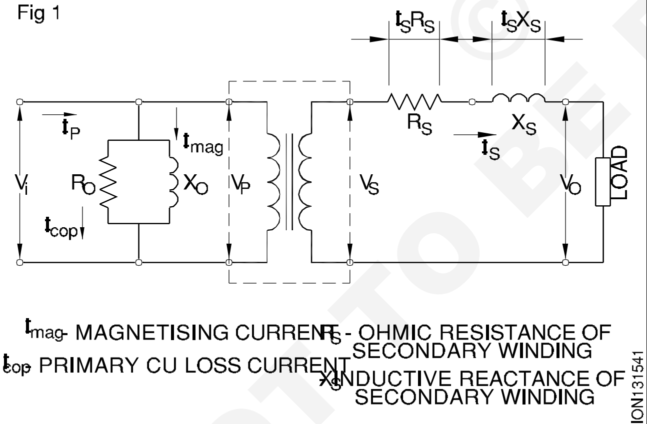
Inductors and inductance

Objectives: At the end of this lesson you shall be able to
- **state meaning of inductor and inductance**
- **explain sudden changes in current due to inductor**
- **state the meaning of self induction**
- **list factors determining the value of an inductor and formula for finding inductance of a coil**
- **list the different classification of inductors**
- **list a few types of inductors their application areas and energy storage in inductors**
- **name the instrument need for measuring inductance values**
- **explain self induction**
- **explain mutual inductance**
- **explain find the value of inductors in series and parallel**
- **explain the time constant in L-R circuits**
- **explain Q factor.**

Inductive reactance/DC resistance of Inductance

Inductors are components consisting of coil of wire as shown in Fig 1. The basic function of an inductor is to **store electric energy in the form of magnetic field**, when current flows through the inductor.

Fig 1



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.

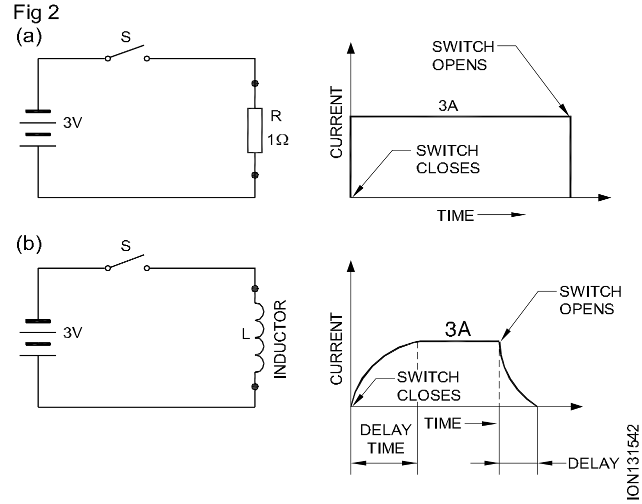
It should be noted that, the inductance cannot completely stop the increase in current because, the induced voltage is caused by the increasing flux, and the increasing flux depends on the increasing current. Therefore, an inductor can restrict only, the rate at which the current can increase or decrease through it.

Example: A Resistor of 1 W is connected to a DC source of 3 volts, as shown in Fig 2a. 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 1W as shown in Fig 2b, 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.

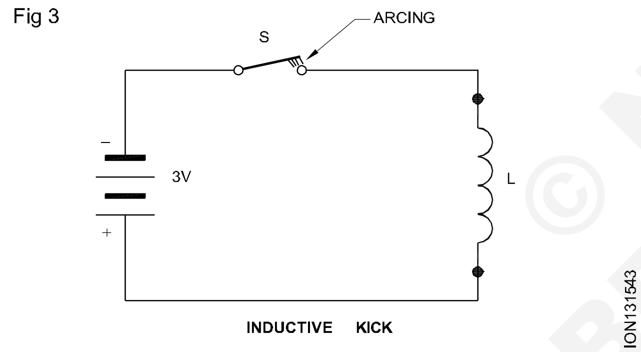
Once the current through the circuit in Fig 2b reaches its steady state value of 3Amps, which is decided by the ohmic value of the inductance, the magnitude of current remains constant and hence the inductive effect stops. At this point, the only opposition the inductor offers is its ohmic/DC resistance.

Fig 2



When the switch S of Fig 2b 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 3. 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 3



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 4,

Inductance, $L = \dfrac{V_L}{di / dt}$

Where, V_L = Induced voltage

and $\dfrac{di}{dt}$ = rate of change of current. Refer Fig 4.

Polarity of Induced emf

The induced emf (voltage) in an inductor (cemf) has polarity that always opposes the source voltage (Lenz's law).

Fig 4

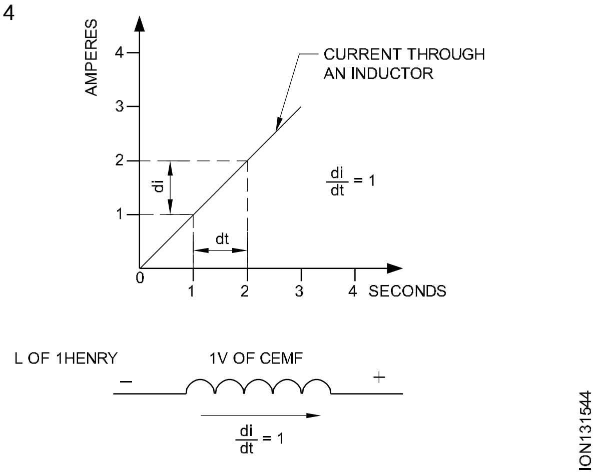
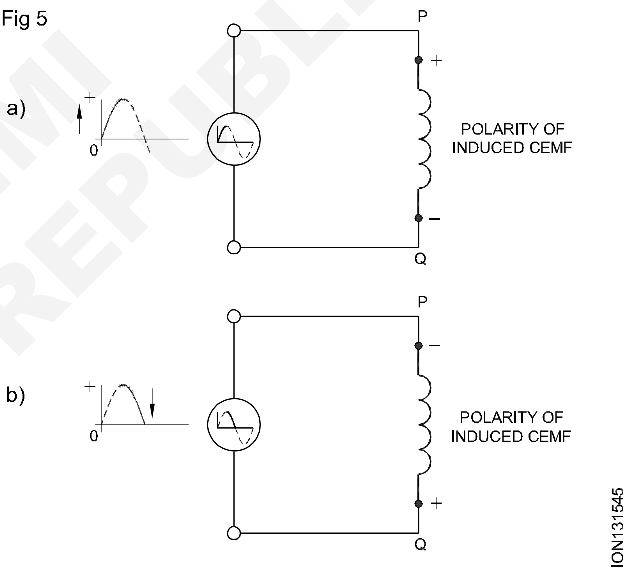


Fig 5 shows an inductor across an AC voltage source. When the applied voltage is increasing from 0 to +ve peak as shown in Fig 5a, the counter emf at end P of inductor will have +ve polarity opposing the increasing source voltage.

In Fig 5b, 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.

Fig 5



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

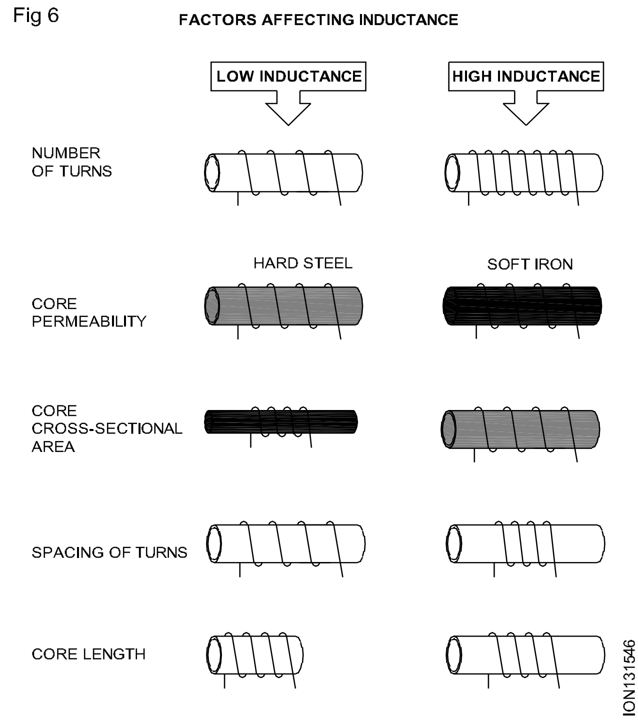
4 The diameter of the coil.

Fig 6 illustrates the effect of these factors on the inductance value.

Given the parameters listed above, the inductance of a coil can be calculated using the formula,

$$L = \mu \frac{N^2 A}{l} \text{ Henries}$$

Fig 6



where,

μ = Permeability of the magnetic core around which the coil is wound, in Wb/At-m ($\mu = \mu_o \mu_r$)

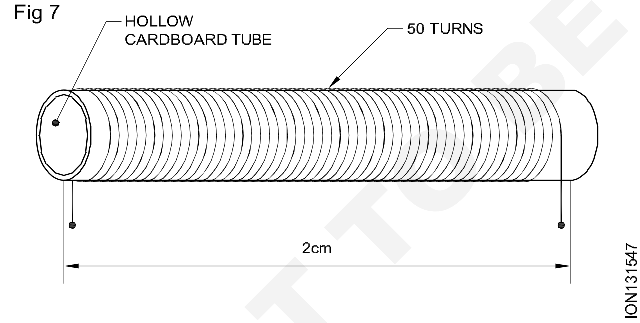
N = Number of turns of the coil

A = Area of cross-section of the core in square metres, m^2

l = length of the coil in meters.

Example: **In Fig 7, a coil of 50 turns is wound on a hollow card board tube of cross sectional area 1 cm². The tube is 2 cms long. Calculate the inductance of the coil.**

Fig 7



Solution:

Since the card board tube is non magnetic and hollow, its permeability (μ) is nothing but permeability of air.

Therefore in this case $\mu = \mu_o = 4p \times 10^{-7}$ Wb/At-m

Area of cross section = 1 cm^2 = 0.0001 m^2 = 1×10^{-4} m^2

Length of the core = 2 cm = 2×10^{-2} m
From above data,

Inductance of the coil, L = $\mu \dfrac{N^2 A}{l}$

$$= \frac{4\pi \times 10^{-7} \times 50^2 \times \left(1 \times 10^{-4}\right) m^2}{\left(2 \times 10^{-2}\right) m^2} = 15.7 \times 10^{-6} \text{H}$$

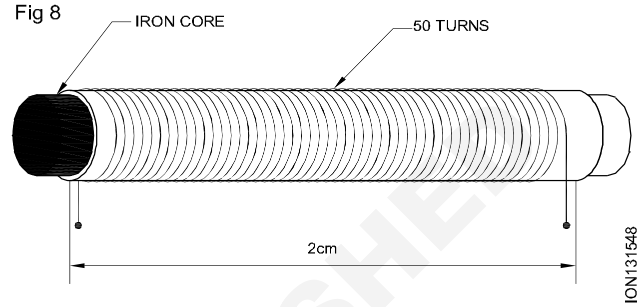
Values of inductance less than 1 Henry can be represented as follows;

1×10^{-3} Henries = 1 milli Henry = 1 mH
1×10^{-6} Henries = 1 micro Henry = 1 μH
1×10^{-9} Henries = 1 nano Henry = 1 nH

Hence the value of inductance calculated in the example above was 15.7 μH.

In the above example if an iron core of relative permeability (μ_r) 200 is inserted in the hollow core as shown in Fig 8, calculate the new value of inductance.

Fig 8



The changed permeability of core is $\mu = \mu_r \times \mu_o$
$= 200\ \mu_o$.

Hence, the new value of L is,

$$= \frac{200 \times 4\pi \times 10^{-7} \times 50^2 \times \left(1 \times 10^{-4}\right) \text{ m}^2}{\left(2 \times 10^{-2}\right) \text{ m}} = 3.1\text{mH}$$

A mere insertion of the iron core increases the inductance by a factor of almost 200. This indicates the major influence of core permeability on inductance value of an inductor. Higher the permeability of the core material used, higher will be the inductance value of an inductor.

In the above example, if the number of turns of coil is doubled, i.e., increased from 50 to 100 turns, inductance value will increase four fold. The new inductance value would be L = 4 x 3.1 mH = 12.4 mH.

The permeability of materials, iron for example varies widely with the amount of flux density (B) and naturally the current in the coil. This means that the inductance of any coil with a magnetic core is never constant. The inductance value varies with the amount of current (flux) in the coil. For this reason many coil manufacturers quote the value of inductance at some specified current. For example, a coil may have 8H of inductance at 85 mA, but if operated at only 1 mA, the inductance would be 14H.

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. Illustration of different types of inductors are shown in Chart-2 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.

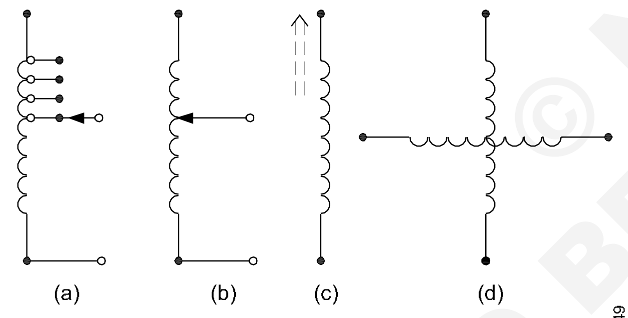
Laminated Iron Core is formed using a group of individual laminations. Each lamination is insulated by a thin coating of iron oxide, silicon steel or varnish. This insulation increases the resistance reducing eddy current losses. These type of inductors are generally used for mains frequency of 50/60 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. The inductance can be varied by any one of the methods as shown in Fig 9.

Fig 9



(a) TAPPED COIL (b) SLIDER CONTACT (c) ADJUSTABLE SLUG (d) VARIOMETER

Methods (a) & (b) shown in Fig 9 are generally used in low frequency application.

Method (c) is used in coils with ferrite as core. These are used in high frequency applications.

Method (d) is known as Variometer arrangement. In this, the position of one coil is varied within the other. The total inductance will be minimum when the coils are perpendicular to each other.

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.

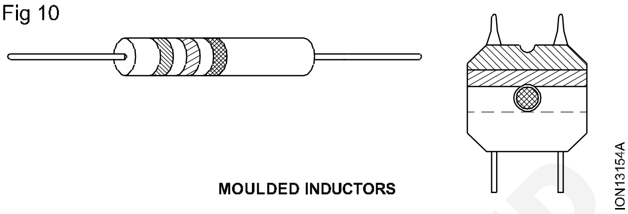
While making a shield/screen for an inductor the following points are to be noted;

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.

Fig 10



MOULDED INDUCTORS

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 (Q stands for quality-factor: discussed in further lessons).

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.

$$W = \frac{1}{2}LI^2$$

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.

CHART – 1
TYPES OF INDUCTORS

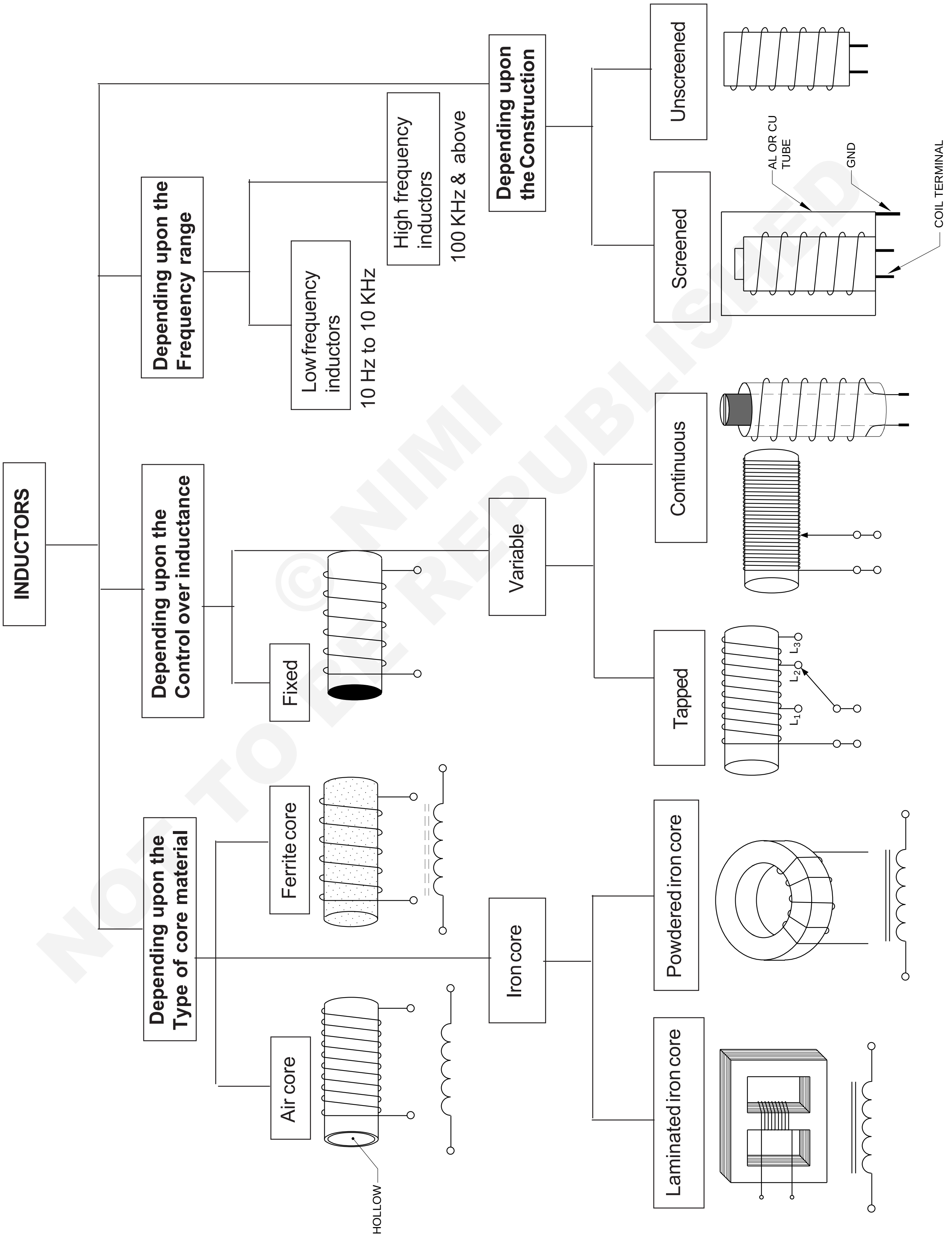


CHART - 2 **PHYSICAL APPEARANCE OF DIFFERENT TYPES OF INDUCTORS**

Fig 1 **IRON CORE INDUCTOR OR CHOKE**

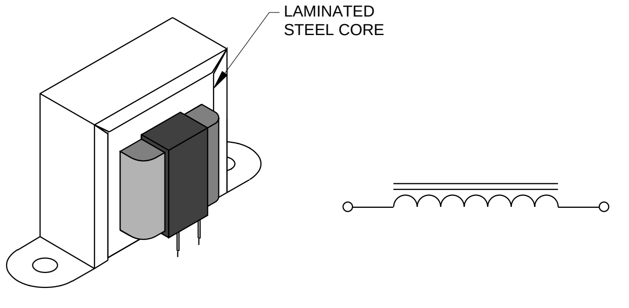


Fig 2 **AIR-CORE INDUCTORs**

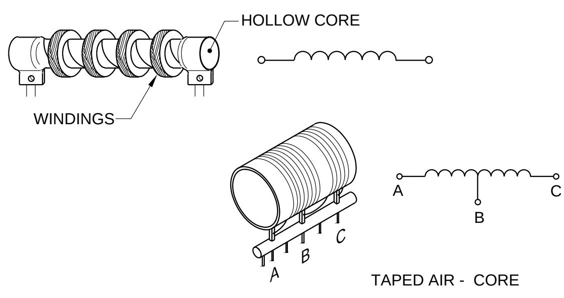


Fig 3 **FERRITE-CORE INDUCTORS**

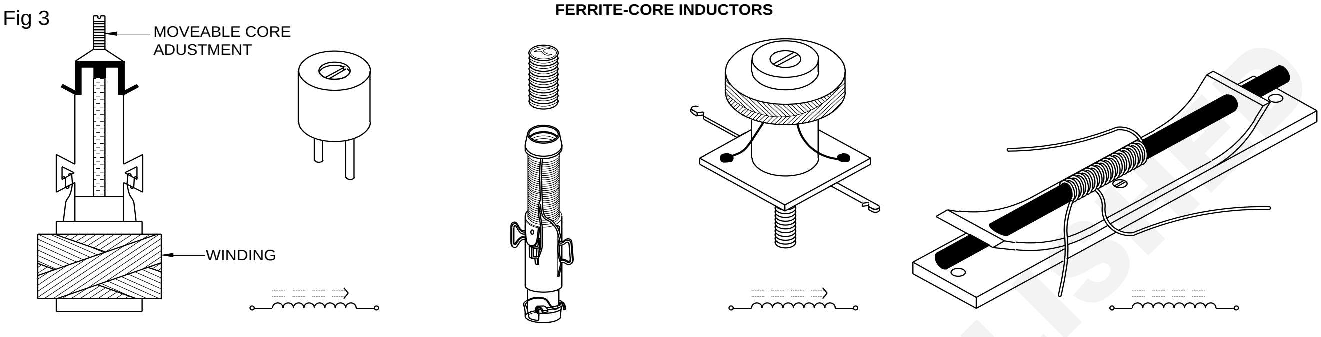


Fig 4 **SHIELDED INDUCTORS**

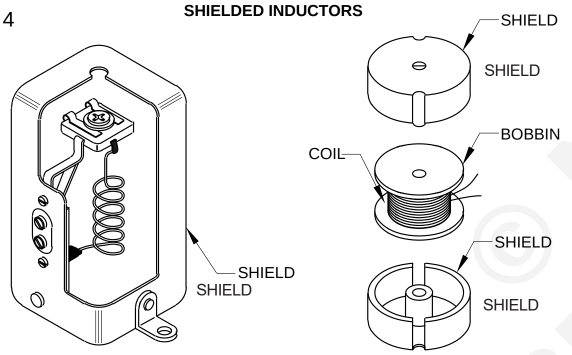


Fig 5 **HIGH FREQUENCY INDUCTORS**

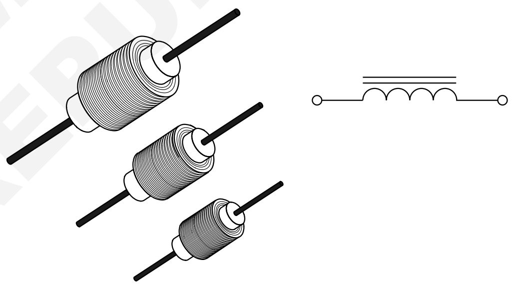


Fig 6 **MOULDED INDUCTORS**

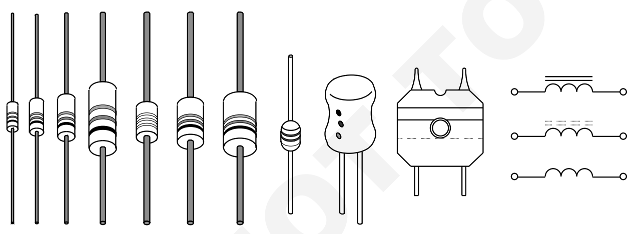


Fig 7 **TOROID FERRITE CORE INDUCTOR**

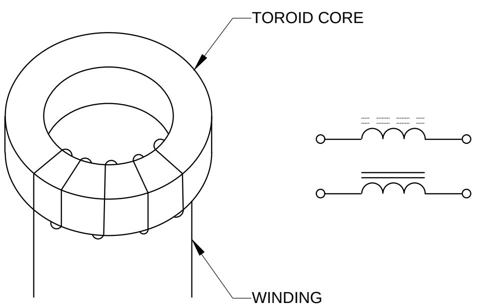
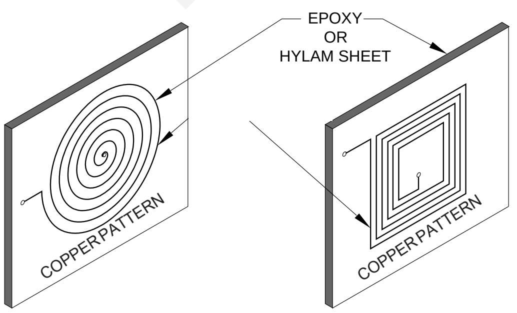


Fig 8 **PRINTED CIRCUIT INDUCTOR/THIN FILM INDUCTOR**



Space for the trainees to fill

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.

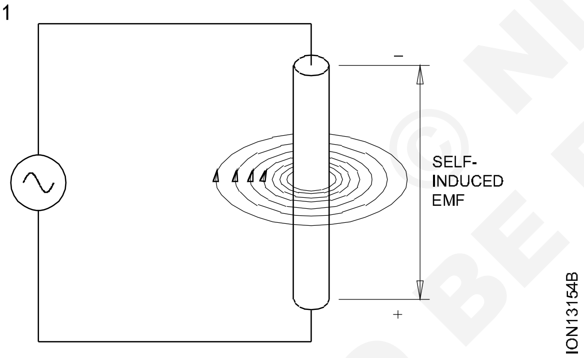
2 **mutually induced emf** produced in the neighbouring coil.

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 11)

Fig 11



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. (Fig 12.)

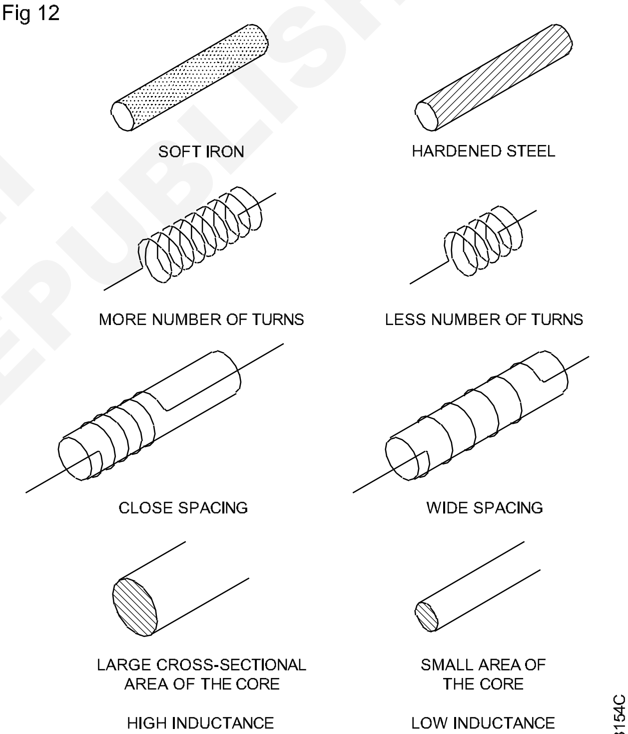
Core (2a): If soft iron is used as a core material instead of hardened steel, the coil will have more inductance.

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 (Fig 12b): 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.

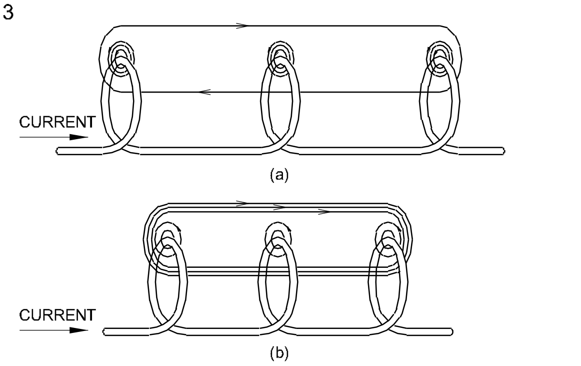
Spacing between turns of wire (Fig 12c): When the distance between the turns of wire in a coil is increased, the inductance of the coil decreases. Fig 13 illustrates why this is so. With widely spaced turns (Fig 13), many of the flux lines from adjacent turns does not link to gether. Those lines that do not link together produce no voltage in other turns. As the turns come closer together (Fig 13b) only a fewer lines of flux fail to link up.

Fig 12



FACTORS DETERMINING INDUCTANCE

Fig 13



WIDELY SPACED TURNS PROVIDE LESS INDUCTANCE THAN CLOSELY SPACED TURNS

EFFECT OF TURN SPACING

Cross sectional area (Fig 13b): 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.

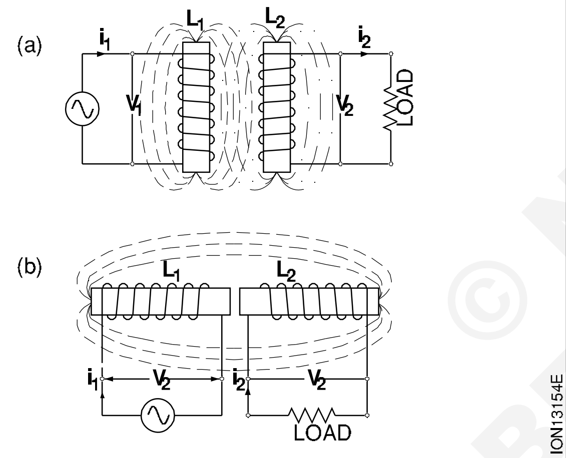
Henry: A conductor or coil has an inductance of one henry if a current that changes at the rate of one ampere per second produces a induced voltage (cemf) of 1 volt.

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 14a or Fig 14b, although the two coils are not electrically connected, the two coils are said to be magnetically inter-coupled.

Fig 14



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 14, 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,

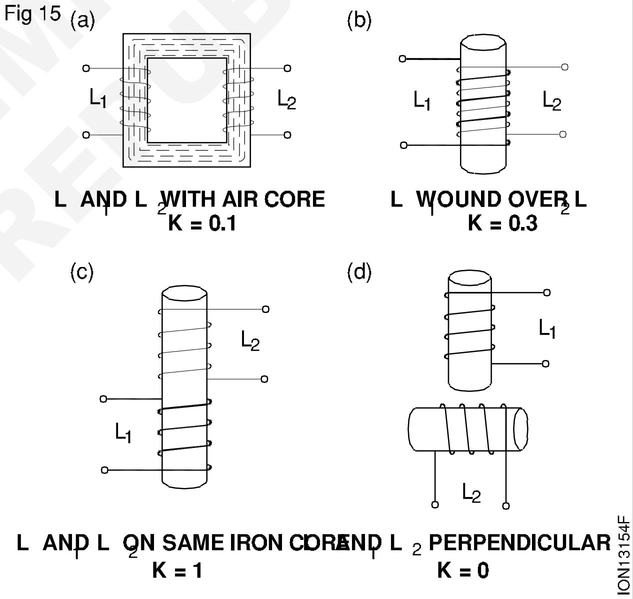
$$k = \frac{\text{Mutual flux between two coils } \phi_m \text{, in Webers}}{\text{Total flux set up by one coil, in Webers}}$$

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**.

In Fig 15b, 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 15c 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.

Fig 15



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

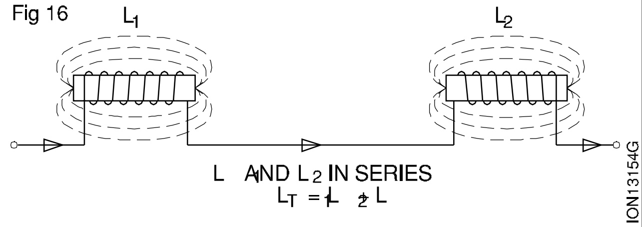
L_1 and L_2 are inductance values, in henrys

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 16 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 16, 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 16


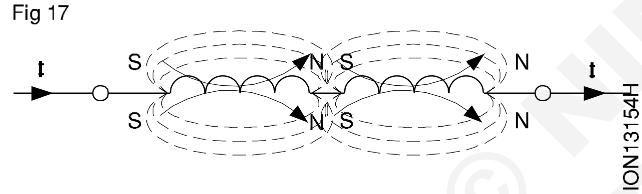
Series coils with mutual inductance

Unlike in Fig 16, when two inductors L_1 and L_2 are connected in series close to each other as in Fig 17 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.

$L_T = L_1 + L_2 + L_3 + \ldots\ldots\ldots.+ L_n$ Henrys (H)

where, L_T is the total inductance across end terminals.

$L_1, L_2 \ldots\ldots. L_n$ are individual inductance values.

Fig 17


In general, the total inductance of two series-connected coils, with mutual inductance M is given by;

$L_T = L_1 + L_2 \pm 2M$

Whether it will be + 2M or - 2M depends on, whether the inductors are connected in series-aiding as shown in Fig 18a or in series-opposing as shown in Fig 18b.

Dot notation

Whether two coils are connected series-aiding or series-opposing, it is often indicated by using *dot notation* as shown in Fig 19. When current enters both dots or leave both dots as shown in Fig 19a the mutual inductance is additive.

When the current enters one dot and leaves the other dot, as shown in Fig 19b, the mutual inductance is subtractive. In other words the dots indicate the in-phase ends of each other.

Dot notation is used in transformers and loud speakers to show correct phasing.

Example (1): ***Two inductors are10H and 15H connected in series. Calculate the total inductance?***

SOLUTION

$L_T = L_1 + L_2 = 10H + 15H = 25H$

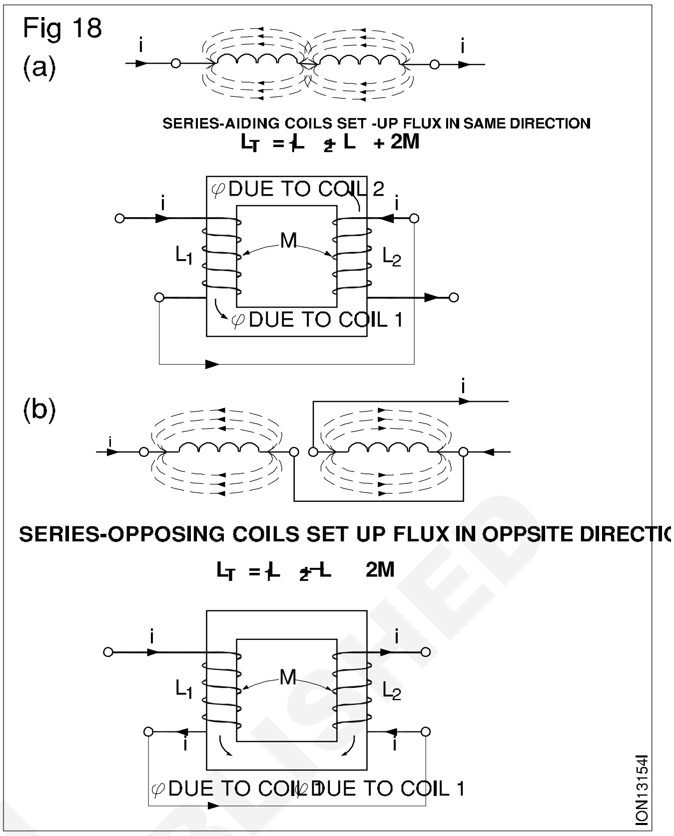
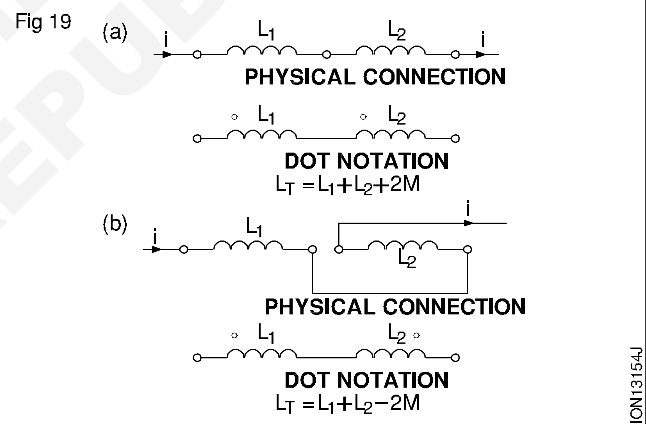
Fig 18


Fig 19


Example (2): ***If the above two inductors are connected parallel to each other on a common core with a mutual inductance of 4H and connected in series, calculate,***

a L_T of coils when connected series-aiding (Fig 18a).

b L_T of coils when connected series-opposing (Fig 18b).

c Coefficient of coupling k.

SOLUTION

a $L_T = L_1 + L_2 + 2M = 10H + 15H + 2 \times 4H = 33H$

b $L_T = L_1 + L_2 - 2M = 10 + 15 - 2 \times 4H = 17H$

c $M = k\sqrt{L_1 . L_2}$

or, $k = \dfrac{M}{\sqrt{L_1 L_2}} = \dfrac{4}{\sqrt{10 \times 15}} = 0.33$

Inductors in parallel

When two inductors are connected in parallel as shown in Fig 20a, the total inductance is given by,

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} \text{ Henrys (H)}$$

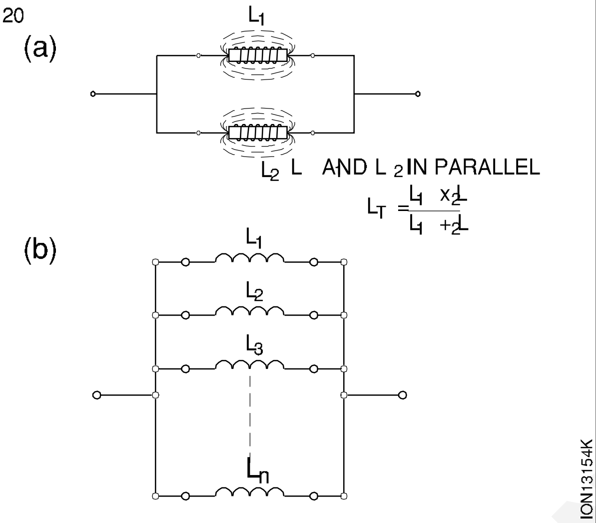
$$L_T = \frac{L_1 \cdot L_2}{L_1 + L_2} \text{ Henrys}$$

This is similar to finding effective value of resistors in parallel.

In general, when several inductors are connected in parallel as shown in Fig 20b the total inductance is given by

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots\ldots + \frac{1}{L_n} \text{ Henrys (H)}$$

Fig 20



Measurement of mutual inductance

The mutual inductance (M) and coefficient of coupling (k) between two coils can be measured as follows;

First : Measure the total inductance with fields aiding,

i.e., $L_{Taid} = L_1 + L_2 + 2M$ ....[1]

Second: Measure the total inductance with fields opposing,

i.e., $L_{Topp} = L_1 + L_2 - 2M$ ....[2]

Solving equations 1 and 2 we get,

$L_{Taid} - L_{Topp} = 4M$ or

$$M = \frac{L_{taid} - L_{TOPP}}{4}$$

knowing values of L_1, L_2 and M, k can be found out using the formula.

$$M = k\sqrt{L_1 \cdot L_2} \quad \text{or} \quad k = \frac{M}{\sqrt{L_1 \cdot L_2}}$$

L-R Time constant (t)

Consider a circuit with a resistor and a pure inductor as shown in Fig 21a. The steady state current of the circuit is not achieved instantaneously but after a lapse of some definite time, as shown in Fig 21b and Fig 21c.

This delay for the current to reach its final value I_f is because, the Inductor opposes changes in circuit current. It is found that, the amount of this *time delay* depends on, the ratio of values of L and R. This *time delay* is referred to as **time constant**, of L-R circuit.

The Time constant t of an inductive circuit is defined as, the time required for the circuit current to reach 63% of its final or steady state current I_f.

Mathematically,

$$\text{Time constant, } t = \frac{L}{R} \text{ seconds}$$

Where,

t is the time constant of the circuit in seconds

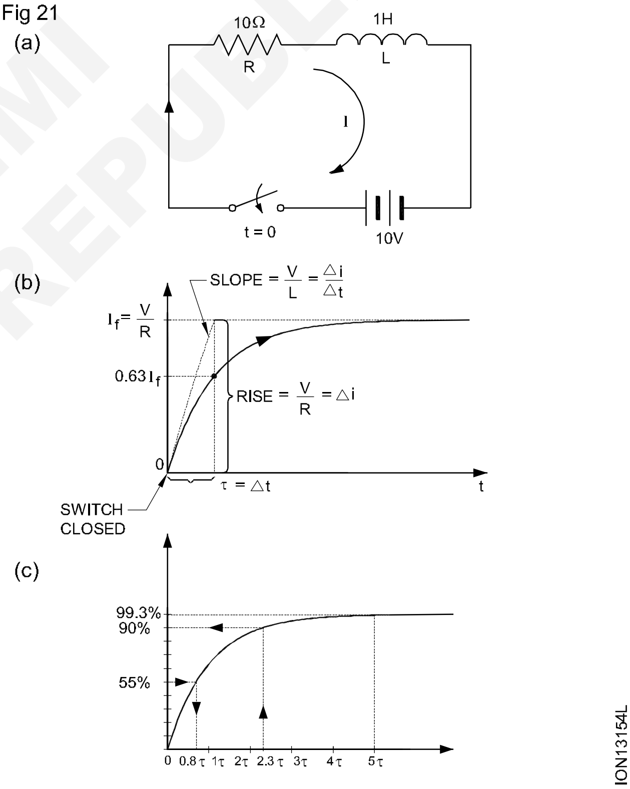
L is the inductance of the circuit in henrys, H

R is the resistance of the circuit in ohms, W

Referring to graph shown in Fig 21b, the circuit current will rise to 63.2% of its final value(I_f) within one time period t.

For the circuit to rise to 99.3% of the final or the steady state value (I_f), as can be seen from Fig 21c, it takes five time-periods or 5t periods. For practical purposes, 99.3% of steady state value can be taken as steady state value (100% of final current I_f). Hence, in a L-R circuit, 5t time is required for the circuit current to reach its steady state value.

Fig 21



Example 1: ***In the RL circuit shown at Fig 21, when switch S is closed find;***

i Time constant t

ii Time required t, for the circuit current to reach steady state value

SOLUTION:

i Time constant t is given by;

$$t = \frac{L}{R} \text{ sec} = \frac{1\text{H}}{10\Omega} = 0.1 \text{ sec}$$

t = 0.1 sec (shown in dashed lines in Fig 2)

ii Time required for the circuit current to reach steady state value (I_f) is given by;

t = 5 x t = 5 x 0.1 sec = 0.5 sec.

Actually it requires slightly more than 0.5 sec for the circuit to reach its final value of 14 (10V/10W). However after 5 t since the current reaches 99.3% (0.9934) it can be taken as almost the steady state current or the final current.

Quality factor - Q of coil

Aligh 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, $\frac{1}{X_C}$

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 than 10 for a low Q coil up-to 1000 for a high

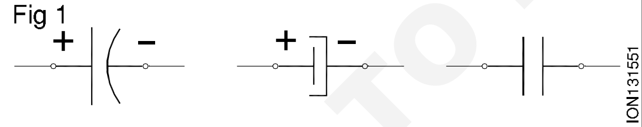
Capacitance and capacitive reactance, impedance

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.

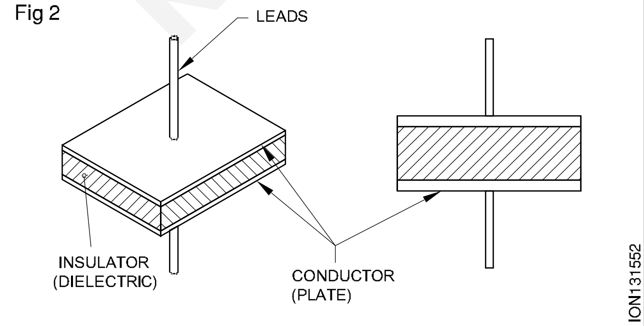
Fig 1



A simple capacitor consists of two pieces of conductors separated by an insulator as shown in Fig 2.

In capacitors the conductors shown in Fig 2 are called **plates** and the insulator is called **dielectric**.

Fig 2



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.

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.

Fig 3

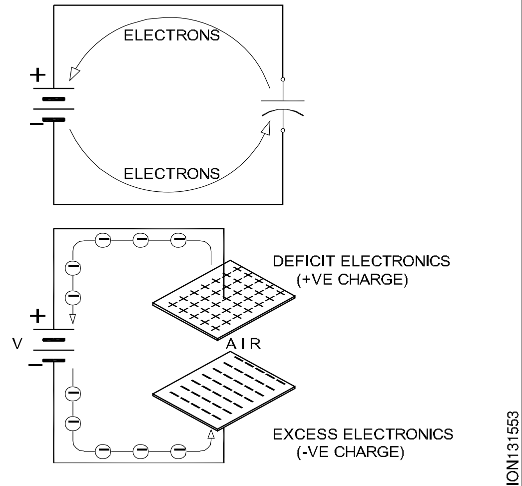
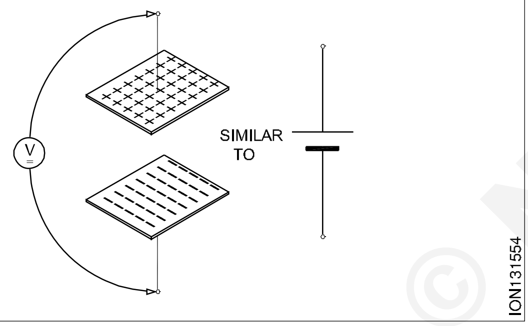


Fig 4



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.**

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:

- For its weight and size, the amount of energy it can store is very small when compared with that of a battery.
- 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^{-6a}	farads
1 Nanofarad or 1 nF	= $1/10^{9}$ F	or 10^{-9}	farads
1 Picofarad or 1pF	= $1/10^{12}$ F	or	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,

$$\text{Capacitance, } C = \frac{Q\ \text{Coloumbs}}{V\ \text{Volts}}\text{Farads}$$

$$\text{Capacitance, } C = \frac{0.5}{25} = 0.02\,\text{Farads}$$

Factors that determine the value of capacitance

The capacitance of a capacitor is determined by the following three main factors;

- Area of the plates
- Distance between the plates
- 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) = $8.85 \times 10^{-12}\ C^2/Nm^2$ 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

- Solves the mechanical problem of keeping two metal plates separated by a very small distance.
- Increases the maximum voltage that can be applied before causing a breakdown, compared with air as dielectric.
- 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

- 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.*

- 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;

- **Type of capacitor**

For example: Ceramic, disc, styroflex, electrolytic and so...on.

- **Capacitance value**

For example: 100μF, 0.01μF, 10pf and so....on.

- **DC working voltage rating (DCWV)**

For example: 100μF-12V, 100μF-100V, 0.01μF-400V and so...on.

- **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%.

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.

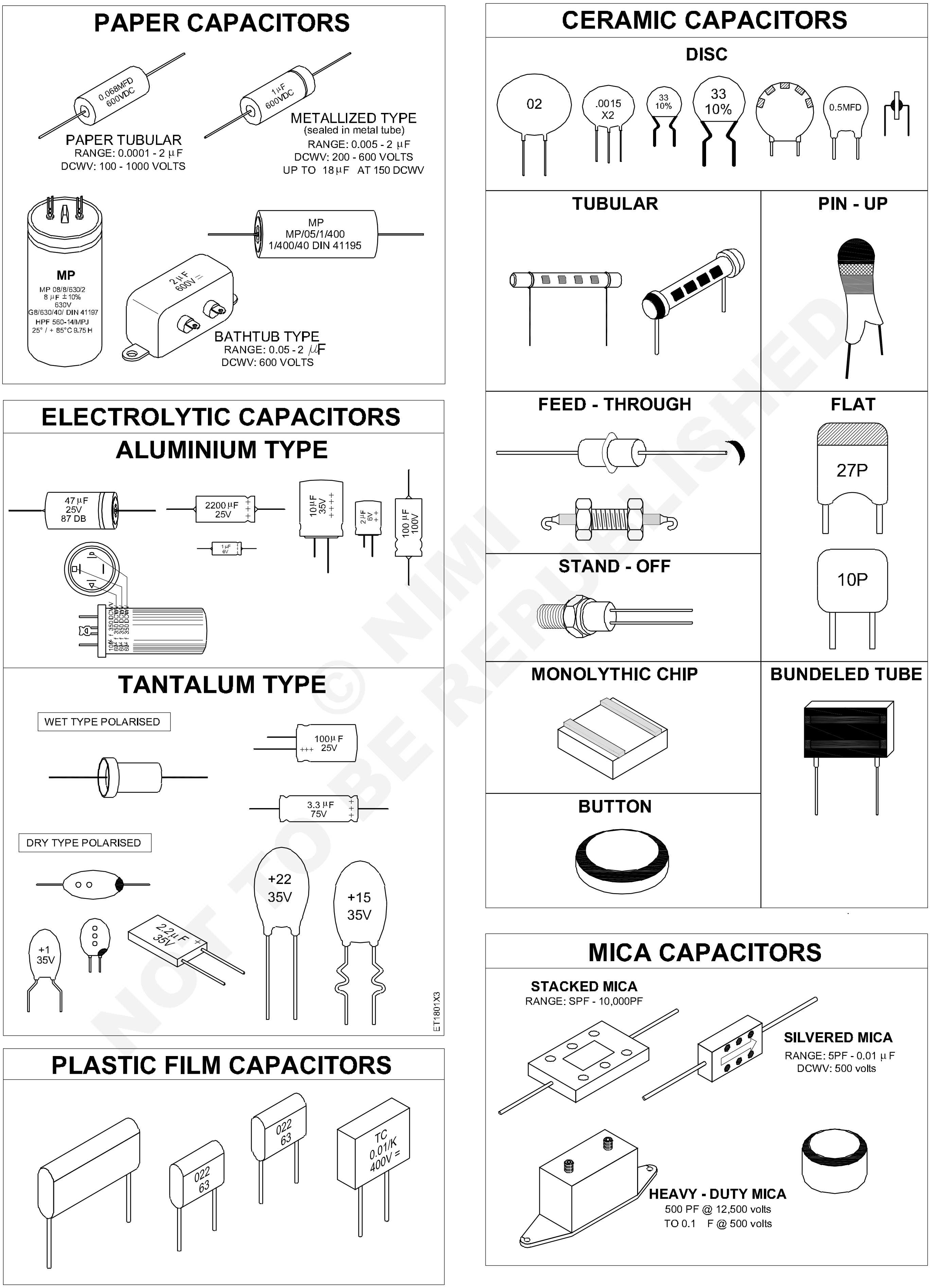
The term FET stands for a type of transistor discussed in subsequent units. A FET input voltmeter is a high quality voltmeter having very high ohms/volts. This meter draws almost zero current while measuring voltage across any two terminals. Other average voltmeters draw current in the range of a few 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

CHART- 1 : Physical appearance of types of fixed value capacitors



Parallel grouping

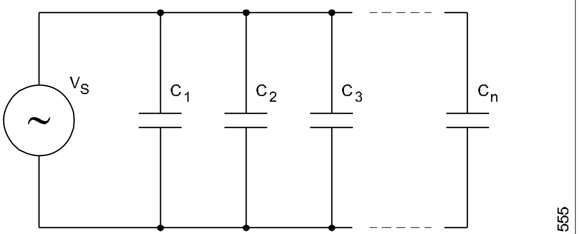
Conditions for parallel grouping

- 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.

Fig 5

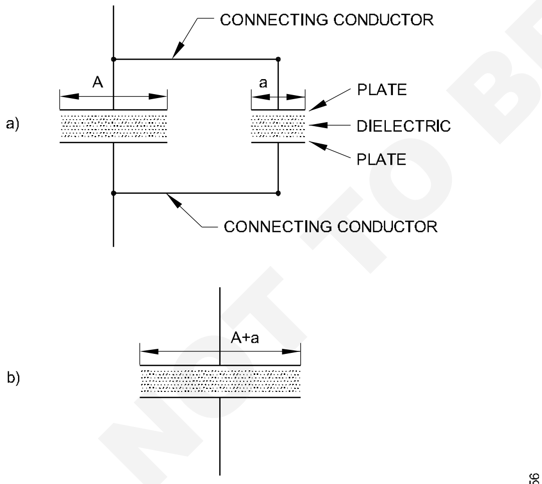


CAPACITORS IN PARALLEL

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.

By comparing Figures 6a and 6b, you can understand that connecting capacitors in parallel effectively increases the plate area.

Fig 6



CAPACITORS IN PARALLEL. THE EQUIVALENT CAPACITANCE IN (b) IS EQUAL TO THE SUM OF THE CAPACITANCES IN (a).

General formula for parallel capacitance: The total capacitance of parallel capacitors is found by adding the individual capacitances.

$C_T = C_1 + C_2 + C_3 + ... + C_n$

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.

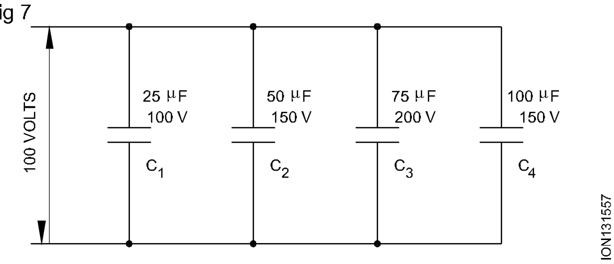
Again $C_T V_S = C_1 V_S + C_2 V_S + C_3 V_S$

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 7.

Fig 7



Solution

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

$= 25 \times 100 \times 10^{-6}$

$= 2500 \times 10^{-6}$

$= 2.5\times10^{-4}$

$= 2.5 \times 10^{-3}$ coulombs.

Q2 = C2V

= 50 x 100 x 10^{-6}

= 5000 x 10^{-6}

= 5 x 10^{-3} coulombs.

Q3 = C3V

= 75 x 100 x 10^{-6}

= 7500 x 10^{-6}

= 7.5 x 10^{-3} coulombs.

Q4 = C4V

= 100 x 100 x 10^{-6}

= 10000 x 10^{-6}

= 10 x 10^{-3} coulombs.

Total charge = Qt= Q1+ Q2 + Q3 + Q4

= (2.5×10^{-3}) + (5×10^{-3})

+(7.5×10^{-3}) + (10×10^{-3})

= (2.5+5+7.5+10) x 10^{-3}

= 25 x 10^{-3} coulombs.

or QT = CTV

= 250 x 10^{-6}x 100

= 25 x 10^{-3} coulombs.

Series grouping

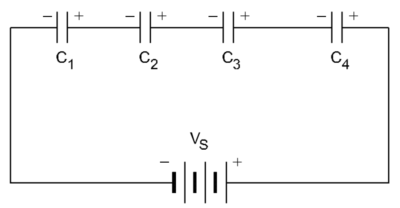
Necessity of grouping of capacitors in series: The necessity of grouping capacitors in series is to reduce the total capacitance in the circuit. Another reason is that two or more capacitors in series can withstand a higher potential difference than an individual capacitor can. But, the voltage drop 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

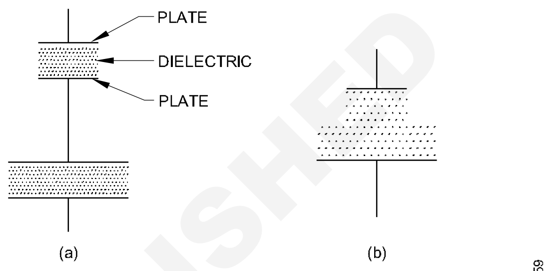
Total capacitance: When capacitors are connected in series, the total capacitance is less than the smallest capacitance value, because

- 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.

$$V_x = \frac{C_T}{C_x} \times V_s$$

where V_x - individual voltage of each capacitor

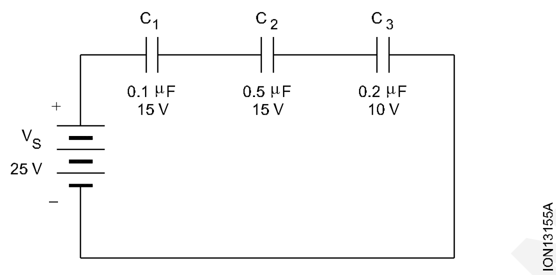
C_x - individual capacitance of each capacitor

V_s - 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.

Example: Find the voltage across each capacitor in Fig 10.

Fig 10



Solution

Total capacitance: CT

Ch revious kn(circuit.

•

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_T} = \frac{1}{0.1} + \frac{1}{0.5} + \frac{1}{0.2} \text{ macro farad}$$

$$\frac{1}{C_T} = \frac{10}{1} + \frac{2}{1} + \frac{5}{1}$$

$$\frac{1}{C_T} = \frac{17}{1}, \text{ and } C_T = 0.0588 \text{ micro farad}$$

$$V_1 = \frac{C_T}{C_1} \times V_s$$

$$V_1 = \frac{0.0588}{0.1} \times 25$$

$$V_1 = 14.71 \text{ Vs}$$

$$V_2 = \frac{C_T}{C_2} \times V_s$$

$$V_2 = \frac{0.0588}{0.5} \times 25$$

$$V_2 = 2.94 \text{ volts}$$

$$V_3 = \frac{C_T}{C_3} \times V_s$$

$$V_2 = \frac{0.0588}{0.2} \times 25$$

$$V_3 = 7.35 \text{ volts}$$

- 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 Q_T.

$$Q_T = Q_1 = Q_2 = Q_3 = \ldots\ldots\ldots\ldots = Q_n$$

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.

$$\frac{V}{1} = V_1 + V_2 + V_3 + \ldots\ldots\ldots + V_n$$

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 $2\pi f$.

$$X_C = \frac{1}{wc}$$

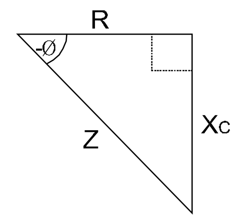
The impedance of an AC capacitance

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

Impedance, $Z = \frac{V}{I}$

$Z = \sqrt{R^2 + X_{C^2}}$

$\therefore Z^2 = R^2 + X_{C^2}$



(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

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

$Z^2 = R^2 + X_c^2$

Properties of magnets and their materials, preparation of artificial magnets, significance of electro magnetism, types of cores

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

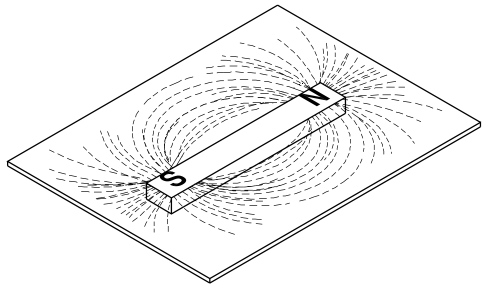
Poles of a magnet

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)

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.

Fig 1



ION131561

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.**

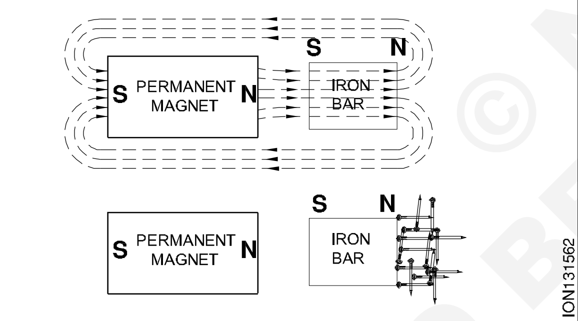
When the north pole of a freely movable permanent magnet is brought near the north pole of a second permanent magnet, an invisible force causes the two poles to repel each other. The two unlike poles actually move away with a jerk. This force of repulsion increases as the distance between the poles decreases. 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.

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.

Fig 2

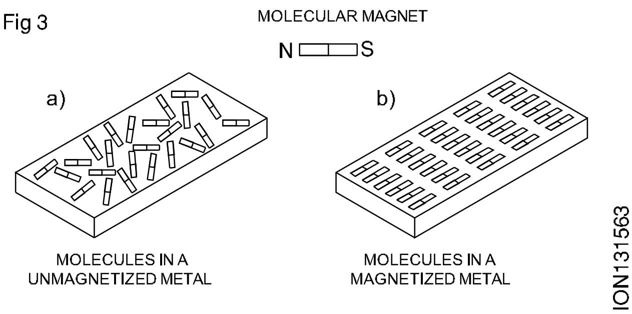


It should be noted that inducing magnetism was possible only because the unmagnetised material was a magnetic material. In Fig 3 instead of iron, a copper bar is used, the permanent magnet will not induce magnetism in copper as copper is a non-magnetic material. The magnetic field lines will be unaffected 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.

Fig 3



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 x 10^8 lines or maxwells. Since weber is a large unit for typical fields, microweber (µWb) unit can be used.

1µWb = 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

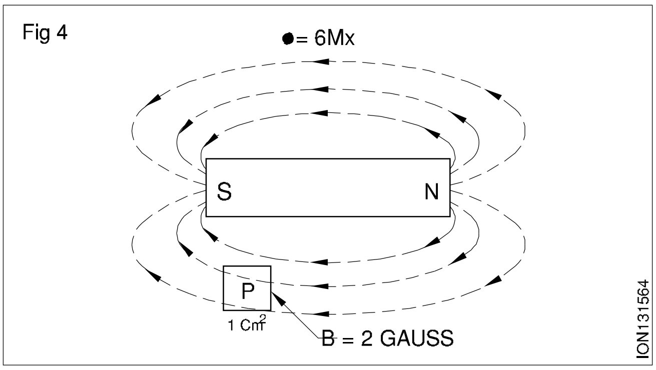
Gauss: One Gauss is equal to one flux line per square centimeter, or 1 Mx/cm^2.

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 cm², what is the flux density in gauss?

$$B = \frac{\varnothing}{A} = \frac{10.000Mx}{5\,cm^2} = 2000Mx\ cm^2$$

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/m²). 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 m², What is the flux density in tesla units?

$$B = \frac{\varnothing}{A} = \frac{400 \times 10^{-6}\ \ Wb}{5 \times 10^{-4}\ \ m^2}$$

$$= \frac{400}{5} \times 10^{-2} = 80 \times 10^{-2}\ \ Wb/m^2$$

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.

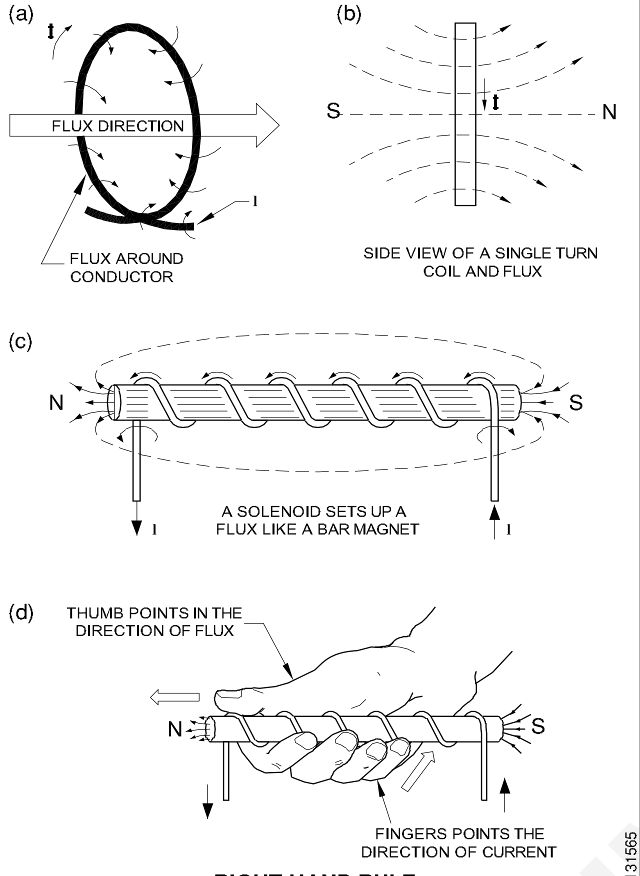
Magnetic field around a coil

Consider the effect of passing a current through a one-turn coil of wire as shown in Fig 5a.

Fig 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.

Fig 5



RIGHT HAND RULE

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.**

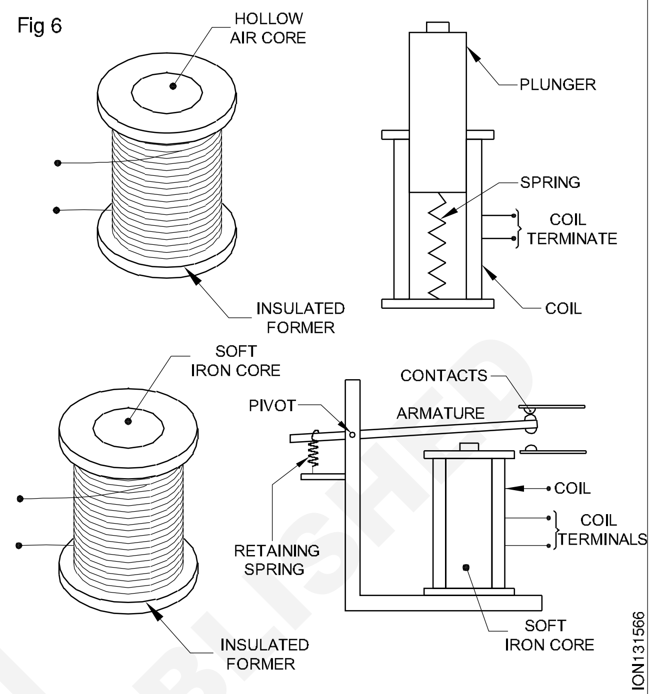
Relays:

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

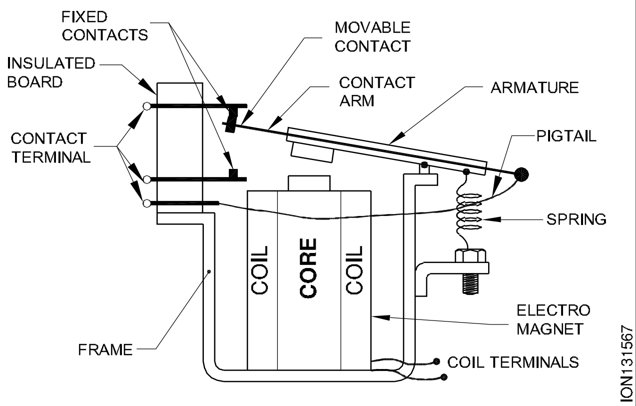
Electromagnetic relay is basically a switch or a combination of switches operated by magnetic force generated by a current flowing through a coil.

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.

Multimeter, use of meters in different circuits

Objectives: At the end of this lesson you shall be able to
- **define multimeter**
- **state use of meters in different circuits.**

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.

Construction of a multimeter

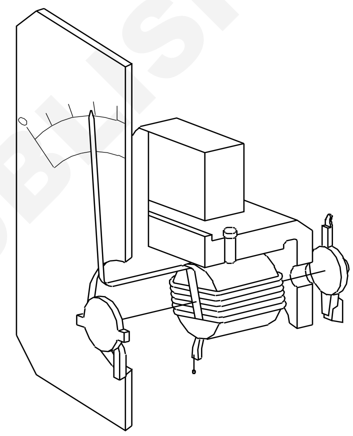
A multimeter uses a single meter movement with a scale calibrated in volts, ohms and milliamperes. The necessary multiplier resistors and shunt resistors are all contained within the case. Front panel selector switches are provided to select a particular meter function and a particular range for that 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 1)

Fig 1



ION131571

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 2.

Controls

The meter is set to measure the current, voltage (AC and DC) or resistance by means of the FUNCTION switch.

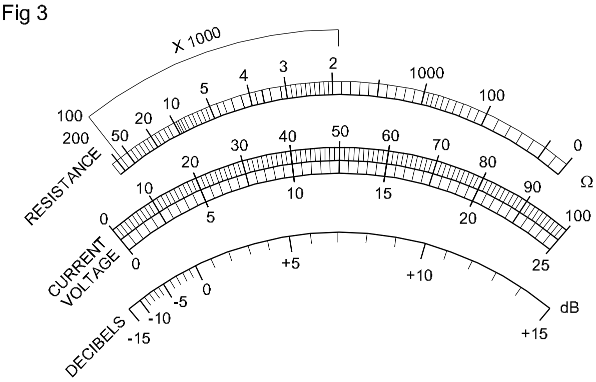
The meter is set to the required current, voltage or resistance range - by means of the RANGE switch. The switch is set to 2.5 volts or mA, depending on the setting of the FUNCTION switch.

Scale of multimeter

Separate scales are provided for:

- resistance
- voltage and current.(Fig 3)

Fig 3

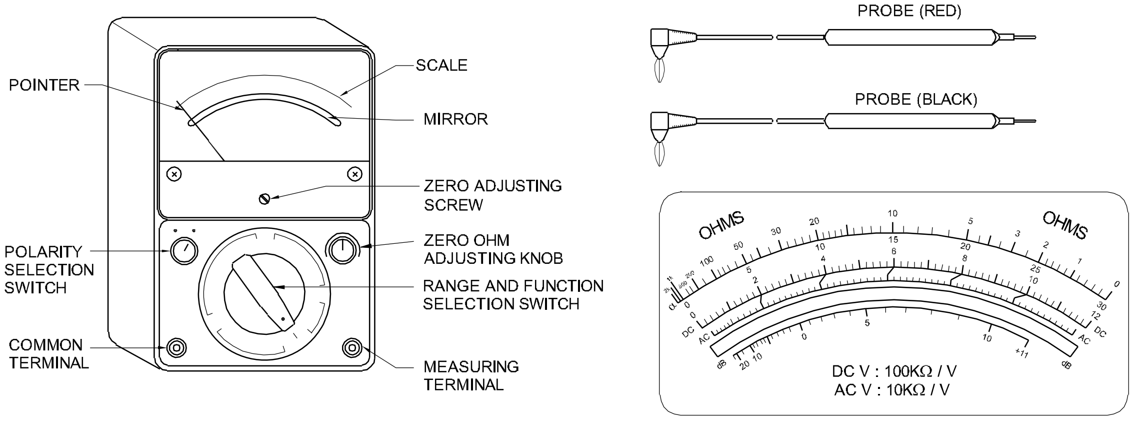


ION131573

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.

Fig 2

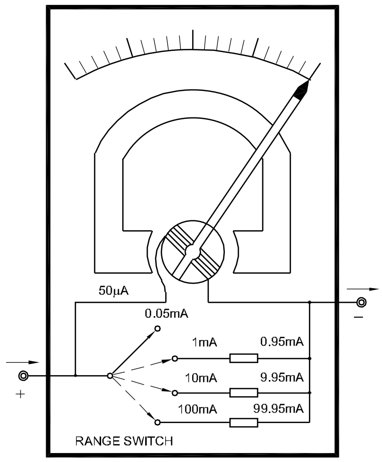


The scale is usually 'backward', with zero at the right.

Principle of working

A circuitry when working as an ammeter is shown in Fig 4.

Fig 4



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 5.

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 6.

To measure resistance, the leads are connected across the external resistor to be measured as shown in Fig 6. 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.

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.

Fig 5

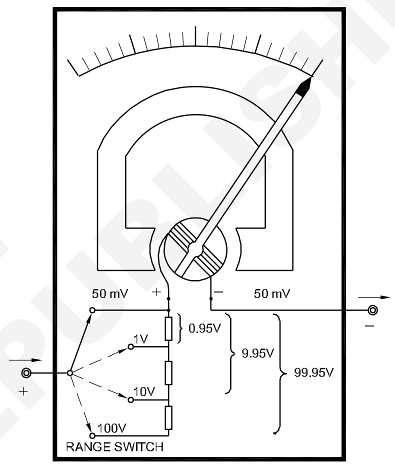
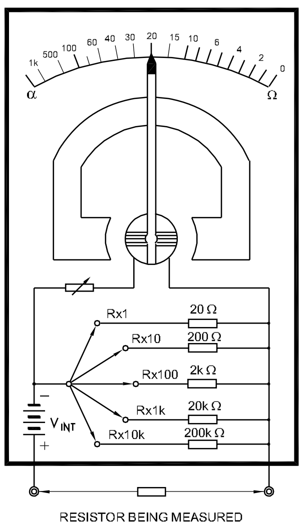


Fig 6



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.

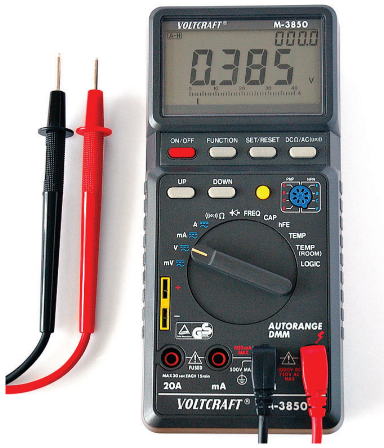
Multiple range

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 7)

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 7 shows the top view of the digital multimeter

Fig 7



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.

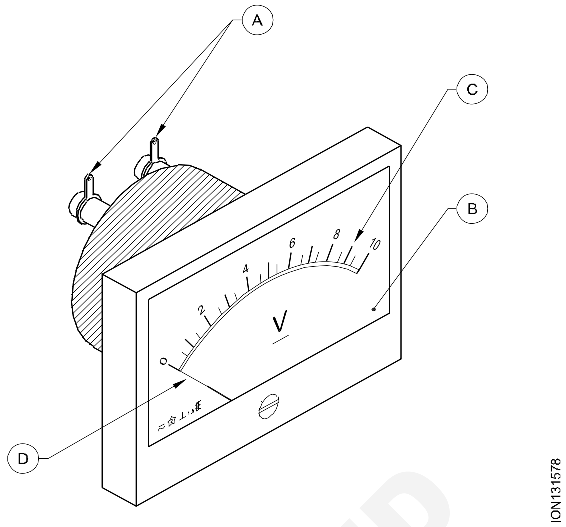
Measurement of voltage

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.

A simple meter is shown in Fig 8.

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).

Fig 8



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 8 can measure DC voltage. This can be found out from the symbol <u>V</u> 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 8, 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 9. Each division is called the Main Scale Division (MSD) of the meter scale.

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 10. These divisions are called Small Scale Divisions (SSD).

Fig 9

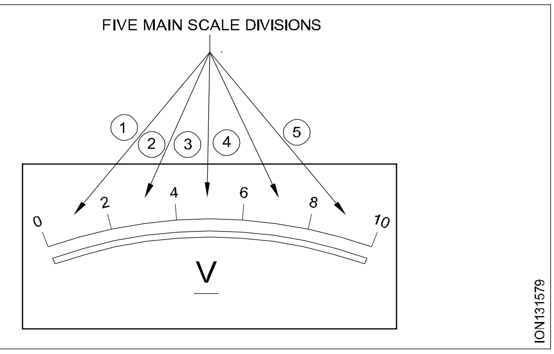
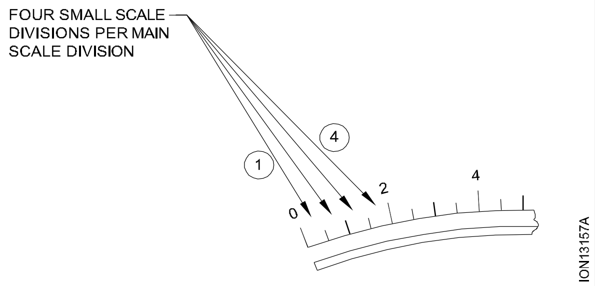


Fig 10



Each small scale division therefore corresponds to,

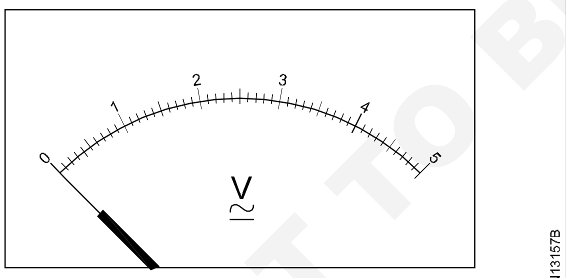
$$\frac{\text{Value of one main scale division}}{\text{Number of small scale division per main scale division}}$$

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

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 11.*

Fig 11



Maximum quantity the meter shown in Fig 11 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.

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

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

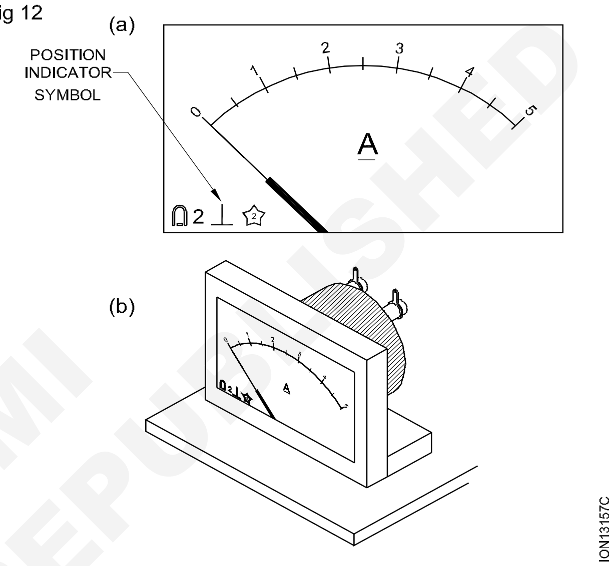
The minimum values that can be measured using the meter in Fig 11 is 0.1 volts and the maximum values that can be measured is 5 volts.

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 12(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 12(b). If this meter is placed horizontally while taking measurement then, the readings shown by the meter will not be accurate.

Fig 12



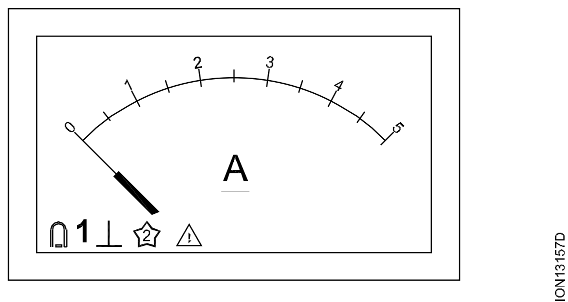
Other symbols indicating the position in which a meter is to be kept while taking readings is given in the Chart 1 of this lesson.

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

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 13. 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.

Fig 13



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

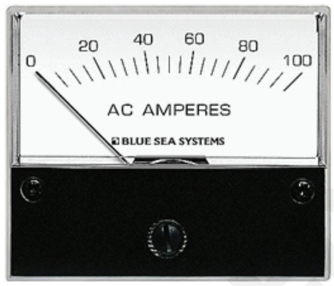
  iii Ohmmeter

  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

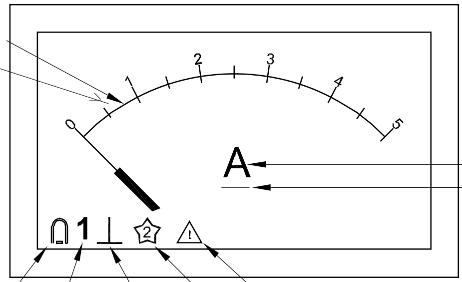
- A clamp meter is an electrical test tool that combines a basic digital multi-meter with a current sensor. It is also called a Tong Tester.
- Clamps measure current. Probes measure voltage. Having a hinged jaw integrated into an electrical meter allows technicians to clamp the jaws around a wire, cable 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 Vmarked 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.

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
	BIMETALLIC
	VIBRATING REED

Symbol	Meaning of the Symbol
M &	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 500 Volts
	TEST VOLTAGE 1 Kilovolts
	TEST VOLTAGE 2 Kilovolts

Indicates special instructions that go with the meter.

Symbol	Meaning of the Symbol
	MAGNETIC SHIELD
	ELECTROSTATIC SHIELD
!	ATTENTION Read Instructions Before Use..

L.C.R. Meter

The LCR meter is an electronic test equipment used to measure among other parameters the impedance of a component (Fig 14 and 15).

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 14

CEC52711

Fig 15

L.C.R. METER

CEC52712

Signal generators

Objectives : At the end of this lesson you shall be able to
- **list the classifications of signal generator based on signal waveform produced**
- **list the classification of signal generator based on frequency coverage**
- **explain principle, specification and applications of function generator**
- **explain the advantage of digital frequency synthesizers.**

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 1 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.

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 Generator

- In electronics laboratory we need to produce different types of signal waveforms with variable, frequencies and shapes of Signal Waveforms such as Square Waves, Rectangular Waves, and Triangular Waves, Saw tooth Waveforms and a variety of pulses and spikes.
- An understanding of testing and test equipment is essential within any area of electronics. Testing and test instruments are keys to any electronics design, development, production and maintenance activity.
- It is used in the test setup, electronic developments, and troubleshooting the electro-acoustic devices and circuits.
- It is also used for testing complex communication systems, measuring the frequency response of the amplifier, aligning of radio receivers, for testing complex telecommunication circuits and networks.

The signal generator produces only a Sine wave signals. It has Limited Frequency stability and No capability of phase locking with the external source. Whereas, Function generators go beyond signal generators and it generates various waveforms like sine, square, saw tooth, triangular, etc. It has High-Frequency Stability and the capability of phase-locking with the external source. Frequency is controlled by varying the magnitude of the current which drives the integrator circuit in it.

Function Generator

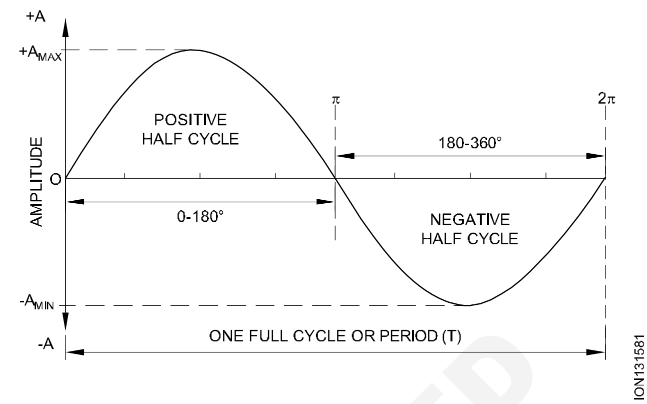
- The function generator is one of the very important electronic equipment that generates different types of waveforms like sine wave, square wave, triangular wave, a saw-tooth wave, (ramp up/down) and other types of output waveforms.
- The frequency and amplitude of these waveforms can be varied over a wide range.
- Another useful feature of the function generator is that it can be phase-locked to an external signal source so that two output signals can be displaced in phase by an adjustable amount.

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

Function generator capabilities: Function generators are capable of producing the following variety of repetitive waveforms;

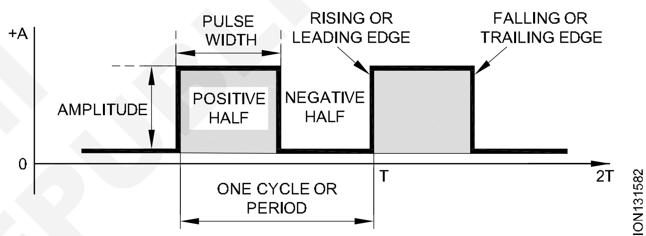
Sine wave: This is the standard waveform that oscillates between two levels with a standard sinusoidal shape. (Fig 1) Using the function generator as a sine wave generator is one of the more commonly used applications. Sine waves are widely used in testing applications.

Fig 1



Square wave: The square wave consists of a signal moving directly between high and low levels. Used as a square wave generator, this test instrument provides a very useful source of a basic digital waveform. (Fig 2)

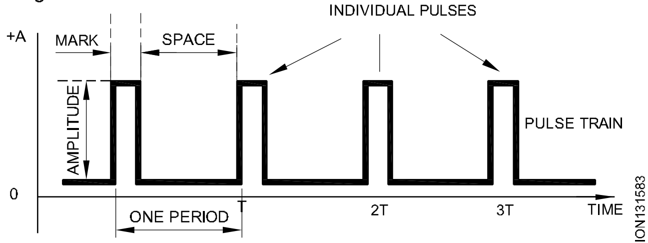
Fig 2



Pulse: A Pulse is a waveform or signal in its own right. It has very different Mark-to-Space ratio compared to a high frequency square wave clock signal or even a rectangular waveform. (Fig 3)

The purpose of a "Pulse" and that of a trigger is to produce a very short signal to control the time at which something happens for example, to start a Timer, Counter, Monostable or Flip-flop etc, or as a trigger to switch "ON" Thyristors, Triacs and other power semiconductor devices.

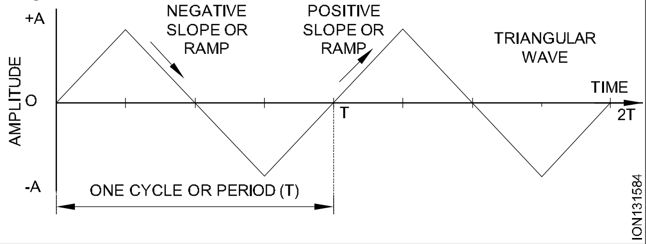
Fig 3



Triangular wave: Triangular wave form is shown in Fig 4. This form of signal produced by the function generator linearly moves between a high and low point. This form of waveform is often generated using an operational amplifier acting as an integrator. The triangular waveform generator typically also has a square wave output as well, and it is used as the basis for generating all the waveforms in a function generator test instrument.

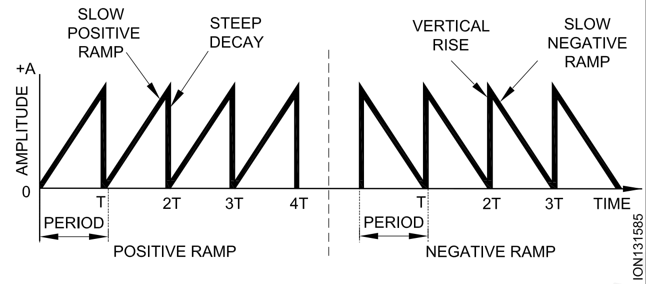
The triangular waveform is often used in testing amplifiers - it is far easier to see distortion and clipping on a triangular waveform than it is on a sine waveform.

Fig 4



Saw tooth wave: Again, this is a triangular waveform, but with the rise edge of the waveform faster or slower than the fall, making a form of shape similar to a saw tooth. It is generated by the same circuit as the triangular waveform, but with the different rise and fall times created by changing the charge rate for the rise and fall elements of the integrator. (Fig 5)

Fig 5



Also a function generator can be adjusted to vary the characteristics of the waveforms, changing the length of the pulse, i.e. the mark space ratio, or the ramps of the different edges of triangular or saw tooth waveforms, but it is only be able to create the waveforms that are built in to the function generator.

The front panel of a typical Function Generator. You can see different controls on the front panel of function generator. Read and identify the controls, their functions and understand the technical informations given by the manufacturer in the instruction manual before operating this test equipment thoroughly.

Function buttons: To change the type of waveform selection of the basic waveforms that are available, other controls on the function generator may include;

Frequency: As would be expected, this control alters the basic frequency at which the waveform repeats. It is independent of the waveform type.

Waveform type: This enables the different basic waveform types to be selected: Sine wave Square wave, Triangular wave etc.

DC offset: This alters the average voltage of a signal relative to 0V or ground. Apart from just generating the waveforms themselves, this type of test instrument has the capability to add a DC offset to the signal. This can be very useful in a number of testing applications.

Coarse and Fine knobs: These knobs are used to set different input frequency. Coarse is used to vary the frequency with large difference. Fine knob is used to precisely vary frequency in decimals.

Frequency Range Buttons: These are to change the range of frequency after it's control we change frequency with the help of Coarse and Fine Knobs.

Duty Cycle knob: It changes the duty cycle of wave.

INV button: It inverts the signal.

Duty cycle: This control on the function generator changes the ratio of high voltage to low voltage time in a square wave signal, i.e. changing the waveform from a square wave with a 1:1 duty cycle to a pulse waveform, or a triangular waveform with equal rise and fall times to a sawtooth. Function generator usage

Direct Digital Synthesis (DDS)

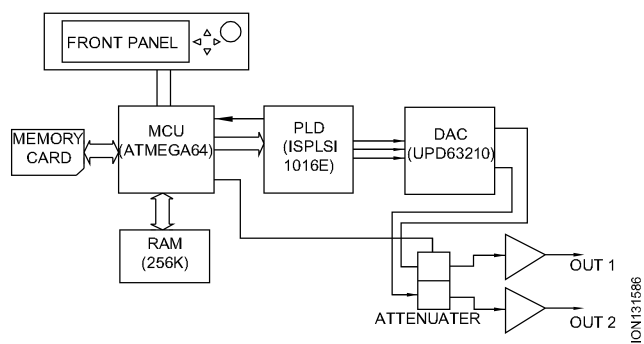
By using this digital synthesizer circuits (DDS), function generators are cable of generating even a fraction of one Hertz that is 0.355 μHz(too much low values) of frequency precision. DDS works by first storing a large repetitive waveform in on board memory. Single cycle of a waveform (sine, triangle, square, arbitrary) can be represented by exactly 16,384 distinct points and stored into the on board memory.

Once the waveform is stored into memory, it can be generated at any precise frequencies. DDS uses a phase accumulator, a look-up table containing a digital representation of the waveform, and a DAC (Digital to analog convertor).

The phase accumulator moves another position each time it receives a clock pulse. The next position in the look-up table is then accessed giving the digital value for the waveform at that point.

This digital value is then converted into an analog value using a digital to analog converter, DAC. At the output a low pass filter is connected, to get low frequencies. (Fig 6)

Fig 6



The front panel of a typical Digital type Function Generator is shown in Fig 7. You can see different controls on the front panel of this modern function generator. It has LCD display screen which shows the set waveform as well as the frequency and other parameters on the screen. The user can observe it even before connecting its output to the Oscilloscope.

Fig 7

Advantages of digital function generators

A digital function generator provides high level of accuracy and stability.

DDS based digital function generators generate much wider frequency range than an analog function generator.

The disadvantage of the digital function generators is that they require a high performance Digital to Analogue Converter and other digital circuitry to operate. So they are more complicated and costly.

Function generator usage

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

A wide variety of synthesized electrical signals and waveforms can be created for testing, repairing and diagnostic applications.

It produces different types of waveforms such as sine, square, triangle and saw tooth over a wide range of frequencies.

It can be implemented with basic expensive components. The saw tooth wave and triangular-wave outputs of function generators are commonly used for those applications which need a signal that increases (or reduces) at a specific linear rate.

They are also used in driving sweep oscillators in the X-axis of X-Y recorders oscilloscopes.

If the zero crossing of both the waves is made to occur at the same time, a linearly varying waveform is available which can be started at the point of zero phase of a sine wave.

Operate the front panel controls of a digital storage oscilloscope

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

- **define digital storage oscilloscope**
- **compare DSO and analog CRO**
- **draw the block diagram and explain the functions of each block**
- **list the functions of each control on the front panel.**

Electronic equipments can be divided into two types: analog and digital. Analog equipment works with continuously variable voltages, while digital equipment works with binary numbers (1 and 0's) that may represent voltage samples. For example, a conventional cassette player is an analog device; a compact disc player is a digital device.

Oscilloscopes also come in analog and digital types. An analog oscilloscope works by directly applying a voltage being measured to an electron beam moving across the oscilloscope screen. The voltage deflects the beam up and down proportionally, tracing the waveform on the screen. This gives an immediate picture of the waveform. In contrast, a digital oscilloscope samples the waveform and uses an analog-to-digital converter (ADC) to convert the voltage being measured into digital information. Then uses this digital information to reconstruct the waveform on the screen. Some of the advantages of a digital oscilloscope over analog oscilloscope include the scope's ability to store digital data for later viewing, upload to a computer, generate a hard copy or store on a disk and its capacity to instantly make measurements on the digital data.

A digital oscilloscope also has the ability to examine digitized information stored in its memory and make automatic measurements based on the selected parameters of the user, such as voltage excursion, frequency and rise times.

Digital Storage Oscilloscopes (DSO)

Digital oscilloscopes are often referred to as digital storage oscilloscope (DSO) or digital sampling oscilloscopes (DSO).

The concept behind the digital oscilloscope is somewhat different to an analog scope.

Rather than processing the signals in an analog fashion, the DSO converts them into a digital format using an analog to digital converter (ADC), then it stores the digital data in the memory, and then processes the signals digitally, finally it converts the resulting signal in a picture format to be displayed on the screen of the scope.

Since the waveform is stored in a digital format, the data can be processed either within the oscilloscope itself, or even by a PC connected to it. One advantage of using the DSO is that the stored data can be used to visualize or process the signal at any time. The analog scopes do not have memory therefore the signal can be displayed only instantaneously. The transient parts of the signal (which may vanish even in milliseconds or microseconds) can not be observed using an analog oscilloscope. The DSO's are widely used in many applications in view of their flexibility and performance.

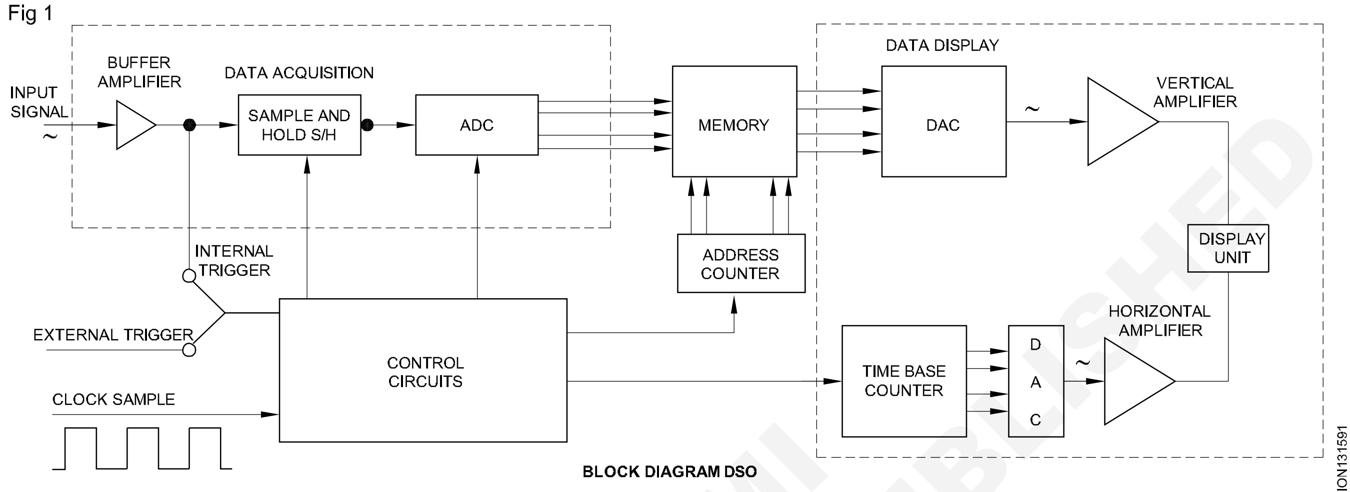
Figure 1 shows the block diagram of DSO as consists of,

1 Data acquisition

2 Storage

3 Data display.

Fig 1



Data acquisition is earned out with the help of both analog to digital and digital to analog converters, which is used for digitizing, storing and displaying analog waveforms. Overall operation is controlled by control circuit which is usually consists of microprocessor.

Data acquisition portion of the system consist of a Sample-and-Hold (S/H) circuit and an analog to digital converter (ADC) which continuously samples and digitizes the input signal at a rate determined by the sample clock and transmit the digitized data to memory for storage. The control circuit determines whether the successive data points are stored in successive memory location or not, which is done by continuously updating the memories.

When the memory is full, the next data point from the ADC is stored in the first memory location writing over the old data. The data acquisition and the storage process is continues till the control circuit receive a trigger signal from either the input waveform or an external trigger source. When the triggering occurs, the system stops and enters into the display mode of operation in which all or some part of the memory data is repetitively displayed on the cathode ray tube.

In display operation, two DACs are used which gives horizontal and vertical deflection voltage for the CRT Data from the memory gives the vertical deflection of the electron beam, while the time base counter gives the horizontal deflection in the form of staircase sweep signal.

The screen display consist of discrete dots representing the various data points but the number of dot is very large as 1000 or more that they tend to blend together and appear to be a smooth continuous waveform.

The display operation ends when the operator presses a front-panel button and commands the digital storage oscilloscope to begin a new data acquisition cycle.

This chapter describes the menus and operating details associated with each front-panel menu button or control.

Digital Storage Oscilloscopes are small, lightweight, bench top packages that you can use to take ground-referenced measurements.

Understanding Oscilloscope Functions

This chapter contains information on what you need to understand before you use an oscilloscope. To use your oscilloscope effectively, you need to learn about the following oscilloscope functions:

- Setting up the oscilloscope
- Triggering
- Acquiring signals (waveforms)
- Scaling and positioning waveforms
- Measuring waveforms

Setting Up the Oscilloscope

You should become familiar with three functions that you may use often when operating your oscilloscope: Autoset, saving a setup, and recalling a setup. Using Autoset the function obtains a stable waveform display for you. It automatically adjusts the vertical scale, horizontal scale and trigger settings. Autoset also displays several automatic measurements in the graticule area, depending on the signal type.

Saving a Setup

The oscilloscope saves the current setup if you wait five seconds after the last change before you power off the oscilloscope. The oscilloscope recalls this setup the next time you apply power. You can use the SAVE/RECALL Menu to permanently save up to ten different setups.

Recalling a Setup

The oscilloscope can recall the last setup before power off, any of your saved setups or the default setup.

Default Setup

The oscilloscope is set up for normal operation when it is shipped from the factory. This is the default setup. To recall this setup, push the DEFAULT SETUP button.

Triggering

The trigger determines when the oscilloscope starts to acquire data and display a waveform. When a trigger is set up properly, the oscilloscope converts unstable displays or blank screens into meaningful waveforms.

When you push the RUN/STOP or SINGLE SEQ buttons to start an acquisition, the oscilloscope goes through the following steps:

- Acquires enough data to fill the portion of the waveform rec frequency and displays the frequency in the lower right corner of the screen.
- Continues to acquire data while waiting for the trigger condition to occur
- Detect the trigger condition
- Continues to acquire data unti thwwaveformrecord full
- Displays the newly acquired waveform

For edge and Puse triggers, the osciloscope counts the rate at which triggedr events occur to determine trigger frequency and displays the frequency in the lower right corner ofthe scren.

Source

You can use the Trigger Source options to select the signal that the oscilloscope uses as a trigger. The source can be any signal connected to a channel BNC, to the EXT TRIG BNC or the AC power line (available only with Edge triggers).

Types

The oscilloscope provides three types of triggers: Edge, Video, and Pulse Width.

Modes

You can select a Trigger Mode to define how the oscilloscope acquires data when it does not detect a trigger condition. The modes are Auto and Normal. To perform a single sequence acquisition, push the SINGLE SEQ button.

Coupling

You can use the Trigger Coupling option to determine which part of the signal will pass to the trigger circuit. This can help you attain a stable display of the waveform.

To use trigger coupling, push the TRIG MENU button, select an Edge or Pulse trigger, and select a Coupling option.

Trigger coupling affects only the signal passed to the trigger system. It does not affect the bandwidth or coupling of the signal displayed on the screen.

To view the conditioned signal being passed to the trigger circuit, push and hold down the TRIG VIEW button. Trigger coupling affects only the signal passed to the triggersystem. It does not affect the bandwidth or coupling of the signal displayed on the screen.

Position

The horizontal position control establishes the time between the trigger and the screen center.

Slope and Level

The Slope and Level controls help to define the trigger. The Slope option (Edge trigger type only) determines whether the oscilloscope finds the trigger point on the rising or the falling edge of a signal. The TRIGGER LEVEL knob controls where on the edge the trigger point occurs.

Acquiring Signals

When you acquire a signal, the oscilloscope converts it into a digital form and displays a waveform. The acquisition mode defines how the signal is digitized and the time base setting affects the time span and level of detail in the acquisition.

Acquisition Modes

There are three acquisition modes: Sample, Peak Detect, and Average.

Sample

In this acquisition mode, the oscilloscope samples the signal evenly spaced intervals to construct the waveform. This mode accurately represents signals most of the time. However, this mode does not acquire rapid variations in the signal that may occur between samples. This can result in aliasing and may cause narrow pulses to be missed. In these cases, you should use the Peak Detect mode to acquire data.

Peak Detect

In this acquisition mode, the oscilloscope finds the highest and lowest values of the input signal over each sample interval and uses these values to display the waveform. In this way, the oscilloscope can acquire and display narrow pulses, which may have otherwise been missed in Sample mode. Noise will appear to be higher in this mode.

Average

In this acquisition mode, the oscilloscope acquires several waveforms, averages them, and displays the resulting waveform. You can use this mode to reduce random noise.

Time Base

The oscilloscope digitizes waveforms by acquiring the value of an input signal at discrete points. The time base allows you to control how often the values are digitized. To adjust the time base to a horizontal scale that suits your purpose, use the SEC/DIV knob.

Scaling and Positioning Waveforms

You can change the display of waveforms by adjusting their scale and position. When you change the scale, the waveform display will increase or decrease in size. When you change the position, the waveform will move up, down, right, or left. The channel reference indicator (located on the left of the graticule) identifies each waveform on the display. The indicator points to the ground level of the waveform record.

Vertical Scale and Position

You can change the vertical position of waveforms by moving them up or down in the display. To compare data, you can align a waveform above another or you can align waveforms on top of each other.

You can change the vertical scale of a waveform. The waveform display will contract or expand about the ground level.

Horizontal Scale and Position;

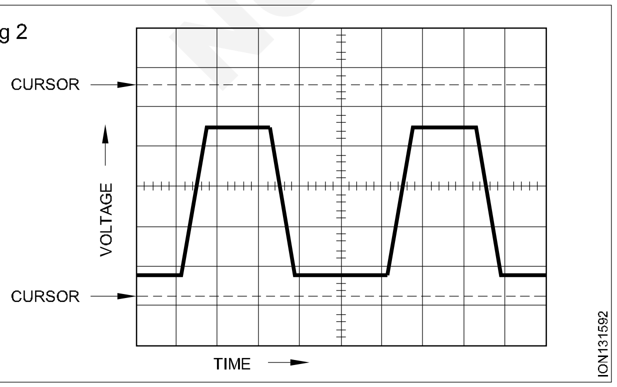
Pretrigger Information You can adjust the HORIZONTAL POSITION control to view waveform data before the trigger, after the trigger, or some of each. When you change the horizontal position of a waveform, you are actually changing the time between the trigger and the center of the display. (This appears to move the waveform to the right or left on the display.) For example, if you want to find the cause of a glitch in your test circuit, you might trigger on the glitch and make the pretrigger period large enough to capture data before the glitch. You can then analyze the pretrigger data and perhaps find the cause of the glitch. You change the horizontal scale of all the waveforms by turning the SEC/DIV knob. For example, you might want to see just one cycle of a waveform to measure the overshoot on its rising edge.

The oscilloscope shows the horizontal scale as time per division in the scale readout. Since all active waveforms use the same time base, the oscilloscope only displays one value for all the active channels, except when you use Window Zone.

Taking Measurements

The oscilloscope displays graphs of voltage versus time as shown in Fig 2 and can help you to measure the displayed waveform. There are several ways to take measurements. You can use the graticule, the cursors, or an automated measurement.

Fig 2



Graticule

This method allows you to make a quick, visual estimate. For example, you might look at a waveform amplitude and determine that it is a little more than 100 mV. You can take simple measurements by counting the major and minor graticule divisions involved and multiplying by the scale factor. For example, if you counted five major vertical graticule divisions between the minimum and maximum values of a waveform and knew you had a scale factor of 100 mV/division, then you could easily calculate your peak-to-peak voltage as follows: 5 divisions x 100 mV/division = 500 mV.

Cursors

This method allows you to take measurements by moving the cursors, which always appear in pairs, and reading their numeric values from the display readouts. There are two types of cursors:

Voltage and Time

When you use cursors, be sure to set the Source to the waveform on the display that you want to measure. To use cursors, push the CURSOR button.

Voltage Cursors

Voltage cursors appear as horizontal lines on the display and measure the vertical parameters.

Time Cursors

Time cursors appear as vertical lines on the display and measure the horizontal parameters.

Automatic

The MEASURE Menu can take up to five automatic measurements. When you take automatic measurements, the oscilloscope does all the calculating for you. Because the measurements use the waveform record points, they are more accurate than the graticule or cursor measurements. Automatic measurements use readouts to show measurement results. These readouts are updated periodically as the oscilloscope acquires new data.

Acquire

Push the Acquire button to set acquisition parameters

Options	Settings	Comments
Sample		Use to acquire and accurately display most waveforms; this is the default mode
Peak Detect		Use to detect glitches and reduce the possibility of aliasing
Average		Use to reduce random or uncorrelated noise in the signal display; the the number of averages is selectable
Averages	4 16 64 128	Select number of averages

RUN/STOP Button: Push the RUN/STOP button when you want the oscilloscope to continuously acquire waveforms. Push the button again to stop the acquisition.

SINGLE SEQ Button: Push the SINGLE SEQ button when you want the oscilloscope to acquire a single waveform and then stop. Each time you push the SINGLE SEQ button, the oscilloscope begins to acquire another waveform. After the oscilloscope detects a trigger it completes the acquisition and stop.

Acquisition mode	Single Seq button
Sample, Peak Detect	Sequence is complete when one acquisition is acquired
Average	Sequence is complete when the defined number of acquisitions is reached

Scan Mode Display: You can use the Horizontal Scan acquisition mode (also called Roll mode) to continuously monitor signals that change slowly. The oscilloscope displays waveform updates from the left to the right of the screen and erases old points as it displays new points.

A moving, one-division-wide blank section of the screen separates the new waveform points from the old. The oscilloscope changes to the Scan acquisition mode when you turn the SEC/DIV knob to 100 ms/div or slower, and select the Auto Mode option in the TRIGGER Menu.

To disable Scan mode, push the TRIG MENU button and set the Mode option to Normal.

Stopping the Acquisition. While the acquisition is running, the waveform display is live. Stopping the acquisition (when you push the RUN/STOP button) freezes the display. In either mode, the waveform display can be scaled or positioned with the vertical and horizontal controls.

Auto set

When you push the AUTOSET button, the oscilloscope identifies the type of waveform and adjusts controls to produce a usable display of the input signal.

Function	Setting
Acquire mode	Adjusted to sample to peak detect
Display format	Set to YT
Display type	Set to dots for a video signal, set to vectors for an FFT spectrum; otherwise, unchanged
Horizontal position	Adjusted
Trigger coupling	Adjusted to DC, Noise reject , or HF reject
Trigger holdoff	Minimum
Trigger level	Set to 50%
Trigger mode	Auto
Trigger source	Adjusted; cannot use Autoset on the EXT TRIG signal
Trigger slope	Adjusted
Trigger type	Edge or Video
Trigger video sync	Adjusted
Trigger video standard	Adjusted
Vertical bandwidth	Full
Vertical coupling	DC (if GND was previously selected); AC for a video signal; otherwise, unchanged

The Autoset function examines all channels for signals and displays corresponding waveforms. Autoset determines the trigger source based on the following conditions:

- If multiple channels have signals, channel with the lowest frequency signal
- No signals found, the lowest-numbered channel displayed when Autoset was invoked
- No signals found and no channels displayed, oscilloscope displays and uses channel 1

Cursor

Push the CURSOR button to display the measurement cursors and cursor menu.

Options	Settings	Comments
Type*	Voltage Time Off	Select and display the measurement cursors; voltage measures amplitude and time measures time and frequency
Source	CH1 CH2 CH3** CH4** MATH REFA REFB REFC** REFD**	Choose the waveform on which to take the cursor measurements The readouts display this measurement
Delta		Displays the difference (delta) between the cursors
Cursor 1		Displays cursor 1 location (time is referenced to the trigger position, voltage is referenced to ground)
Coursor 2		Displays cursor 2 location (time is referenced to the trigger position, voltage is referenced to ground)

*For a math FFT source, measures magnitude and frequency.

Display

Push the DISPLAY button to choose how waveforms are presented and to change the appearance of the entire display.

Options	Settings	Comments
Type	Vectors	Vectors fills the space between adjacent sample points in the display. Dots displays only the sample points
Persist	OFF 1 sec 2 sec 5 sec Infinite	Sets the length of time each displayed sample point remains displayed
Format	YT	YT format displays the vertical voltage in relation to time (horizontal scale) XY format displays a dot each time a sample is acquired on channel 1 and channel 2 Channel 1 voltage determines the X coordinate of the dot (horizontal and the channel 2 voltage determines the Y coordinate (vertical)
Contrast Increase		Darkness the display; makes it easier to distinguish a channel waveform from persistence.
Contrast Decrease		Lightens the display

For a math FFT source, measures magnitude and frequency.

Utility

Push the UTILITY button to display the Utility Menu.

Options	Settings	Comments
Systems status		Displays summaries of the oscilloscope settings
Options	Display Style*	Displays screen data as black on white, or as white on black
	Printer Setup*	Displays the setup for the printer; see page 131
	RS232 Setup**	Displays the setup for the RS-232 port; see page 134
	GPIB Setup**	Displays the setup for the GPIB port; see page 143
Do self cal		Performs a self calibration
Error Log		Displays a list of any errors logged This list is useful when contacting a Tektronix service center for help This list is useful when contacting a Tektronix Service Center for help
Language	English French German Italian Spanish Portuguese Japanese Korean Simplified Chinese Traditional Chinese	Selects the display language of the operating system

Capturing a single shot signal

Objectives : At the end of this lesson you shall be able to
- **capture a single shot signal**
- **optimizing the acquisition**
- **measure the propagation delay.**

Capturing

Some events which do not occur frequently, but occurs very rarely for short duration of time can be viewed with the help of digital storage oscilloscope. In other words, the transient part of the signal which vanish even in few milliseconds or microseconds can be observed using a digital oscilloscope.

For example

The transient response of Rh, Rc circuits, A and E signal in microprocessors, switch bouncing signal etc.

The DSO can display captured data in various ways.

Capturing a Single-Shot Signal

The reliability of a reed relay in a piece of equipment has been poor and you need to investigate the problem. You suspect that the relay contacts arc when the relay opens. The fastest you can open and close the relay is about once second so you need to capture the voltage across the relay as a single-shot acquisition.

Optimizing the Acquisition

The initial acquisition shows the relay contact beginning to open at the trigger point. This is followed by a large spike that indicates contact bounce and inductance in the circuit. The inductance can cause contact arcing and premature relay failure. You can use the vertical, horizontal, and trigger controls to optimize the settings before the next single-shot event is captured. When the next acquisition is captured with the new settings (when you push the SINGLE SEQ button again), you can see more detail about the relay contact opening.

Measuring Propagation Delay

You suspect that the memory timing in a microprocessor circuit is marginal. Set up the oscilloscope to measure the propagation delay between the chip-select signal and the data output of the memory device.

Interface the DSO to external devices

Objectives: At the end of this lesson you shall be able to
- **state the applications of USB rear and host port**
- **uses of save/recall menu**
- **state the advantages of using a USB flash drive**
- **interface the USB port to the external device**
- **understand the printer setups before printing the waveforms.**

A typical DSO may come with two USB ports that allow flexible communications with a number of devices.

The USB host port on the front of the oscilloscope can transfer

- Wave form and setup data to and from a USB flash drive
- Screen images to a USB flash drive

The USB device port on the rear of the oscilloscope can transfer

- Waveform and setup data to and from a computer
- Screen images to a computer
- Screen images directly to a PictBridge compatible printer

The USB port Host port on the front of the oscilloscope is designed to support a single USB flash drive. The port will not support multiple USB flash drives by use of a USB hub.

The USB device port on the rear of the oscilloscope can either be connected to a computer or to a PictBridge compatible printer, but not both simultaneously.

SAVE/RECALL waveforms

You can use the SAVE/RECALL menu, Save Waveform options to save wave from data points and acquisition parameters information to a USB flash drive. You can use the Recall Waveform menu option to display saved waveforms. Also called as reference waveforms. Reference waveforms are displayed with a lower intensity than live waveforms

You can use Print button or SAVE /RECALL menu, Save option to save the current screen image to a file on a USB flash drive. The PRINT button is more versatile than the option button, because it can send to any menu

Saving setups on a USB flash drive has several advantages over savings setups in internal memory;

- A USB flash drive has much greater capacity then internal memory.
- You can copy the setup into a word processing or spreadsheet program on a computer.
- You can give the setup file a meaningful name.
- You can use the USB flash drive to copy the setup to a different oscilloscope.

You can set the print button to do the following

- Send the current image to a Pictbridge compatible printer or computer to the rear USBport
- Save the current screen image to a USB flash drive choosing among a number of formats.
- Save the current image, the waveform data points of each displayed waveform, and the current set up parameters to a USB flash drive, with a single button push

You can also set the following options before printing

Ink saver: ON prints colour waveforms on a whites back round. **OFF** prints colour waveforms on a black background, as they appear on the screen

Abort printing : select to stop sending data to the printer and to end printing

Layout: Select the orientation of the screen image to be printed either portrait or landscape.

Pape size: (Select from a lot for paper sizes supported by your printer.) The default choice allows the printer to select its default paper size.

Image size: Select from a list of image sizes supported by your printer. The default choice is generally the largest image size which will fit on the default to allow the printer to control paper type.

Print quality: Select from a list of print qualities supported by your printer. Select default to allow the printer to control print quality.

Data print: Select On to print the date and time on the hard copy. Some printer do not support this option.

The selected printer options will be saved when you turn off the oscilloscope power whenever you start a print, the oscilloscope compares your selected printer settings, and it changes them to Default.

Differentiate a CRO with DSO

Diffrerence between Cathods Ray Oscilloscope (CRO) & Digital storage Oscilloscope (DSO):

The Following points will make you understand the basic diffrent between cathode ray oscilloscope and digitalstor -age oscilloscope.

- The advantage of the analong storage oscilloscope (CRO) is that it has a higher bandwidth and writing speed than a digital storage oscilloscope, being capable of operating speeds about 15 GHz.
- The digital storage oscilloscope is primarily limited in speed by the digitising capability of the analog to digital converter. Aliasing effects also limit the useful storage bandwith(usb) of the oscilloscope to a value given by the ratio.

- The Value of constant C is dependent on the interpolation method used between the dots. For a dot diaplay C should be about25, to give an eligible display: for straight line interpolation it should be about 10, and for sinusoidal interpolation C should be about 2.5.
- The digital storage oscilloscope has a CRT which is much cheaper than an anlong storage oscilloscope, making replacement, more economical. The digital storage time, using its digital memory.
- Furthermore, it can operate with a constant CRT refresh time, so giving a bright image even at very fast signal speeds. The digital storage oscilloscope is not, however, capable of functioning in a variable persistance storage mode.
- The time base in a digital storage oscilloscope is generated by a crystal clock so that it is more accurate and stable than a CRO, where the time base is generated by a ramp circuit.
- The analong to digital converter used in a digital storage oscilloscope also gives it a higher resolution than an anlong oscilloscope(CRO). For example, a twelve bit digitizer can resolve one part in 4096. A convertional analong oscilloscope typically resolves to about one part in 50, equivalnet to 6 bit resolution.
- Digital storage oscilloscopes are also capable of operting in a look back mode, as described for waveform recorders. An anlong oscilloscope(CRO) collects data after it has been triggered.
- A digital storage oscilloscope (DSO) is always collecting data, and trigger tells it when to stop. The oscilloscope can stop immediately on trigger, so that all the stored information is pretrigger, if the delay is longer than the storage capability of the oscilloscope, then all the stored information is post trigger, as for an analog oscilloscope.
- The digital storage oscilloscope is also able to operate in a babysitting mode. When the scope is trigered it print out the stored results onto a hard copy recorder (or disc storage), and then re-arms itself ready for another reading .

Uses of Digital Storage Oscilloscope

- Used for testing signal voltage in circuit debugging.
- Testing in manufacturing
- Designing
- Testing of signals voltage in radio broadcasting equipment.
- In the field of research
- Audio and video recording equipment.

Analog Oscilloscope	Digital Oscilloscope
Directly reads voltage and displays its on screen.	Its reads the analong and converts it into digital form before being dispaly on the screen.
Do not require ADC, microprocessor and acquision memory.	Require ADC, microprocessor and acquisition memory.
Can only analyze signal in real time as there is no storage memory available.	Can analyze signal in real time as well as can analyze previously acquired large sample of data with facility of storage available.
Can not analyze high frequency sharp rise time transients.	Can not analyze high frequency transients due to advanced DSP algorithms available and ported on microprocessor with can operate on stored samples of input voltage.

Fig 1

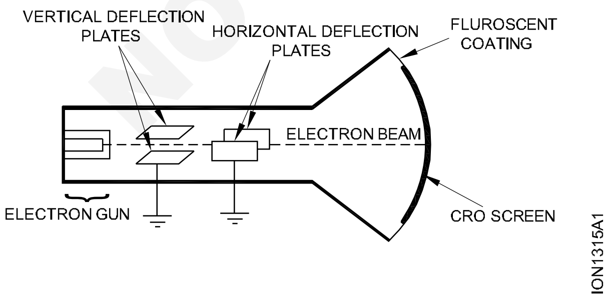


Fig 2

Fig 3

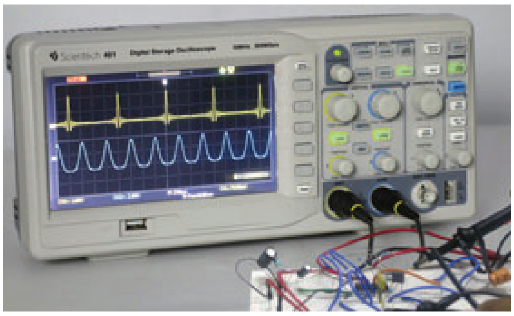
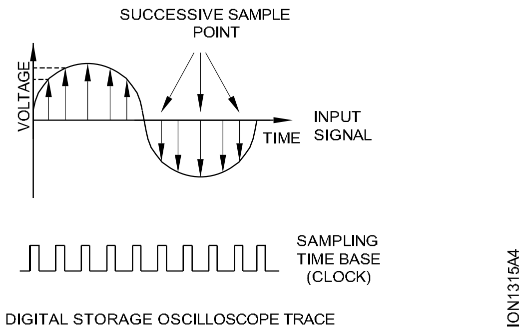


Fig 4



Arbitrary waveform generator

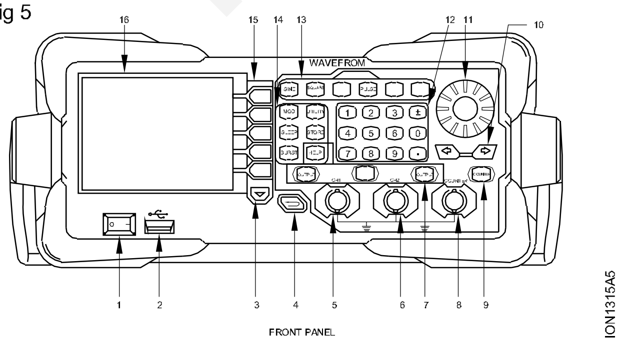
Arbitrary waveform generator (AWG) is sophisticated electronic test equipment that generates waveforms based on stored digital data. The AWG can create virtually any type of waveform with high precision and accuracy. It is designed for generating a wide variety of basic waveforms such as Sine, Square, Ramp, Pulse, Noise signals and arbitrarily defined wave shapes also as its output.

AWG can generate repetitive or single shot waveforms either with internal or outside triggering source. It can create very specific waveform for use in testing a variety of applications. The output is from less than 1 Hz to several MHz with variable amplitude and adjustable DC offset.

AWG uses synthesizer circuits by the digital signal processing techniques, they generate desired output signal waveform and it is available across two channels either CH1 or CH2 using BNC connector with 50 Ohms output impedance.

It also include additional features such as higher frequency capability, variable symmetry, frequency sweep, AM, FM, PM, PWM, ASK, FSK, PSK modulations either with internal source or external source for modulation. The front panel and the rear panel of a typical Arbitrary waveform generator is shown in Fig 5 below.

Fig 5



AWGs are contained within digital oscilloscope with a minimum of 10cm TFT colour LCD display. The content displayed on the LCD screen that shows you the picture of output waveform also be saved onto USB storage media device as a picture file (*.BMP) and the saved file can be read on / or edited in the AWG.

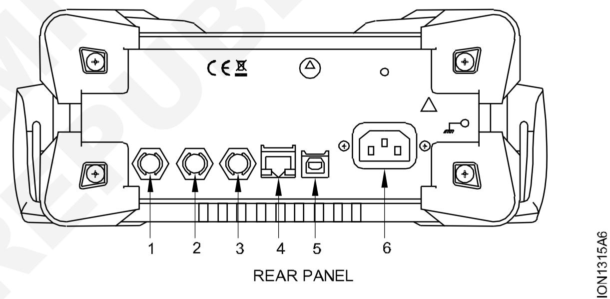
A numeric key pad is provided on the front panel for inputting parameters and a rotary knob is provided to move the direction of cursor to select the digit or character to be edited.

AWG features though menus controlled by function keys provided to set desired output waveform. By pressing that particular key on the panel, Sine, Square, and Ramp, Pulse, Noise signals or arbitrary waveform signals generated. There is backlight provided to turn on the selected function key.

In addition a digital frequency counter is a special feature of AWG. By connecting the unknown frequency signal and pressing the key for counter function it directly display the result on the screen.

The rear panel of a typical Arbitrary waveform generator is shown in Fig 6.

Fig 6



On the rear panel sockets/ connectors are provided for Chl/Ch2/Sync/Ext.ModlTrig/FSK

functions. BNC female connector with suitable impedances are used for the functionality.

In some models a 10MHz- In/Out socket is provided to connect the clock signal generated by the internal crystal oscillator inside the generator or 'accept the external 10MHz clock signal when external source selected.

USB socket for connectivity to a computer or to a PictBridge printer to print the contents displayed on the screen. And of course a three pin panel mount socket for 240V AC mains power supply input also provided.

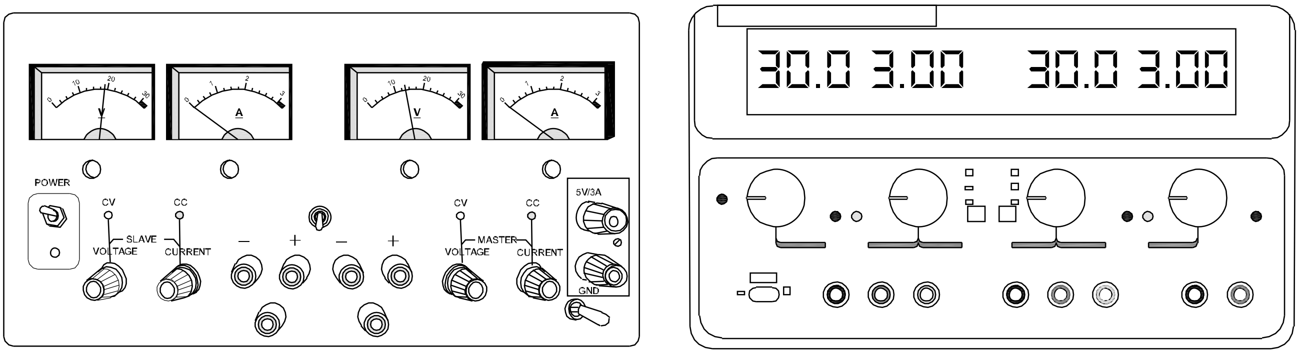
Dual Tracking Power supply

There are many types of adjustable DC power supply units available to be used in laboratories, industries, field testing and many other applications for powering analog circuit as well as digital circuits.

Front panels of both Old model and Latest model Typical Dual Tracking Power supply units are shown in Fig 7a&b.

This instrument consists of two identical independently adjustable DC power supply units with Coarse and Fine controls. It is designed with the output voltage and current of each supply are controlled separately and each supply is isolated from output to chassis or output to output.

Fig 7



(a) (b)

DUAL - TRACKING DC POWER SUPPLY

ION1315A7

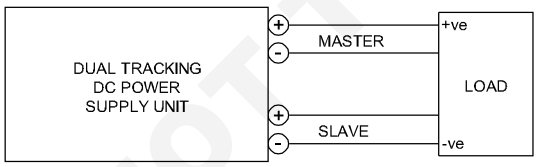
It is designed as one power supply is used as a Master supply controlling the other one Slave supply for furnishing various voltage or current for any system. It has two sets of output terminal sockets for Positive and Negative polarity of supply. To indicate output parameters two sets of panel meters are provided for both voltage and current readings independently.

The front panel switches selects the modes of operation such as 1) Independent operation, 2) Positive and Negative supply, 3) Series operation (Single supply), 4) Parallel Tracking operations as explained below:

1 Independent Operation of Dual tracking power supply is shown in Fig 8.

The "MASTER" and "SLAVE" supplies each provide any desired set output voltage or rated current. When used in the INDEPENDENT operating mode, disengage both TRACKING mode switches (both switches out) so that the operating controls of the two power supplies are completely independent and either supply can be used individually or both can be used simultaneously to control the desired output voltage and current.

Fig 8



INDEPENDENT OPERATION

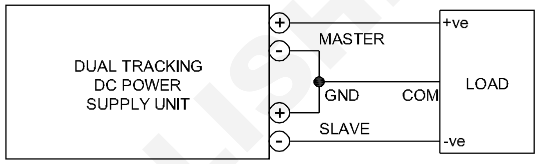
ION1315A8

2 Positive and Negative supply operation of Dual tracking power supply is shown in Fig 9.

Positive and Negative supply operation is used to power Op-Amp and Logic circuits where separate positive and separate negative supply lines with respect to Common ground line, that is three lines are taken out from this instrument following the connections as shown in Fig 9.

3 Series Tracking Operation of Dual tracking power supply is shown in Fig 10.

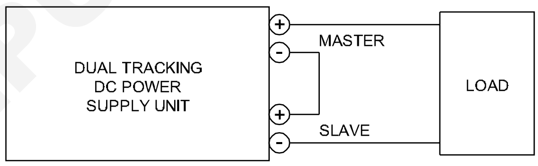
Fig 9



POSITIVE AND NEGATIVE SUPPLY

ION1315A9

Fig 10



SINGLE SUPPLY OPERATION (SERIES)

ION1315AA

Set the TRACKING SERIES mode switch of power supplies to the respective Tracking switch and release the other. The maximum SLAVE supply voltage is automatically set to the same value as the MASTER supply by using the MASTER VOLTAGE controls. The MASTER display is set for voltage metering and the SLAVE display for current metering.

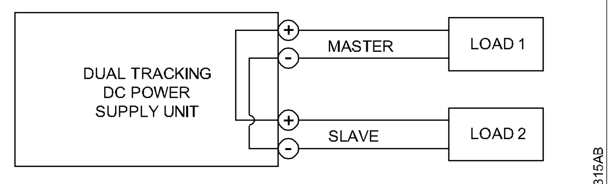
In the series tracking mode of operation, the maximum output voltage of both MASTER and SLAVE supplies can be simultaneously varied with one control. In this case, the output voltage (across the two supplies) is actually double the displayed value.

The actual output current would be the value read from the SLAVE LED Display (since the two supplies are wired in series, current flowing through each supply must be equal).

4 Parallel Tracking Operation of Dual tracking power supply is shown in Fig 11.

In the parallel tracking mode of operation, both supplies are strapped together (in parallel). Set the power supply to the TRACKING PARALLEL mode by engaging both TRACKING switches.

Fig 11



PARALLEL TRACKING OPERATION

Adjust the output voltage to the desired level using the MASTER VOLTAGE controls.

This allows for a rated voltage supply with a double rating current capability.

Only the MASTER output terminals are used for parallel tracking operation.

In the parallel tracking mode, the SLAVE supply output voltage and current are tracking the MASTER supply output voltage and current.

Because both voltage and current of the SLAVE supply track the MASTER supply,

the maximum current and voltage are set using the MASTER controls. Remember that the actual current output at the MATER supply output jack is double the reading on the SLAVE indicator meter.

Using the MASTER supply output jacks, follow the instructions for "Setting Current Limit".

Different types of soldering guns, related to temperature and wattages, types of tips

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,

- The electrical joint must provide ideally zero resistance or at least a very low resistance path, for the flow of current.
- 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.
- 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.

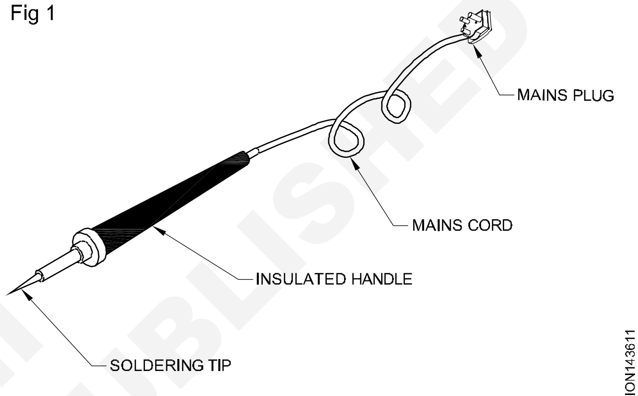
The tin content of the solder diffuses with the metal surface to form a layer of a completely new alloy. The alloy so formed will have the same structure as the constituent metals and retain their metallic properties and strength.

Soldering and soldering irons

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.

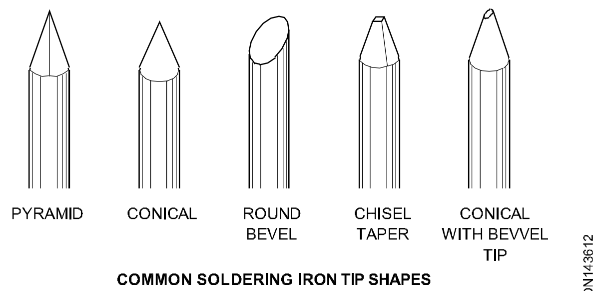
Fig 1



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

- Controlling the temperature of the workpiece.
- 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:

- Selection and preparation of materials.
- Heating the joint and adding solder.
- Cooling the joint.
- Cleaning the joint.
- 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.

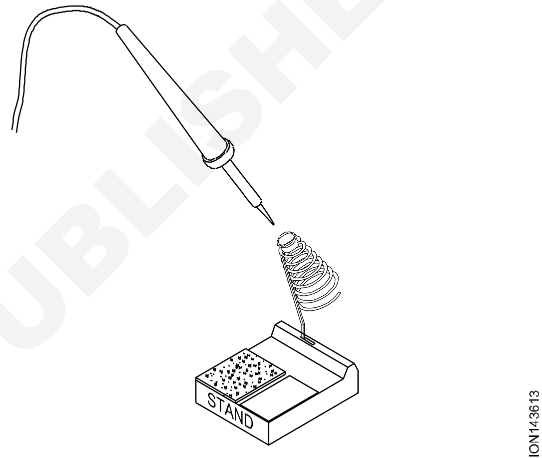
Flux is a chemical substance which has acidic properties. Therefore, it is advised not to touch flux by hand. Use a stick or a thin stiff brush to apply flux on workpieces. Hands should be washed after soldering work.

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.

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.

Fig 3



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

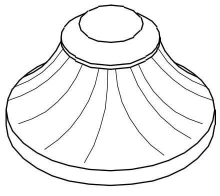
HEATING THE JOINT AND ADDING SOLDER

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.

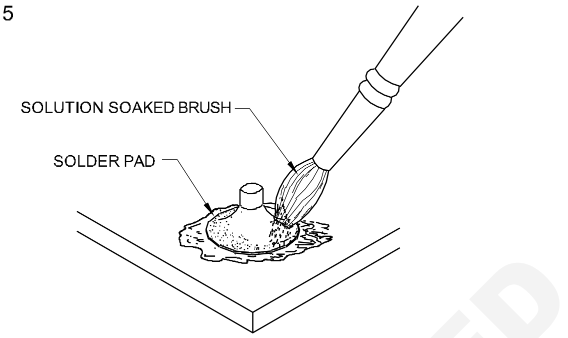
Removal of flux residue requires the use of solvents. The type of solvent depends on the flux used.

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 connetcrion** - 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;

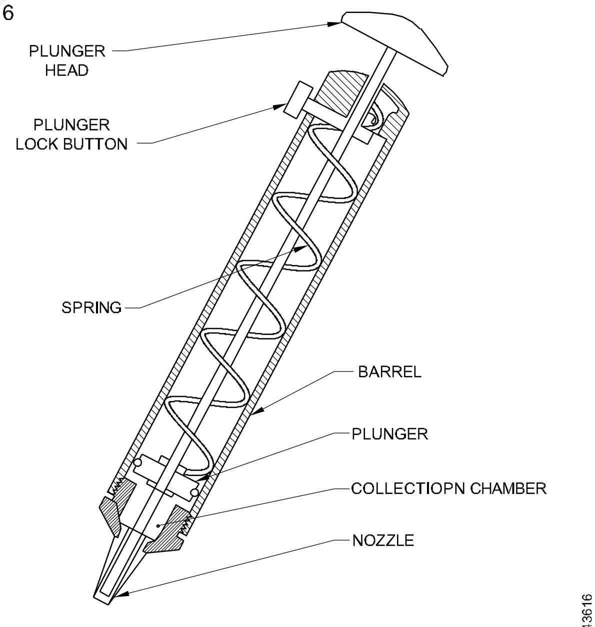
- Plunger de-soldering tool or desoldering pump.
- Wicking braid.

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.

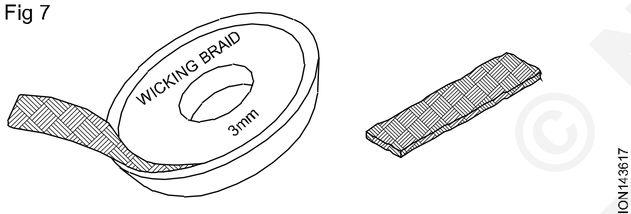
After doing one suction of molten solder, while cocking the tool for second suction, face the nozzle into a dirt collector. This is because, the solder collected at the tip of the nozzle gets pushed out every time the tool is cocked.

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.

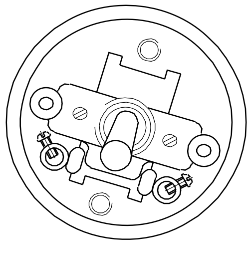
Types of switches according to their function and place of use

- Single pole, tumbler switch
- Single pole, two-way switch
- Intermediate switch
- Bell-push or push-button switch
- Pull or ceiling switch
- Single pole single throw switch (SPST)
- Single pole double throw switch (SPDT)
- Double pole single throw switch (DPST)
- 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

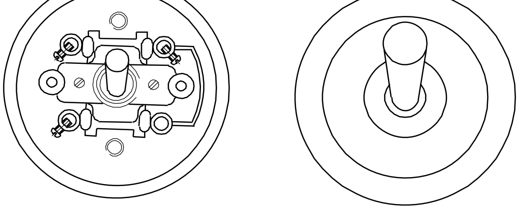


6 AMP SINGLE-WAY SURFACE MOUNTING SWITCH (COVER REMOVED)

ION143619

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 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.

Fig 10

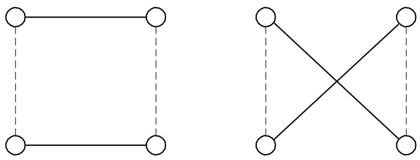


(a) 6 AMP 2-WAY SURFACE MOUNTING SWITCH (COVER REMOVED)   (b) A 2-WAY SWITCH WITH A METAL CAP

ION14361A

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



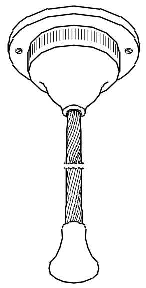
INTERMEDIATE SWITCH CONNECTIONS

ION14361B

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.

Fig 12



PULL SWITCH

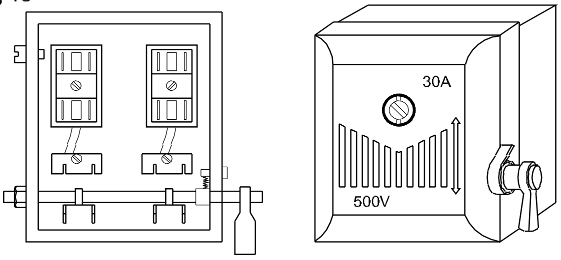
ION14361C

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.

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

ION14361D

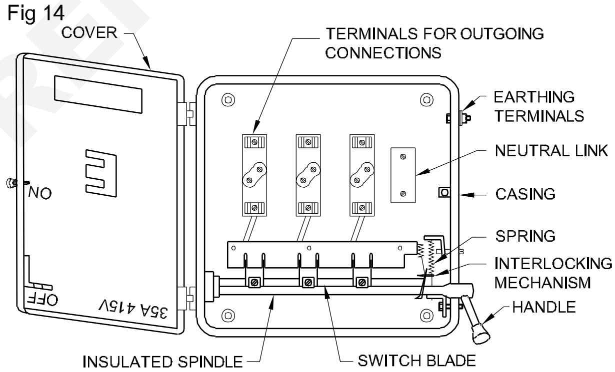
Specification of these switches should have:

- 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.

Fig 14



FUSED ICTP `N' SWITCH

ION14361E

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

- 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.

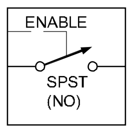
Most widely used switch configurations in the industry today are:

- Single Pole Single Throw (SPST)
- Single Pole Double Throw (SPDT)
- 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

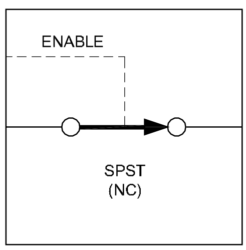


SINGLE POLE SINGLE THROW
NORMALLY

ION14361F

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

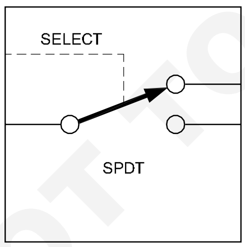


SINGLE POLE SINGLE THROW

ION14361G

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

ION14361H

Schmitt trigger action at select and enable control pins results in higher reliability.

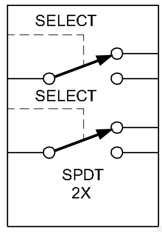
Digital bus switches are widely used multiple peripheral and host selection functions, power and clock management, sample and hold circuits, test and debug interfaces etc.

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.

Fig 18



ION14361I

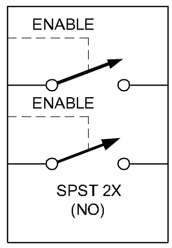
The **dual SPDT** and dual SPST switches are available either for simultaneous selection or for simultaneous enable.

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.

The symbol of dual SPST switch is shown in (Fig 19)

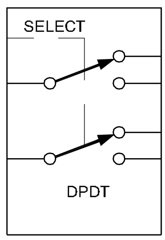
Fig 19



ION14361J

A DPDT switch is a dual SPDT switch into a single select pin as shown in (Fig 20).

Fig 20



DOUBLE POLE DOUBLE THROW

ION14361K

Introduction to SMD technology identification of 2, 3, 4 terminal SMD components

Objectives: At the end of this lesson you shall be able to
- **explain briefly SMT & SMD**
- **state the need for SMD**
- **list the advantages of SMDs**
- **state the safety precautions required while handling SMDs**
- **list the tools and equipments used in SMT**
- **understand to perform test and measurement of the circuit.**

Introduction

Surface Mount Devices (SMDs) are used in a growing number of commercial and industrial products. Due to their small size, prototype manufacturing, rework and repair can be difficult and are best performed using specialized techniques specific to this technology. Learning these techniques will help you succeed when working with these small components. The SMT technique opens advantages and new applications through miniaturizing of the components and increasing of reliability.

Surface Mounted Devices (SMD) are active and passive electronic components without conventional connecting wires.

In the conventional through - hole technology (THT) the components are placed on the "components side" of the printed circuit board (PCB), wires inserted into holes, and soldered to the copper pads on the opposite, "solder side" of the PCB.

The SMD components will be placed on the 'solder side' of the PCB and their metal caps soldered to the copper pads of the PCB. Therefore both layers of the PCB could be used as active areas. A thickness of PCBs used for SMD is between 0.8 and 1.00mm. Historically roots of SMD are hybrid circuits on the ceramic substrates (middle of seventies) but a huge industrial applications of SMD started in the beginning of eighties.

The industrial standard unfortunately allows that most of the SMD components do not have a clear description. Since a tiny size of the components they are labeled with a code. Therefore a sure identification of the components is impossible without appropriate technical documentation. Moreover the polarity and pin-outs of different components could be not identified without data sheets. For these reasons SMD for beginners became a very hard job.

Need of surface mount technology

SMDs have improved performance over through-hole components due to their smaller size, shorter internal leads, and smaller board layouts. These factors reduce the circuit's parasitic inductance and capacitance. SMDs can also be more cost effective than traditional through - hole components due to the smaller board size, fewer board layers, and fewer holes. SMDs can be challenging to solder, so it is best to learn general soldering skills on larger components before attempting to work with SMDs.

Advantages of SMDs are given below

- PCBs area much smaller than by conventional through - hole components
- Since the both layers of the PCB could be used for assembling, the final PCBs area for the same circuits could be decreased by 50%.
- Simple assembling-no bending and cutting of the wires.
- Automatic assembling very easy. Low cost of the assembling.
- Small size of components makes very high packing density possible. For the same circuits a volume of a module assembled with SMD could be reduced to 30% of the device assembled with the conventional technique. Therefore a size of the whole instrument decreases, too.
- Very high resistance to mechanical shock and vibration.
- Low store and transport cost. Low store area and volume.
- Lack of hole's drilling and metallization.
- Thin pads.
- For larger volumes, low manufacturing cost.

SMD safety precautions

Surface mount components are very small, and therefore special precautions (in addition to those required when working with through - hole components) must be taken

- Do not eat or drink when working with surface mount components.
- Do not use cups, plates, or any food related items to hold or store surface mount components.
- Keep surface mount components away from children and pets.
- Always wear safety goggles.
- Work away from the edge of a desk or workbench to ensure that components will not fall on the floor.
- Keep a strong light and magnet available to search for components that have dropped on the floor.

Work area for dealing with SMD

Because SMDs are very small, it is important to make them "look" bigger. This can be accomplished by illuminating the work surface with a very bright light. A swing - arm desk lamp with a 100-watt frosted bulb positioned close to the work surface works very well. The lamp should be adjustable from 6 to 24 inches above the desktop. Regular room lighting or shop lights just are not bright enough. The second trick is to work on an absolutely clean, bright white surface. The SMD work tray works very well. The white paper gives contrast to the components and the small sides help prevent the SMDs from getting lost.

Tools and Equipment required for SMD

The tools and equipment required for SMD used are self - locking tweezers which work much better than regular tweezers. Vacuum pick-up tools can also be used, but are considerably more expensive. Select a low wattage (15 or 25 watt) or temperature controlled (600^{0}F) pencil soldering iron with a pointed tip.

List of tools & equipments

- Safety Goggles
- Self locking tweezers (Fig 1)

Fig 1

EMN3218421

- 600^{o}F or low wattage soldering gun with sharply pointed tip
- Small diameter solders wire (63/37)
- RMA solder paste
- Desoldering braid
- Plastic scouring pads
- Deco cement
- Magnet
- Flexible neck lamp with 100w frosted bulb.
- Magnifying glass.

To clean the circuit board before soldering you will need a nonconductive abrasive pad. Don't use steel wool or a steel wool scouring pad, since they may leave small (almost microscopic) steel wires behind. A strong magnet is useful for finding dropped components. You will also need a magnifying glass. Use this to read the component markings on chip resistors and electrolytic capacitors.

Types of SMD components

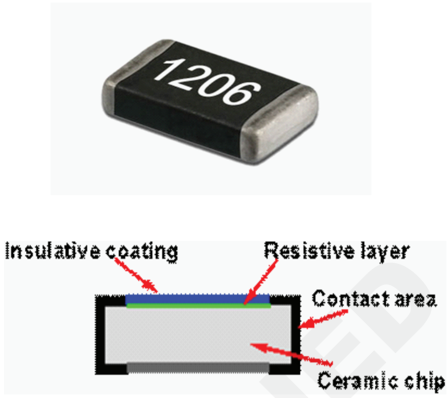
Now a days, almost all active components are available in SMD packages for example diodes, transistors, FET, Triac etc. But in passive components only resistor and capacitors are available in different sizes and values. Due to size and mounting limitations -inductors and transformers are not available in SMDs. In active devices, some power electronic components are available in limited varieties due to large current drawing and problems for mounting heat sink on SMDs. Large surface space is required for mounting the heat sinks whereas SMDs are in small size.

SMD resistors

SMD resistors are in shape of rectangle with metalized in both ends of body for convenient to solder on PCBs.

SMD resistors are constructed with use of the thick film technique on a ceramic substrate. They have metallic areas on the narrow ends of the chip, which allows soldering. The resistive path is covered wtih a protective glaze. Chip resistors could be soldered with all common soldering techniques:reflow, wave and solder iron. A sample of SMD resistor is shown in Fig 2.

Fig 2



EMN3218422

Case forms of same SMD components ae tabulated table1.

SMD resistor packages

SMD resistors are available in different types of packages and they are mostly differ some part of specifications from manufacturer to manufacturer. The size of resistors are also reduced day by day due to technological enhancement. The most common packages and their sizes are shown in table 1.

Table 1

Form	Power (watt)	Length (mm)	Width (mm)
0402	0.063	1.0	0.5
0503	0.063	1.27	0.75
0505		1.27	1.25
0603	0.062	1.60	0.80
0705		1.91	1.27
0805	0.1	2.00	1.25
1005	0.125	2.55	1.25
1010		2.55	2.55
1206	0.25	3.2	1.6
1210	0.25	3.2	2.6
1505		3.8	1.25
2010	0.5	5.08	2.55
2208		5.72	1.90
2512	1.0	6.5	3.25
MELF		5.5	2.2
MINIMELF		3.6	1.4
MICROMELF		2.0	1.27

SMD resistor specifications

SMD resistor specifications differ from one manufacturer to other. For selecting a SMD resistor, one needs to refer to manufacturer ratings.

Some most important specifications are shown below.

a **Power rating:** The size of the resistor will increase by power rating and current drawn by it. The power rating of resistor should be always smaller than PCB layer current rating. Some power ratings are shown in table.

b **Tolerance:** SMD resistors are mostly metal oxide film resistor which are having more accurate values. So they mostly having tolerance of 1% to 5%. But in some special applications they may available in less than 1% tolerance.

c **Temperature coefficient:** SMD are having very good temperature coefficient than normal resistors due metal oxide film material. Generally they may available in 25 to 100 ppm/c.

SMD Resistors Code Table

SMDC	0201	B	P	4	2R2
Product Type	Dimensions	Resistance Tolerance	Function Code	Package Code	Resistance Valve
	01005	B:±0.1%	L:Standard & High Precision	0:7" Reel 15Kpcs	---1R2: 1.2Ω
	0201	C:±0.25%	E: TC50	4:7" Reel 4Kpcs	---3K3: 3.3Ω
	0402	D:±0.5%	P: High Power	6:7" Reel 10Kpcs	---10K:10KΩ
	0603	F:±1%	H: Ultra High Power	7:7" Reel 5Kpcs	---100:100KΩ
	0805	J:±5%		9:10" Reel 8Kpcs	--- to fill up 6 spaces
	1206			A:10" Reel 10Kpcs	
	1210			B:10" Reel 20Kpcs	
	2010			C:13" Reel 40Kpcs	
	2512			D:13" Reel 20Kpcs	
				F: Bulk	

SMD capacitors

SMD capacitors are mostly used components after SMD resistors in practical electronic circuits. SMD capacitors are similar to general capacitors in construction and the only difference is that instead of leads SMD capacitors have metalized connections at their both ends.

Advantages of SMD over a general capacitors

- Due no leadless, manufacturers are using different techniques and they are available in small in size.
- Easy to assemble and mount in automated manufacturing techniques.
- Less effected by static field and electro-magnetic effects.

Types of SMD capacitors

- SMD Ceramic capacitors
- SMD tantalum capacitors
- SMD electrolytic capacitors

Ceramic multilayer chip capacitors

Ceramic multilayer chip capacitors are available with a very wide range of values, from 0.47pF to 1 F. This values are covered by seven cases forms. The forms depends of the capacitors values. The most popular case are 0805 and 1206.

SMD tantalum capacitors

SMD tantalum capacitors are available in different case forms, partly without printed values. The + polarity is marked by white line, or white "M". The case forms depend of capacitance value and nominal voltage.

SMD tantalum capacitors standard sizes are:

3.2 x 1.8 mm

3.5 x 2.8 mm

6.0 x 3.2 mm

7.3 x 4.3 mm

The values are coded with digits, or with alphanumerical characters.

Fig 4

EMN3218424

They are low cost and smaller size than general capacitors.

Electrolytic capacitors are now being used increasingly in SMD designs. SMD capacitors are available in two types are value marking

1 Direct value printing

2 Coding technique

Generally, SMD ceramic and tentalum capacitors are having coding technique for reading values and they may differ from one manufacturer to other. Most of Electrolytic capacitors are having values with their working voltage printed on their surface because of their large surface area.

SMD diodes and transistors

SMD diodes and transistors are available mostly in similar packages. Diodes are avilable in mainly two forms as shown in below fig.

Fig 5

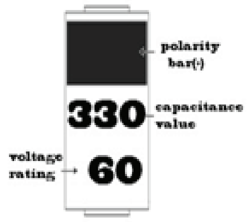
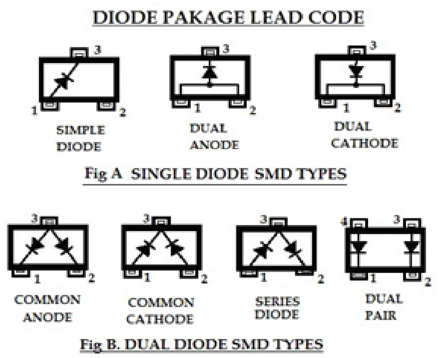


Fig 6



Those are

1 Single diode form

a Simple diode

b Dual anode

c Dual cathode

2 Dual diode form

a Common anode

b Common cathode

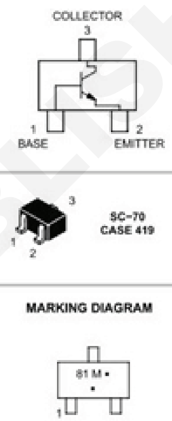
c Series diodes

d Dual pair

Almost all standard diodes and transistors are available as SMD components in SOT - 23, SOT - 89 and SOT - 143 cases. In general electrical parameters of SMD diodes and transistors are the same as comparable standard types in conventional cases. SOT - 23, and SOT - 143 cases are used for components with power dissipation 200 to 400 mW. SOT - 89 cases are used for power dissipation 500 mW to 1W. SMD LEDs are available in SOT - 23 cases. All SMD transistors are marked with codes.

Similarly FET and MOSFET in SMD forms are shown in below figures.

Fig 7



SMD code	Package	Device name	Manufacturer	Data
A7	SOT-23	BAV99	National	Switching diodes
A7	SOT-23	BAV99	Zowie	Switching diodes
A7	SOT-323	BAV99WT1	Motorola	Switching diodes
A7	SOT-523	MMBD4448H TC	BL Galaxy Electrical	Switching diodes
A7 -	SOT-23	BAV99	NXP	Switching diodes
A7	SOT-23	BAV99	National	Switching diodes
A7	SOT-23	BAV99	National	Switching diodes
A7	SOT-23	BAV99	Zowie	Switching diodes
A7	SOT-323	BAV99WT1	Motorola	Switching diodes
A7	SOT-523	MMBD4448H TC	BL Galaxy Electrical	Switching diodes
A7	SOT-23	BAV99	National	Switching diodes

Fig 8

Fig 9

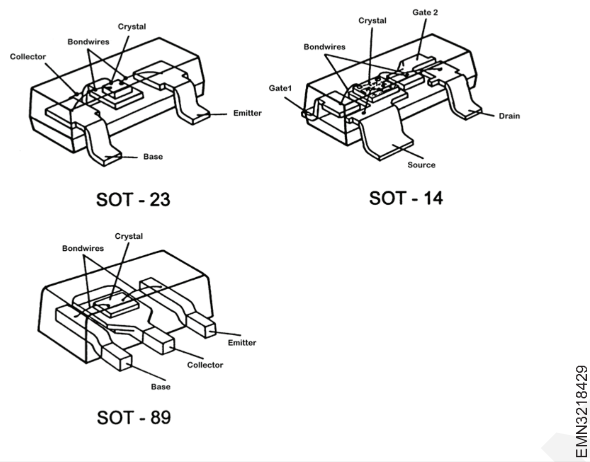
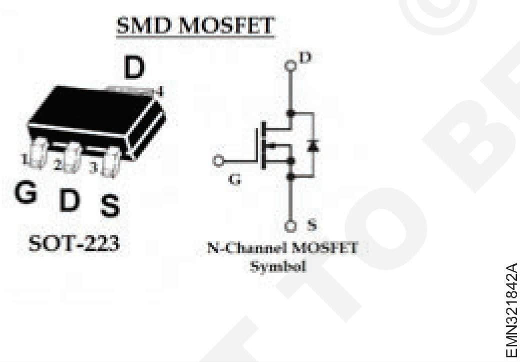


Fig 10



Examples of SMD transistors coding.

MARK	COMPONENT	CASE
1J	BC848A	SOT -23
4G	BC860C	SOT -23
1F*	MMBT5550	SOT -23
1F*	BC847B	SOT -23
AA*	BCW60A	SOT -23
AA*	BCX51	SOT -89

* Hint

The same mark does not means the same component!

If SMD transistors with the same marks have different case forms their technical specifications are different as well!

SMD Integrated circuits

The first SMD ICs were manufactured on begin 70' for hybrid technique. Nowadays (February 1999) are many of new ICs design manufactured in SMD only.

ICs in SMD cases are electrically fully compatible to types in DIL cases therefore both of them have the same marking. The different for SMD (SO-xx case)is only the last character of the mark; i.e. LM 324 N (DIL) = LM 324 D (SO).

SO cases are produced with two different pin forms:

1 pins bent outside of the case

2 pins bent under the case

Fig 11

Pin 1 is marked by a white line on atop of the case or a cut on a front of the case.

Abbreviate the full form of term used in surface Mount technology

SMD **S**urface **M**ounted **D**evices (active, passive and electromechanical components)

SMT **S**urface **M**ounted **T**echnology (assembling and montage technology)

SMA **S**urface **M**ounted **A**ssembly.

Solder paste and its Application in SMT

Solder paste or solder cream is simply a suspension of fine solder particles in a flux vehicle. In electronic industry, solder paste is used in surface mount technology (SMT) to solder SMDs on to the printed circuit board, The composition of the particles can be tailored to produce a paste of the desired melting range. Additional metals can be added to change paste compositions for specialized applications. Particle size and shape, metal content and flux type can be varied to produce pastes to varying viscosity. Availability of solder paste

Solder paste is available in both leaded (with lead) and lead-free (with no lead) forms. It can be no-clean or water soluble. With no-clean solder paste, there is not need to clean the board after soldering. Water soluble solder paste is easily soluble in water with no harm.

How to Get the Best Solder Joints from Solder Paste Application?

In order to achieve good solder paste printing results, a combination of the right solder paste material, the right tools and the right process are necessary. Kester is a trusted brand in manufacturing solder paste and other soldering material including solder wire, solder bar, solder flux etc. Although the supplier is essentialy responsible for providing the desired solder paste and screens or stencils and the squeegee blades, the user must control process and equipment variables to achieve good print quality. Even the best solder paste, equipment, and application methods are not sufficent by themselves to ensure acceptable results.

Using solder paste

Start by applying flux to the circuit board pads. Then apply solder paste on the all pads of the components you want to solder.

Using tweezers, place the component in its correct position and hold it there. Place the tip of the soldering iron onto each of the pads so that the solder melts and makes good connections between the component and the board Flood with solder

This method is for soldering chips.

As usual start by applying flux too the pads on the circuit board. Fasten one of the corner pins of the chip to its pad by using a bit of solder. Make sure the chip is properly aligned on the pads.

Hold the chip in place while touching the corner pad with the tip of the soldering iron so that the solder melts the pin and the pad together.

Check the alignment of the chip. if it is not in its place, use your soldering iron to loosen the pin chip and align the chip properly. Continue soldering on the opposite corner by putting a bit of solder on the soldering iron tip then touching the circuit board pad and pin at the same time. Do this for all the pins of the chip one by one.

After all the pins have been soldered you should inspect the solder joints carefully with microscope or loupe to check for bad joints or solder bridges.

Reflow solder process Description

The basic reflow solder process consists of: Application of a solder paste to the desired pads on a printed circuit board (PCB) Placement of the parts in the paste. Applying heat to the assembly which causes the solder in the paste to melt (reflow). wet to the PCB and the part termination resulting in the desired solder fillet connection.

A Solder paste the solder paste mixes are improving as the demands of reflow soldering of SMT increase. Selection and specification of the optimum paste is a key item in the reflow solder process.

B Placement of the parts in the paste is not difficult if the pad design considers all the application tolerances. (see KEMET Application Bulletin “Surface Mount- Mounting Pad Dimensions and Considerations”). Care should be taken during the transportaion of the PCB,s not to smear the solder paste or move parts. Inspection of palcement accuracies and subsequent to increase repair rates after soldering.

C Appplication of heat to result in the eventual solder joint must consists of the following discrete items:- Preheat cycle is intended to drive off most of the volatile solvents contained in the paste before the flux begains to work. This assists in intiating fluxing action on the solder powder and the metal surface to be joined.- Additional preheat time to elevate the temperature of the PCB, Solder paste, and terminations to a temperature near the melting point of the solder.- Additional heat transfer to elevate the temperature over the liquidous point of the solder.- Temperature to be achieved are the liquidous melting point of solder. Liquidous points for-60 Sn/40 Pb solder is... 188C 63 Sn/37 Pb solder is... 183C 62 Sn/36 Pb/2 Ag solder is 179C Additional heat is reuired to insure activation of the rosins. However, heat should be limited to minimize the time some parts are above critical temperature. As temperature cooldown to the solder solidification temperature, followed by gradual (static) cooling to temperature near cleaning temperature.Equipment unique to surface mounting in electronics has not matured yet. There are two main types of automated inspection equipment on the market: x-ray and laser. However, most electronic companies depend on visual inspection at 2 to 10x, using either microscope of magnifying lamp.

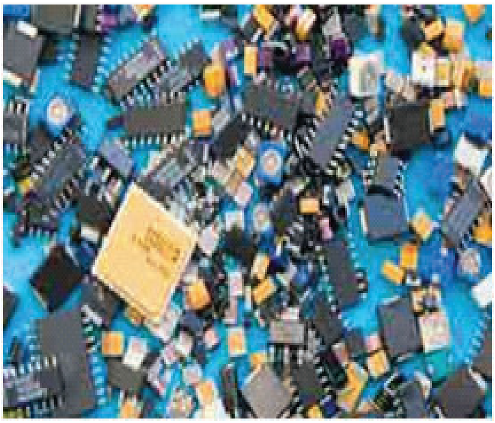
Surface Mount Technology (SMT)

Objectives: At the end of this lesson you shall be able to
- **explain surface mount technology**
- **describe advantages and disadvantages surface mount components.**

Surface-mount technology (SMT) is a method for producing electronic circuits in which the components are mounted or placed directly onto the surface of printed circuit boards (PCBs). An electronic device so made is called a surface-mount device (SMD). In the industry it has largely replaced the through-hole technology construction method of fitting components with wire leads into holes in the circuit board. Both technologies can be used on the same board for components not suited to surface mounting such as large transformers and heat-sinked power semiconductors.

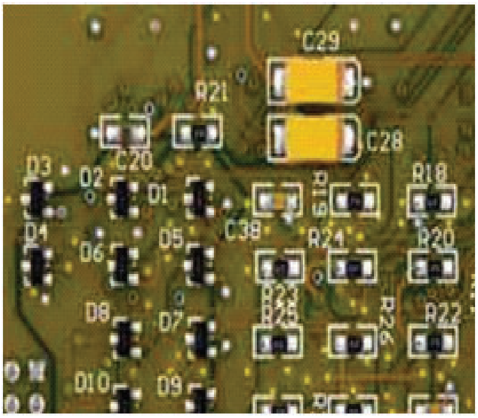
An SMT component as shown in Fig1 is usually smaller than its through-hole counterpart because it has either smaller leads or no leads at all. It may have short pins or leads of various styles, flat contacts, a matrix of solder balls (BGAs), or terminations on the body of the component.

Fig 1



SMT COMPONENT

Fig 2



TYPICAL SMT BOARD WITH TRANSISTORS, AND PASSIVE COMPONENTS

Virtually all of today's mass produced electronics hardware is manufactured using surface mount technology, SMT. The associated surface mount devices, and SMDs provide many advantages over their leaded predecessors in terms of manufacturability and often performance.

It was not until the 1980's that surface mount technology, SMT became widely used. Once SMT started to be used, the change from conventional leaded components to surface mount devices, SMDs took place quickly in view of the enormous gains that could be made using SMT.

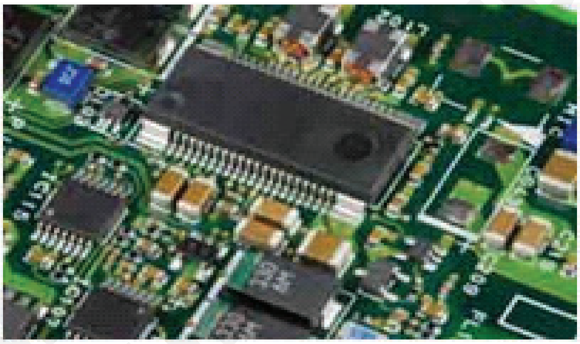
Mass produced electronic circuit boards need to be manufactured in a highly mechanized manner to ensure the lowest cost of manufacture. The traditional leaded electronic components do not lend themselves to this approach. Although some mechanisation was possible, component leads needed to be pre-formed. Also when the leads were inserted into boards automatically problems were often encountered as wires would often not fit properly slowing production rates considerably.

It was reasoned that the wires that had traditionally been used for connections were not actually needed for printed circuit board construction. Rather than having leads placed through holes, the components could be soldered onto pads on the board instead. This also saved creating the lead holes in the boards which added cost to the production of the bare PCBs.

As the components were mounted on the surface of the board, as shown in the Fig 2, rather than having connections that went through holes in the board, the new technology was called surface mount technology or SMT and the devices used were surface mount devices, SMDs. The idea for SMT was adopted very quickly because it enabled greater levels of mechanisation to be used, and it considerably saved on manufacturing costs.

To accommodate surface mount technology, SMT, a completely new set of components was needed. New SMT outlines were required, and often the same components, e.g. ICs were sold as shown in Fig 3 in both traditional leaded packages and SMT packages. Despite this, the gains of using SMT proved to be so large that it was adopted very quickly.

Fig 3



ICS WERE SOLDERED IN PCB BOARD

SMT board with typical IC packages

SMT Components

Surface mount devices, SMDs by their nature are very different to the traditional leaded components. They can be split into a number of categories.

Passive SMDs: There is quite a variety of different packages used for passive SMDs. However the majority of passive SMDs are either resistors or capacitors for which the package sizes are reasonably well standardized. Other components including coils, crystals and others tend to have more individual requirements and hence their own packages.

Resistors and capacitors have a variety of package sizes. These have designations that include: 1812, 1206, 0805, 0603, 0402, and 0201. In other words the 1206 measures 12 hundreds by 6 hundreds of an inch. The larger sizes such as 1812 and 1206 were some of the first that were used. They are not in widespread use now as much smaller components are generally required. However they may find use in applications where larger power levels are needed or where other considerations require the larger size.

The connections to the printed circuit board are made through metallised areas at either end of the package.

Transistors and diodes: These components are often contained in a small plastic package. The connections are made via leads which emanate from the package and are bent so that they touch the board. Three leads are always used for these packages. In this way it is easy to identify which way round the device must go.

Integrated circuits: There is a variety of packages which are used for integrated circuits. The package used depends upon the level of interconnectivity required. Many chips like the simple logic chips may only require 14 or 16 pins, whereas other like the VLSI processors and associated chips can require up to 200 or more. In view of the wide variation of requirements there is a number of different packages available.

For the smaller chips, packages such as the SOIC (Small Outline Integrated Circuit) may be used. These are effectively the SMT version of the familiar DIL (Dual In Line) packages used for the familiar 74 series logic chips. Additionally there are smaller versions including TSOP (Thin Small Outline Package) and SSOP (Shrink Small Outline Package).

The VLSI chips require a different approach. Typically a package known as a quad flat pack is used. This has a square or rectangular footprint and has pins emanating on all four sides. Pins again are bent out of the package in what is termed a gull-wing formation so that they meet the board. The spacing of the pins is dependent upon the number of pins required. For some chips it may be as close as 20 thousandths of an inch. Great care is required when packaging these chips and handling them as the pins are very easily bent.

Other packages are also available. One known as a BGA (Ball Grid Array) is used in many applications. Instead of having the connections on the side of the package, they are underneath. The connection pads have balls of solder that melt during the soldering process, thereby making a good connection with the board and mechanically attaching it. As the whole of the underside of the package can be used, the pitch of the connections is wider and it is found to be much more reliable.

A smaller version of the BGA, known as the micro BGA is also being used for some ICs. As the name suggests it is a smaller version of the BGA.

Advantages

The main advantages of SMT over the older through-hole technique are:

- Smaller components. As of 2012 smallest was 0.4 × 0.2 mm (0.016 × 0.008 in: 01005). Expected to sample in 2013 are 0.25 × 0.125 mm (0.010 × 0.005 in, size not yet standardized)
- Much higher component density (components per unit area) and many more connections per component.
- Lower initial cost and time of setting up for production.
- Fewer holes need to be drilled.
- Simpler and faster automated assembly. Some placement machines are capable of placing more than 136,000 components per hour.
- Small errors in component placement are corrected automatically as the surface tension of molten solder pulls components into alignment with solder pads.
- Components can be placed on both sides of the circuit board.
- Lower resistance and inductance at the connection; consequently, fewer unwanted RF signal effects and better and more predictable high-frequency performance.
- Better mechanical performance under shake and vibration conditions.
- Many SMT parts cost less than equivalent through-hole parts.
- Better EMC performance (lower radiated emissions) due to the smaller radiation loop area (because of the smaller package) and the smaller lead inductance

Disadvantages

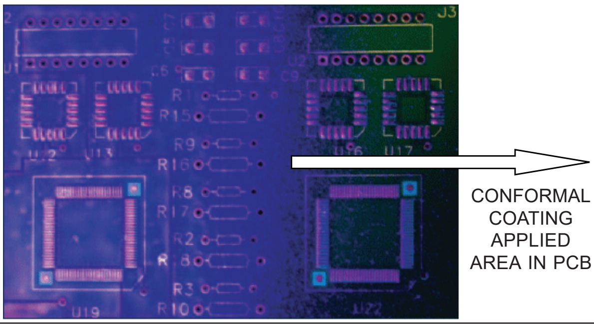
- Manual prototype assembly or component-level repair is more difficult and requires skilled operators and more expensive tools, due to the small sizes and lead spacings of many SMDs.
- SMDs cannot be used directly with plug-in breadboards (a quick snap-and-play prototyping tool), requiring either a custom PCB for every prototype or the mounting of the SMD upon a pin-leaded carrier. For prototyping around a specific SMD component, a less-expensive breakout board may be used. Additionally, strip board style proto boards can be used, some of which include pads for standard sized SMD components. For prototyping, "dead bug" bread boarding can be used.
- SMDs' solder connections may be damaged by potting compounds going through thermal cycling.
- Solder joint dimensions in SMT quickly become much smaller as advances are made toward ultra-fine pitch technology. The reliability of solder joints becomes more of a concern, as less and less solder is allowed for each joint. Voiding is a fault commonly associated with solder joints, especially when re- flowing a solder paste in the SMT application. The presence of voids can deteriorate the joint strength and eventually lead to joint failure.
- SMT is unsuitable for large, high-power, or high-voltage parts, for example in power circuitry. It is common to combine SMT and through-hole construction, with transformers, heat-sinked power semiconductors, physically large capacitors, fuses, connectors, and so on mounted on one side of the PCB through holes.
- SMT is unsuitable as the sole attachment method for components that are subject to frequent mechanical stress, such as connectors that are used to interface with external devices that are frequently attached and detached.

Identification of lose / dry solders, broken tracks on printed wiring assemblies

Objectives: At the end of this lesson you shall be able to
- **define conformal coating & its types**
- **explain how to coat the conformal coating**
- **describe various method of removal of conformal coating.**

Conformal coating is a protective chemical coating or polymer film 25-75μm thickness that is applied onto the printed circuit board .It is used to protect PCB from damages due to contamination, salt spray, moisture, fungus, dust and corrosion and also a physical barrier. When coated, it is clearly visible as a clear and shiny material as shown in Fig 1.

Fig 1



Types of Conformal Coating

Conformal coatings can be classified in to five main categories by their chemical composition.

1 Silicone Resin (SR)

2 Epoxy Resin (ER)

3 Acrylic Resin (AR)

4 Poly para xylylene (XY).

5 Polyurethane(Urethene) Resin (UR)

Silicone

Fig 2 shows the silicon conformal coating pack.

Fig 2

Silicone conformal coatings provide excellent protection in high temperature environments. It has good moisture ,humidity, chemical résistance and salt-spray resistance. It's typical temperature range is -65 °C to 200 °C. It is very flexible. Removal of this coating requires specialized solvents and long soak time.

Epoxy

Epoxy coatings are available as a two part thermosetting mixture. These conformal coatings are very hard and good humidity resistance, chemical resistance and high abrasion. Epoxy coating is quite easy to apply but impossible to remove without damaging the components.

Fig 3a shows SMD IC on PCB.

Fig 3a

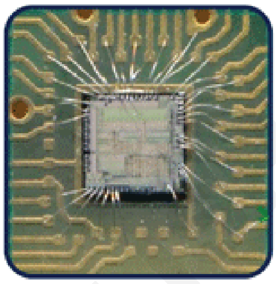


Fig 3b shows how to apply epoxy coating on SMD IC's.

Fig 3b

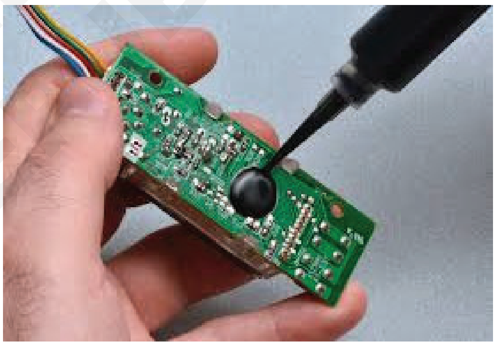
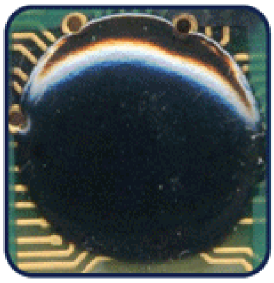


Fig 4 Shows the epoxy applied COB (chip on board).

Fig 4



Acrylic

Acrylic coatings are solvent based. It provides Fair elasticity and general protection.

They are low cost, easy to apply and remove. It exhibits low moisture absorption and have short drying times.

These types of coating have high di-electric strength, abrasion resistance. It typical dielectric withstand is greater than 1500 volts and has a temperature range of -59 °C to 132 °C.

Fig 5 Shows the acrylic type conformal coating.

Fig 5

Para - Xylylene

Paraxylene coatings are applied by chemical vapour deposition (CVD). These coatings provide excellent di-electric strength and resistance to solvents.

Poly Urethene

Urethene coatings are hard and durable which has excellent resistance to solvents. It has similar moisture resistance to acrylic and silicon. It is difficult to apply and hard to be removed. Temperature range is quite similar to acrylic.

Fig. 6 Shows as urethane containers.

Coating process

The coating material can be applied by various methods, from brushing, spraying and dipping.

Before coating a printed circuit board must be cleaned and de-moisturized.

The following steps are used for coating.

1 Board is cleaned.

Fig 6

2 Protected areas like terminal pins, connectors are masked off or removed.

3 Coating is applied using a spray process on both sides of the PCB and its edges.

4 Coating isto be cured according to the coating type. (air dry, oven dry or UV light cure.)

5 Masking is removed and any removed parts are reassembled.

Characteristics Conformal Coating Type

Characteristics	Conformal Coating Type				
	Epoxy	Acrylic	Polyurethane	Silicone	Paraxylylene
Hard	✓		✓		✓
Medium Hard		✓	✓		
Soft			✓	✓	
Heat Reaction	✓	✓	✓		
Surface Bond, Very Strong	✓			✓	✓
Surface Bond, Strong		✓		✓	
Surface Bond, Meduim			✓	✓	
Surface Bond, Light				✓	
Solvent Reaction		✓			
Smooth Surface	✓	✓	✓	✓	✓
Nonporous Surface	✓	✓	✓		✓
Glossy Surface	✓	✓	✓		
Semi glossy Surface				✓	
Dull Surface					✓
Rubbery Surface				✓	
Brittle	✓	✓			

Conformal Coating Removal Methods

On occasion it is necessary to remove a conformal coating from the circuit board to replace damaged components. The methods and materials used to remove coatings are determined by the coating resins as well as the size of the area. The basic methods are as follows.

- Solvent
- Peeling
- Thermal/Burn - through
- Micro Blasting
- Grinding /Scraping

Solvent Removal: Most conformal coating are susecpitble to solvent removal, however it must be determined if the solvent will damage parts or components on the circuit board. Acrylics are the most sensitive to solvents hence their easy removal; epoxies,urethanes and silicones are the least sensitive. Parlylene cannot be removal with solvent.

Peeling: Some conformal coating can be peeled from the circuit board. Silicone conformal coating and some flexible conformal coatings can be removed by peeling method.

Thermal/Burn - through: A common technique of coating removal is to simply burn through the coating with a soldering iron as the board is reworked. The process can be used to remove small areas of conformal coating.

Micro blasting: Micro blasting removes the conformal coating by using a concentrated mix of soft abrasive and compressed air to abrade the coating. The process can be used to remove small areas of conformal coating. It is most commonly used when removing Parylene and epoxy coatings.

Grinding/Scraping: In this method the conformal coating is removed by abrading the circuit board. This method is more effective with harder conformal coatings, sucha as parylene, epoxy and polyurethane. This method is only used as a method of last resort, as serious damage can be incurred.

Thermal: The thermal removal technique (including using a soldering iron to burn through the conformal coating) is the least recommended technique of coating removal. Most conformal coatings require a very high temperature and /or long exposure times. Thermal removal can cause the lifting of surface mount pads from boards also, temperature - sensitive components may be damaged. Extreme caution must be taken when burning through conformal coating because some coatings emit very toxic vapors that are hazardous to the people doing the stripping and those around them.

Mechanical

Mechanical removal techniques include cutting, picking, sanding or scraping the area of coating to be removed. However, most of the conformal coating are very tough and abrasion- resistant, making the probability of damage to the board very high.

Chemical: Chemical removal techniques were the most popular techniques for the removal of conformal coatings without affectingthe board or its components. But there is no one perfect solvent for all applications, and in some cases no solvent will be suitable at all.

Introduction to rework and repair concepts

Objective: At the end of this lesson you shall be able to
- **explain the solder mask, solder joints, tracks, pads and plated through hole.**

Solder mask

Solder mask or solder stop mask or solder resist is a thin layer of polymer applied to the copper traces of a printed circuit board (PCB) for protection against oxidation short circuits, corrosion, and other problems. Solder mask is a thin layer of polymer and to prevent solder bridges from closely spaced solder pads. A solder bridge is an unintended electrical connection between two conductors by means of a small blob of solder. Once applied, openings must be made in the solder mask wherever components to be soldered. This is done by photolithography. Solder mask is mostly green in color, but is now available in many colors.

- Green
- Matte Green
- Red
- Blue
- Yellow
- White
- Black
- Matte Black

Mostly Green colours used as solder mask as shown in Figs 1a & 1b.

Fig 1a

Solder mask as shown in fig 2a & 2b comes in different media depending upon the demands of the application.

Fig 1b

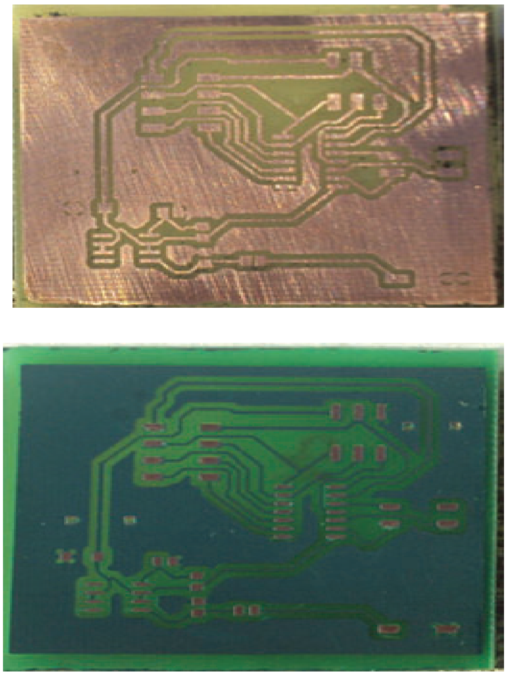


Fig 2a

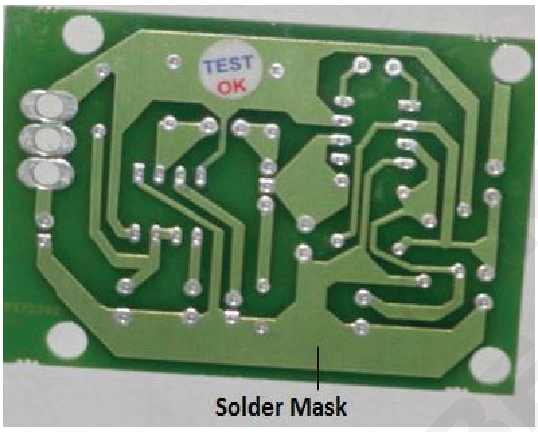
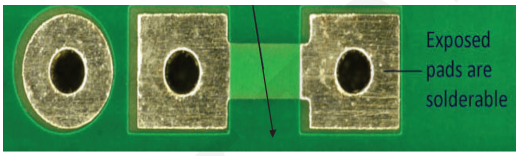


Fig 2b



SOLDER MASK COVERS UP THE SIGNAL TRACES BUT LEAVES THE PADS TO SOLDER.

The lowest-cost solder mask is epoxy liquid that is silkscreened through the pattern onto the PCB. Other types are,

Liquid photoimageable solder mask (LPSM) inks.

Dry film photoimageable solder mask (DFSM).

LPSM are silkscreened and sprayed on the PCB, exposed to the pattern and developed to provide openings in the pattern for parts to be soldered to the copper pads.

DFSM is vacuum laminated on the PCB then exposed and developed.

All three processes go through a thermal cure after the pattern is defined.

Solder joints

The solder joints are very much important in construction of PCB as shown in Figs3a & 3b.

Fig 3a

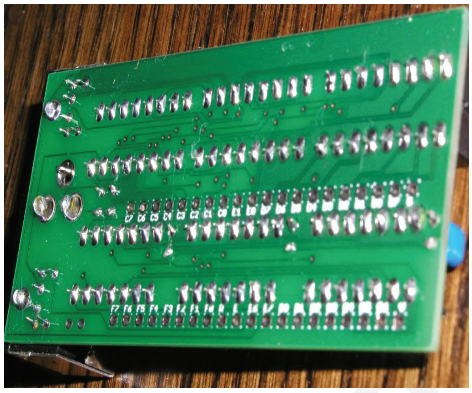
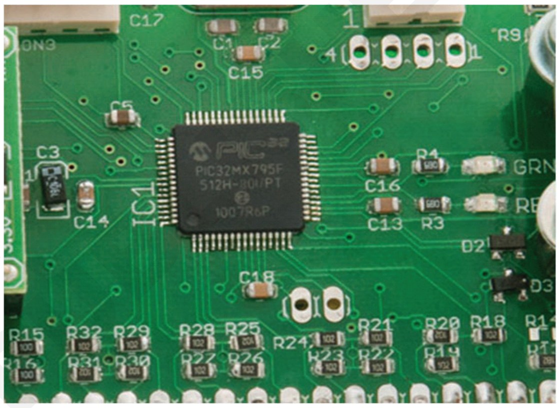


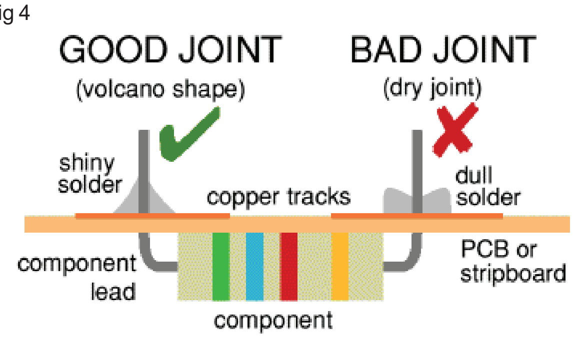
Fig 3b



- If the solder joints are poor
- It will cause the equipment to not to work.
- There is a possibility that the solder joint could fail intermittently.
- It will introduce noise into the circuit.

Fig 4 Shows the method of solder joints on PCB

Fig 4

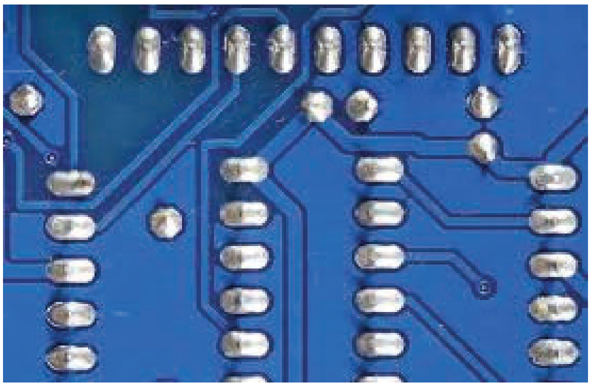


Good solder joint

Most solder joints are good and do not cause any problems. A good solder joint will have a shiny finish to it, and it should not have too much solder as shown in Fig 5.

The contour of the solder around the joint should be slightly concave.

Fig 5



Poor solder joints

Too much solder on a joint may lead to poor joints as shown in Figs 6a, 6b&6c.

Fig 6a

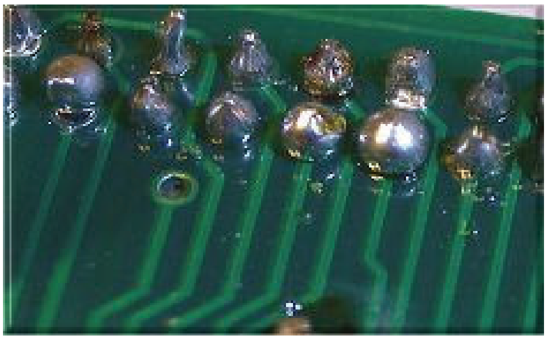
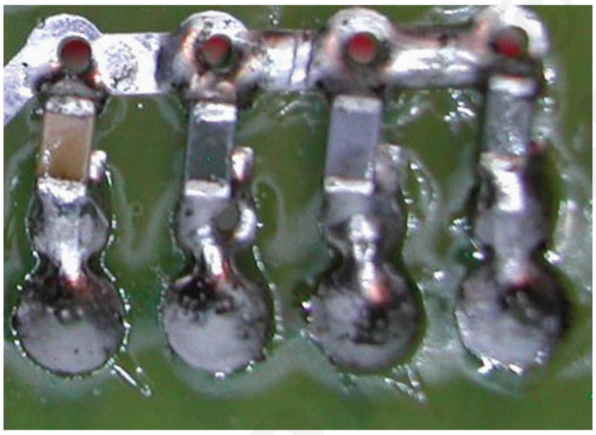


Fig 6b



Excess solder on joints

On printed circuit boards if too much solder is used then it could spill over onto another track, causing a short circuit as shown in Figs 7a & 7b.

Dry joints

Dry joints are the main problem of solder joint. These solder joints may be completely open circuit, or they may be intermittent, high resistance or noisy. Therefore it is essential that no dry solder joints are present in any electronics equipment.

Fig 6c

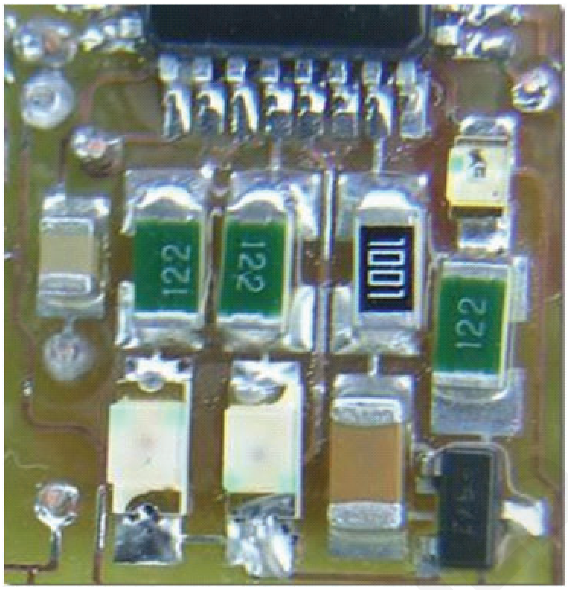


Fig 7a

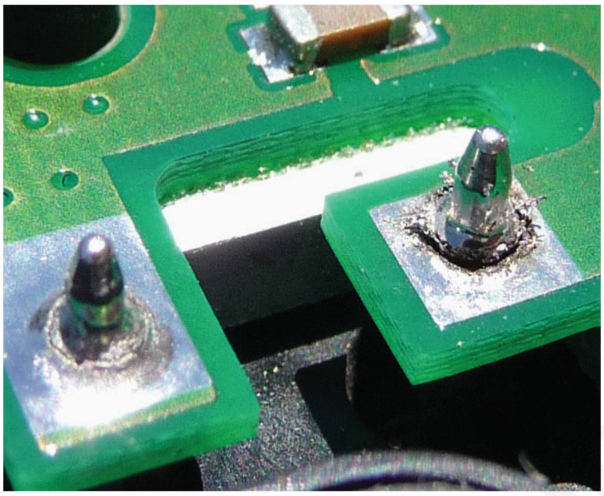
Fig 7b

It is easy to identify dry joints as shown in Fig 8a & 8b. Good solder joints are shiny, where as dry joints have a dull or matt finish.

When a dry joint is found, the solder on the joint should be removed and care to be taken when re-soldering it, to ensure that a good joint is made.

Fig 8a

Fig 8b



Tracks

Commonly there is no recommended standard for track sizes. Size of track will depend upon the requirements of the design, the routing space and clearance. Every design will have a different set of electrical requirements which can vary between tracks on the board. As a general rule bigger the track width is better. Bigger tracks have lower DC resistance, lower inductance, can be easier and cheaper for the manufacturer to etch, and also easier to inpsect and rework. The lower limit of track width will depend upon the "track/space" resolution. For example, a manufacturer may quote a 10/8 track /space. This means that tracks can not be less than 10 thou wide, and the spacing between tracks, or pads, or any part of tracks are the copper, can not be less than 8 thou. Always quoted in thou's, with track width first and then spacing. IPC standard recommands 4 thou as being a lower limit.

A "thou" is 1/1000th of an inch = 1 thou (0.001 inch)

Fig 9 shows the tracks on the PCB.

Fig 10 shows the damaged track on PCB which is to be repaired.

Pads

Fig 11 shows the pads of PCB.

Fig 9

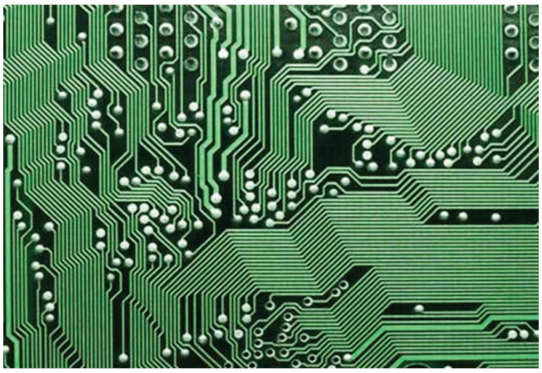


Fig 10

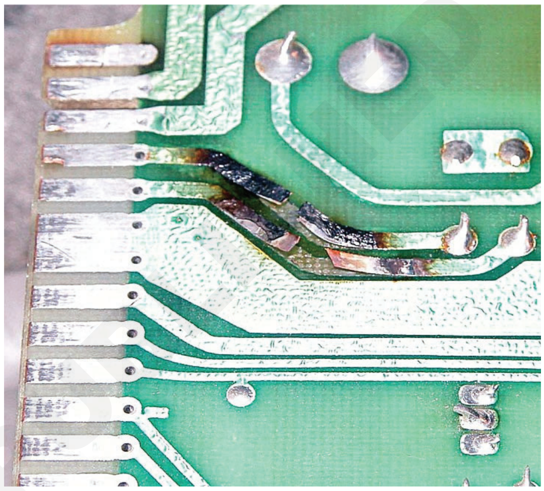
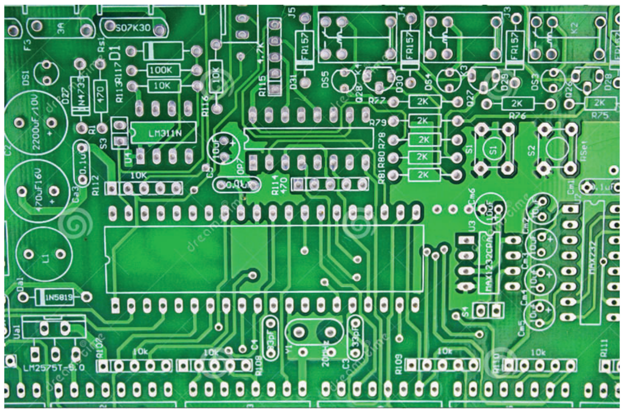


Fig 11

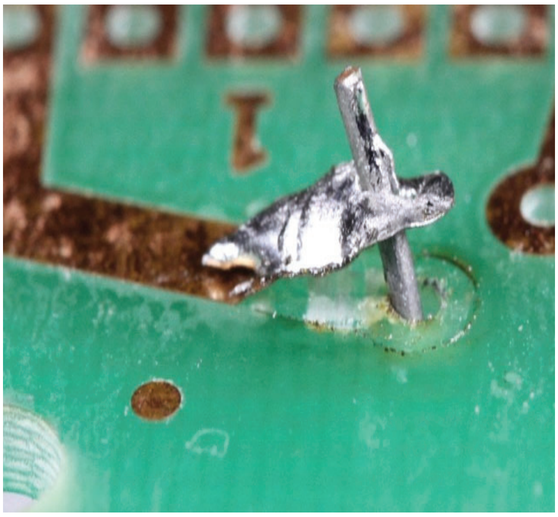


Pad sizes, shapes and dimensions will depend upon the component used to assemble the board. There is an important parameter known as the pad/hole ratio. This is the ratio of the pad size to the hole size. The pad should be at least 1.8 times the diameter of the hole, or at least 0.5 mm larger. This is to allow for alignment tolerances on the drill and the artwork on top and bottom layers. This ratio gets more important the smaller the pad and hole become, and particularly relevant to vias. Pads for components like resistors, capacitors and diodes should be round, with around 70 thou. diameter being common. Dual in line (DIL) components like IC's are oval shaped pads.

Pin.1 of the chip should be rectangular shape and other pins are circular or oval.

Fig 12 shows the damaged pad which is to be reworked.

Fig 12



Plated-Through Hole

"Through-hole technology", refers the mounting system used for electronic components inserted into holes in PCBs and soldered to pads on the opposite side either by manual assembly or automated insertion mount machines. PCBs are initially had tracks printed on one side only. Later two sides are used, and then multi-layer boards are using now a days. Similarly, through holes became plated-through holes (PTH), Fig 13 is a Plated-Through Hole in a ten layer board.

Plated-through holes are used to make the components contact with required conductive layers and making interconnections between the layers called vias.

In PTH electrolysis deposition are done after the holes are drilled, then copper is electroplated to build up the thickness, Finally the boards are screened, and plated with metal.The amount of plating used in the hole depends on the number of layers in the printed circuit board, however only the least amount of metal is used for this process. Holes through a PCB are typically drilled with small-diameter, drill bits are made up of solid coated tungsten carbide. Fig 14 shows the eyelets, which can be used to repair if PTH or vias are damaged.

Fig 13

Fig 14

Semiconductor materials, components, number coding for different electronic components such as diodes and zeners etc

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.**

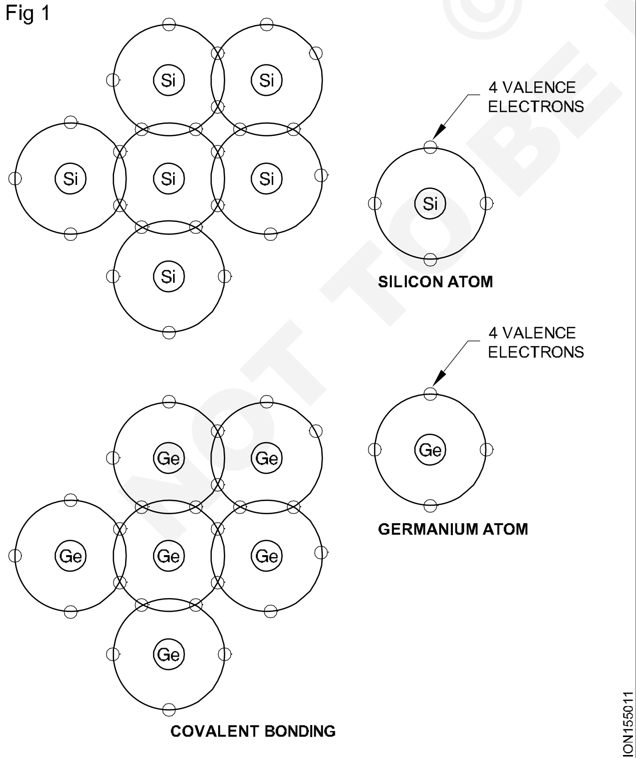
Semiconductors

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

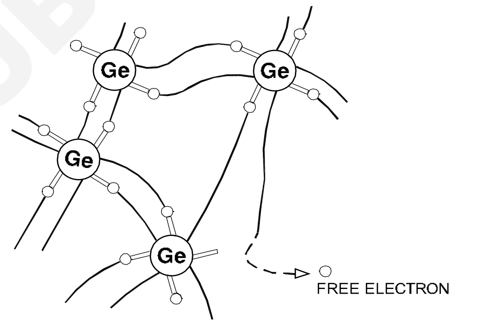


Intrinsic semiconductors

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.**

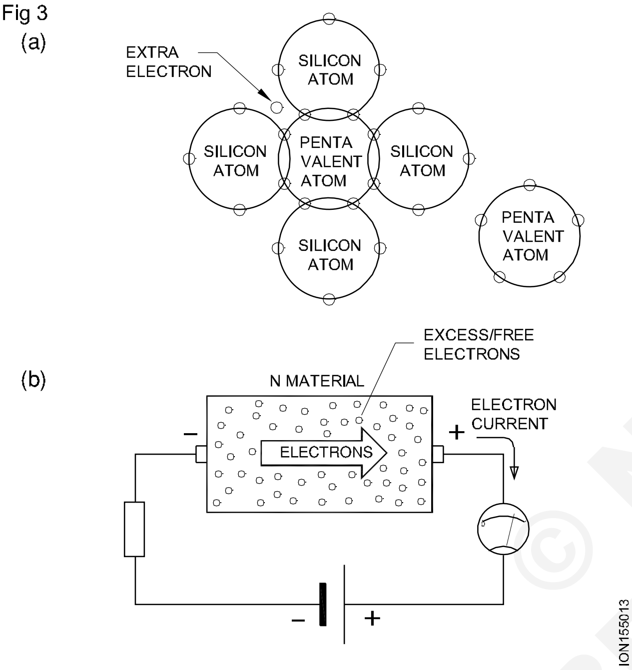
Depending upon the type of impurity used, extrinsic semiconductors can be classified into two types;

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.**

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.

Fig 3



In N type semi conductor the current is due to electrons, therefore the electrons are the majority charge carriers.

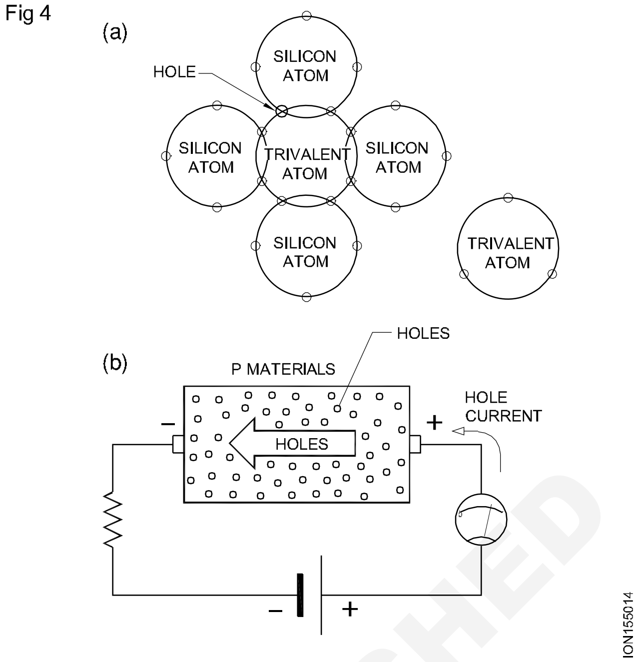
The semi conductor materials are temperature sensitive, heating causes the covalent bonds to break down by creating electron-hole pair. The holes are minority charge carriers - in N type semi-conductors.

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.

Fig 4

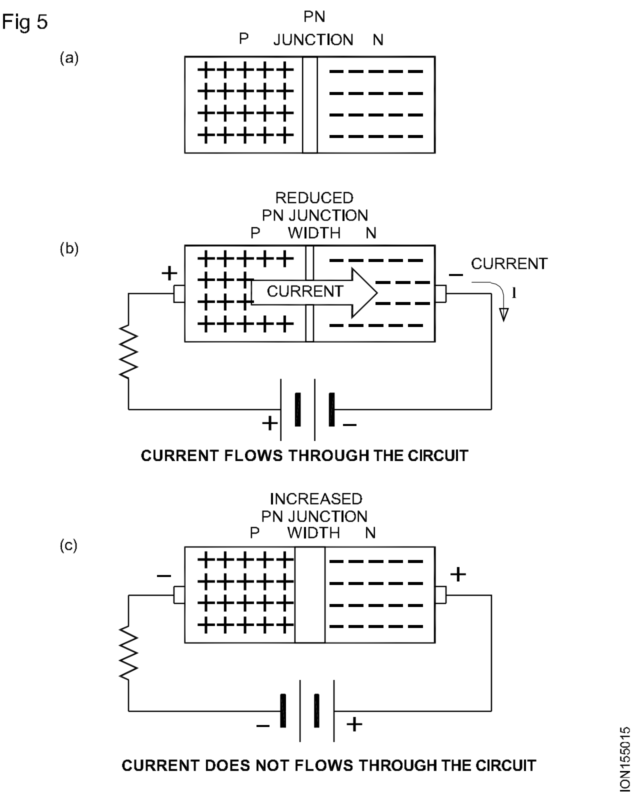


The holes are the majority charge carriers in P type semi conductor and the electrons are the minority charge carriers.

P-N junction

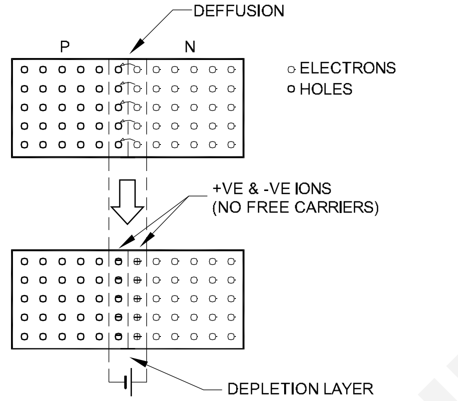
When a P-type and a N-type semiconductors are joined, a contact surface between the two materials called PN-junction is formed, as shown in Fig 5. This junction has a unique characteristic. This junction, has the ability to pass current in one direction and stop current flow in the other direction. To 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 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.

Fig 6

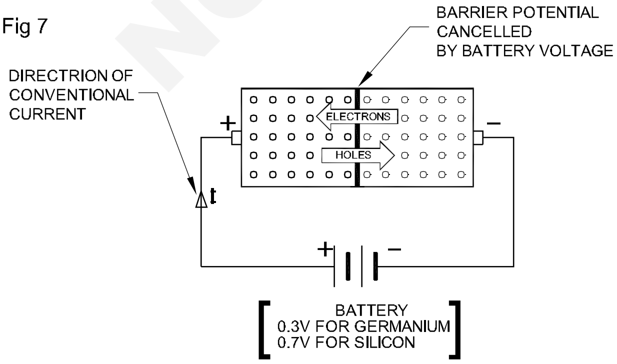


BATTERY EQUIVALENT OF JUNCTION

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.

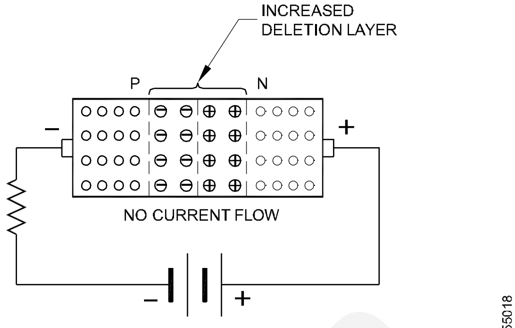
Fig 7



FORWARD BIASED P N JUNCTION

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.

Fig 8



REVERSE BIASED P N JUNCTION

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.

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

- **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.
- **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.

• **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

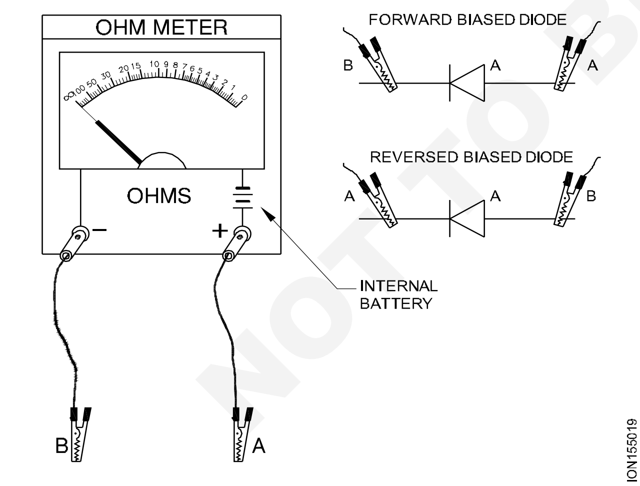
The type of packaging given to diodes is mainly based on the current carrying capacity of the diode. Low power diodes have either glass or plastic packaging. Medium power diodes have either plastic or metal packaging. High power diodes will invariably have either metal can or ceramic packaging. High 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.

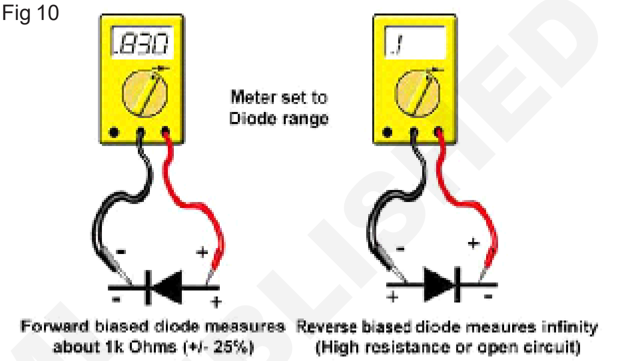
On the other hand, if the meter leads are reversed, the diode will be reverse-biased. Very little current will flow because a good diode will have very high resistance when reverse biased, and the meter will indicate a very high resistance.

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.

Fig 10



On the other hand, if the meter leads are reversed, the diode will be reverse biased and MM will display 1.

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.

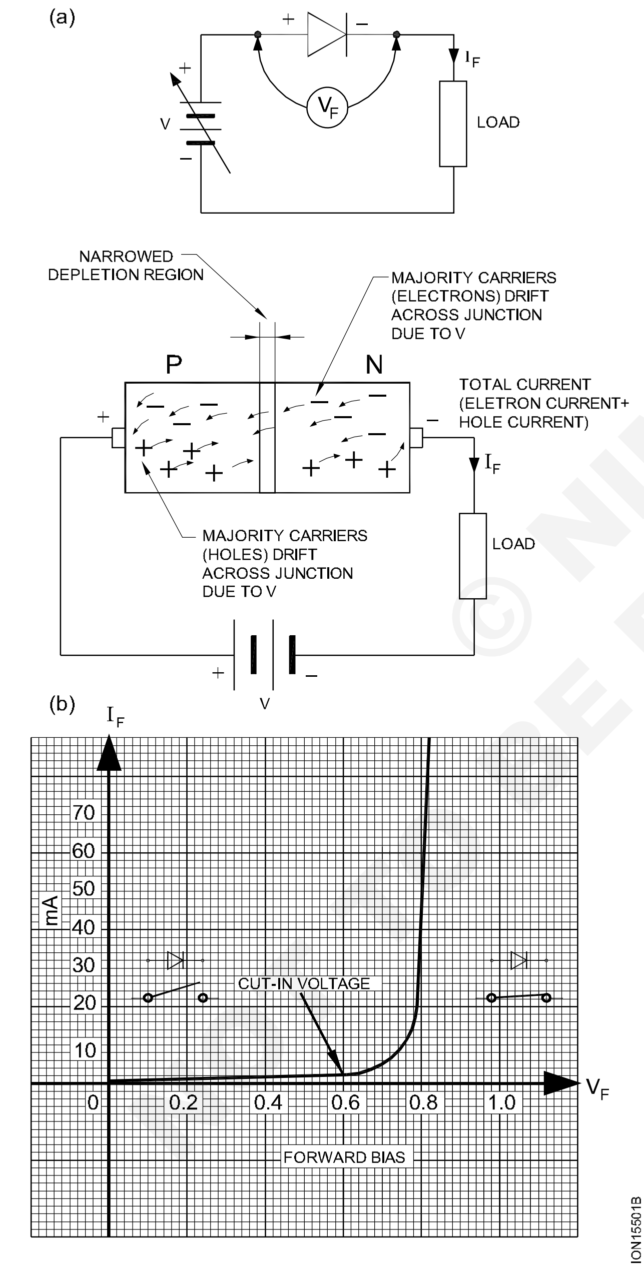
But once the voltage V_F across the diode becomes equal to or greater than the barrier potential 0.6 to 0.7V, there will be a canceling effect of the barrier potential. Hence, the free electrons from the N region get pushed away by the -ve battery terminal(remember like charges repel) and cross over 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.

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.*

Fig 11

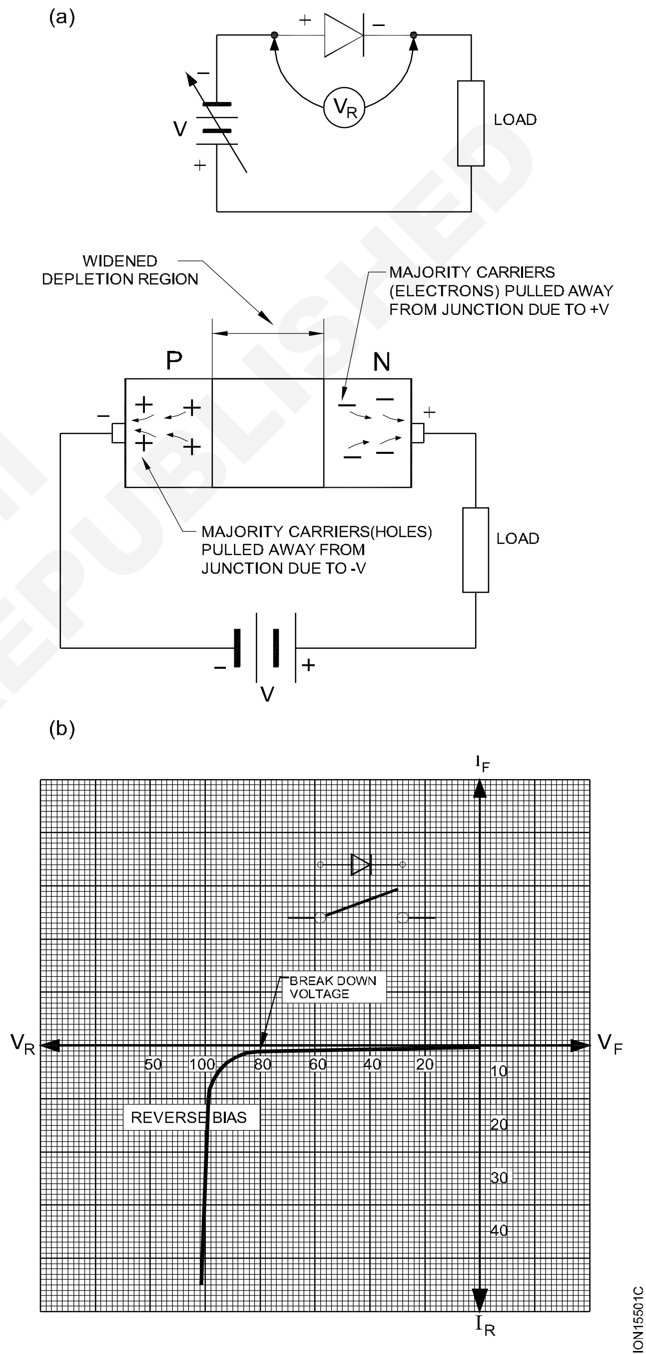


If the applied forward voltage is further increased beyond the cut-in voltage, the depletion layer further narrows down allowing more and more current to flow through the diode. It can be seen from the graph at Fig 11b, that beyond the cut-in voltage, the current increases sharply for very small voltage 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.

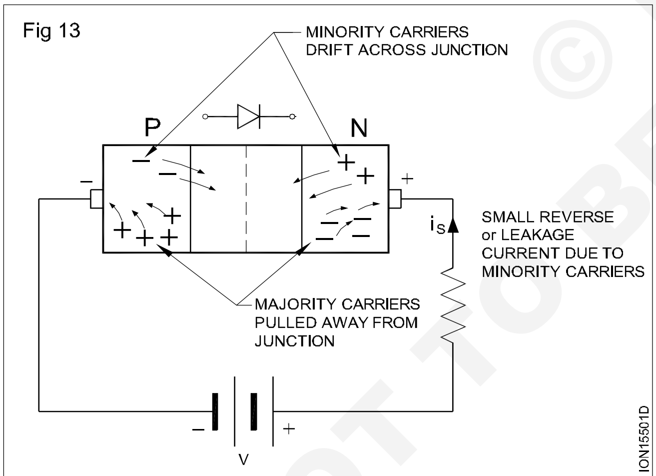
It the applied reverse voltage is kept on increased, say to hundred volts (this depends from diode to diode), at one stage the applied voltage V_R across the junction is so large that it punctures the junction damaging the diode. This results in shorting of the diode. This short results in uncontrolled 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.

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,* $T_{j\,max}$.

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.

Classification of Transformers

1 Classification based on the type of Core Material used

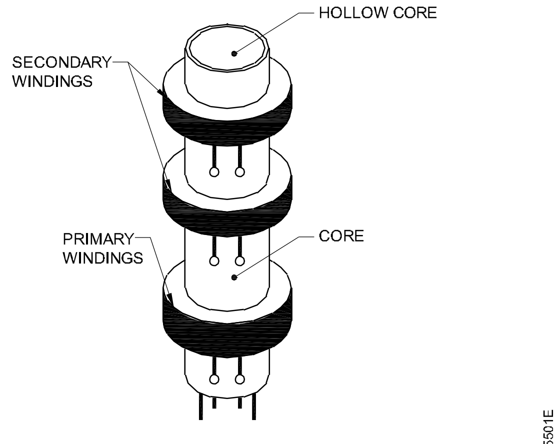
Transformers can be classified according to the type of material used for the core as;

a **Air core transformers** : As shown in Fig 14, 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.

Iron-loss is a type of transformer loss due to core material. Transformer losses are discussed in detail in further lessons.

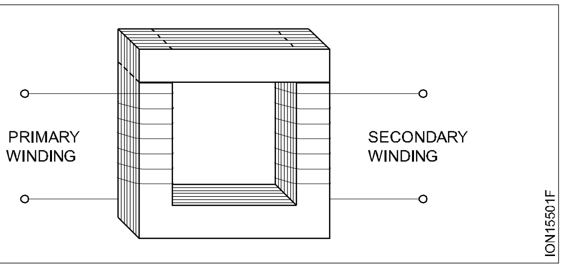
b **Iron core transformers**: Fig 15 shows a laminated iron-core transformer. These transformers have stacked laminated sheets of silicon steel over which the windings are wound. This is the most common type of transformer used with mains power supply(240V,50Hz). In these transformers, since the core is a magnetic material and due to the shape of the core, the value of k is almost equal to 1.

Fig 14



AIR CORE TRANSFORMER

Fig 15



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*.

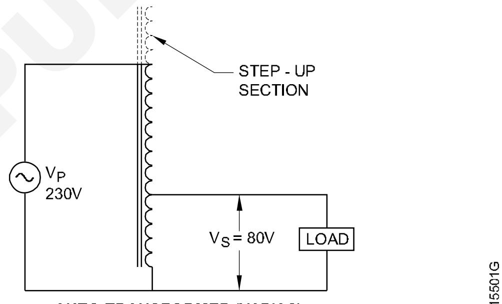
b **Step-down Transformers**: Transformers in which, the induced secondary voltage is lower than the source voltage given at primary are called *step-down transformers*.

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.

3 Auto-transformers:

Auto-transformer as shown in Fig 16 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 21



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 15, 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.

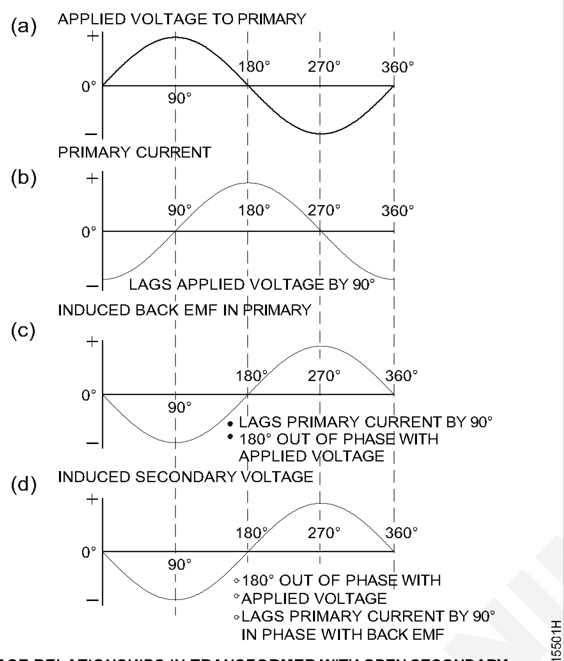
Phase relationship between primary and secondary

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 17, with open secondary, the primary winding works similar to that of an inductor.

This means that,

Fig 17

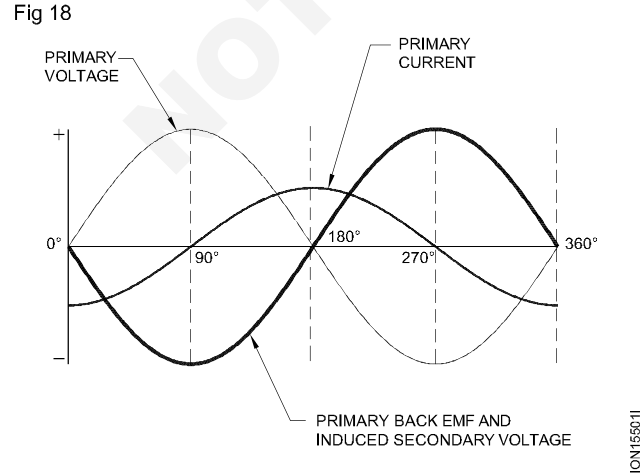


PHASE RELATIONSHIPS IN TRANSFORMER WITH OPEN SECONDARY

- **The primary current lags behind the applied voltage V_i by 90°.**
- From Lenzs' law the back-emf produced in the primary, which opposes the cause, therefore lags behind the primary current by 90°.

  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 18



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°,

- **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 x 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 x I x Cos θ where Cosθ 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 x I x Sin θ

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 10)

Therefore

$P_a^2 = P^2 + P_q^2$ Volt- amperes (VA)

where 'P_a' is the apparent power in volt-ampere (VA)

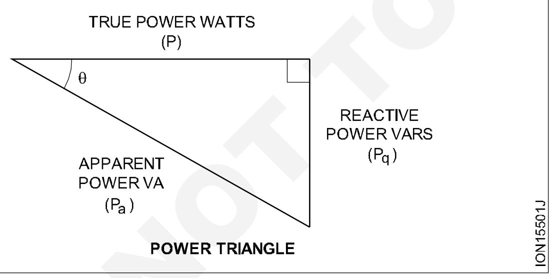
'P' is the true power in watts (W)

P_q is the reative power in volt-amperes reactive. (VAR)

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 19), the ratio of the true power to the apparent power is the cosine of the angle q.

$$\text{Power Factor} = V \times \frac{P}{Pa} = \cos\theta$$

Fig 20



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.

A 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

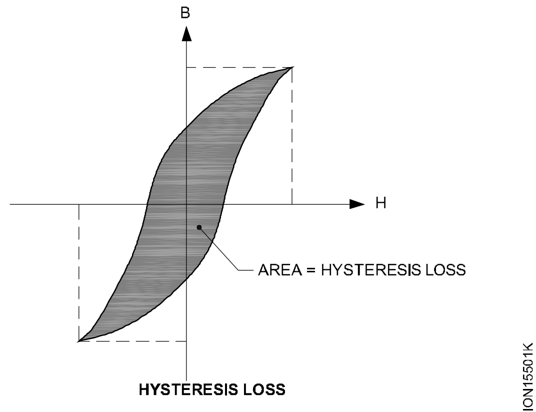
i Hysteresis loss

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 20.

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.

Fig 20



It should be noted that air core transformer will not have hysteresis loss as air core transformers do not use magnetic core material.

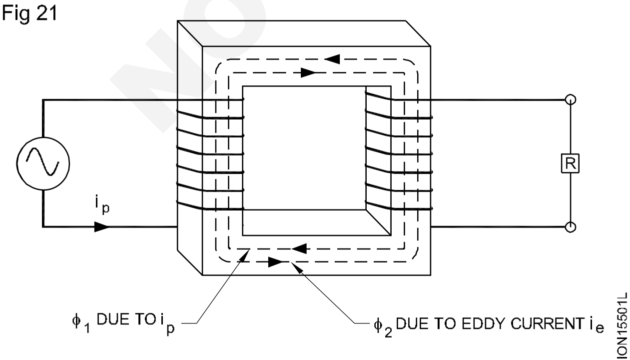
ii Eddy current loss

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*.

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 21.

In addition, the induced eddy currents set-up an opposing flux ($ø_2$) in the core as shown in Fig 21. 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.

Fig 21



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 saturation 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.

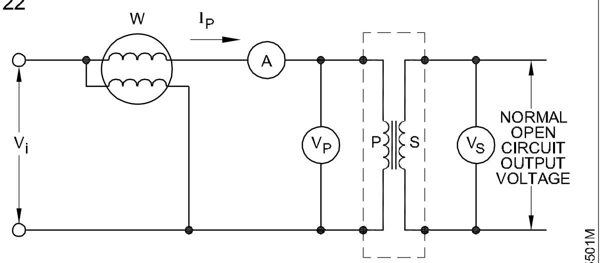
Measuring transformer losses

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 22 shows the circuit arrangement for O-C test on a transformer.

Fig 22



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

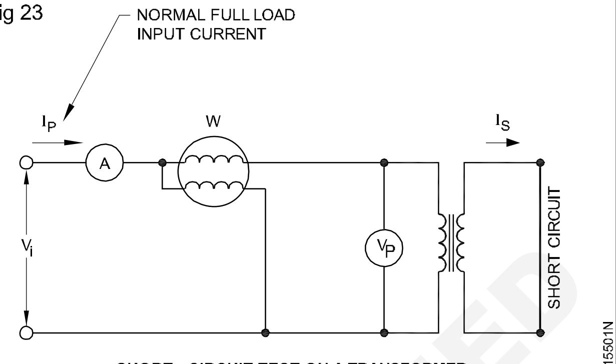
= 0 + Iron loss

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 23 shows the circuit arrangement for S-C test on a given transformer.

Fig 23



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;

$$\text{Power factor, } \cos\theta = \frac{\text{True power}}{\text{Apparent power}}$$

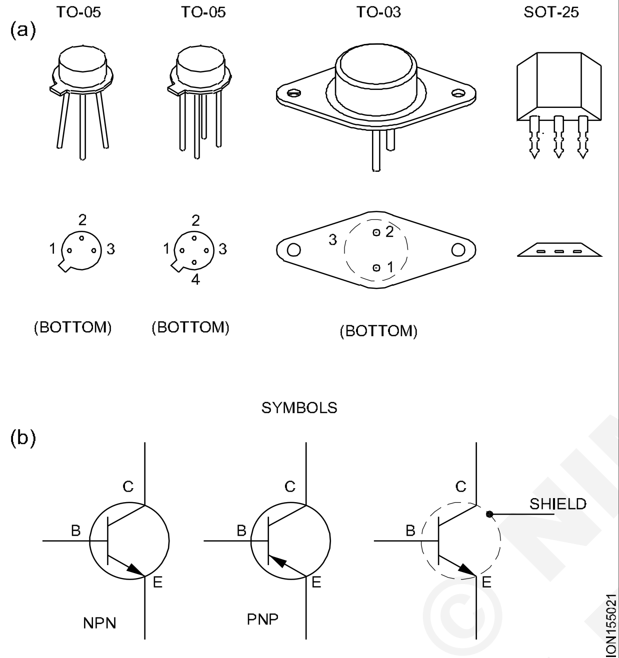
Construction, working of a PNP and NPN transistors, purpose of E, B & C terminals

Objectives: At the end of this lesson you shall be able to
- **perform construction, working of PNP and NPN transistors**
- **state the purpose of E,B & C terminals.**

INTRODUCTION - TRANSISTORS

Transistors are the semiconductor devices having three or four leads/terminals. Fig 1a shows some typical transistors. Fig 1b shows the symbols used for different types of transistors.

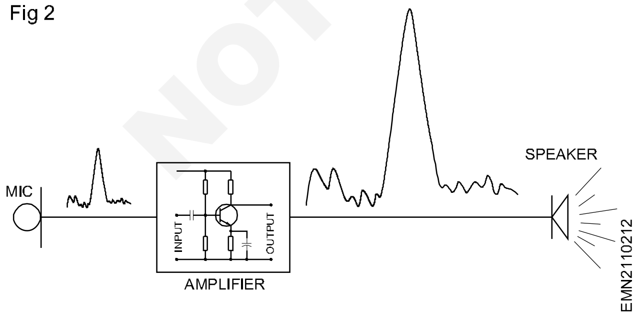
Fig 1



Transistors are mainly used for enlarging or amplifying small electric/electronic signals as shown in Fig 2. The circuit which uses transistors for amplifying is known as a transistor amplifier.

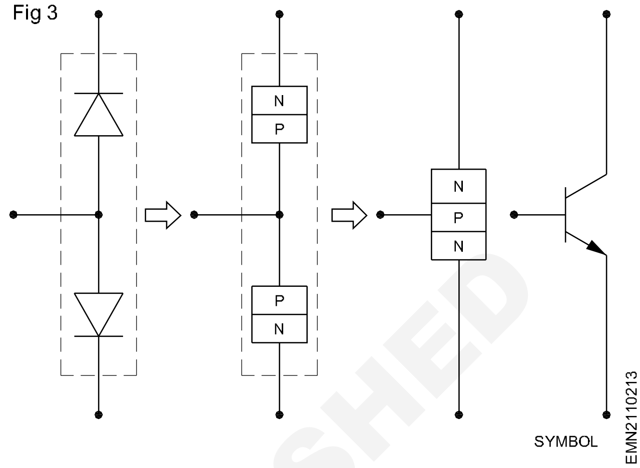
One other important application of transistors is its use as a solid state switch. A solid state switch is nothing but a switch which does not involve any physical ON/OFF contacts for switching.

Fig 2



Transistors can be thought of as two PN junction diodes connected back to back as shown in Fig 3.

Fig 3



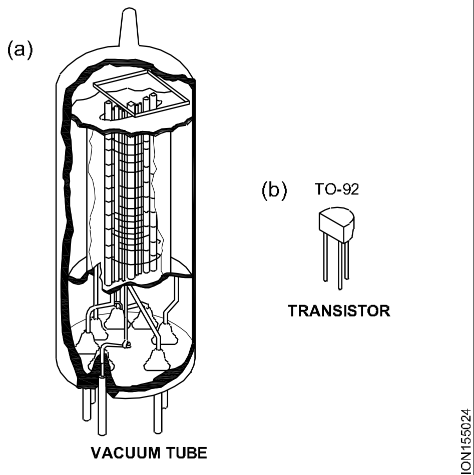
Before the transistors were invented (1947), there was what were known as vacuum tubes which were used in amplifiers. A typical vacuum tube is shown in Fig 4a.

Compared with the present day transistors the vacuum tubes were big in size , consumed more power, generated lot of unwanted heat and were fragile. Hence vacuum tubes became absolute as soon as transistors came to market.

Transistors were invented by Walter H. Brazil and John Barlow of Bell Telephone Laboratories on 23rd Dec. 1947. Compared to vacuum tubes (also known as valves), transistors have several advantages. Some important advantages are listed below;

- Very small in size (see Fig 4b)
- Light in weight
- Minimum or no power loss in the form of heat
- Low operating voltage
- Rugged in construction.

Fig 4



To satisfy the requirements of different applications, several types of transistors in different types of packaging are available. As in diodes, depending upon the characteristics, transistors are given a type number such as BC 107, 2N 6004 etc., The characteristics data corresponding to these type numbers are given in *Transistor data books*.

Classification of Transistors

- **Based on the semiconductor used.**
  - Germanium transistors
  - Silicon transistors

Like in diodes, transistors can be made, using any one of the above two important semiconductors. However, most of the transistors are made using silicon. This is because, silicon transistors work better over a wide temperature range (higher thermal stability) compared to germanium transistors.

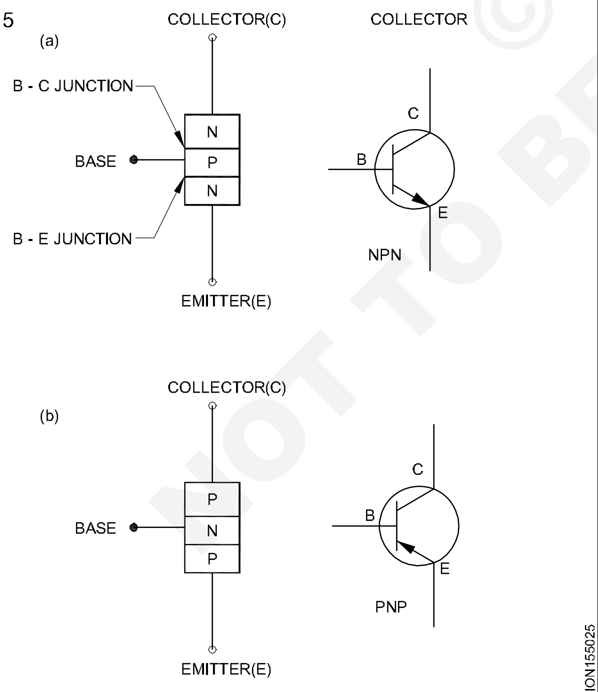
Transistor data books give information about the semiconductor used in any particular transistor.

- **Based on the way the P and N junctions are organized as shown in Fig 5.**
  - NPN transistors
  - PNP transistors

Both NPN and PNP transistors are equally useful in electronic circuits. However, NPN transistors are preferred for the reason that NPN has higher *switching speed* compared to PNP.

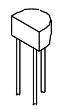
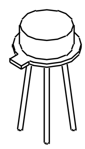
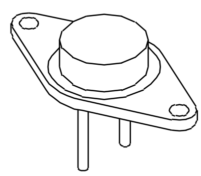
Details of switching speed is discussed in further lessons.

Fig 5



Whether a transistor is PNP or NPN can be found with the help of transistor data book.

- **Based on the power handling capacity of transistors as shown in Table below (Fig 6).**

Low power transistors (less than 2 watts)	**Medium power transistors** (2 to 10 watts)	**High power transistors** (more than 10 watts)
TO-92 	TO-05 	TO-03 

Low power transistors, also known as small signal amplifiers, are generally used at the first stage of amplification in which the strength of the signal to be amplified is low. For example, to amplify signals from a microphone, tape head, transducers etc.,

Medium power and high power transistors, also known as large signal amplifiers are used for achieving medium to high power amplification. For example, signals to be given to loudspeakers etc. High power transistors are usually mounted on metal chassis or on a physically large piece of metal known as heat sink. The function of heat sink is to, take away the heat from the transistor and pass it to air.

Transistor data books give information about the power handling capacity of different transistor.

- **Based on the frequency of application**
  - Low freq. transistors (Audio frequency or A/F transistors)
  - High freq. transistor (Radio frequency or R/F transistors)

Amplification required for signals of low or audio range of frequencies in Tape recorders, PA systems etc., make use of A/F transistors. Amplifications required for signals of high and very high frequencies as, in radio receivers, television receivers etc., use R/F transistors.

- **Based on the manufacturing method**
  - Grown junction
  - Alloy junction
  - Planar type
  - Point contact
  - Epitoxial
  - Mesa

The aim of each manufacturing process is to yield transistors most suitable for a particular type of application.

Transistor data books generally do not give information about the adopted manufacturing process of transistor. However, the relevant details can be obtained from the transistor manufacturer.

- **Based on the type of final packaging**
    - Metal
    - Plastic
    - Ceramic

Metal packaged transistors are generally used in medium and high power amplifications. Plastic packaging is generally used for low power amplification. Some plastic packages come with a metal heat sink. Such transistors are used for medium power amplification. Ceramic packaging is used for special purpose very high frequency applications, for higher temperature stability etc.,

Some examples of packaging type codes used with transistors are, TO-3, TO-92, SOT-25 and so on.

Transistor data books give information about the type of packaging and its case outline.

Inside a transistor

Inside a transistor there are two PN junctions connected to each other as shown in Fig 3 and Fig 5. Outside a transistor, one can see only three leads. These leads are known as **base, emitter** and **collector** as shown in Fig 5. As shown in Fig 5, the three leads/pins/pigtails called **base, emitter** and **collector** are taken from each of doped semiconductor material.

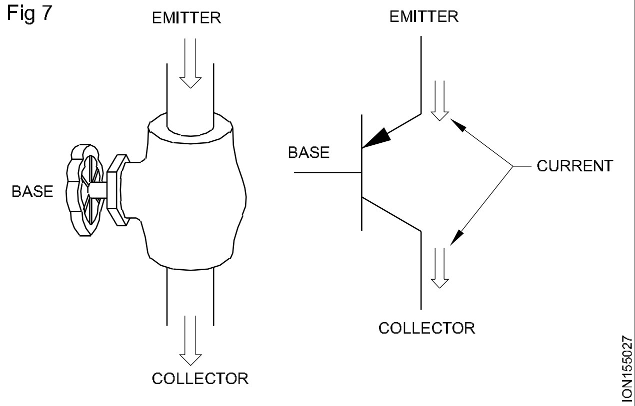
In simple terms, as shown in Fig 7, the function of the **base, emitter** and **collector** regions of a transistor are,

Emitter - emits current carriers(electrons/holes)

Collector - collects current carriers

Base - controls flow of current carriers from emitter to collector.

Fig 7



While connecting a transistor to a circuit, it is necessary to identify the base, the emitter and the collector pins. A Transistor data book gives information on pin identification of transistors. However, it is convenient to put sleeve wires over the transistor pins for the following reasons;

- for easy identification while wiring
- sleeves act as spacers while mounting and soldering
- they ensure the required minimum lead distance from the solder joint to the transistor body.

Following colour scheme is suggested for putting sleeves to transistor pins although, any convenient colour scheme may be adopted.

Base pin	-	Blue colour sleeve
Emitter pin	-	Red colour sleeve
Collector pin	-	Yellow colour sleeve
Shield pin	-	Black colour sleeve

Transistor applications as switch and CE amplifier

Objectives: At the end of this lesson you shall be able to
- **explain the function of the transistor**
- **explain the operation of a transistor as a switch**
- **describes the operation of a transistor switching circuit**
- **state the application of transistor switch.**

The function of a transistor at cut-off condition: the transistor is operation at cut-off condition when the emitter and collector junction are both reverse biased

Consider the circuit in Fig 1

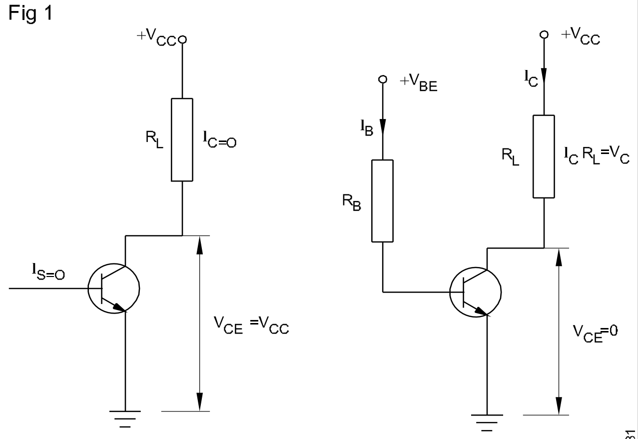
$V_{ce}=V_{cc}-(I_c*R_l)$……………..(1)

Since $I_b=0$ and $I_c= 0$ $V_{ce}=V_{cc}$

The transistor is said to be cut off for the simple reason that it does not conduct any current as in Fig 1a.this corresponds to a switch in an open state, therefore a transistor at cut off is said to be open state.

The function of a transistor at a saturation condition: The transistor is operated at a saturated condition when both the emitter and collector are in forward bias.

Fig 1



a) TRANSISTOR AT CUT OFF CONDITION

b) TRANSISTOR AT SATURATED CONDITION

In Fig 1b if the value of R_b and R_l are such that V_{ce} tends to zero, then the transistor is said to be saturates. Putting V_{ce}=0 in the eqn (1) we get,

$V_{ce}=0=V_{cc}-I_cR_l$ or $I_c=V_{cc}-R_l$

The operation of a transistor as a switch: The switch action for Q_1 in Fig 2 illustrated how the output current can be conducted at the input .note the following importance operating characteristics.

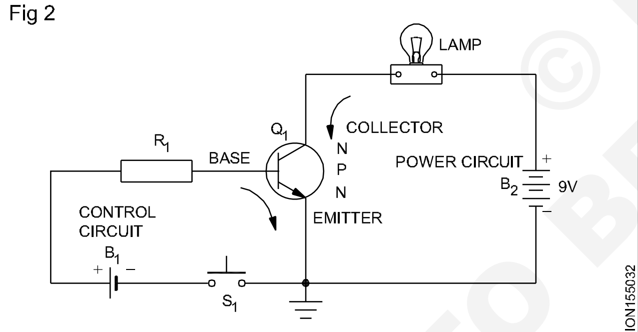
- transistor is normally off without output current unless forward voltage is applied in the base emitter circuit.
- the forward voltage controlling the base current mines the amount of output current.

In Fig 2 the control circuit of the input determines the base current determines the amount of output current.

In Fig 2 the control circuit of the input determines the base current. For the power circuit the output is the collector current. An NPN transistor is used for Q_1.the emitter is common to both (a) the current circuit at the input and (b) the power output circuit

The base emitter junction of Q in Fig 2 can be forwards biased by the battery B_1.Switch S_1 must be closed apply the forward voltage. reverse polarity means that the N collector is more positive than base, with switch S_1 open ,no current flow in base emitter .The reason is that the forward voltage is not applied .therefore the resistance of the emitter to the collector of the transistor is very high. No current flows in the power circuit and the lamp does not glow.

Fig 2



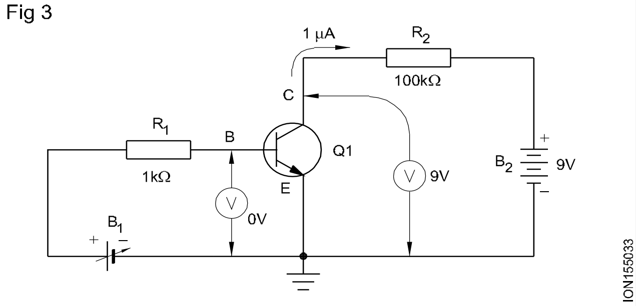
Next assume that switch that S_1 is closed this cause a small change in current flow in the control circuit .R is the current limiting resistor for the base current. Therefore the resistance from the emitter from the collector for the transistor drops. Consequently a large current flow in the power circuit causing the lamp to glow.

Operation of transistor switching circuit: The schematic circuit in the Fig 3 shows the measured voltage and collector current Ic in the 'transistor OFF' condition. Note that only a tiny leakage current of 1micro amp flow from the emitter to collector. The resistance from E to C is calculated as

R=V/I=9V/0.000001A=9 M Ω

The transistor has a resistance of 9 mega ohms, which is like the open or off condition of a switch.

Fig 3

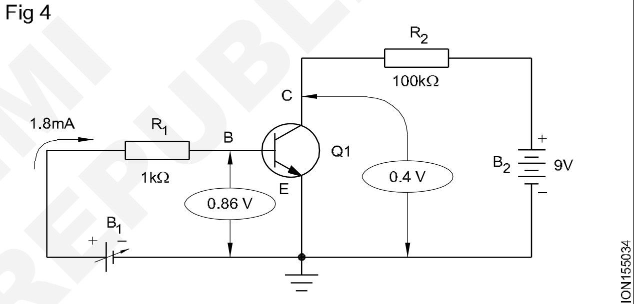


The fig 4 shows the measured voltage and current in the 'transistor ON condition. First, the voltage from the emitter to the base has been increased by adjusting B1,The forward –biased voltage of 0.86V at the emitter-base junction of the transistor cause the resistance of the transistor from E to C drop this resistance from E to C is calculated as,

R=V/I=0.4V/0.085A=4.7 ohms

The transistor in Fig 4 is said to be at saturation, when it has reached its maximum collector current. when used as switch, the transistor is divided into cut off and saturation by the base current varied by the emitter –base voltage.

Fig 4



Transistor switching time: Now let pay attention to the behavior of the transistor as a transistor from one state to the other. consider the transistor circuit shown in Fig5b.this wave form makes transistor between the voltage level V_2 and V_1 at V_2 the transistor is at cut off and at V_1 is applied between the base and the emitter through a resistor R_2 which may be included explicitly in the circuit or may represent the output impedance of the source furnishing the wave form.

In the fig the current does not immediately responds to the input signal. Instead there is a delay and the time escaped during this delay,

$t_{off}=t_d+t_r$

When the input signal is at state t=T the current again falls to the responds. Immediately,

$t_{off}=t_s+t_f$

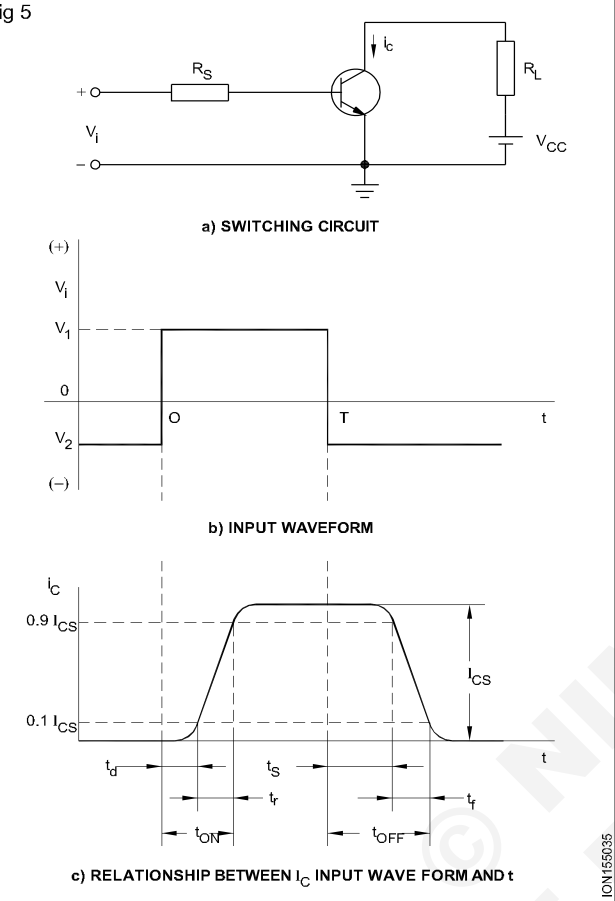
The application of transistor as a switch:

The transistor switch is used as

- as an electronic on off switch
- in the mono stable and bi-stable multi vibrators.
- In counter and pulse generator circuit

- in clipping and clamping circuit
- as a sweep starting switch in the cathode ray oscilloscopic equipments
- as a relay, but unlike the machanical relay the transistor has no moving mechanical parts.

Fig 5

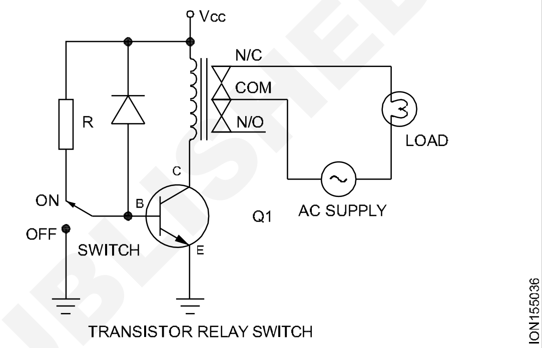


Transistor relay switch: Transistor driven relay electronic switch circuit shown in Fig 6. This type of circuits are mostly used in electronic circuits to drive high current and voltage circuits by using a small input voltage or current.

Circuit in Fig 5 is same as transistor switch. In this relay will be the load for transistor. Transistor will ON-OFF relay by operating base current and relay will be operated high by current or voltage load.

When is connected to small current (in Fig 6 switch connected to Vcc through current limitting resistor Rs.), transistor will go in saturation, so transistor will act as close switch so, current flows through relay. Due to current flowing in Relay. Relay will be magnetised and N/O contact will close. So, bulb load connected to the AC supply will ON.

Fig 6



When in put switch is OPEN, there is no current flowing to base of transistor. Transistor will goes in cut off, so transistor will act as OPEN switch *** current how through relay. Relay will not be energized and N/O contact remains open. So, bulb load is not getting current, it will not glow.

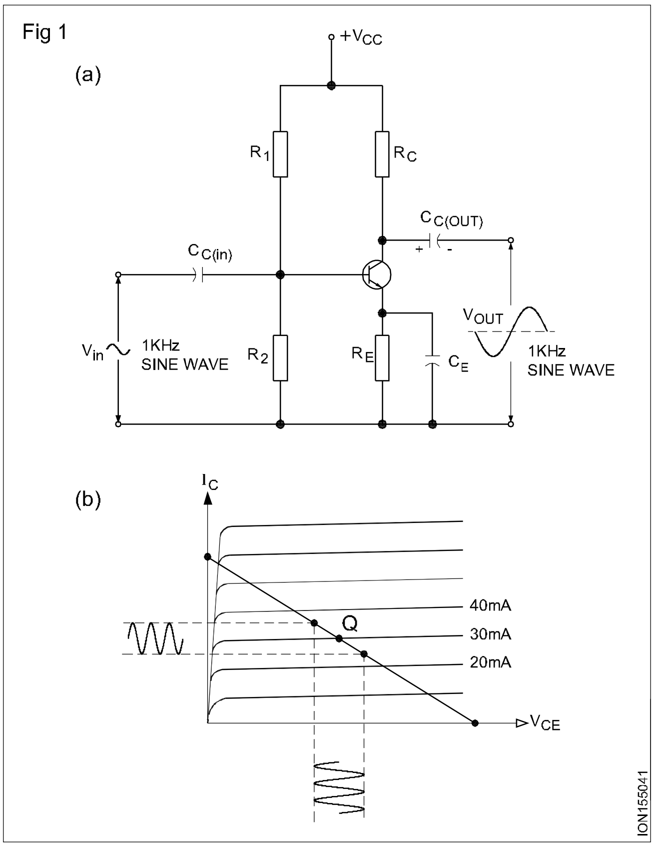
Gain and impedance of common emitter amplifier

Objectives: At the end of this lesson you shall be able to
- **state the meaning and method of finding voltage gain**
- **state the meaning and method of finding input impedance**
- **state the meaning and method of finding output impedance**
- **state the meaning and method of finding power gain**
- **state the phase relationship between input and output in a CE amplifier.**

After a transistor is biased with the Q point near the middle of the DC load line, the transistor can be made to amplify AC and DC signals as shown in Fig 1a. When we use a transistor to amplify a small AC signal, the small AC signal to be amplified is coupled to the base of the transistor using a capacitor. A capacitor is used for AC coupling because as discussed in earlier lessons capacitors behave as short for AC signal and open for DC signal. The varying amplitude and frequency of the coupled AC signal produces greater value variations in the collector current of the same shape and frequency as shown in Fig 1b.

As shown in Fig 1a, if the input is a 1 kHz sine wave, the output will be an enlarged 1 kHz sine wave. The small sine wave given at the base of the transistor produces variations in the base current. Hence, the collector current is an amplified sine wave of the same frequency. The sinusoidal collector current flows through the collector resistor and produces an amplified sine wave output. Such amplifiers which retain the shape of the input signal at the output are called linear amplifiers.

Fig 1b, shows the DC load line, the Q point and AC input and output signals. This is generally referred to as the *AC* load line. As can be seen from Fig 1b, the AC input voltage produces variations in the base current. This results in sinusoidal variations about the Q point. Variations in Q point are nothing but the variations in the collector current resulting amplified form of the input signal.



For small input signal levels, generally referred to as small signal operation, the peak to peak swing in the collector current should be less than the ±10% of the collector current at Q point to keep the distortion in the amplified output with in acceptable limits.

For large input signal levels, generally referred to as large-signal operation, the peak to peak swing in the collector current will be larger(more than 10%). If the swing is very large, the transistor may go into saturation and cut off. This swing into saturation and cut off will clip the positive and negative peaks of the output signal. This clipping is nothing but distortion, meaning, the output will not be an exact replicate of the input signal.

AC Current Gain A_i, of a CE amplifier

The AC current gain of a CE amplifier shown in Fig 1 is the ratio of the AC component of the collector current i_c, to the AC base current i_b.

$$A_i = \frac{i_c}{i_b}$$

Small letter i is used to represent AC current whose value keeps changing with time.

It is to be noted that in most linear CE amplifier circuits the current gain A_i is almost equal to b_{dc} of the transistor. Therefore the following approximation can be used for A_i.

$$A_i \approx \beta$$

In the amplifier at Fig 1, if b_{dc} of the transistor is 100, then the current gain A_i of the amplifier can be taken as 100.

Voltage gain, A or A_v of CE amplifier

The voltage gain of an amplifier is the ratio of AC output voltage to the AC input voltage. This is represented as,

$$\text{Voltage gain, } A_v = \frac{V_{out}}{V_{in}}$$

Small letter v is used for voltage because it is AC voltage whose amplitude keeps changing with time.

For example, in Fig 1, if the input voltage v_{in} is 80 m $V_{(p-p)}$ and the corresponding output voltage v_{out} is 7.2 $V_{(p-p)}$, then the voltage gain A_V is given by,

$$\text{Voltage gain, } A_v = \frac{7.2\,(p-p)}{80\text{m } V_{(p-p)}} = 90$$

A voltage gain of 90 means that, in this amplifier, a base voltage of 1 mV produces an output voltage of 9 mV.

The input and output voltage may be rms, peak, peak-to-peak, as long as the input and output are measured the same way consistently.

Input impedance, Z_{in} of CE amplifier

Recall that the maximum transfer of power takes place when the impedances of the supplying and receiving circuits are matched.

If impedances are to be matched for best circuit operation, both impedances must be known. If a single device such as a microphone, speaker, relay, etc. is to be used, its impedance will be given by the manufacturer. The amplifier to be designed for such a circuit must have an input or output impedance to match the input-output devices.

The AC source driving the amplifier has to supply AC current to the amplifier. The less the current the amplifier draws from the source, the better because the supplying source does not get loaded. The input impedance of the amplifier determines how much of current the amplifier takes from the ac source or the preceding stage of the amplifier.

In the normal frequency range of an amplifier, the coupling and by pass capacitors behave as a short for ac. The AC input impedance Z_{in} sometimes referred to as input resistance R_{in} is defined as the ratio of input signal voltage to input signal current.

$$Z_{in} = \frac{v_{in}}{i_{in}}$$

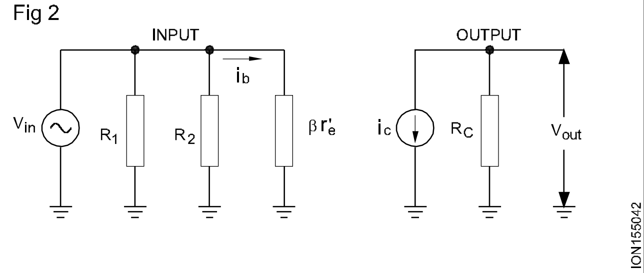
where, V_{in} and i_{in} are rms or peak or peak-to-peak values.

Fig 2 shows the AC equivalent circuit of the CE amplifier shown in Fig 1.

From the AC equivalent circuit the input impedance Z_{in} is given by,

$$Z_{in} \approx R_1 \parallel R_2 \parallel \beta r'_e \qquad .....[1]$$

Fig 2



where,

R_1 and R_2 are the voltage divider resistors,

b is the DC current gain and r'_e is the ac emitter resistance (V_{BE}/I_E). r'_e is approximately equal to 25W when the Q point is chosen at the mid of the load line.

In the CE amplifier at Fig 1, if R_1 = 18KW, R_2 = 8.2KW and the transistor b is 100, the input impedance Z_{in} will be,

br'_e = 100(25 W) = 2.5 KW

$Z_{in} = R_1 \parallel R_2 \parallel b\,r'_e$

= 18 KW $\parallel$ 8.2 KW $\parallel$ 2.5 KW

= 1.73 KW.

Practical way of finding Z_{in}

To find Z_{in} of a given CE amplifier circuit, it is merely necessary to measure the AC signal input voltage and current. Then, use these values in the formula, and calculate Z_{in}.

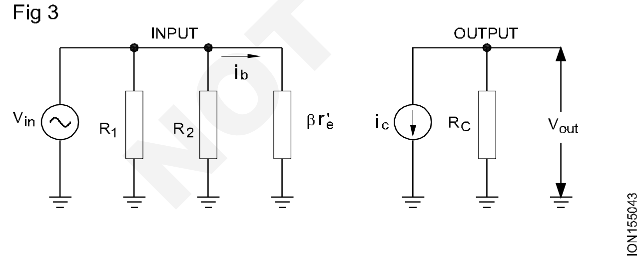
A simpler method to measure i_{in} is to connect a series input resistance of known value in series with the input signal, as in Fig 3.

The voltage drop across the resistor R_s is measured, and Ohm's law is used to determine i_{in}.

$$I_{in} = \frac{V_X - V_Y}{R_S}$$

The value of V_{in} can be measured directly, as shown in Fig 3.

Fig 3



Output impedance, Z_{out}

The output impedance of a CE amplifier is naturally the impedance at the output terminals.

To find the Z_{out} of the CE amplifier shown in Fig 4, consider the AC equivalent of the output as shown in Fig 4a.

Recall that a transistor operating in the linear portion of its characteristics curve is like a current source. Therefore, we can represent it as a current source i_C.

As can be seen from Fig 4a, this collector current source is in parallel with the collector resistor R_C. Assuming that the collector current source is ideal, it has infinite internal impedance. Then, the only impedance in the output is the collector resistor R_C.

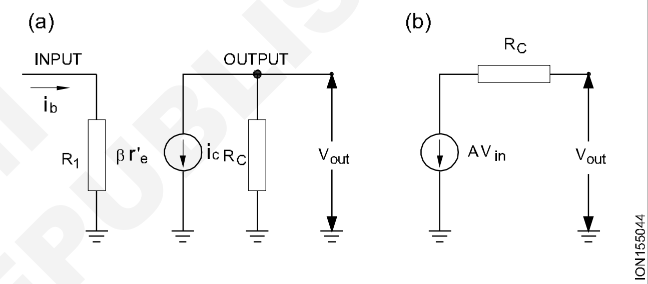
The Thevinin's voltage appearing at the output is the voltage gain(A) times the input v_{in}.

Therefore, $V_{out} = A.v_{in}$

Hence, the output AC equivalent circuit of the amplifier can be simplified as shown in Fig 4b. In Fig 4b, an ideal output voltage source AV_{in} with zero internal impedance is in series with the collector resistor R_C. Therefore, the output impedance of the CE amplifier is approximately equal to the collector resistor R_C,

$Z_{out} \approx R_c$

Fig 4



In the CE amplifier circuit at Fig 1, if R_C = 1000W, the output impedance of the amplifier is equal to the value of R_C, that is 1000 W.

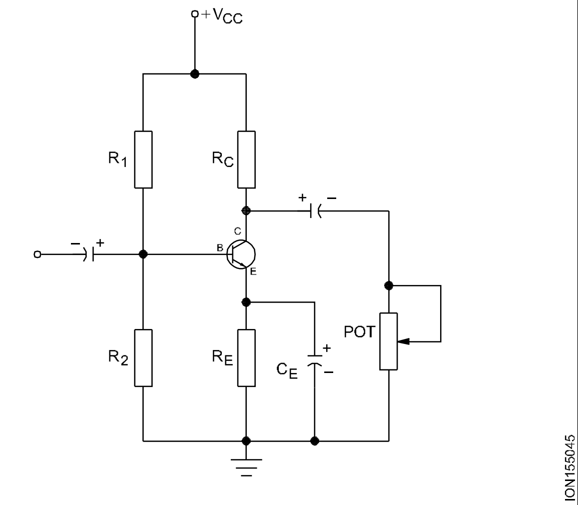
Practical way of finding Z_{out}

The easiest way of measuring the output impedance of a CE amplifier circuit is given below;

- Measure the unloaded output voltage V_{out} of the CE amplifier.
- Place a variable resistor across the load terminals, as shown in Fig 5.
- Adjust the variable resistor until the voltage drop across it is one-half of the unloaded output voltage V_{out}.
- Remove the variable resistor and measure its value. This value is equal to Z_{out}.

Z_{out} is not a fixed value; it varies with transistor voltages and the load resistance. Care must always be taken to maintain an undistorted signal when input or output impedances are measured.

Fig 5



Power gain, A_p of a CE amplifier

In the CE amplifier shown in Fig 1, the input power is given by,

$P_{in} = v_{in}.i_b$

and the output power is given by,

$P_{out} = - v_{in}.i_b$

The negative sign associated with output power. This is because, in a CE amplifier, the output is 180° out of phase with the input signal. Details are discussed in the forthcoming paragraphs.

In the CE amplifier at Fig 1, power gain A_p is the ratio of output signal power to input signal power. The formula is,

$$= \text{ Power gain} = \frac{P_{out}}{P_{in}}$$

Power gain is also given by,

$A_p = – A_v . A_i$

where,

A_v is the voltage gain (v_{out}/v_{in})

A_i is the current gain (i_c/i_b)

For the amplifier at Fig 1, if A_v = 90 and the b of the transistor is 100, then the power gain A_p of the amplifier is given by,

$A_p = - A_v.A_i = 90 \times 100 = 9000.$

This means that if an AC input power of 1 µW is given to the amplifier, the output power will be 9mwatts.

Practical way of finding A_p

Since the formula for power is, $P = I^2 \times R = I \times I \times R$

Since,

$$I = \frac{V}{R} \text{ (substituting this in above equation, we get)}$$

$$P = \frac{V^2}{R}$$

Therefore, by Ohm's law, power gain is easy to calculate when signal voltages and impedances are known as given below;

$$P_{out} = \frac{V_{out}^{\ 2}}{Z_{out}} \text{ and } Pin = \frac{V_{in}^{\ 2}}{Z_{in}}$$

Knowing the values of P_{out} and P_{in} power gain of the circuit can be calculated.

Power gain, A_p in decibels, dB

The power gain of amplifiers is often expressed in decibels (dB). To calculate the power gain of an amplifier in decibels, use the following formula.

$$\text{Power gain dB} = 10 \ \log \frac{P_{out}}{P_{in}}$$

Input - Output phase relationship

Recall, that while calculating the power gain it was mentioned that the output signal of a CE amplifier is 180° out of phase with its input signal. To find out why this happens in a CE amplifier, assume that the DC base bias current I_B at the set Q point is 30 µA. The corresponding collector current is 1 mA. When the AC signal is applied to the input, the base bias varies from 20 to 40 µA, as shown in Fig 1b. Since the type of transistor used is NPN, as base bias is increased to 40 µA, collector current i_c increases. The resultant effects are,

- the increased transistor conduction causes less voltage drop across the transistor (V_{CE}).
- increased i_C causes a larger voltage drop across R_C. Hence, the voltage across the collector to ground gets reduced.

In Fig 1a, as the output signal is taken across the transistor collector and ground, an increasing signal voltage causes a decreasing output signal.

As the input signal level decreases, say to 20 µA, the forward bias is less and transistor conduction decreases . When transistor conduction decreases, its resistance is higher and so the voltage drop across it increases. With increased voltage drop across the transistor, the output voltage V_{out} increases. This increase in V_{out} reduces the voltage drop across the collector load resistance R_C.

From this, it can be concluded that in a CE amplifier, a negative-going input signal causes a higher, or, more positive-going output signal. Therefore, in a CE amplifier the output is 180° out of phase with the input.

Practical way of finding input-output phase relationships

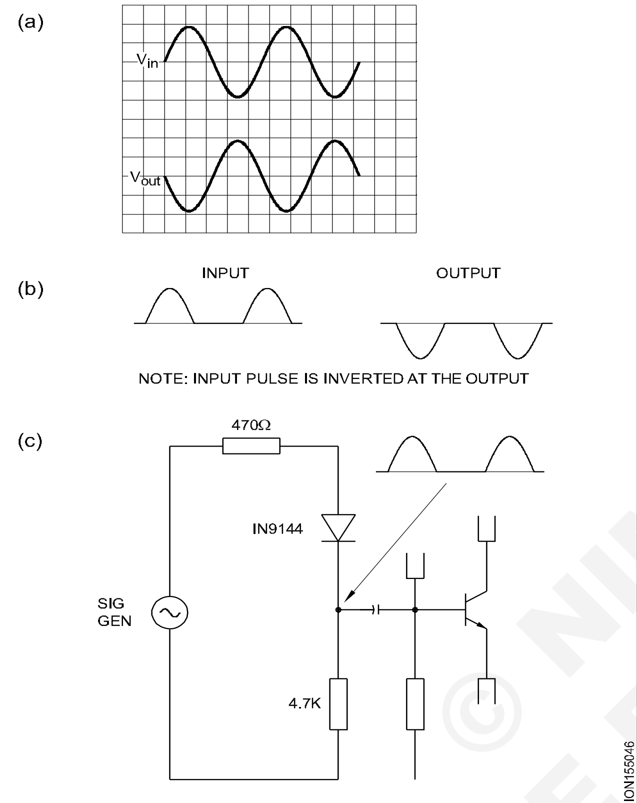
The phase relationship between input-output can be found in two ways as given below.

Method 1: Using a dual trace CRO, connect one of the CRO inputs to the input of the amplifier and the other CRO input to the output of the amplifier. Make the oscilloscope to trigger on the input signal. The waveforms shown on the CRO show the phase relationship between input and output as shown in Fig 6a.

Method 2: If a single trace CRO is used, then instead of feeding complete sinewave to the input, feed only the positive signal pulses as shown in Fig 6b. These positive pulses can be generated using a simple half-wave rectifier as shown in Fig 6c.

With the positive pulse fed at the input, the output of the CE amplifier will be negative pulse as shown in Fig 6b. Use the signal as an external trigger source for the CRO to view the waveform.

Fig 6



dB vs dBm

When a physical quantity, such as power or intensity, is measured relative to a reference level it is expressed in decibels (dB), which is a logarithmic unit. Decibel is considered as a dimensionless unit because it is a ratio of two quantities with the same unit thus cancellation takes place. It is used for quntifying the ratio between two values. The best example of this is the signal - to -noise ratio.

Sound pressure level is typically measured in dB but the unit is not limited to that quantity alone. There are a lot of uses of this measuring unit particularly in engineering. Since it is applicable in measuring signals, anything that can be expressed in waves may also be measured with dB. In the disciplines of acoustics electronics,dB is liberally utilized.

To be exact, decibel dB is expressed in this term: dB 10log (P1/P2). Where P1 and P2 are two different values of power.

It is primarily used because it can represent an extremely huge number into a convenient scale. Inradio link designs, values often differ enormously and to contrast these values decibel is used. Its logarithmic properties make calculation easier. With the implementation of dB, engineers and physicist are now able to calculate values with simple few numbers as an aiternative of arduous 9 to 10-digit ones.

dBm is different but definitely related to dB. dBm stands foran absolute power level. It is in reference to another unit of power the milliwatt.

Mathematically, dBm = 10* log (P/1mW)

The value of "P" is power in watts. Then, with further calculation, you can convert the absolute power unit "P" into dBm. The value of power level "P" is now referenced to 1 mW. The unit dBm is devised because in practice, 1 mW is a convenient reference point from which to measure power. dBm is considered as an absolute unit "a unit to measure power.

Additionally, based on what value the power is referred to, a particular absolute value of power can be in any kind. If dBm "which can be written in dBmW by the way - is acquired because of 1mW reference, a value can be in a form of dBW if it is referred to 1 watt.

Transistor input and output characteristics

Objectives: At the end of this lesson you shall be able to
- **state the necessity of characteristic curves for transistors**
- **list and explain the two important characteristic curves of transistors**
- **state the importance of DC load line curves**
- **state the method of fixing Q-point for a given transistor using the transistor data.**

A semiconductor diode, as shown in Fig 1, has only one PN junction. When the voltage across the PN junction is increased or decreased, the current through the diode increases or decreases. There is only one voltage parameter(V_d) and one current parameter(I_d). Therefore, the relationship between these two parameters is easy to understand through the diode characteristic graph of V_d versus I_d as shown in Fig 1b.

In a transistor since there are two PN junctions there are three voltage parameters V_{BE}, V_{BC}, V_{CE} and three current parameters I_B, I_C, I_E, as shown in Fig 2.

Any change in any one parameter causes changes in all the other parameters. Hence it is not very easy to correlate the effect of one parameter with the others. To have a clear understanding of their relationship a minimum of two characteristics graphs should be plotted for any transistor. They are,

- Input characteristics
- Output characteristics.

Fig 1

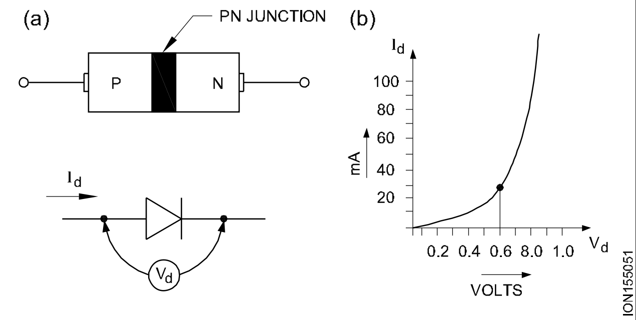
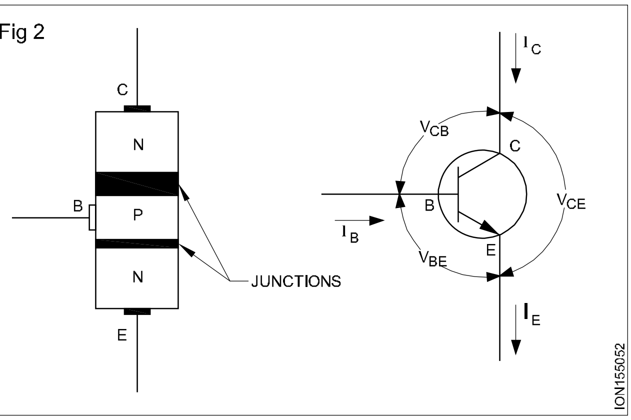


Fig 2



For simplicity in understanding, consider a common-emitter amplifier. The two characteristics graphs are shown in Fig 3.

Input characteristics or Base characteristics

The graph at Fig 3a shows the relationship between the input voltage V_{BE} and input current I_B for different values of V_{CE}.

Since the base-emitter section of a transistor is nothing but a diode, the graph resembles a diode curve as in Fig 1b. But, it is important to note that in Fig 3a, there is a diode curve for each value of the collector-emitter voltage V_{CE}.

While plotting the diode curve 1 of Fig 3a, the value of V_{CE} was maintained constant at 1V. In curves 2 and 3, the value of V_{CE} was increased and hence the path of the curve becomes different.

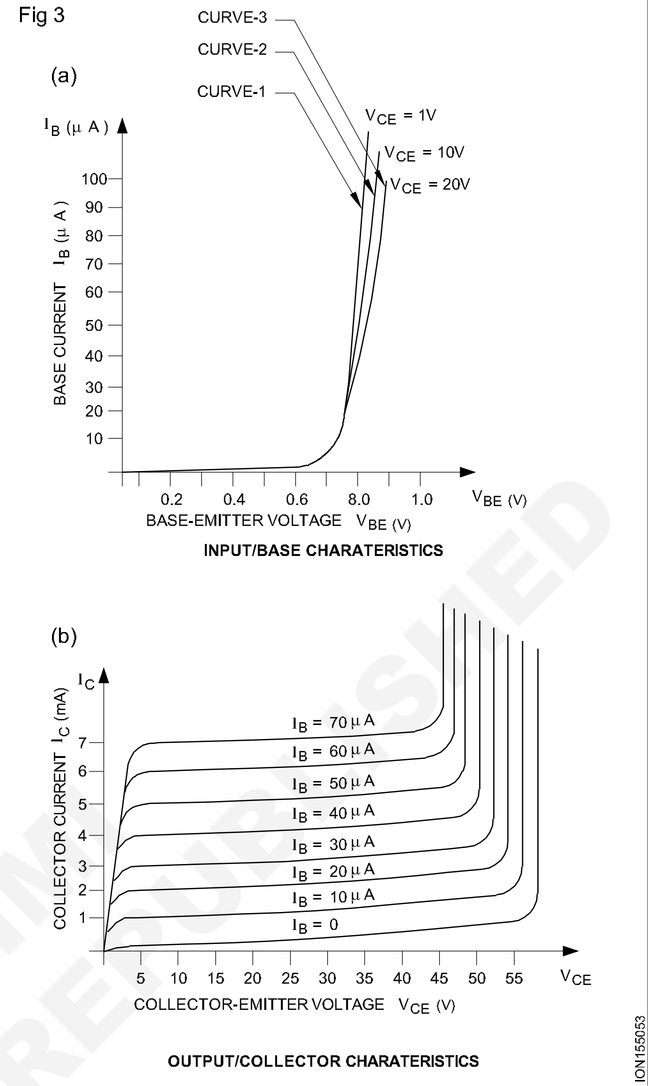
Why does this happen? The answer is, because of the higher collector voltages, the collector gathers a few more electrons flowing through the base-emitter. This reduces the base current. Hence, the curve with higher V_{CE} has slightly less base current for a given V_{BE}. This phenomenon is known as Early effect.

The gap shown between the curves in Fig 3a is very small. In practice, this gap will be so small, sometimes not even noticeable.

Plotting input/base curves of any given transistor

Necessary data for plotting the input or base characteristics can be obtained by constructing a simple test circuit as shown in Fig 3.

Fig 3



In this test circuit, V_{CE} is set to the required value by adjusting the voltage source V_{CC}. A resistor is introduced in the collector of the transistor to prevent excessive current in the collector which may damage the transistor.

The base-emitter voltage V_{BE} can be set by adjusting the potentiometer. An additional resistor is introduced in series with the DC supply V_{BB} and the POT only to limit the voltage across V_{BE}, and hence, the base current.

Output characteristics or Collector characteristics

The graph at Fig 3b, shows the relationship between the output voltage V_{CE} and output current I_C for different values of I_B.

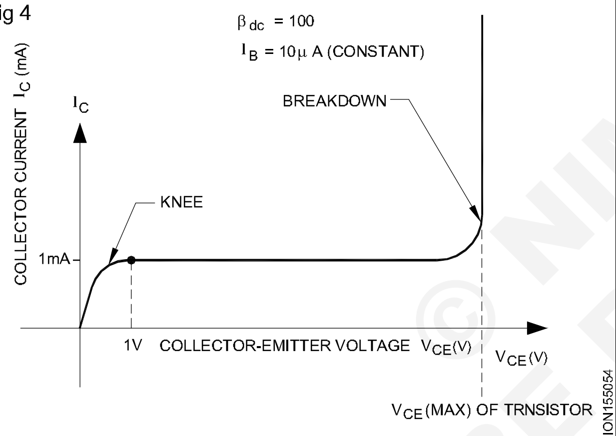
For simplicity in understanding, consider one of the curves of Fig 3b for a particular value of I_B as shown in Fig 4.

Fig 4 shows the collector characteristics for a constant I_B of 10μA. Behavior of I_C for different values of V_{CE} is explained below;

- When V_{CE} is 0, the collector-base diode is not reverse-biased. Therefore, the collector current is negligibly small.

- For V_{CE} between 0.7V and 1V, the collector diode gets reverse-biased. Once reverse biased, the collector gathers all the electrons that reach its depletion layer. Hence the collector current rises sharply and then becomes almost constant.
- Above the knee voltage and below the break down voltage, the collector current does not rise steeply or the current is almost constant even if the value of V_{CE} is increased. Thus the transistor works like a controlled constant current source in this region.
- Assuming that the transistor has a β_{dc} of approximately 100, the collector current is approximately 100 times the base current as shown in Fig 4 (1mA is 100 times 10 μA).
- If V_{CE} is further increased, beyond the break down level, $V_{CE(max)}$, the collector-base diode breaks down and normal transistor action is lost. The transistor no longer acts like a current source. As the collector-base gets ruptured, the junction is shorted and hence current increases rapidly above the breakdown point as shown in Fig 4.

Fig 4



If several curves for different I_B are drawn on the same graph, the collector curves look like what is shown in Fig 3b.

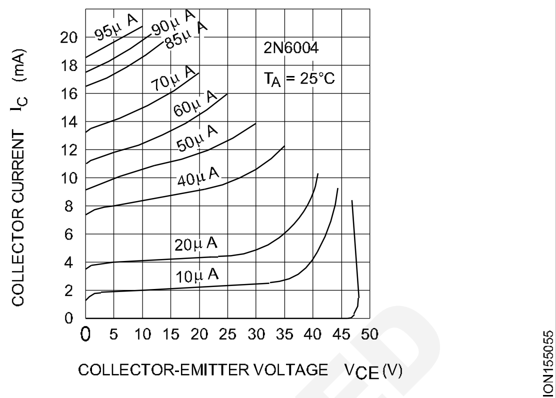
Since the assumed β_{dc} of the transistor was approximately 100, the collector current is approximately 100 times greater than the base current at any point in the active region. These curves are sometimes called as *static* collector curves because DC currents and voltage are being plotted.

In Fig 3b, notice that at the bottom most curve, eventhough the base current is zero, a small collector current exists. This is because of the leakage current of the collector diode. For silicon transistors this leakage current is so small that it can be almost ignored.

In Fig 3b, also note that the break down voltages become lower at higher currents. This means that the base-emitter voltage from *knee* point till the *break down*, known as the voltage compliance of a transistor, decreases for larger collector currents. Hence, it is necessary to avoid very high collector current such that the transistor operates in a wider active region.

Generally transistor data sheets/books do not show collector curves of transistors. To see the collector curves of a particular transistor, an instrument known as *curve tracer* is used. This instrument looks similar to an oscilloscope. It displays collector curves similar to those shown in Fig 5.

Fig 5



If different transistors are tried on the curve tracer, you will notice changes in knee voltage, β_{dc}, breakdown voltage, etc.

TIP: Two transistors of the same type number (e.g. 2N6004) may have a wide variation in the collector curves.

The collector curves are very important because, from these curves the following important information required while designing an amplifier circuit using a particular type of transistor can be obtained;

- DC current gain β of the transistor at different set DC values of I_B and V_{CE}.
- Maximum value of V_{CE} that can be applied for a set value of I_B and I_C.
- Maximum value of I_C that can be made to flow for a set value of I_B.

DC LOAD LINES of transistors

To have a further insight into how a transistor works and in what region of the collector characteristics does it work better can be found using DC load lines.

Consider a forward biased transistor as shown in Fig 6a. Fig 6b shows the collector characteristics of the transistor used.

In the circuit at 6a, consider the following two situations,

- Maximum collector current, $I_{C(max)}$
- Minimum collector current, I_C

For situation (1), assume that V_{CE} is zero or collector-emitter is a short. In that case, the collector current is limited only by the collector resistor R_C. Therefore,

$$I_C = \frac{V_{CC}}{R_C} \text{ at } I_{CE} = 0$$

Under such a condition, for the circuit at Fig 6a, I_C will be equal to 10V/1KΩ = 10mA.

Mark this I_C = 10mA point along V_{CE} = 0 on the collector characteristics of the transistor as shown in Fig 7a.

Fig 6

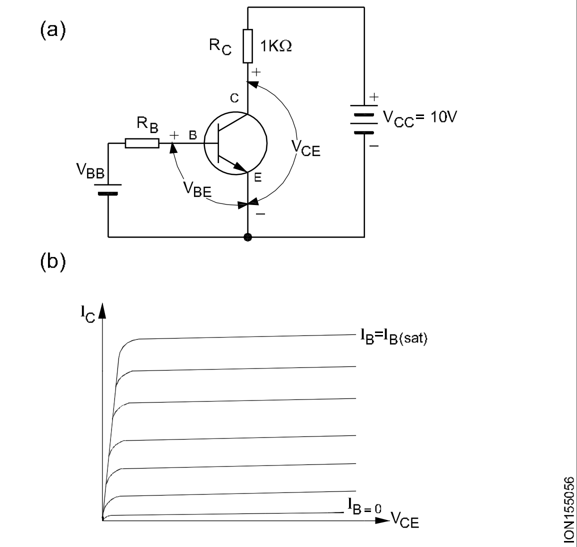
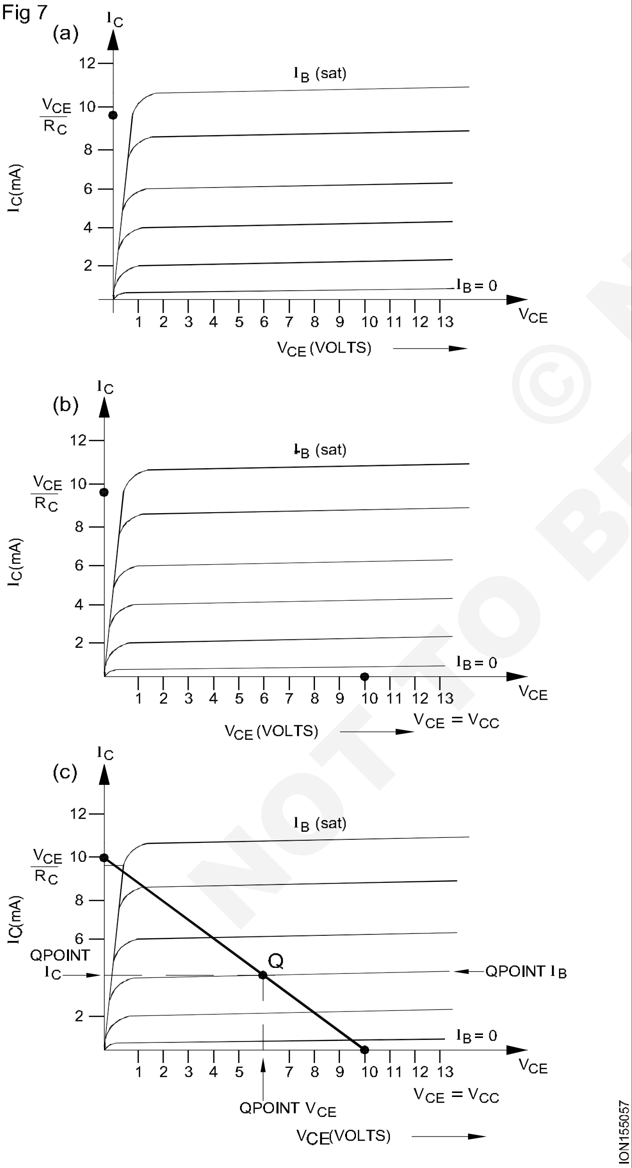


Fig 7



For situation (2), assume that V_{CE} is maximum or collector-emitter is open. In that case, the collector current is zero.

Therefore,

$V_{CE} = V_{CC}$ In the circuit at 6a, $V_{CE} = V_{CC}$ = 10V

Mark this point of I_C = 0 and V_{CE} = 10V on the collector characteristics of the transistor as shown in Fig 7b.

Connect the two marked points through a straight line as shown in Fig 7c. This line is called the load line.

The point at which the load line intersects the I_B = 0 is known as the cut off point. At cut off, I_B = 0; hence, emitter diode is out of forward bias and the transistor action is lost.

The point at which the load line intersects $I_B = I_{B(sat)}$ is called the saturation point. At this point the base current is maximum and the collector current is also maximum. At saturation, the collector diode comes out of the reverse bias, and hence, the normal transistor action is lost.

For a transistor to work in a normal way, i.e. as a controlled current source, it must not be made to work either in the cut off or in saturation. Therefore the ideal point would be somewhere in the middle of these extreme points on the load line. This middle point is known as *Quiescent point or* Q-point as shown in Fig 7c.

Knowing the Q point, you can fix-up the value of resistors R_C and R_B of the circuit.

The DC load line shows at a glance the active V_{CE} voltage range of the transistor. In other words, it indicates that the transistor acts like a current source anywhere along the DC load line, excluding the saturation or cut off, where the current-source action of the transistor is lost.

Fixing Q point from the data available in data sheets

The Q point can be fairly accurately fixed from the data of a transistor given in transistor data books. This reduces the time consuming work of plotting the collector characteristics and the load line. To do so, the following points are very important to remember;

- The chosen V_{CC} must be less than $V_{CE(max)}$ given in the data book

  TIP: Preferably restrict value of V_{CC} to 3/4 of $V_{CE(max)}$

- Fix the Q point I_C at 1/2 of $I_{C(max)}$ given in the data book.
- At the Q point assume 1/2 of V_{CC} will be across V_{CE}.
- From points (2)&(3) calculate the value of R_C.
- From the H_{FE} value given in data book, fix the approximate value of the base current at the Q point as given below.

  I_B at Q point =

  $$\frac{\text{Chosen value of } I_C \text{ at the Q – point(tipno.2)}}{\text{Typical value of } H_{FE} \text{ from data book}}$$

- From the value of I_B at the Q point and allowing a 0.7 volts drop across the base-emitter, calculate the value of R_B.

Introduction to digital electronics

Objectives: At the end of this lesson you shalll be able to
- **define the basic terms related to digital IC gates**
- **recognize the different types of packages of ICs used in the digital IC**
- **list different levels of integration used in fabrication of digital IC**
- **differentiate logic families and their characteristics**
- **compare the TTL and CMOS families**
- **explain digital IC numbering system.**

Introduction

A digital system is a combination of devices designed to Process information that are represented in digital form. Example of a few most popular digital systems are,

- Digital computers
- Calculators,
- Digital audio and video equipments
- Telephone system ..... etc.,

Digital Telephony is probably the world's largest digital system.

In electronic circuits, signals are represented in voltage or current. In these circuits, the signal representation will have a number of voltage or current levels.

In such analog signals, the transition from one level to another is usually smooth rather than sudden difference between and the transition between them is also smooth rather than sudden.

Digital signals on the other hand can have only two discrete states. These states can be called as,

- **ON state**: A state at which a predefined voltage is present. For example, the level could be, +5 Volts, +10Volts and it is also represented as high, one, etc.
- **OFF state**: A state at which a predefined voltage is other than the ON state voltage is present. For example, the level could be, 0 Volts, -5 Volts and it is also represented as low, zero etc.,

The discrete levels in digital signals are technically referred to as logic levels. Generally, the ON state described above is referred as the LOGIC 1 state and the OFF state as the LOGIC 0 state. It is very essential to note that, in digital signal representation, no state exists in between the logic-0 and logic-1 state.

For example,if we say Logic-0 corresponds to 0 volts and Logic-1 corresponds to 1 volt. In such a digital system, voltage levels of 2V,3V,4V etc., have no meaning (further details are discussed in lessons that follows).

Because the transition time between ON to OFF state or vice versa is abrupt in digital signals, analysis of digital systems varies from that of pure analog systems such as amplifiers etc.,

Compared to analog circuits, digital circuits contains less number of discrete components such as resistors, capacitors etc., This is mainly for the reason that the Integrated circuit(IC) technology has advanced so much, millions of components can be prefabricated in a single IC. Most digital circuits are made of such VLSI (very large scale Integration) IC as its main circuit component with a few decoupling capacitor for suppling clean DC voltage.

It is important to note that any analog signal can be converted to a digital signal (in the form 1s or 0s). Example given below gives a clue about how analog signals can be represented as digital signals,

ANALOG VOLTAGE	DIGITAL VALUE
0 volt	0 0 0 0
1 volt	0 0 0 1
2 volt	0 0 1 0
3 volt	0 0 1 1
4 volt	0 1 0 0
5 volt	0 1 0 1
6 volt	0 1 1 0
7 volt	0 1 1 1
8 volt	1 0 0 0
9 volt	1 0 0 1
10 volt	1 0 1 0

Details of how this conversion is done is discussed in further lessons.

Digital systems offer the following advantages over analog systems.

- Easier to design
- Information storage is easy
- Accuracy and precision are greater
- Programmable
- Circuitry can be fabricated on IC chips more easily
- High speed functions

The operations carried out using digital signals are called Logic operations. Example of Logic operation are given below;

Assuming there are two inputs and if the Inputs are,

- the circuit output should be Logic-1 if atleast anyone of the two inputs is Logic-1.

  A circuit that performs such a logical operation is called as a **OR** gate.

- the circuit output should be Logic-1 only when both the inputs are Logic 1's.

  A circuit that performs such a logical operation is called as a **AND** gate.

- the circuit output should be inverse of the input. If the input is Logic-1, then the output should be Logic-0 and vice-versa.

  A circuit that performs such a logical operation is called as a **NOT** gate.

Every logic operation, even the most extensive and the most complicated - can be reduced to combinations of the above said three basic logic functions. By combining these three operations, several other functions such NAND, NOR and so on (discussed in further paragraphs).

These basic functional circuits are called Gates, such as OR gate, AND gate and NOT gate. The practical implemantation of logic operations is effected by logic circuits. In the meantime, a large number of circuit families have been produced in integrated circuit technology. The starting point of standard development was the TTL (Transistor-Transistor-Logic) family(earlier to it was the RTL and DTL families), from which several other families with improved properties have been derived. The TTL family of gates have defined voltage levels and permissable tolerences. Some of the important terminologies associated with digital ICs are given below;

Terminology of digital ICs

Saturated logic gate

A form of logic gate in which one output state is the saturation voltage of a transistor.

Example

Resistor Transistor Logic (RTL), Diode Transistor Logic (DTL) and Transistor Transistor Logic (TTL).

Unsaturated logic or current mode logic gate

A form of logic with transistors outside the saturated region.

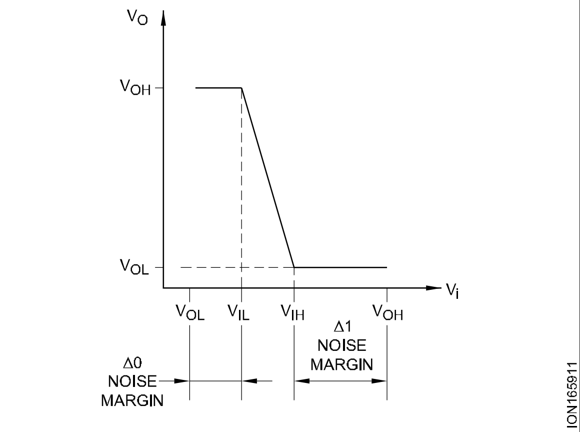
Example

Current Mode Logic (CML) and Emitter Coupled Logic. This has ultra-fast switching speed and low logic swing.

Operating voltages

The various operating voltages of a logic gate can be understood with the help of the transfer characteristic of the gate as shown in Fig 1.

Fig 1



V_{OH} - The minimum voltage which will be available at a gate output when the output is supposed to be at logic '1'.

V_{IL} - The minimum gate input voltage which will unambiguously be accepted by the gate as logic '1'.

V_{OL} - The maximum voltage which will appear at a gate output when the output is supposed to be at logic '0'.

V_{IL} - The maximum gate input voltage which will unambiguously be accepted by the gate as logic '0'.

Logic swing: The difference between the two output voltages (V_{OH} - V_{OL}) is known as the logic swing of the circuit. That is,

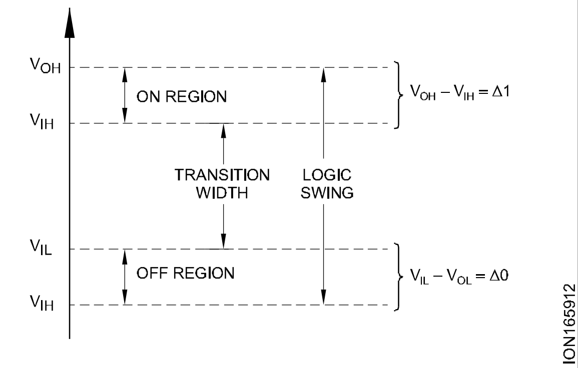
logic swing = $V_{OH} - V_{OL}$

Noise margin

The amount of voltage of extraneous signal which can be tolerated before an output voltage of gate deviates from the allowable logic voltage levels.

The different noise margins of a logic gate can be understood with the help of logic level diagram at Fig 2.

Fig 2



Low-level noise margin

The difference (V_{IL} - V_{OL}) is low level noise margin (D_o) $D_o = V_{IL} - V_{OL}$

High level noise margin

The difference (VOH - VIH) is high level noise margin (D_1) $D_1 = V_{OH} - V_{IL}$

Transistion width:

From Fig 2, transistion width = $V_{IH} - V_{IL}$

It can be seen that an increased noise margin capability is obtained as either VOH and VOL move away from each other or as VIH and VIL move toward each other. With a larger logic swing or a narrower transistion width, the noise margins will improve.

Noise immunity

Stray electric and magnetic fields can induce voltages on the connecting wires between logic circuits. These unwanted signals are known as noise and they may cause the voltage at the input to a logic circuit to drop below VIH (min) or rise above VIL (max), which may lead to unpredictable operation. The noise immunity of a logic circuit refers to the ciruit's ability to tolerate noise without causing unwanted changes in the output voltage.

Fan-out

The number of loads connected to a gate is known as fan-out of the gate. The number of load gates need not be a limiting number of load gates need not be a limiting number. It is also known as loading factor. For example, a logic gate that is specified to have a fan-out of 10 can drive 10 standard logic inputs. If this number is exceeded, the output logic-level voltages cannot be guaranteed.

Types of IC package

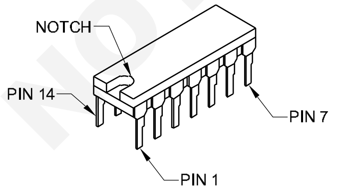
The ICs come in a wide variety of package types. The factors which determine the type of package are

- amount of circuitry contained in the IC.
- number of external connections that need to be made to it.
- humidity of the environment, ambient temperature at which the IC is to operate.
- method of mounting on the PCB.

DIP [Dual in line package]

The external connecting pins are in parallel rows along the two long edges of the package as shown in Fig 3. In DIP ICs, number of pins varies from 4 to 64 depending on the internal circuitry. For low temperature and low humidity, epoxy plastic packages are used. For high temperature or for devices that dissipate large amount of power, ceramic packages are used.

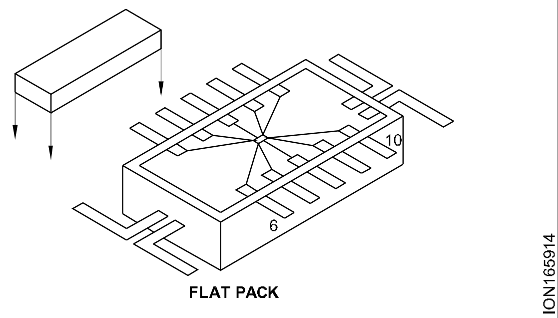
Fig 3



Ceramic flat package

This type of IC packages are hermetically sealed as shown in Fig 4, which means that they are totally immune to the effects of humidity. These packages are often used in military equipments that they must be able to withstand harsh environments. Pins are counted around the package from notch or dot. These packages are usually mounted in high quality sockets on the circuit board.

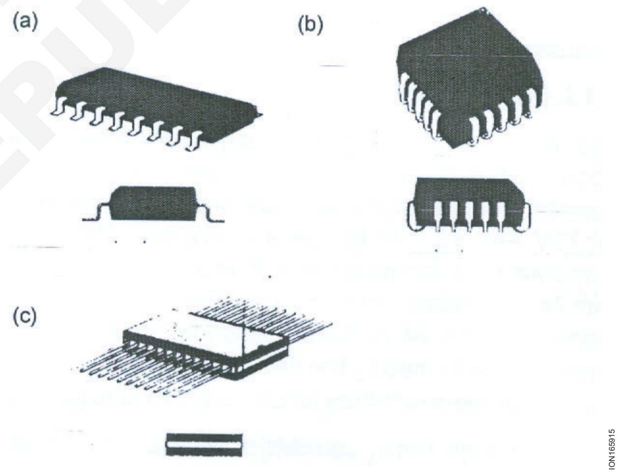
Fig 4



Surface mount package

This popular package is similar to the standard DIP except that it is smaller and, as the name implies, its pins are constructed so that it can be soldered directly to metal pads on the PCB. One type of SMT package called small out line IC is shown in Fig 5a. Since surface mount packages are soldered on one surface of the circuit board, holes don't have to be drilled on the PCB. Surface mount devices have further advantages, that they are more easily handled by equipment, which automatically mounts components in the correct position on circuit boards during manufacturing. The PLCC (Plastic Leaded chip carrier) type package is shown in Fig 5b. Another variety of SMT package is known as Flat pack is shown in Fig 5c.

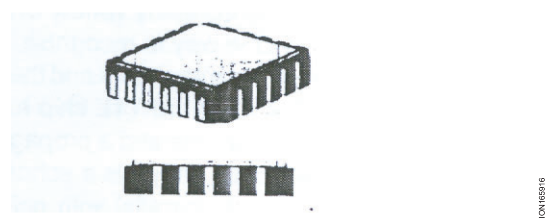
Fig 5



Ceramic chip carrier package

These chips are intended to be clamped into a socket as shown in Fig 6 so that the pads press against contacts which are connected to P.C.B signal lines pin 100 this package is to the right of the notched corner.

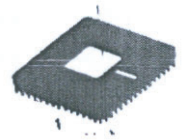
Fig 6



Pin grid array package

These ICs are used for VLSI digital circuits such microprocessor. The number of pins in the array depends on the complexity of the internal circuit. The four corner pin positions are usually left without pins. Common array sizes are 10 x 10, 13 x 13 and 14 x 14, large ICs such as these are put in sockets so they can easily be replaced if the device fails. (Fig 7)

Fig 7



S.No.	Complexity	Number of Gates	Application
1	Small-Scale Integration (SSI)	Fewer than 12	Basic gates
2	Medium-Scale Integration (MSI)	12 to 99	Flip-flops, regiater etc.
3	Large-Scale Integration (LSI)	100 to 9999	Memories, microprocessor
4	Very large-Scale Integration (VLSI)	10,000 to 99,999	-do-
5	Ultra large-Scale Integration (ULSI)	100,000 or more	-do-

Logic family

Digital ICs are classified not only by their complexity, logical operation, speed of operation but also by the specific circuit technology to which they belong. The circuit technology is referred to as a digital logic family. Each logic family has its own basic electronic circuit upon which more complex digital circuit and components are developed. The basic circuit in each technology is NAND, NOR or an inverter gate. The electronic components, and material used in the construction of the basic circuit are usually used as the name of the technology. The various logic families of ICs used in electronic circuit are briefly discussed below.

TTL Logic family

The word TTL is expanded as Transistor-Transistor Logic. In this family ICs are built with transistors. Most standard TTL ICs require a power supply voltage between +4.75V and +5.25V to operate properly. The ICs of standard TTL family are identified by numbers that start with 74 or for military specification devices 54, two or three digits after the 74 or 54 are used to identify the logic functions performed by the device. Some of the 74 series TTL IC numbers with their functions given at Appendix 'D'.

The TTL logic family consists of several sub families as shown in logic family tree. The difference between the various TTL series are in their electrical characteristics, such as power dissipation, propagation delay and switching speed. They do not differ in the pin assignment or logic operation performed by the internal circuits.

The most popular 7400 series is a line of standard TTL chips. This bipolar family contains variety of compatible SSI and MSI devices. One way to recognise TTL design is the multiple emitter input transistors and the totem pole output transistors. The standard TTL chip has a power dissipation of about 10mw/gate and a propagation delay of around 10ns. The series 74S00 is a schottky version having a schottky diode in parallel with collector-base terminals. In this, transistors are prevented from saturating thereby propagation delay is reduced typically to 3ns. By increasing internal resistances and including schottky diodes, low power schottky diodes numbered from 74LS00 are manufactured limiting the power dissipation to 2mw per gate low power schottky TTL is the most widely used of the TTL types. In this family of devices, a floating input is equivalent to a high input. In electrically noise environment, floating inputs may pick up enough noise voltage to produce unwanted changes in the output stages and hence inputs should not kept be floating in TTL family. A modified TTL design namely three state TTL allows us to connect outputs directly. Earlier computers used open-collector devices with their bases but the passive pull-up limited the operating speed. These newer devices are much faster and have a control input that can turn off the devices. When this happens the output floats and presents a high impedance to whether it is connected to and hence are widely used for connecting to bases.

E.C.L

Emitter-coupled logic circuits provide the highest speed with propagation delay typically of 5ns. The most common ECL ICs are designated as the 10000 series. E.C.L is used in systems such as super computers and signal processors where high speed is essential. The ECL family IC use is restricted to few applications because of the following reasons.

- The gates in ICs dissipate relatively large amounts of power.
- Needs extra circuitry for gates to operate.
- The -ve power supply voltage and logic levels make ECL gates difficult to interface with other logic family members.

MOS

The Metal Oxide Semiconductor is a unipolar transistor that depends upon the flow of only one type of carrier, which may be either electrons or holes. A p-channel MOS is referred to as PMOS and an N-channel as NMOS. NMOS is the one that is commonly used in circuits with only one type of MOS transistor. MOS technology allows a very large number of circuits to be built in a single IC. It is this technology which has made possible the microprocessors, memories and other LSI devices which are used to build microcomputers.

CMOS

PMOS circuitry or NMOS circuitry can't be used alone for making simple logic gate devices such as done in T.T.L devices, for various reasons. However by building the circuits on the IC by using one PMOS and NMOS transistors connected in complementary fashion, it is possible to produce logic gate devices which have the desired characteristics. That is why these ICs are called complementary metal oxide semiconductors or just CMOS.

CMOS ICs are designated in 4000 series. The family includes logic functions such as those available in T.T.L family. CMOS sub families operate properly with a power supply voltage of +3V to +15V.

By the time the 4000 series of CMOS was developed, most logic designers has become very familiar with the logic functions, part numbers and pin connections of the devices in the standard T.T.L sub family. So as to make CMOS ICs more compatible with T.T.L standards, the CMOS, TTL compatible ICs are made available in 74C00 series. 74HC00 series (high speed) 74HCT00 series, refer Table Performance comparison of CMOS and TTL logic families is given in the Table below:

Technology	CMOS		TTL				
	Silicon Gate	Metal-Gate	Std.	Low-Power Schottky	Advanced Schottky	Low-Power Schottky	Advanced Schottky
Device series	74HC	4000	74	74LS	74S	74ALS	74AS
Power dissipation (mW/gate) Static	0.0000025	0.001	10	2	19	1	8.5
AT 100 kH$_z$	0.17	0.1	10	2	19	1	8.5
Propagation delay time (ns) (CL = 15 pF)	8	50	10	10	3	4	1.5
Maximum clock frequency (MHz) (CL = 15 pF)	40	12	35	40	125	70	200
Speed/Power product (pJ) (at 100 kHz)	1.4	11	100	20	57	4	13
Minimum output drive IOL (mA) (VO = 0,.4V)	4	1.6	16	8	20	8	20
Fan-out;							
LS loads	10	4	40	20	50	20	50
Same-series	*	*	10	20	20	20	40
Maximum input current, IIL (mA) (VI = 0.4V)	±0.001	-0.001	-1.6	-0.4	-2.0	-0.1	-0.5

*Fan-out is frequency dependent

COMPARISON OF TYPICAL NOISE MARGINS:

Noise Margin	HCMOS (V)	Std TTL (V)	LS TTL (V)	S TTL (V)	AS TTL (V)
V_{NH}	1.4	0.4	0.7	0.7	0.7
V_{NL}	0.9	0.4	0.4	0.4	0.4

Digital I.C numbering system

Number and letters on IC packages identify the logic family and the logic function of a device. In addition to these numbers and letters, an IC may have numbers and letter which indicate manufacturers name, the factory where the device was manufactured, the year and month the device manufactured, the package type and a code which indicates how thoroughly the device was tested.

Ex: 74HCTOON

74 HCT OO N

XXX XXX X

Letter codes for common package type

N = Plastic dip

J = Ceramic dip

D = Glass/metal dip

W = Flat p\ack

Manufacturer code

Code	Manufacturer
AM	Advanced microdevice
CD	GE/RCA
DM	National semiconductor
F	Fair child
GD	Gold star
H	Harris
HD	Hitachi
IM	Intersil
KS	Samsung
LR	Sharp

Code	Manufacturer
M	SGS
MC	Motorola
MM	Monolithic memories
MN	Panasonic
N	Signetics
P	Intel
SN	Texas instruments
SP	SPI
US	Sprague
TC	Toshiba

Number systems

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

- **differentiate between different number systems like decimal, octal, binary and hexadecimal and conversion between them and different types of codes**
- **explain NOT gate using transistor**
- **explain the characteristics of TTL NOT gate IC 7404, list commercially available NOT gate IC**
- **explain logic probe based on CMOS NOT gate IC.**

Introduction

When we hear the word 'number' immediately we recall the decimal digits 0,1,2....9 and their combinations. Modern computers do not process decimal numbers. Instead, they work with binary numbers which use the digits '0' and '1' only. The binary number system and digital codes are fundamental to digital electronics. But people do not like working with binary numbers because they are very long when representing larger decimal quantities. Therefore digital codes like octal, hexadecimal and binary coded decimal are widely used to compress long strings of binary numbers.

Binary number systems consists of 1s and 0s. Hence this number system is well suited for adopting it to the digital electronics.

The decimal number system is the most commonly used number system in the world. It uses 10 different characters to show the values of numbers. Because this number system uses 10 different characters it is called base-10 system. The base of a number system tells you how many different characters are used. The mathematical term for the base of a number system is radix.

The 10 characters used in the decimal number systems are 0,1,2,3,4,5,6,7,8,9.

Positional notation and weightage

A decimal integer value can be expressed in units, tens, hundreds, thousands and so on. For example decimal number 1967 can be written as 1967 = 1000 + 900 + 60 + 7. In powers of 10, this becomes

10^3	10^2	10^1	10^0
1	9	6	7

$1 \times 10^3 = 1000$

$9 \times 10^2 = 900$

$6 \times 10^1 = 60$

$7 \times 10^0 = 7$

1967

i.e. $[1967]_{10} = 1(10^3) + 9(10^2) + 6(10^1) + 7(10^0)$

This decimal number system is an example of positional notation. Each digit position has a weightage. The positional weightage for each digit varies in the sequence 10^0, 10^1, 10^2, 10^3 etc starting from the least significant digit.

The sum of the digits multiplied by their weightage gives the total amount being represented as shown above.

In a similar way, binary number can be written in terms of weightage.

To get the decimal equivalent, then the positional weightage should be written as follows.

$[1010]_2 = 1(2^3) + 0(2^2) + 1(2^1) + 0(2^0)$

$= 8 + 0 + 2 + 0$

$[1010]_2 = [10]_{10}$

Any binary number can be converted into decimal number by the above said positional weightage method.

Decimal to Binary conversion

Divide the given decimal number by 2 as shown below and note down the remainder till you get the quotient - zero.

Example

	0		
2	1	1	→ MSB
2	2	0	
2	4	0	
2	8	0	
2	17	1	
2	34	0	LSB

The remainder generated by each division form the binary number. The first remainder becomes the LSB and the last remainder becomes the MSB of binary number.

Therefore, $[34]_{10} = [100010]_2$

Counting binary number

To understand how to count with binary numbers, let us see how an odometer (Km indicator of a car) counts with decimal numbers,

The odometer of a new car starts with the reading 0000.

After traveling 1km, reading becomes 0001.

Successive km produces 0002, 0003 and so on upto 0009

At the end of 10th km, the units wheel turns back from 9

to 0, a tab on this wheel forces the tens wheel to advance by 1. That is why the number changed from 0009 to 0010. That is, the units wheel is reset to 0 and sent a carry to the tens wheel. Let us call this familiar action as reset and carry. The other wheels of odometer also reset and carry. For instance, after covering 999km, the odometer shows 0999.

After the next km, the unit wheel resets and carries, the tens wheel resets and carries, the hundreds wheel resets and carries and the thousands wheel advances by 1 to get the reading 01000.

Binary odometer

Visualize a binary odometer, a device whose wheels have only two digits 0 and 1. When each wheel turns, it displays 0 then 1 and then back to 0 and the cycle repeats. A four digit binary odometer starts with 0000.

After 1km, it indicates - 0001.

The next km forces the units wheel to reset and sends carry. So the number changes to 0010.

The third km results in 0011.

After 4km, the units wheel resets and sends carry, the second wheel resets and sends carry and the third wheel advances by 1. Hence it indicates 0100.

Table below shows all the binary numbers from 0000 to 1111 equivalent to decimal 0 to 15.

Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

Hexadecimal number system: In hexadecimal system there are 16 characters. They are 0,1,2,3,4,5,6,7,8,9, A,B,C,D,E,F where A=10, B=11, C=12, D=13, E=14, F=15 in decimal. In this system, the base is 16. This system is mainly used to develop programmes for computers.

For Example

$[23]_{16} = [35]_{10}$; $16^1 \times 2 + 16^0 \times 3 = 32 + 3 = 35$;

$[2C]_{16} = [44]_{10}$; $16^1 \times 2 + 16^0 \times 12 = 32 + 12 = 44$;

Decimal to hexadecimal conversions

The conversion of decimal to hexadecimal is similar to binary conversion. Only difference is that divide the decimal number successively by 16, and note down the remainder.

	0		
16	1	1	MSB
16	27	11 or B	
16	432	0	LSB

$[432]_{10} = [1B0]_{16}$

Hexadecimal to Decimal

This conversion can be done by putting it into the positional notation.

Ex: $223A_{16} = 2 \times 16^3 + 2 \times 16^2 + 3 \times 16^1 + A \times 16^0$

$= 2 \times 4096 + 2 \times 256 + 3 \times 16 + 10 \times 1$

$= 8192 + 512 + 48 + 10$

$= 8762_{10}$

Octal number

The octal number system provides a convenient way to express binary numbers. It is used less frequently compared to hexadecimal in conjunction with computers and microprocessors to express binary quantities for input and output purposes.

The octal number system is compared of digit symbols such as right symbols such as 0,1,2,3,4,5,6,7.

Since there are 8-symbols, radix or base is 8. Positional weightage is ....8^3, 8^2, 8^1, 8^0.

To distinguish octal numbers from other number systems subscript 8 is used as follows:

Ex: $(15)_8 \sim (13)_{10}$

Octal Decimal

Octal to Decimal conversion

```
      0
8 |   1   1   MSB
8 |  13   5   LSB
```

As in other number systems, each digit should be multiplied by its positional weightage and added to get decimal equivalent.

Convert $(2374)_8$ into decimal number

Positional weightage : 8^3, 8^2, 8^1, 8^0

Octal number 2 3 7 4

$(2374)_8 = (2 \times 8^3)+(3 \times 8^2)+(7 \times 8^1)+(4 \times 8^0)$

$= (2 \times 512)+(3 \times 64)+(7 \times 8)+(4 \times 1)$

$= 1024 + 192 + 56 + 4$

$(2374)_8 = (1276)_{10}$

Decimal to octal conversion

A method of converting a decimal number to an octal number is the repeated division by 8, each successive division by 8 yields a remainder that becomes a digit in the equivalent octal number. The first remainder generated is the least significant digit (LSD).

$(359)_{10} = (547)_8$

```
       0
8 |    5    5   MSB
8 |   44    4 or B
8 |  359    7   LSB
```

Octal to binary

Each octal digit can be represented by a 3-bit binary number, because of this it is very easy to convert from octal to binary. Each octal digit is represented by three bits as shown in the table.

Octal digit	0	1	2	3	4	5	6	7
Binary	000	001	010	011	100	101	110	111

To convert each octal number to a binary, simply replace each octal digits with the corresponding binary bits.

Example

1 $(25)_8 = (\ \ )_2$

2 5

010 101

$(25)_8 = (010101)_2$

2 $(7526)_8 = (\ \ )_2$

7 5 2 6

111 101 010 110

$(7526)_8 = (111101010110)_2$

Binary to octal

Conversion of a binary number to an octal number is the reverse of the octal-to-binary conversion. The procedure is as follows.

1 Start with the right most group of three bits and moving from right to left, convert each 3-bit group to the equivalent octal digit.

2 If there are not three bits available for the left most group, add either one or two zero's to make complete group. These leading zero's will not affect the value of the binary number.

Example

$(110101)_2 = (\ \ )_8$

110 101

6 5 $= (65)_8$

$(11010000100)_2 = (\ \ )$

011 010 000 100 $= (3204)_8$

3 2 0 4

BCD (Binary Coded Decimal)

Binary Coded Decimal (BCD) is a way to express each of the decimal digits with a binary code, since there are only ten code groups in the BCD system, it is very easy to convert between decimal and BCD. Because decimal system is used for read and write, BCD code provides an excellent interface to binary systems. Examples of such interfaces are keypad inputs and digital readouts.

8421 code

The 8421 code is a type of binary coded decimal (BCD), binary coded decimal means that each decimal digit, 0 through 9 is represented by a binary code of four bits. The designation 8421 indicates the binary weights of the four bits (2^3, 2^2, 2^1, 2^0). The ease of conversion between 8421 code numbers and the familiar decimal numbers in the main advantage of this code. All you have to remember are the ten binary combinations that represents the ten decimal digits as shown in Table.

Decimal digit	0	1	2	3	4	5	6	7	8	9
BCD	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001

The 8421 code is the pre-dominant BCD code, and when we refer to BCD, we always mean the 8421 code unless otherwise stated.

Invalid code

You should realize that with four bits, sixteen numbers (0000 through 1111) can be represented, but in the 8421 code only ten of these are used. The six code combinations that are not used 1010, 1011, 1100, 1101, 1110 and 1111 are invalid in the 8421 BCD code.

To express any decimal number in BCD, simply replace each decimal digit with the approximate 4-bit binary code.

Example

1 $(35)_{10}$ = (?) 8421 code

3 5

0011 0101 = 00110101

2 $(2458)_{10}$ = (?) 8421 code

2 4 5 8

0010 0100 0101 1000 = 0010010001011000

There are many specialized codes used in digital system other than BCD code. Some codes are strictly numeric, like BCD and others are alphanumeric which are used to represent numbers, letters, symbols and instructions.

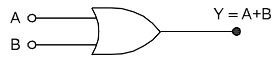
The commonly used codes other than BCD codes are

1 Gray code
2 Excess 3 code
3 ASCII code - American, Standard code for Information interchange
4 Alphanumeric code

Inverters (NOT Gate)

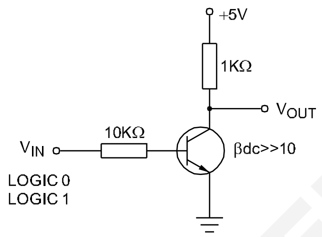
An inverter is a gate with only one input signal and one output signal. The output state is always the opposite of the input state. Logic symbol is shown in Fig 1.

Fig 1



Transistor inverter (Fig 2)

Fig 2



TRANSISTOR INVERTER

The above circuit shows the transistor inverter circuit. The circuit is a common emitter amplifier which works in saturation or in cut off region depending upon the input voltage. When V_{in} is in low level, say less than the transistor cut in voltage 0.6V in silicon type, the transistor goes to cut off condition and the collector current is zero. Therefore, V_{out} = +5V which is taken as high logic level. On the other hand, when V_{in} is in high level, the transistor saturates and $V_{out} = V_{sat}$ = 0.3V i.e low level.

The table summarizes the operation

Vin	Vout
Low(0)	High(1)
High(1)	Low(0)

The logic expression for the inverter is as follows: If the input variable is 'A' and the output variable is called Y, then the output Y = A.

Logic gates and logic probes

Objectives: At the end of this lesson you shall be able to
- **explain the funtion of logie gates**
- **explain the AND gate using diode and its truth table**
- **explain the OR gate using diode and its truth table**
- **explain a NOT gate using transisteor and its truth table**
- **explain the NAND,NOR gate and their truth table**
- **explain the EX-OR and EX - NOR gates and their truth table.**

Introduction

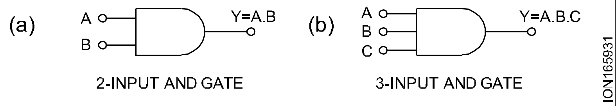
Lagic gates are electcronic circuits used in digital circuits for the purpose of decisions. Logic circuits are basically of two types namely decision making circuits and memory circuits. Their functioning depends on the binary inputs they receive and produce binary output which are a function of the input as well as the characteristics of the logic circuit they implemented.All logic gates have a single output and they may have two or more inputs. For specific decision making function there are several types of logic gates are used. Basic Logic gates are a group of the logic gates spcifically called as AND,OR and NOT gates.All these gates have their own identical,logical function. By the combination of these gates we can obtain any Boolean or logical functions or any logical function.

AND gates

The AND gate has two or more inputs but only one output. All input signals must be held high to get a high output. Even if one of the inputs is low, the output becomes low.

The schematic symbols for 2 input and 3 input AND gates are shown in Fig 1a and 1b.

Fig 1



Truth table

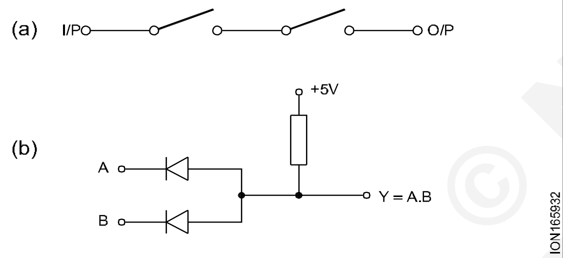
Two input AND gate

A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

Electrical equivalent circuit of an AND gate

The electrical equivalent of AND gate and AND gate using diodes are shown in Fig 2a and 2b.

Fig 2



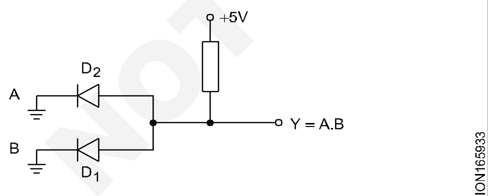
Two input AND gate using diode

Condition-1

A=0, B=0, Y=0 as shown in Fig 3.

During the above condition inputs A and B are connected to ground to make logic low inputs. During this condition, both the diodes conduct, and pulls the output Y to logic0.

Fig 3

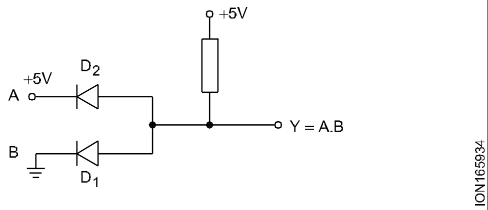


Condition-2

A=0, B=1, Y=0 as shown in Fig 4.

In the condition shown in Fig 4, diode D_1 is connected to logic-0 input and diode D_2 is connected to +5V [Logic high]. Diode D_1 is in forward bias and conducts. Diode D_2 is having equal potential (+5V) at anode and cathode. So potential difference between anode and cathode is 0. Hence diode D2 does not conduct. The output Y is pulled down to logic zero, since D_1 is conducting.

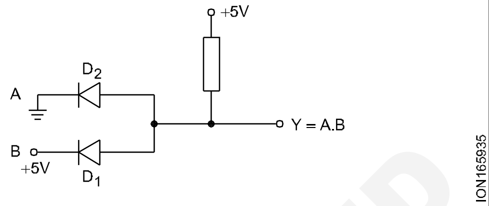
Fig 4



Condition-3

A=1, B=0, Y=0 as shown in Fig 5.

Fig 5

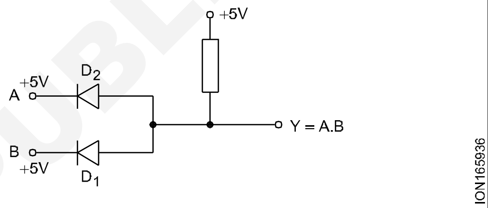


The condition-3 is similar to the condition-2. D_2 is forward biased. D_1 is reverse biased. Hence, output Y is pulled to logic-0.

Condition-4

A=1, B=1, Y=1 as shown in Fig 6.

Fig 6



In this condition both the diodes are reverse biased. So both the diodes act as open circuit. Therefore, output Y is +5V i.e y is in logic1 condition.

For pin diagram refer to the data sheet of the IC.

A. For example, if 1000 pulses pass through the gate in the 1 second interval of the enabled pulse, there are 1000 pulses/sec. That is, frequency is 1000Hz.

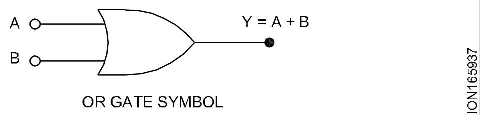
AND gates are available in the form of IC.IC7408 is a TTL type AND gate IC having 4 numbers of AND gates in side it.

OR gate

The OR gate has two or more inputs,but only one output.

The output of an OR gate will be in 1 state if one or more of the inputs is in 1 state. Only when all the inputs are in 0-state, the output will go to 0-state. Fig 7 shows the schematic Symbol of an OR Gate

Fig 7



The boolean expression for OR gate is Y=A+B.

The equation is to be read as Y equals A ORed B. Two-input truth table given below is equivalent to the definition of the OR operation.

Truth table for OR gate

A	B	Y=A + B
0	0	0
0	1	1
1	0	1
1	1	1

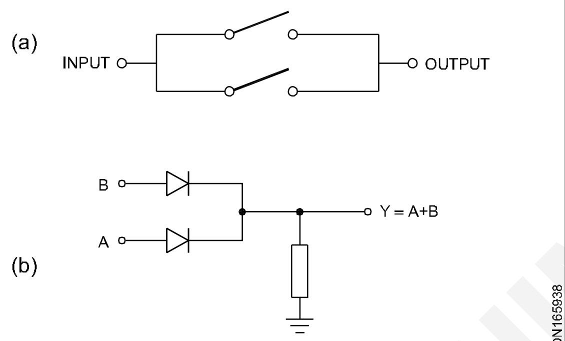
Electrical equivalent circuit

The Fig 8a shows the electrical equivalent circuit of an OR gate. It is evident that if any one of the switch is closed, there will be output.

2 in-put OR gate using diode

The Fig 8b shows one way to build a 2-input OR gate, using diodes. The inputs are labeled as A and B, while the output is Y.

Fig 8



Assume logic 0 = 0V (low)

logic 1 = +5V (high)

Since this is a 2 input OR gate, there are only four possible cases,

Condition:1 A is low and B is low. With both the input voltage low, both the diodes are not conducting. Therefore the output Y is in low level.

Condition:2 A is low and B is high, The high B input voltage (+5V) forward biases the lower diode, producing an output voltage that is ideally +5V (actually +4.3V taking the diode voltage drop 0.7V into consideration). That is, the output is in high level. During this condition, the diode connected to input A is under reverse bias or OFF condition.

Condition:3 A is high and B is low, the condition is similar to case 2. Input A diode is ON and Input B diode is OFF and Y is in high level.

Condition:4 A is high, B is high. With both the inputs at +5V, both diodes are forward biased, since the input voltages are in parallel, the output voltage is +5V ideally [+4.3V to a second approximation]. That is, the output Y- is in high level.

OR gates are available in the IC form. IC7432 is a TTL OR gate IC having 4 OR gates inside it. For pin diagram refer to the data sheet of the IC.

Simple application of OR gate

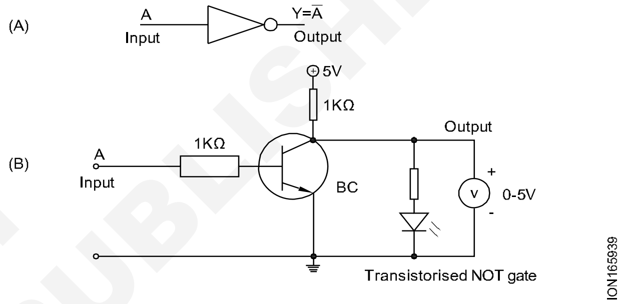
Intrusion detection

Simplified portion of an intrusion detection and alarm system is two windows and a door. The sensors are magnetic switches that produce a high(1) output when windows and doors are opened and a low(0) output when closed. As long as the windows and the door are secured, the switches are closed and all three of the OR gate inputs are in low(0). When one of the windows or the door is opened, a high(1) output is produced on that input of the OR gate and the gate output goes high. It then activities an alarm circuit to warn of the intrusion.

NOT gate

The NOT gate has only one input and one output as per the schematic symbol shown in Fig 9a and the circuit to construct the NOT gate using descrete comporents in Fig 9b.

Fig 9



The NOT gate inverts the logic stage of a binary signal input. The small circle (bubble) at the output of the symbol is formally called a negation indicator and designates the logical complement.

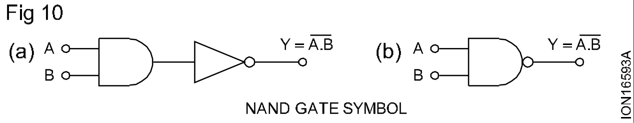
NAND gate

The **NAND** gate is the complement of the **AND** operation.Its name is an abbreviation of NOT **AND**.

The schematic symbol for the NAND gate consists of an AND symbol with a bubble on the output, denoting that that a complement operation is performed on the output of the AND gate.

The schematic symbol and truth table of NAND gate is shown in Fig 10a &b.

Fig 10



Truth table

A	B	Y=$\overline{A.B}$
0	0	1
0	1	0
1	0	0
1	1	0

The truth table cleary shows that the NAND gate opertion is the complement of the AND gate.

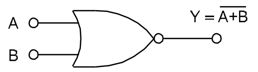
NOR gate:

The NOR gate is the complement of the OR operation. ITS name is an abbreviation of NOT OR.

The schematic symbol for the NOR gate consists of an OR symbol with a bubble on the output, denoting that a complement opertaion is performed on th eoutput of the OR gate.

The schematic symbol and the truth table of NOR gate is shown in the Fig 11.

Fig 11



NOR GATE SYMBOL

Truth table

Input		Output
A	B	Y=A+B
0	0	1
0	1	0
1	0	0
1	1	0

The output of NOR gate is '0' even if one of the input is in logic1. Only when both the inputs are in logic '0', the output is in logic '1'.

The IC 7402 is a TTL type NOR gate IC.It contains 4 NOR gates. For pin details of the IC refer to the data sheet of the IC.

EX-OR gate

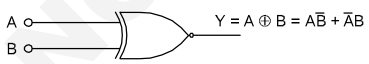
Exclusive-OR gate

Exclusive OR gate is actually formed by a combination of other gates already discussed. However, because of their fundamental importance in many applications, these gates are treated as basic logic elements with their own unique symbols.

The EX-OR gate has only two inputs unlike the other gates, it never has more than two inputs.

The schematic symbols of Exclusive-OR (XOR for short) is gate shown in Fig 12.

Fig 12



EX-OR GATE SYMBOL

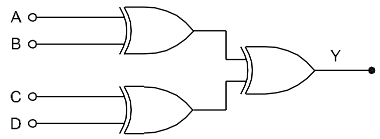
The truth table of EX-OR gate is given below.

Truth Table

A	B	Q=A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

Using 2-input EX-OR gates as building blocks, an EX-OR gate with more than two inputs can be built as shown in Fig 13.

Fig 13



FOUR INPUT EX-OR GATE

Four input EX-OR gate

Y = A+B+C+D

Truth Table

A	B	C	D	Y	Remarks for input
0	0	0	0	0	Even
0	0	0	1	1	Odd
0	0	1	0	1	Odd
0	0	1	1	0	Even
0	1	0	0	1	Odd
0	1	0	1	0	Even
0	1	1	0	0	Even
0	1	1	1	1	Odd
1	0	0	0	1	Odd
1	0	0	1	0	Even
1	0	1	0	0	Even
1	0	1	1	1	Odd
1	1	0	0	0	Even
1	1	0	1	1	Odd
1	1	1	0	1	Odd
1	1	1	1	0	Even

To summarizes the action by referring truth table of 4-input XOR gate, each input word with an odd number of 1's produces a logic HIGH(1) output and for words with an even number of 1's it produces logic-Low(0) output. Because of this reason the EX-OR gate is used for parity check, IC 7486 is an quad 2 input EX-OR gate which is available both in TTL and CMOS family.

Application of EX- OR gate as a parity checker.

Parity is the term used to mention the number of 1's in a binary word. Even parity means an n-bit input has even number of 1s. For instance, 110011 has even parity because it contain four 1s. Odd parity means an n-bit input has an odd no. of 1s. For example, 110001 has odd parity because it contains three 1s.

Parity checker

Exclusive-OR gates are ideal for checking the parity of a binary number because they produce an output 1 when the input has an odd no. of 1s. Therefore an even parity input to an Exclusive-OR gate produces a low output, while an odd parity input produce a high output.

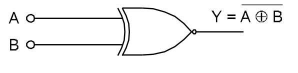
Exclusive-NOR gate

Truth Table

Input		Output
A	B	Q = A+B
0	0	1
0	1	0
1	0	0
1	1	1

The schematic symbols for the EX-NOR (XNOR) gate is shown in Fig 14. Like the XOR gate, XNOR has only two inputs. The bubble on the output of the XNOR symbol indicates that its output is opposite that of the XOR gate.

Fig 14



EX-NOR GATE SYMBOL

In an exclusive-NOR gate operation, “Output Q is LOW’ if input A is LOW and input B is HIGH or if A is HIGH and B is LOW, Q is HIGH if A and B are both HIGH or both LOW.

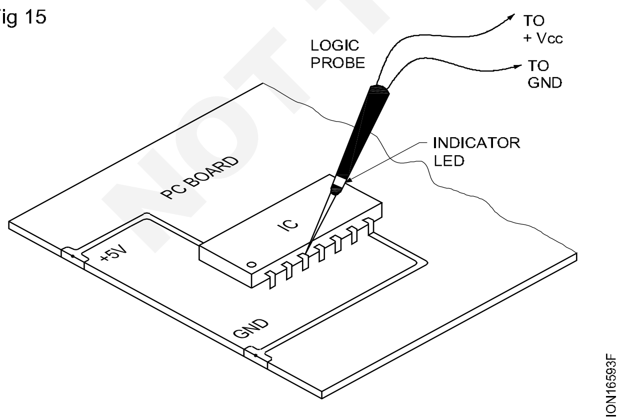
Application

EX-OR gate can be used as a controlled inverter. One of its inputs can be used to control whether the signal at the other input will be inverted or not. This property will be useful in certain application.

Logic probe:

A logic probe is used to monitor the logic level activity at an IC pin or any other accessible point in a logic circuit. Logic probe normally has one or more indicator LEDs that indicate the various conditions of the logic signal. The indication may be related to logic HIGH, LOW, Intermediate & Pulsing states that are present at that point in the circuit which the probe tip is touching. Fig 15 shows how a logic probe is connected to an IC pin.

Fig 15



A logic probe is used as a troubleshooting tool of digital systems. The most common internal failures of digital ICs are as follows

1 Malfunction in the internal circuitry.

2 Inputs or Outputs open circuited.

3 Inputs or Outputs shorted to ground or Vcc.

4 Short between two pins (other than ground or Vcc).

Malfunction in the internal circuitry

This is usually caused by one of the internal components failing completely or operating outside its specifications. When this happens the IC do not respond properly to the IC inputs. The behaviour of outputs cannot be predicted because it depends on what internal component has failed. This type of internal IC failure is not as common as other three.

Inputs shorted to ground or Vcc

This type of internal failure will cause the input to be struck in the LOW or HIGHstate. This kind of faults result short circuiting either with Vcc or ground depending on the state of input.

Outputs shorted to ground or Vcc

This type of internal failure will cause the output to be stuck in the LOW or HIGHstate. This type of failure has no effect on othe logic signals at the inputs.

Open circuited input or output

Sometimes very fine conducting wire that connects an IC pin to the ICs internal circuitry will break, producing an open circuit. The open gate will be in the floating state and this state will be assumed by TTL devices as a valid logic 1 and CMOS devices will respond erratically and may even become damaged from overheating.

Short between two pins

An internal short between two pins of an IC will force the logic signals at those pins always be identical. Whenever two signals that are supposed to be different show the same logic-level variatiions, there is a good possiblility that the signals are shorted together.

In most of the cases discussed above, a logic probe acts as a good troubleshooting tool to diagonise faulty circuits. Among other things, the logic probe is useful for locating short circuits that occur in manufacturing. For example during the stuffing and soldering of printed circuit boards, an undesirable splash of solder may connect two adjacent tracks. Known as solder bridge, this kind of trouble can short-circuit a node to the ground or to the supply voltage. The node is then stuck in a low or high state. The probe helps you to find short-circuited nodes because it stays in one state, no matter how the inputs are changing.

Logic probe circuit using inverters

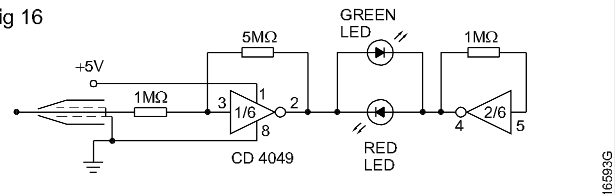
A simple circuit for indicating the logic levels using NOT gates is shown in Fig 2. The circuit consists of two inverters biased in the linear region. If the logic probe is connected to a ‘low’ level input, the ‘high’ going output of NOT gates makes LED-1 to glow. On the other hand, if the input probe is connected to a high level, the low going output of NOT gate makes LED-2 to glow. The two back to back connected LEDs protect each other against excessive reverse voltage. As the input impedance is very high, a shielded wire is required to connect the probe to the input of IC.

7404 is a TTL IC having six inverters inside, CD4011 is a CMOS IC having six inverters, refer table book for IC pin configuration.

1s complement circuit using inverter

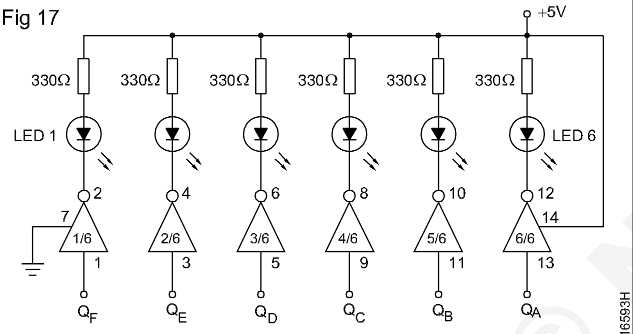
The Fig 16 shows a circuit for producing the 1s complement of an 6-bit binary number. The bits of the binary number are applied to the inverter inputs and the 1s complement of the number appears at the o/ps. LED1 to LED6 indicate the status of inputs Q_F to Q_A. Logic 1 on any of the inverter inputs Q_F to Q_A, will make the output low causing corresponding LED to glow. If the LED glows, input to that particular inverter gate is high. In this matter the above circuit works as logic level indicator (Fig 17). Logic probe

Fig 16



LOGIC PROBE

Fig 17



1'S COMPLIMENT CIRCUIT

An universal gate is a that can be used to implement any Boolean function without the need to use any other type of gate.

The NAND and NOR gates are universal gates.

In actual practice, teh NAND and NOR gates are used to fabricate all the basic gates required in IC digital logic famillies.

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

In the some way an OR gate is typically implemented as a NOR gate followed by a NOT gate.

Now let us discuss how to implement the NOT,AND,and OR gates using universal gate.

NAND gate as a universal gate:

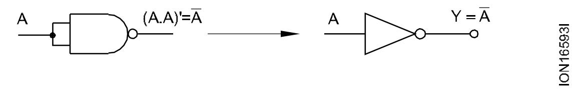
To prove that any Boolean function can be implemented usinmg only NAND gates,we will show that the AND,OR, and NOT operations can be performed using only these gates.

NAND gate implemented as NOT gate.

In the following circuit NAND gate is used as **an inverter (NOT gate).**

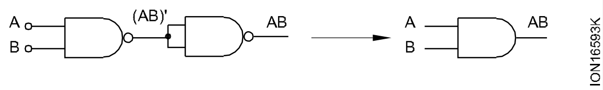
All input pins of NAND gates are connected to the input signal A gives an output A as shown in Fig 18.

Fig 18



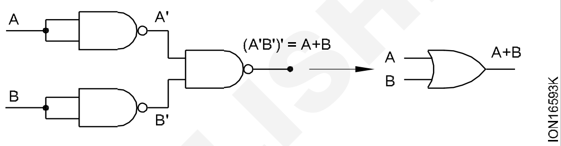
NAND gate implemented as AND gate. An AND gate can be implemented by NAND gate as shown in Fig 19. (The AND is replaced by a NAND gate with its output complemented by a NAND gate inverter).

Fig 19



NAND gates implemented as OR gate. An OR gate can be implemented by NAND gates as shown in Fig 20. (The OR gate is replaced by a NAND gate with all its inputs complemented by NAND gate inverters).

Fig 20



Thus it is proved that the NAND gate is auniversal gate since it can implement the AND, OR and NOT logic functions.

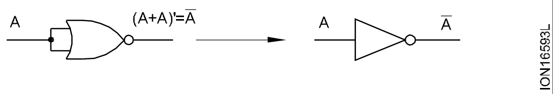
NOR gate as a universal gate. In the following paragraphs the NOR gate is used to prove that any Boolean function can be implemented only with NOR gates.NOR to replace the AND,OR and NOT opertaions .

NOR gate implemented as NOT gate.In the following circuit a NOR gate is used as **an inverter (NOT gate).**

All input pins of NOR gate is connected to the input signal

A gives an output $\overline{A}$ as shown in Fig 21.

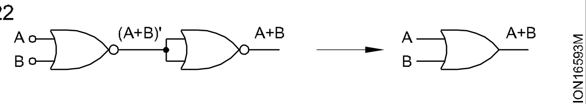
Fig 21



NOR gate implemented as AND gate.

An OR gate can be implemented by NOR gates as shown in Fig 22. (The OR is replaced by a NOR gate with its output complemented by a NOR gate inverter).

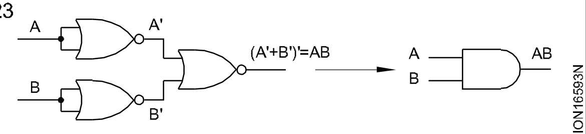
Fig 22



NOR gate implemented as AND gate

An AND gate can be implemented by NOR gates as shown in the figure 23. (The AND gate is replaced by a NOR gate with all its inputs complemented by NOR gate inverters).

Fig 23



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

Heat Sink used in electrical and electronic component

In any electrical circuit some amount of heat while the circuit is functioning.Typically power handling semiconducter devices like power transistors and the opto electronics such as light emitting diodes, lasers generate heat in considerable amounts and these components are inadequate to dissipate heat,as their dissipation capability is signnificantly low.

Due to this, heating up of the components leads to malfuncting problems and may cause failure of the entire circuit or system's performance.So,to solve these problems, heat sinks are the solution that must be provided to those semiconductor devices for cooling purpose.

Heat sink is a device made of aluminium metal attached of an electronic circuit , that dissipates heat mainly from the power transistors of a circuit into the surrounding medium and cools them for improving their performance, reliability and also avoids the damage to the components. For the cooling purpose, it incorporates a fan or cooling device.

Whenever two objects with different teperature come into contact with each oher, conduction occurs causing the fast- moving molecules of the high - heat object to collide with the slow- moving molecules of the cooler objects, and thus, transfers thermal energy to the cooler object, and this is termed as thermal conductivity.

Similarly, heat sink transfers the heat or thermal energy from a high- temperature component to a low- temperature medium like air.

The heat sinks are classified into different categories based on different criteria. Let us consider the major types, namely active heat sinks and passive heat sinks.

Binary arithmetic

Objectives: At the end of this lesson you shalll be able to
- **define binary arithmetic**
- **perform binary addition**
- **perform binary subtraction using 1's compliment and 2's compliment**
- **explain half adder circuit, full adder circuit**
- **explain 4 bit parallel adder circuit using IC 74LS83**
- **explain IC 74LS83 4 bit parallel adder can be used for subtraction.**

Binary arithmetic is essential in all digital computers and in many other types of digital systems. To understand digital systems, you must know the basics of binary addition, subtraction, multiplication and division.

Binary addition

Physical quantities are represented by numbers. Addition represents combining of physical quantities. Digital computers do not process decimal numbers, they process binary numbers. Addition is a key process to perform subtraction, multiplication and division. The four basic cases for adding binary digits are as follows.

0 + 0 = 0; Sum is 0 with a carry of 0.

0 + 1 = 1; Sum is 1 with a carry of 0.

1 + 0 = 1; Sum is 1 with a carry of 0.

1 + 1 = 10; Sum is 0 with a carry of 1.

Notice that the first three cases result in a single bit and in the forth case the addition of two 1's yields a binary two i.e. 10. When binary numbers are added, the last condition creates a sum of 0 in a given column and a carry of 1 over to the next column to the left, as illustrated in the following addition of 11 + 01.

carry	1	1	
	0	1	1
+	0	0	1
	1	0	0

In the right most column, 1+1=0 with a carry of 1 to the next left column. In the middle column, 1+1+0=0 with a carry of 1(one) to the next left column. In the left most column, 1 remains as final carry of the 2 bit addition. Hence the result is 100.

Example:

1		carry	1110
	14		1110
	10		1010
	24		11000
2	10 + 12		
	10		1010
	12	+	1100
	22		10110

The above process is column-by-column addition which can be applied to find the sum of two binary numbers of any length. The following example shows 8-bit arithmetic addition operation.

$A_7A_6A_5A_4A_3A_2A_1A_0$

$B_7B_6B_5B_4B_3B_2B_1B_0$

?

The most significant bit (MSB) of each number is on the left side and least significant bit is on the right side. For the first number, A7 is the MSB and A0 is the LSB, similarly for the 2nd number B7 and B0 are the MSB and LSB respectively.

Signed numbers

Digital systems such as the computer, must be able to handle both +ve and -ve numbers, A signed binary numbers consists of both sign and magnitude information. The sign indicates whether a number is +ve or -ve and the magnitude is the value number. There are three ways in which signed numbers can be represented in binary form: sign magnitudes, 1s compliment, and 2's compliment.

Sign-magnitude system

The left most bit in a signed binary number is the sign bit, which tells you whether the number is +ve or -ve, A zero in the left most position represents +ve number and a ONE represents -ve number. The remaining bits are the magnitude bits. The magnitude bits are in true (uncomplimented) binary form for both +ve and -ve numbers.

Example:

+25 is expressed as an 8 bit signed binary number using the sign magnitude system as

+ 25 = 0 0 0 1 1 0 0 1

Sign bit Magnitude bit

- 25 = 1 0 0 1 1 0 0 1

Notice that the only difference between +25 and -25 is with the sign bit because the magnitude bits are same for both +ve and -ve numbers.

"In the sign-magnitude system, a -ve number has the same magnitude bits as the corresponding +ve number but the sign bit is a 1." Although sign magnitude system is straight forward, calculators and computers do not use it, because circuit implementation is more complex than other systems.

1's complement system

Positive numbers in the 1's complement system are represented the same way as the positive sign magnitude numbers. In the 1's complement system, a negative number is the 1's compliment of the corresponding +ve number.

Example:

The decimal number -25 is expressed as the 1's compliment of +25 (00011001) as 11100110.

i.e 1's compliment of 00011001 (+25) = 11100110 (-25)

(The 1's compliment of a binary number is obtained by simply changing each 0 to a 1 and each 1 to a 0).

Example:

Determine the decimal value of the signed binary numbers expressed in 1's compliment.

1 1 1 0 1 0 0 0

The bits and their powers of two weights for the -ve number are as follows.

Notice that the -ve sign bit has a weight of -2^7 or -128.

-2^{+7}	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	1	1	0	1	0	0	0

Summing the weights where there are 1s.

1×-2^7 (128) = -128

1×2^6 (64) = +64

1×2^5 (32) = +32

1×2^3 (8) = +8

= -128+104

= -24

Adding 1 to the result, the final number is = -24 + 1 = -23.

The decimal value of the signed number 11101000 expressed in 1's compliment is = - 23.

2's compliment system

Positive numbers in the 2's complement system are also represented the same way as in sign magnitude and 1's complement system. Negative numbers are 2's complement of the corresponding positive no's.

2's compliment of a binary number is found by adding ONE(1) to the LSB of the 1's compliment.

2's Compliment = (1's compliment) + 1

Example:

Find the 2's compliment of 1011011

Solution

1011011 - Binary number

0100100 - 1's compliment

1 - Add 1

+ 0100101

For example, the decimal number -25 can be expressed in binary form by writing 2's complement for +25.

+25 = 00011001 - Binary number

11100111 - 2's compliment

Example:

Express the decimal -39 as an 8 bit number in sign-magnitude using 2's compliment system.

Solution

In the 2's compliment system, -39 is produced by taking the 2's compliment of +39 (00100111) as follows.

+39 = 00100111 Binary number

11011000 1's compliment

+ 1

11011001 2's compliment

-39 = 11011001

Verification =

-2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
-128	64	32	16	8	4	2	1
1	1	0	1	1	0	0	1

Since the MSB of the binary equivalent is one so, 2^7 should be taken as -ve sign.

-128+64+16+8+1 = -128+89

= -39

The 2's complement system is preferred for representing signed numbers as it requires a summation weights regardless of whether the number is +ve or -ve. It is used in most computers because it makes arithmetic operations earier.

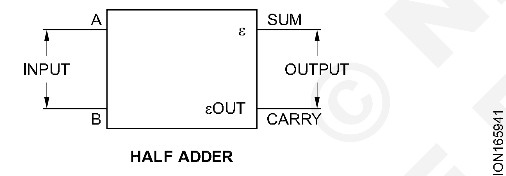
Basic Adder

Adders are used in many types of digital systems in which numerical data are processed. Computers and calculators perform binary operations on two binary numbers at a time, where each number can have several binary digits. The logic symbol for a half adder is shown in Fig 1. There are two basic categories of adders.

1 Half adder

2 Full adder

Fig 1



Half adder

The half-adder accept two binary digits on its inputs and produces two binary digits on its outputs, a sum bit and a carry bit.

Table 1 (Truth table)

A	B	Sum	Carry
		S=A + B	C_{out} = AB
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

From the logic operation of the half-adder as stated in the Table 1, expression can be derived for the sum and the output carry as functions of the inputs, notice that the output carry is a 1 only when both A and B are 1s. Therefore carry (C_{out}) can be expressed as the AND of the input variables.

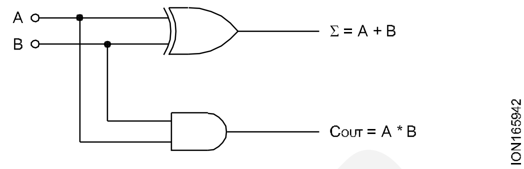
C_{out} = A.B ——> 1

The sum output(S) is a 1 only if the input variables, A and B are not equal. The sum can therefore be expressed as the exclusive -OR of the input variables.

Sum(S) = A + B ——> 2

From equation 1 and 2 the logic implementation required for the half-adder function can be developed. The output carry is produced with an AND gate with 'A' and 'B' on the inputs and the sum outputs is generated with an Ex-OR gate, as shown in Fig 2.

Fig 2



Full adder

The full adder accepts three inputs including an input carry and generates a sum output and an output carry.

The basic difference between a full-adder and a half-adder is that the full-adder accepts an input carry. A logic symbol for a full-adder is shown in Fig 3 and the truth table in the Table 2 shows the operation of a full-adder.

Fig 3

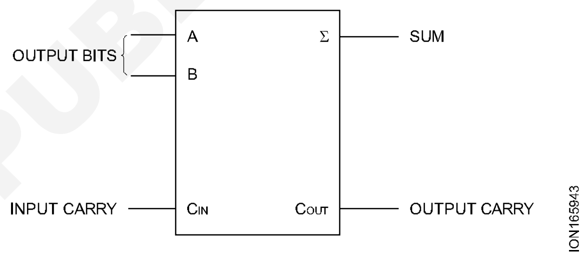


Table 2 (Truth table)

A	B	C_{in}	Cout	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

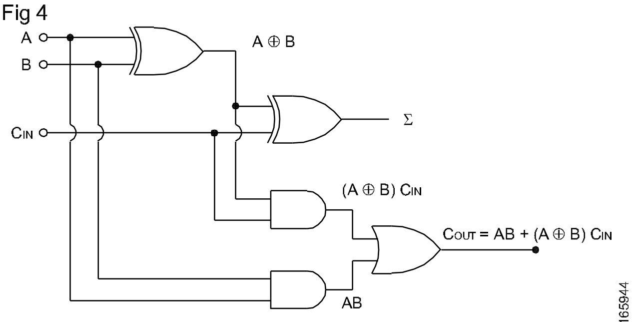
The full-adder must add the two input bits alongwith the input carry. From the truth-table of the half-adder we know that the sum of the input bits A and B is A + B. To get the sum output of the full edder the input carry (C_{in}) must be exclusive-ORed with A + B. Then the sum

S = (A + B) + C_{in}

This means that to implement the full-adder sum function, two exclusive-Or gates can be used. The first must generate the term A + B, and the second has the inputs from the output of the XOR gate and the input carry, as shown in Fig 4.

The output carry of the full-adder is therefore produced by the inputs A, ANDed with B and A + B ANDed with C_{in}. These two terms are ORed, and expressed in equation shown below and this function is implemented and combined with the sum logic to form a complete full-adder circuits, as shown in Fig 4.

Fig 4



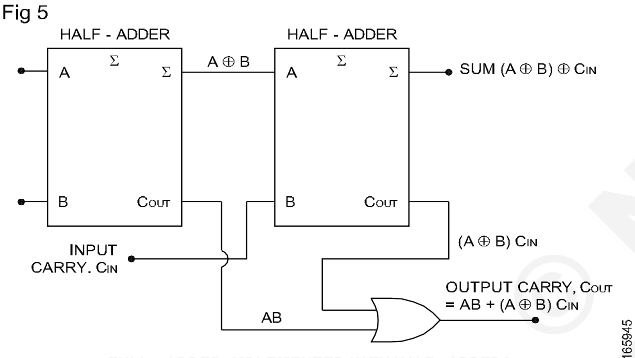
LOGIC DIAGRAM OF FULL ADDER

2 Bit parallel adder (para)

C_{out} = AB + (A + B) C_{in}

The Fig 5, shows there are two half-adders, connected as shown in block diagram to form full-adder.

Fig 5

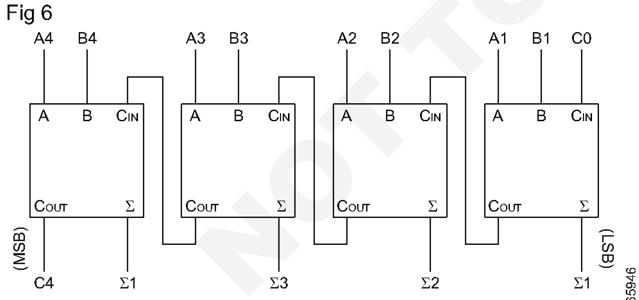


FULL - ADDER IMPLEMENTED WITH HALF - ADDERS

Four bit parallel adder

A basic 4-bit parallel adder is implemented with four full-adders as shown in the Fig 6.

Fig 6



BLOCK DIAGRAM OF 4 BIT PARALLEL ADDER

Block diagram of 4 bit parallel adder

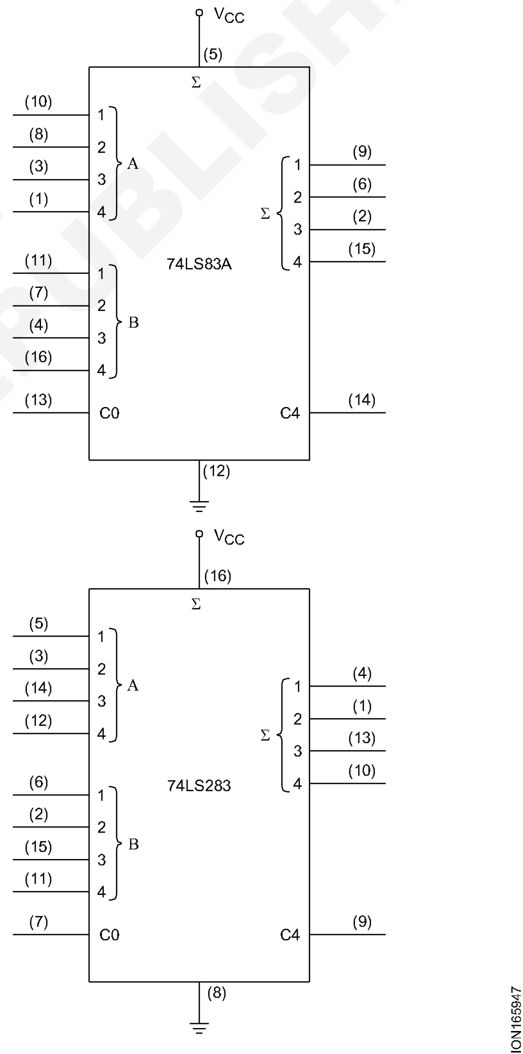
The LSB, (A1 and B1) in each number being added into the right most full-adder; the higher order bits are applied as shown to the successively higher order adders, with MSBs (A4 and B4) in each number being applied to the left most full adder. The carry output of each adder is connected to the carry input of the next higher order adder as indicated.

In the manufacturer's data sheets the input labeled C_0 is the input carry to the least significant bit adder, C_4 is the output carry of the most significant bit adder, and S_1(LSB) through S_4(MSB) are the sum outputs.

74LS83 4 bit parallel adder

4-bit parallel adders that are available as Medium-Scale Integrated(MSI) circuits are the 74LS83A and the 74LS283 low-power Schottky TTL devices. These devices are also available in other logic families such as standard TTL (7483A and 74283) and CMOS (74HC283). The 74LS83A and the 74LS283 are functionally identical to each other but not pin compatible, that is the pin numbers for the inputs and outputs are different due to different power and ground pin connections. For the 74LS83A, V_{CC} is pin 5 and ground is pin 12 on the 16-pin package. For the 74LS283, V_{CC} is pin 16 and ground is pin-8, which is a more standard configuration. Logic symbols for both of these devices are shown in Fig 7 with pin numbers in parenthesis.

Fig 7



The 4 bit parallel adder can be expanded to handle the addition of higher bit numbers by a process called cascading. In this process, the carry output of the lower-order adder is connected to carry input of the higher-order adder being cascaded.

Binary subtraction

Subtraction is a special case of addition. For example Subtracting +6 (the subtrahend) from +9 (the minuend) is equivalent to adding -6 to +9. Basically the subtraction operation changes the sign of the subtrahend and adds it to the minuend. The result of a subtraction is called the difference.

9 - 6 = 9+(-6)

The sign of a positive or negative binary number is changed by taking its 2's compliment.

Example:

The result of 2's compliment of the positive number 0110(+6) is 1's compliment of the number + 1

i.e   1001 + 1 = 1010

1010 is 2's compliment of 0110(+6), which is equal to -6 in decimal system, as shown below.

1   0   1   0

-8 + 0 + 2 + 0 = -6

Example:

Subtract 6 from 9 in 2's compliment method

9-6 = 3   normal method

9+(-6) = 3   2's compliment method

Binary form

9 = 1001 (minuend)   1001 - 0110 = 0011

6 = 0110 (subtrahend)

2's compliment method

I step: 2's compliment of subtrahend 0110 is

1's compliment of subtrahend + 1

i.e 1001 + 1 = 1010 (equal to -6 in decimal system)

II step: Add minuend with 2's compliment of subtrahend

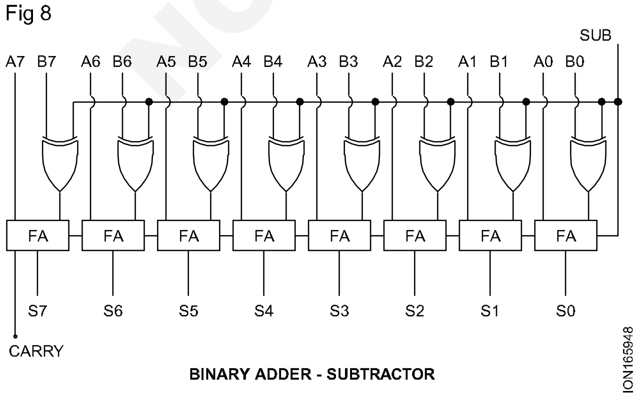
i.e 1001 + 1010 = 10011

Discard the carry 1, then the result is 0011.

Adder-Subtracter

Full adder can be used for to add or subtract binary numbers. The Fig 8 shows the how adder circuit can be used as subtractor.

Fig 8



BINARY ADDER - SUBTRACTOR

The carry out from each full adder is the carry into the next-higher full adder. The numbers being proposed are A_7....A_0 and B_7.......B_0 while the output sum is S_7......S_0. With 8 bit arthimetic, the final carry is ignored. With 16-bit arthimetic, the final carry is the carry into the addition of the upper byte.

Addition

A_7.........A_0

+ B_7.........B_0

S_7.........S_0

During an addition, the SUB signal is deliberately kept in the low state, therefore the binary number B_7..........B_0 passes through the controlled inverter (through Ex-OR gate) with no change. The full-adders then produce the correct output SUM.

For instance, suppose that the numbers being added are +125 and -67, then $A_{7.........A0}$ = 01111101 and B_7..........B_0 = 10111101.

Since SUB=0 during an addition, the CARRY IN to the LSB column is 0.

0 <—— Sub input

01111101 <—— Input 'A'

+ 10111101 <—— Input 'B'

100111010

During 8 bit arithmetic operation 'last carry' is ignored, therefore the answer is S_7..........S_0 = 00111010.

Subtraction

A_7..............A_0 (minuend)

(-) B_7..............B_0 (subtrahend)

S_7..............S_0

During the subtraction, the SUB signal is deliberately put into high state. Therefore the controlled inverter (Ex-OR gates) produces the 1's compliment of 'B' inputs, because the SUB is the carry IN, to the first full-adder (tied to logic-1) circuit processes the data as given.

1 <—SUB

A_7 A_6 A_5 A_4 A_3 A_2 A_1 A_0

+ B_7 B_6 B_5 B_4 B_3 B_2 B_1 B_0

S_7 S_6 S_5 S_4 S_3 S_2 S_1 S_0

When A_7...........A_0 is applied with all zeros the circuit produces the 2's compliment of B_7............B_0 because 1 is being added to the 1's compliment B_7............B_0, when A_7...........A_0 doesn't equal zero the effect is equivalent to adding A_7..........A_0 and the 2's compliment of B_7............B_0.

Example:

(A - B)

82 - 17

A B S

= 01010010 - 00010001 = ?

The controlled inverter produces the 1's compliment of B, which is 11101110, since SUB=1 during a subtraction, the circuit performs the following condition.

1	<—— SUB	
	01010010	<—— A input
	11101110	<—— B input
	101000001	<—— S output

For 8-bit arithmetic, the final carry is ignored, therefore the answer is S_7..........S_0 = 01000001.

This answer is equivalent to decimal +65 which is the algebraic difference between the number +82 and +17.

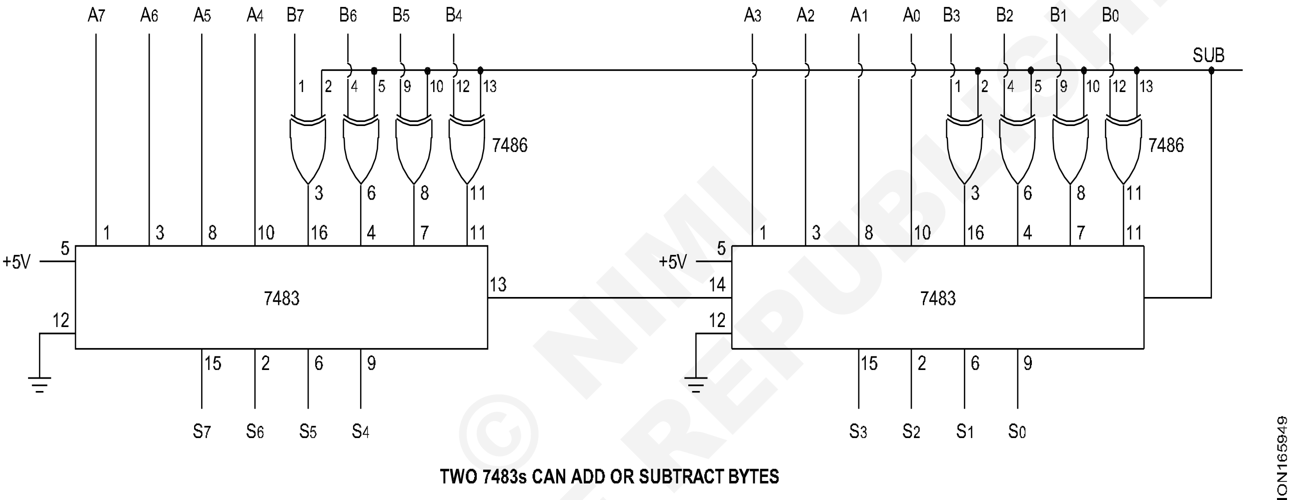
Subtraction circuit based on 2's compliment method using Adder IC

In this circuit the Minuend is applied to the A inputs of IC 7483 and Subtrahend is fed to the B inputs, through EX-OR gates and output is taken at S outputs, as shown in Fig 9.

The IC 7486 is on Exclusive-OR gate used for 1's complimenting the SUBTRAHEND.

Carry input and one input from each Ex-or-gate is tied to some logic status. For addition SUB input should be logic-0, for subtraction sub input should be at logic-1 state.

Fig 9



TWO 7483s CAN ADD OR SUBTRACT BYTES

Digital comparator [Magnitude comparators]

Another common and very useful combinational logic circuit is that of the **Digital Comparator** circit.

Digital or Binary compartors are made up from standard AND,NOR and NOT gates that compare the digital signals present at their input terminals and produce an output depending upon the condition of those inputs.

The digital comparator accomplishes this using several logic gates that operate on the principles of Boolean Algebra. There are two main types of Digital Comparator available and these are.

1 Identity comparator - an identity comparator is a digital comparator with only one output terminal for when A =B, either A=B, either A= B = 1 (HIGH) or A =B= 0 (LOW)

2 Magnitude comparator - a Magnitude comparator is a digital comparator which has three output terminals, one each for equality, A = B greater than, A > B and less than A<B

The purpose of a Digital Comparator is to compare a set of variables or unknown numbers, for example A (A1,A2,A3,.....An, etc) against that of a constant or unknown value such as B (B1,B2,B3,.....Bn, etc) and produce.

1 - bit Digital comparator circuit

The operation of a 1- bit digital comparator is shown in the the below truth table.

Digital Comparator Truth Table

Inputs		Outputs		
B	A	A>B	A=B	A<B
0	0	0	1	0
0	1	1	0	0
1	0	0	0	1
1	1	0	1	0

In the circuit does not distinguish between either two "0" or two "1" 's as an output A=B is produced when they are both equal, either A = B= "0" or A = B= "1". the output condition for A=B resembles that of a commonly avilable logic gate, the Exclusive -NOR or Ex - NOR function (equivalence) on each of the n-bits giving : Q =A + B

Digital comparators actually use Exclusive - NOR gates within their design for comparing their respective pairs of bits. When we are comparing two binary or BCD values or variables against each other, we are comparing the "Magnitude" of these values, a logic "0" against a logic "1" which is where the term Magnitude Comparator comes from.

As well as comparing individual bits, we can design larger bit comparators by cascading togethern of these and produce a n - bit comparator just as we did for the n-bit adder in the previous tutorial. Multi - bit comparators can be constructed to compare whole binary or BCD words to produce an output if one word is larger, equal to or less than the other.

A very good example of this is the 4- bit Magnitude Comparator. Here, two 4 - bit words ("nibbles") are compared to each other to produce the rrelevant output with one word connected to inputs A and the other to be compared.

4 - bit Magnitude comparator

Some commercially available digital comparators such as the TTL 74LS85 or CMOS 4063 4 - bit magnitude comparator have additional input terminals that allow more individual comparators to be "cascaded" together to compare words larger than 4 - bits with magnitude comparators of "n" - bits being produced. These cascading inputs are connected directly to the corresponing outputs of the previous comparator as shown to compare 8,16 or even 32-bit words.

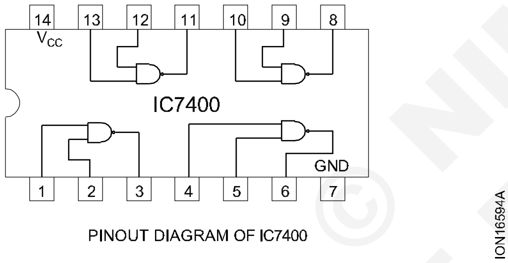
8 - bit word comparator

When comparing large binary or BCD numbers like the example above, to save time the comparator starts by comparing the highest - order bit (MSB) first. If equality exists, A = B then it compares the next lowest bit and so on until it reaches the lowest - order bit, (LSB).If equality still exists then the two numbers are defines as being equal.

If inequality is found, either A> B or A<B the relationship between the two numbers is determined and the comparison between any additional lower order bits stops. Digital Comparator are used widely in Anlogue - to - Digital converters, (ADC) and Arithmetic Logic Units, (ALU) to perform a variety of arithmetic operations.

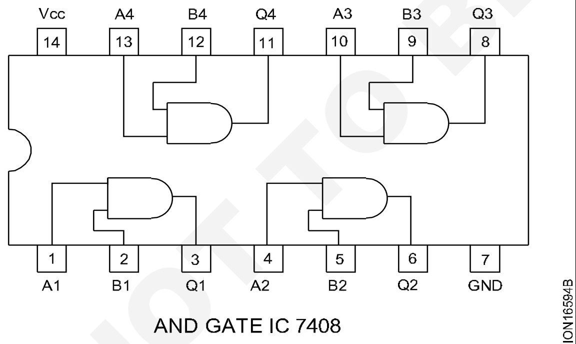
PIN DIAGRAM OF LOGIC ICs

Fig 10



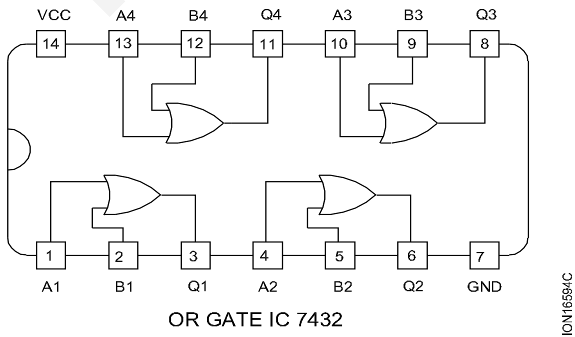
PINOUT DIAGRAM OF IC7400

Fig 11



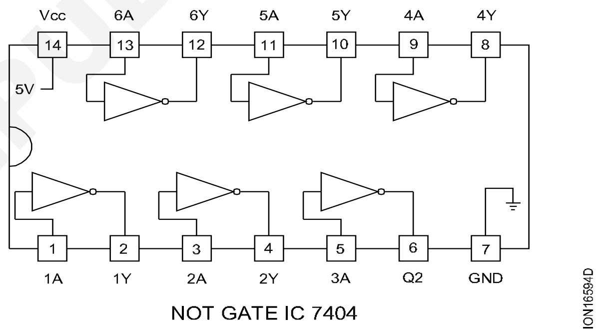
AND GATE IC 7408

Fig 12



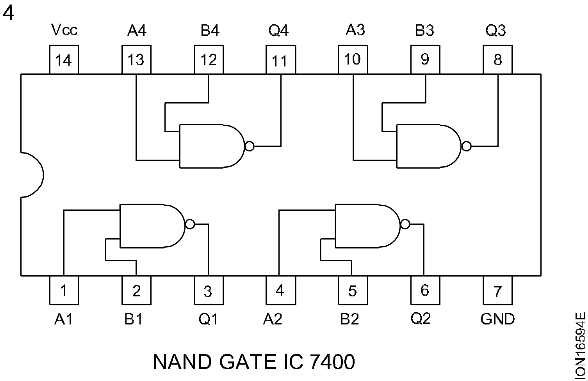
OR GATE IC 7432

Fig 13



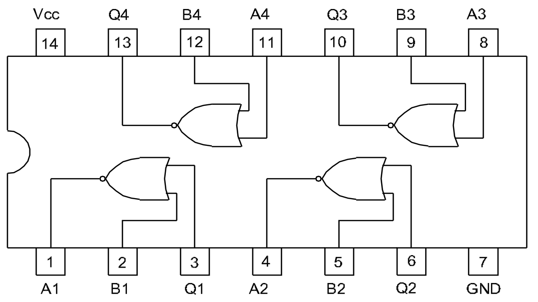
NOT GATE IC 7404

Fig 14



NAND GATE IC 7400

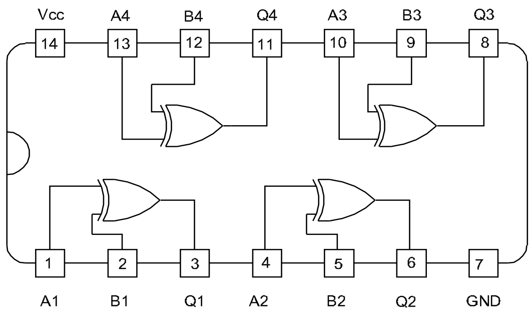
Fig 15



NOR GATE IC 7402

ION16594F

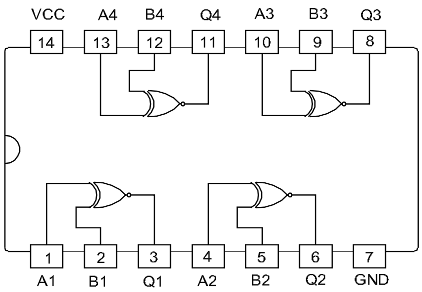
Fig 16



EX-OR GATE IC 7486

ION16594G

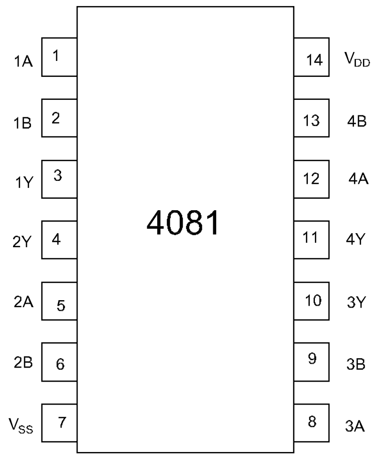
Fig 17



EX-NOR GATE IC 74266

ION16594H

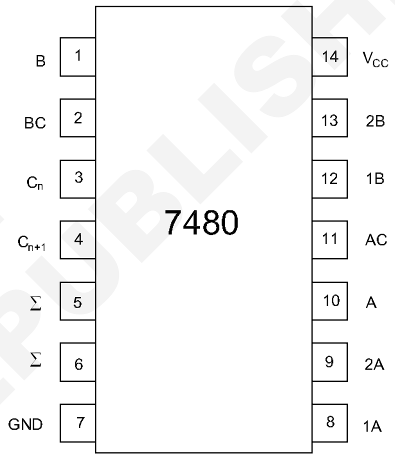
Fig 18



HALF ADDER IC 4081

ION16594I

Fig 19



FULL ADDER IC7480

ION16594J

Concept of encoder and decoder

Objectives: At the end of this lesson you shalll be able to
- **concepte of encoder and decoder**
- **explain 2 to 4 binary decoder its working**
- **explain 4 to 2 binary encoder and its working.**

Concept of encoder and decoder

The encoders and decoders play an essential role in digital electronics.

- Encoders & decoders are used to convert data from one from to another form.
- These are frequently used in communication system such as telecommunication, networking, etc... to transfer data from one end to the other end.
- Similarly, in the digital domain, for easy transmission of data, it is often encrypted or placed within codes, and then transmitted. At the receiver, the coded data is decrypted or gathered from the code and is processed in order to be displayed or given to the load accordingly.

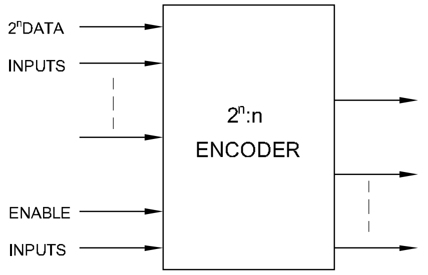
Binary Encoder

A binary encoder is shown in Fig 1. It has 2^n input lines and n output lines, hence it encodes the information from 2^n inputs into an n- bit code. From all the input lines, only one of an input line is activated at a time, and depending on the input line, it produces the n bit output code.

The figure below shows the block diagram of binary encoder which consists of 2^n input lines and n output lines. It translates decimal number to binary number.

The output lines of an encoder correspond to either true binary equivalent or in BCD coded form of the binary for the input value. Some of these binary encoders include decimal to binary encoders, decimal to octal, to binary encoders, decimal to BCD encoders, ect.

Fig 1



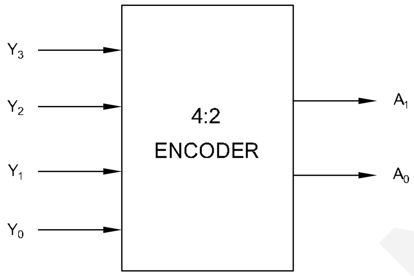
2^n:n ENCODER

Depending on the number of input lines, digital or binary encoders produce the output codes in the form of 2 or 3 or 4 bit codes.

4 - to - 2 Bit Binary Encoder

The block diagram and truth table of a 4 input encoder is shown in Fig 2. The truth table consists of four rows, since, it is assumed that only one input is the value of 1 then the corresponding binary code associated with that enabled input is displayed at the outputs.

Fig 2



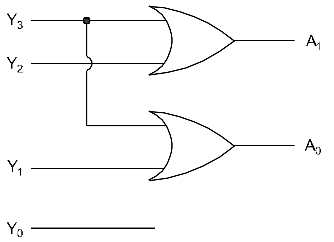
4:2 ENCODER

The output Y_0 is 1 when either input Y_1 or Y_3 is 1, also the output Y_1 is set to 1 when either input Y_2 or Y_3 is 1.

Y_3	Y_2	Y_1	Y_0	A_1	A_0
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1

The output from 4-to-2 encoder is generated by the logic circuit implemented by a set of OR gates as shown in Fig 3. In the figure a, the output of the encoder is same if input activated is the Io input (Io = 1) or if no input is activated i.e. all the inputs are zero.

Fig 3



4 to 2 ENCODER USING OR GATES

This causes ambiguity in the encoding output. To avoid this ambiguity, a valid encode output can be added as an additional output assumes a value 1 when Io is equal to 1.

Decimal to BCD Encoder

This type of encoder usually consists of ten input lines and 4 output lines, Each input line corresponds to the each decimal digit and 4 outputs correspond to the BCD code.

This encoder accepts the decoded decimal data as an input and encodes it to the BCD output which is available on the output lines.

The figure below shows the basic logic symbol of decimal to BCD encoder along with its truth table. The truth table represents the BCD code for each decimal digit.

From this we can formulate the relationship between the BCD bit and decimal digit. It is important to note that there is no explicit input line for decimal zero. When this condition occurs, i.e. decimal inputs 1 to 9 all are zero. than the BCD output is 0000.

Binary Decoder

The **Binary Decoder** is another combinational logic circuit constructed from individual logic gates and is the exact opposite to that of an Encoder

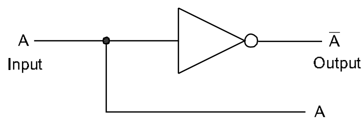
The name "Decoder" means to translate or decode coded information from one format into another, so a digital decoder transforms a set of digital input signals into an equivalent decimal code at its output.

Binary Decoders are another type of digital logic device tha t has inputs of 2 - bit or 3- bit or 4-bit codes depending upon the number of data input lines, so a decoder that has a set of two or more bits will be defined as having an n - bit code, and therefore it will be possible to represent 2^n possible values. Thus,a decoder generally decodes a binary value into a non - binary one by setting exactly one of its n outputs to logic "1".

If a binary decoder receives n inputs (usually grouped as a single Binary or boolean number) it activates one and only of its 2^n outputs based on that input with all other outputs deactivated.

So for example, an inverter (NOT - gate) can be clased as a 1- to -2 binary decoder as 1 - input and 2- output (2^1) is possible because with an input A it can produce two outputs A and $\overline{A}$ (not - A) as shown in Fig 4.

Fig 4



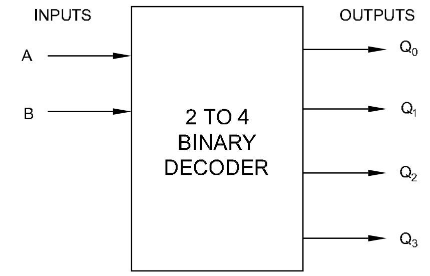
1 to 2 BINARY DECODER

Then we can say that a standard combinational logic decoder is an **n- to - m** decoder, when $m \leq 2^n$, and whose output , Q is dependent only on its current inputs, determines which binary code or binary number is corresponds to that binary input.

A Binary Decoder converts coded inputs into coded outputs, where the input and output codes are different and decoders are available to "decode" either a binary or BCD (8421 code) input pattern to typically a decimal output code. Commonly available BCD - to - Decimal decoders include the TTL 7442 or the CMOS 4028. generally a decoders output decoder" circuits include, 2- to- 4, 3- to - 8 and 4- to -16 line configurations.

An example of a 2- to -4 line decorder along with its truth table is shown in Fig 5a and 5b.

Fig 5



A2-to-4 Binary Decoder

(b)

A	B	Q_0	Q_1	Q_2	Q_3
0	0	**1**	0	0	0
0	1	0	**1**	0	1
1	0	0	0	**1**	0
1	1	0	0	0	**1**

This simple example above of a 2- to-4 line binary decoder consists of an array of four AND gates. The 2 binary inputs labelled A and b are decoded into one of 4 outputs, hence the description of 2- to -4 binary decoder.

This simple example above of a 2- to-4 line binary decoder consists of an array of four AND gates. The 2 binary inputs labelled A and b are decoded into one of 4 outputs, hence the description of 2- to -4 binary decoder. Each output represents one of the miniterms of the miniterms of the 2 input variables, (each output = a miniterm).

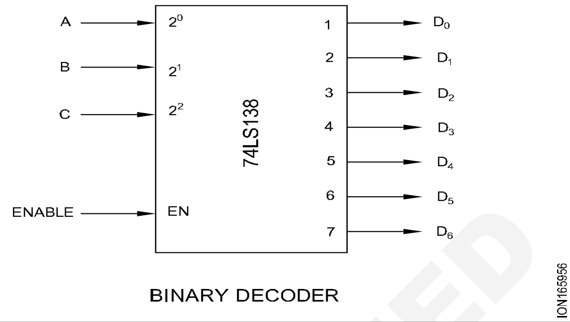
The binary inputs A and B determine which output line from Q0 to Q3 is "HIGH" at logic level "1" while the remaining outputs are held "LOW" at logic "0" so only one output can be active (HIGH) at one time. Therefore, whichever output line is "HIGH" identifies the binary code present at the input, in other words it "de - codes" the binary input.

Some binary decoders have an additional input pin labelled "Enable" that controls the outputs from the device. This extra allows the decoders outputs to be turned "ON" or " "OFF" as required. These types of binary decoders are commonly used as "memory adderss decoders" in microprocessor memory applications.

The binary decoder is a demultiplexer with an additional data line that is used to enable the decoder. An alternative way of looking at the decoder circuit is to regard inputs A,B and C as address signals. Each combination of A,B or C defines a unique memory address.

A 2-to-4 line binary decoder (TTL 74155)can be used for

Fig 6



BINARY DECODER

decoding any 2-bit binary code to provide four outputs, one for each possible input combination. However, sometimes it is required to have a Binary Decoder with a number of outputs greater than is available, so by adding more inputs, the decoder can potenially provide 2^n more outputs as show in Fig 6.

So for eample, a decoder with 3 binary inputs (n=3), would produce a 3-to- 8 line decoder (TTL 74138) and 4 inputs (n = 4) would produce a 4-to-16 line decoder (TTL 74154) and so on. But a decoder can also have less than 2^n outputs such as the BCD to sevensegment decoder (TTL 7447) which has 4 inputs and only 7 active outputs to drive a display rather than the full 16 (2^n) outputs as you would expect.

Here a much larger 4 (3 data plus 1 enable) to 16 line binary decoder has been implemented using two smaller 3-to-8 decoders.

An encoder is device which converts familar numbers or characters or symbols into a coded format. it accepts the alphabetic characters and decimal numbers as inputs and produces the outputs as a coded representation of the inputs.

It encodes the givesn information into a more compact form. In other words,it is a combinatiaonal circit that performs the opposite function of a decoder.

These are mainly used to reduce the number of bits needed to represent given information. In digital systems, encoders are used for transmitting the information. Thus the transmission link uses fewer lines to transmit the encoded information.

In addition, these encoders are used for encoding the data which is to stored for later use asit facilitates fewer bits storing over the available space.

Multiplexers & demultiplexers

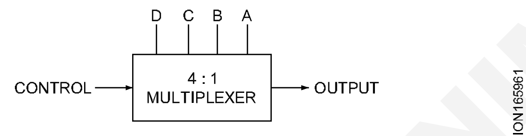
Objectives: At the end of this lesson you shalll be able to
- **state the need of multiplexers and demultiplexers in digital circuits**
- **explain the function of a multiplexer with an example**
- **state the relationship between number of input lines and required number of control lines**
- **list a few commercially available multiplexer and demultiplexer ICs**
- **explain the application of a multiplexer & demultiplexer in data transmission**
- **explain Four to One line multiplexer and its working**
- **explain One to Four Demultiplexer and its working.**

Many applications in digital logic requires circuit with multiple input and single output, single input and multiple outputs. The output of such circuits should however be uniquely determined by a set of control signals. Such circuits find immense application in computer and data transmission. Such circuits that have one or more input lines and give one or more output which are uniquely determined by the inputs are called *Combinational circuits.* Two of the most important combinational circuits are the Multiplexers and Decoders.

Multiplexers

A multiplexer having 2^n data inputs, one data output and an *n*-bit control input which selects one of the input and routes it to the output is shown in Fig 1.

Fig 1



In Fig 1, the multiplexer has two inputs ($2^n = 2^1=2$, hence n=1). It has 1-bit control signal (because, n=1) which selects A or B as the output as given in the Truth Table 1.

Truth Table

INPUTs		Control	Output
A	B		
1	0	0	1 (A -->output)
1	0	1	0 (B -->output)

Demultiplexer

The inverse of a Multiplexer is a Demultiplexer as shown in Fig-2. This has n input (in this case, n=1), 2n output (in this case, $2^n=2^1=2$ outputs) and n number of control signals (in this case n=1, hence control line=1). The single input is routed to one of the 2^n outputs, depending on the value of the n control lines. The truth table for the demultilexer at Fig 2 is given in Table 2.

Fig 2

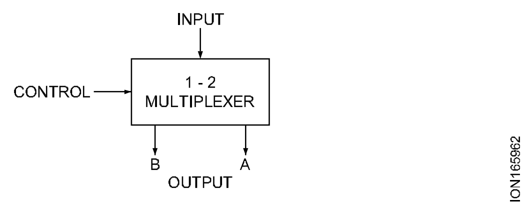


Table 2

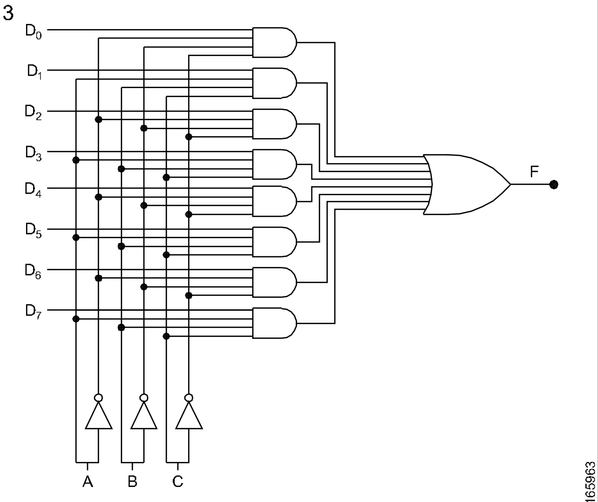
INPUT	Control	Output
1	0	Input --> A (Therefore, A=1)
1	1	Input --> B (Therefore, B=1)

8-line Multiplexer

As discussed in earlier paragraphs, a multiplexer is a circuit with 2^n data inputs, one data output and *n* control inputs. The selected data is gated or routed to the output. Fig 3 shows the schematic of an eight-input or eight-line multiplexer.

As can be seen in Fig 3, the three control lines A,B and C encode a 3-bit number that specifies which of the eight input lines is gated to the OR gate and then to the output. Immaterial of what value is on the control lines, seven of the AND gate will always output 0, the other one may output 0 or 1 depending on the value of the selected input line. Each gate is enables by a different combination of the control inputs.

Fig 3



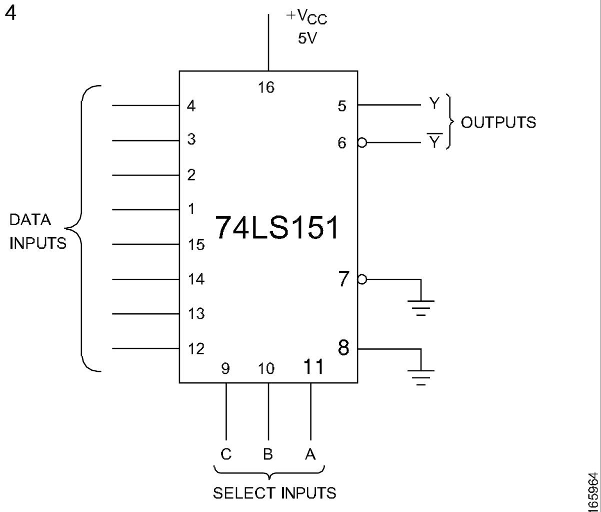
AN EIGHT DIGIT MULTIPLEXER CIRCUIT

Such a eight-line multiplexer is available as a MSI chip. With 8 input lines, 3 control lines, one output, may be an additional compliment output line and power supply and ground lines is implemented as a 16 pin package. One such package is the 74LS151 , 8-line multiplexer IC shown in Fig 4.

Demultiplexer

The inverse of a multiplexer is a demultiplexer. A demultiplexer routes its single input signal to one of 2n outputs, depending on the values of the n control lines. For instance, if the binary value on the control signal is all zeros, the 0th output line is selected and if the binary value on the control lines is *k,* then, the k^{th} output line is selected for routing the input signal. Such demultiplexers are also available in IC package. One such IC is the 1line to 8 line demultiplexer 74LS138 as shown in Fig 5.

Fig 4



8 LINE MULTIPLEXER

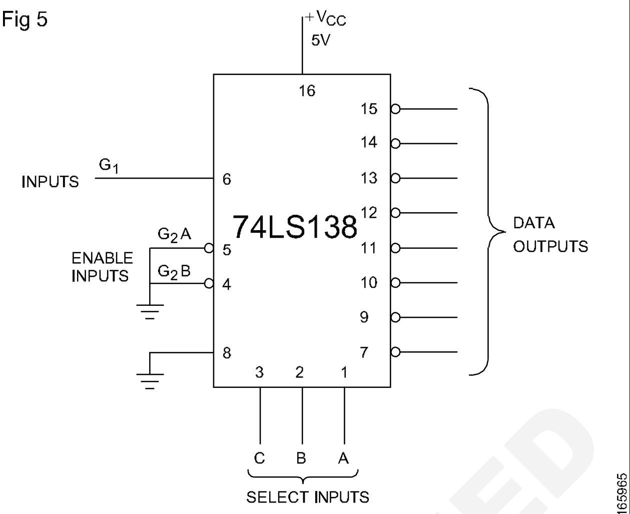
Application of Multiplexers and Demultiplexers

There are almost innumerable applications of multiplexers and demultiplexers. Just to list a few are in implementing a multiplexed display, parallel to serial data converter etc.,

The application of multiplexer and demultiplexer can be appreciated in data transmission as shown in Fig 6.

In Fig 6, the eight inputs could be eight signals coming from different transducers measuring eight different type of data (say, temperature, pressure,...) in a industrial environment. At the other end the output of the demultiplexer may be fed to eight different measuring instruments meant for measuring the individual parameters.

Fig 5

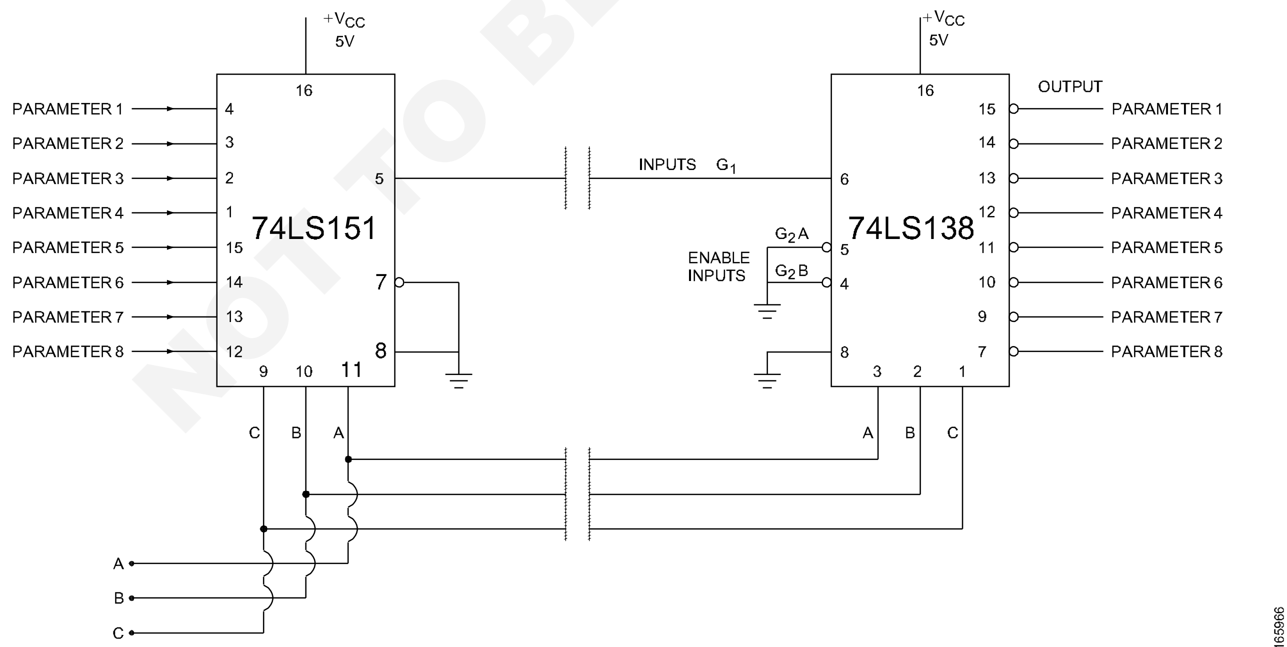


8 LINE DEMULTIPLEXER

If the control lines of the multiplexer and demultiplexer are simultaneously fed with binary signals sequentially from 000 to 111, then each of the parameter of the input at any given time is communicated over the line to the demultiplxer which in-turn routes it to meter which is meant for displaying the value of the value of the parameter.

Observe from Fig 6, that only one transmission line is used for communicating all the eight parameters at different intervals of time. This is known as Time division multiplexing. Hence, multiplexers and demultiplexers are invariably used in such communication. The three control lines shown in Fig 6 could even be generated at sending and receiving station independently using one of the input line as the synchronizing input.

Fig 6



APPLICATION OF MULTIPLEXER AND DEMULTIPLEXER

Latch circuits and applications

Objectives: At the end of this lesson you shall be able to
- **explain NOR latch and NAND latch using discrete gates**
- **state the concepts of clocked flip flops**
- **discuss the effect of bouncing and debounce circuits**
- **explain 'T', 'D' flip-flop and its truth table**
- **explain clocked D flip-flop and its truth table**
- **discuss the difference between edge triggering and level triggering and types of edge trigger**
- **write logic diagram for the given boolean equations**
- **simplify the logic diagram using boolean algebra.**

Introduction

A flip-flop is a digital circuit that has two stable states. It remains in one of these states until triggered into the other.

Flip-flops are used to store binary information. Digital memory circuits that can store bits of data are an essential part of any computer system.

RS flip flops

The most basic type of flip flop is the reset/set type, hence it is known as RS flip flop.

The basic RS flip-flop can be constructed from either two NOR gates or two NAND gates. The circuit symbols is shown in Fig 1. Fig 1a shows RSF/F with active HIGH inputs. Fig 1b shows RSF/F with active LOW inputs. The NOR gate latch and NAND gate latch both are shown in Fig 2 and Fig 3 respectively.

Fig 1

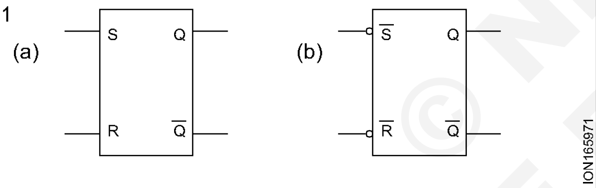


Fig 2

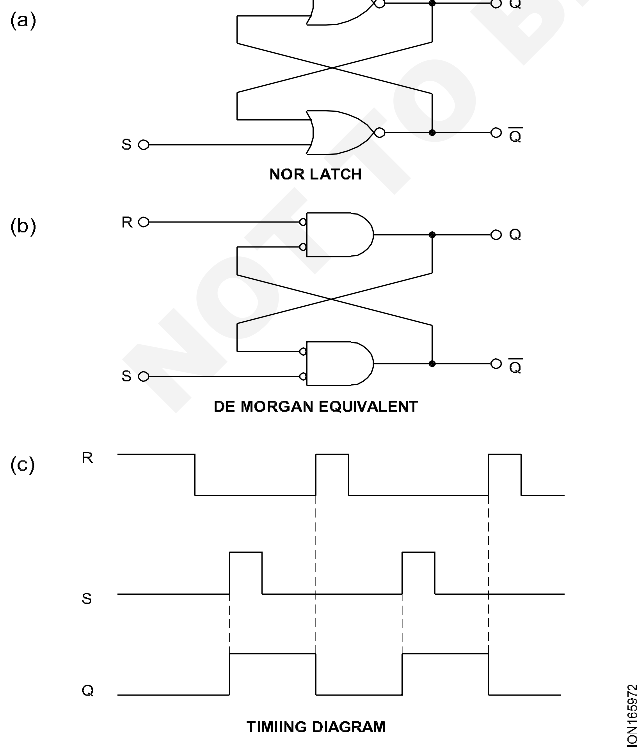
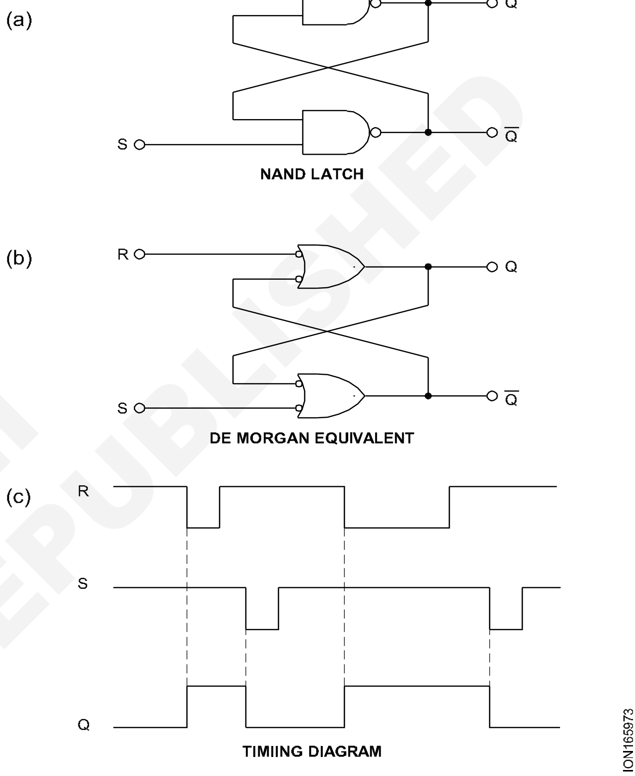


Fig 3



NOR latch

From Fig 2, the two NOR gates are cross-coupled so that out of one NOR gate is connected to other NOR gate input and vice versa.

Truth table for NOR latch

R	S	Q	Comment
0	0	NC	No change
0	1	1	Set
1	0	0	Reset
1	1	*	Race

Truth table for NAND latch

R	S	Q	Comment
0	0	*	Race
0	1	1	Set
1	0	0	Reset
1	1	NC	No change

The NOR latch output are labelled as Q and Q. The outputs will always be the inverse of each other. From the truth table of NOR latch, it can be summarised as follows.

Condition 1

R=0 S=0, this condition produce the inactive state. Output `Q' will remain with no change.

Condition 2

R=0 S=1, this condition cause to go to the Q=1 state where it always remain after R returns high. This is known as setting the latch.

Condition 3

R=1 S=0, this condition cause to go to the Q=0 state where the output remain even after S returns HIGH. This is called resetting the latch.

Condition 4

R=1 S=1, this condition produce a race condition. Therefor avoid R=1 and S=1 condition while using a NOR latch.

NAND latch

From the NAND gate latch as shown in Fig 3. The two NAND gates are cross-coupled so that output of one NAND is connected to other NAND gate input and vice versa. The NAND latch outputs are labelled as Q and Q. These outputs will always be the inverse of each other.

From the truth table, it can be summarized as follows.

Condition 1

R=0, S=0. This condition produce ambiguous results. It should not be used.

Condition 2

R=0, S=1. This condition cause the output to go the Q=1 state where it will remain after R returns high. This is known as setting the latch.

Condition 3

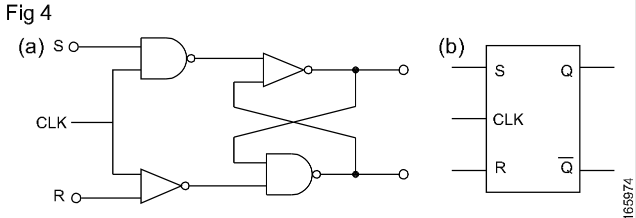
R=1, S=0. This condition cause the output to go the Q=0 state, where the output will remain even after S returns HIGH. This is called clearing or resetting the latch.

Condition 4

R=1, S=1. This condition is the normal resting state and it has no effect on the output state. The Q and Q outputs will remain in whatever state they were prior to this input condition.

Clocked RS flip-flop (Fig 4)

Fig 4



CLOCKED R-S FLIP FLOP

It is possible to strobe or clock the flip-flop in order to store information (set it or reset it) at any time, and then hold the stored information for any desired period of time. This flip-flop is called a clocked RS flip-flop and is shown in Fig 4a and the circuit symbol in 4b.

Truth Table

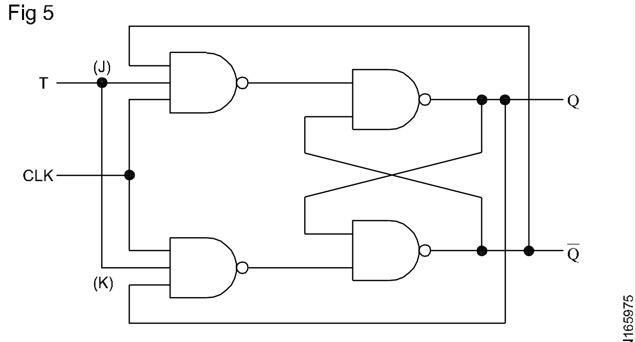
Clock	R	S	Q
0	0	0	NC
0	0	1	NC
0	1	0	NC
0	1	1	NC
1	0	0	NC
1	0	1	1
1	1	0	0
1	1	1	Illegal

For the flip-flop to operate properly there must be a transition form low to high on the clock input, while clock is high, the information on R and S causes the latch to set or reset. Then when clock transitions back to low, this information is retained in the latch. When this high to low transition occurred both R and S inputs were low(0) and thus there was no change of state.

T flip-flop

The "T Flip Flop" is designed by passing the AND gate's output as input to the NOR gate of the "SR Flip Flop". The inputs of the "AND" gates, the present output state Q, and its complement Q' are sent back to each AND gate. The toggle input is passed to the AND gates as input. (Fig 5)

Fig 5



T FLIP FLOP

D-flip-flop

The RS flip-flop has two data inputs, R and S. To store a high bit, you need a high S and to store a low bit, you need a high R. Generation of two signals to drive a flip-flop is a disadvantage in many applications. Further more the RS flip-flop is susceptible to a race condition. We will modify the design to eliminate the possibility of a race condition, to overcome the above disadvantage, R.S flip is slightly modified to have a single input called D-flip-flop.

Unclocked D latch	
D	Q
0	0
1	1

Clock D latch		
CLK	D	Q
0	X	NC
1	0	0
1	1	1

Contact bounce circuit

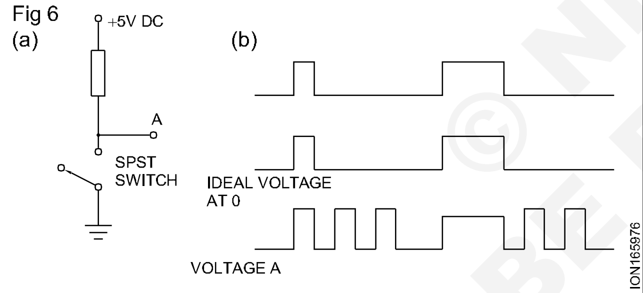
Any mechanical switching device consists of a moving contact arm restrained by some sort of spring system. As a result when the arm is moved form one stable position to the other, the arm bounces as much as hard ball bounces when dropped on a hard surface. The number of bounces that occurs and the period of the bounce differ for each switching device.

In digital system there will be occasions to use mechanical contacts for the purpose of conveying an electrical signal, for example the keyboard of computer. In each case the intent is to apply a high logic level usually [+5V dc] or a low logic level (0 volts DC).

As shown in the Fig 6 above, when the SPST switch is open, the voltage at point 'A' is +5V DC when the switch is closed the voltage at point 'A' is 0 volts.

Ideally the voltage waveform at 'A' should appear as shown in the waveform 6b as the switch is moved from open to closed, or vice-versa.

Fig 6



In actuality, the waveform at point 'A' will appear more or less as shown in waveform(C), as a result of contact bounce. Notice carefully that in this particular instance, eventhough actual physical contact bounce occurs each time the switch is opened or closed, contact bounce appears in the voltage level at point 'A' only when the switch is closed.

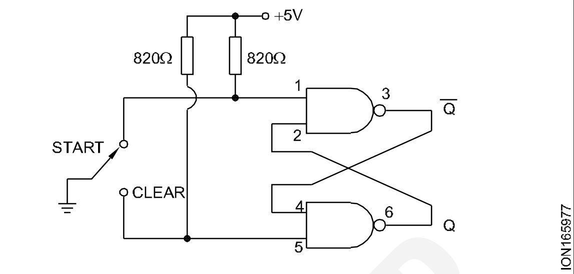
If the voltage at point 'A' is applied to the input of a T.T.L circuit, the circuit will respond properly when the switch is opened, since no contact bounce occurs. However when the switch is closed, the circuit will respond as if multiple signals were applied, rather than the single-switch closer-intended.

R.S.Latches are often used as switch debouncers. Whenever a switch is thrown from open to the closed position.

Bounce less switch

Floating T.T.L inputs are equivalent to high inputs. With the switch in the start position, Pin 1 is low and pin 5 is high therefore $\overline{Q}$ (pin no.3) is high and Q (pin no.6) is low. When the switch is thrown to the clear position, pin no.1 goes high, as shown in Fig 7. Because of contact bounce, pin 5 goes alternately low and high for a few milliseconds before sets in the low state. The first time pin 5 goes low, the latch sets, Q going high and $\overline{Q}$ going low. Subsequent bounces have no effect on Q and Q because the latch stays set.

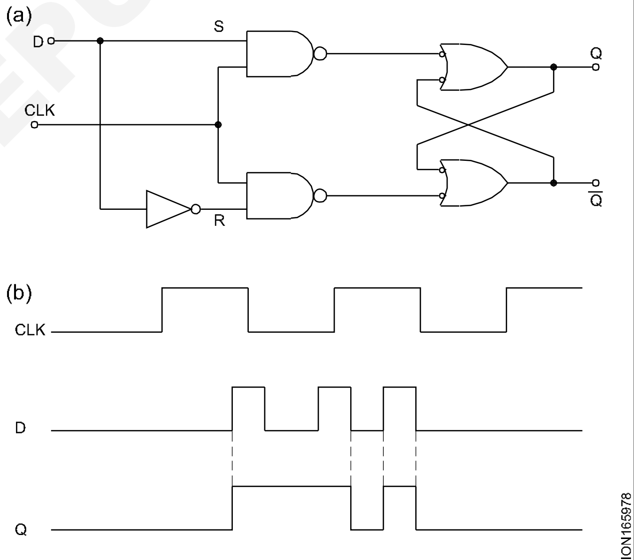
Fig 7



When the switch is thrown back to start, pin 1 bounces low and high for a while. The first time pin 1 goes low, Q goes to low and $\overline{Q}$ going high, later bounces have no effect on Q and $\overline{Q}$.

The Fig 8 shows one way to build a D, latch because of theinverter databit 'D' drives the 'S' input of a NAND latch and the complement of D, drives the 'R' input. Therefore a high 'D' sets the flip-flop, low 'D' resets the flip-flop. Most important thing is no race condition.

Fig 8



Truth table for D-latch

D	Q	Q
1	1	0
0	0	1

Clocked D-flip-flop

The Fig 8a shows the level clocked D type flip-flop. A low clock disables the input gates and prevents the latch from changing states, in other words, while clock is low, the latch is in the inactive state D controls the output, A high D sets the latch, while a low D resets it.

Truth table for level clocked D flip flop

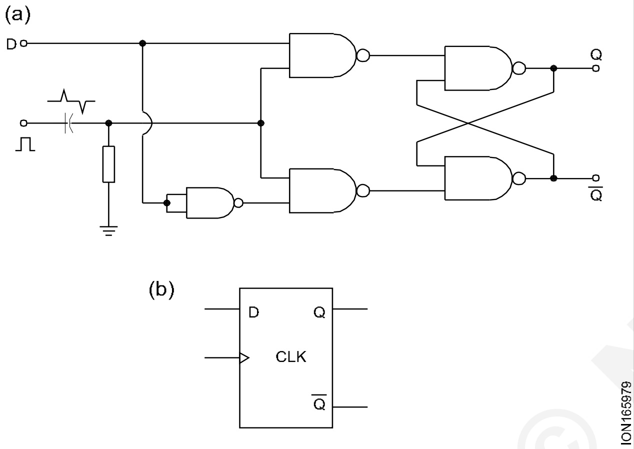
Clk	D	Q
0	X	NC
1	0	0
1	1	1

The truth table summarizes the operation 'X' represents a don't care condition, it stands for either 0 or 1, while clock is low the output can't change, no matter what 'D' is, when clock is high, the output equals the input. Q = D.

Edge triggering versus level clocking

When a circuit is edge triggered, the output can change only on the rising or falling edge of the clock. Edge triggered D - F/F using discrete gate is shown in Fig 9a and the circuit symbol is shown in Fig 9b.

Fig 9



When the circuit is level clocked, the output can change while the clock is high or low.

With the edge triggering, the output can change only at one instant during the clock cycle. With level clocking, the output can change during the entire period the level of the clock is maintained.

Edge triggered D-flip-flops

Boolean algebra is convenient and systematic way of expressing and analysing the operation of logic circuits.

Truth table

Edge triggered D-Flip-flop

CLK	D	Q
0	X	NC
1	X	NC
↓	X	NC
↑	0	0
↑	1	1

Variable

A variable is a symbol (usually an Italic uppercase letter) used to represent a logical quantity. Any single variable can have a 1 or 0 value.

Ex: A,B,C,D or X,Y,Z etc

Complements

The complement is the inverse of a variable and is indicated by a bar over the variable.

Ex: The complement of A is $\overline{A}$, the complement of A is read as "A bar".

Literal

A literal is a variable or the complement of a variable.

Boolean addition

0 + 0 = 0

0 + 1 = 1

1 + 0 = 1

1 + 1 = 0 with carry 1

In Boolean algebra, a sum term is a sum of literals. In logic circuits, a sum term is produced by an OR operation with NAND operation involved.

Ex: A+B, A+$\overline{B}$, $\overline{A}$ + B

A sum term is equal to 1 when one or more of the literals in the term are 1. A sum term is equal to 0 if and only if each of the literal is 0.

Boolean multiplication

Boolean multiplication is equivalent to the AND operation and the basic rules are as follows.

0.0 = 0

1.0 = 0

0.1 = 0

1.1 = 1

In Boolean algebra a product term is the product of literals. In logic circuits a product term is produced by an AND operation with NO OR operations involved.

Ex: AB, $\overline{A}$B, A$\overline{B}$, $\overline{A}\,\overline{B}$

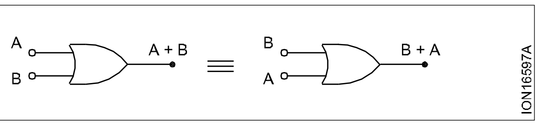
A product term is equal to 1 if and only if each of the literals in the term is one(1). A product term is equal to 0 when one or more of the literal are 0.

Laws of Boolean algebra

Commutative law

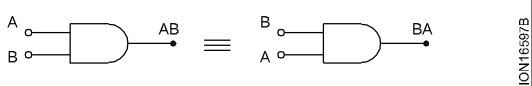
The commutative law for addition for two variables is written algebraically A + B = B + A as shown in Fig 10.

Fig 10



The commutative law for two variable multiplication is AB = BA as shown in Fig 11.

Fig 11



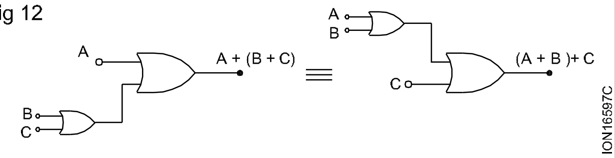
This law states that the order in which the variables are ORed/ANDed make no difference.

Associative law

The associative law of addition is written algebraically as follows for three variables as shown in Fig 12.

A+(B+C) = (A+B)+C

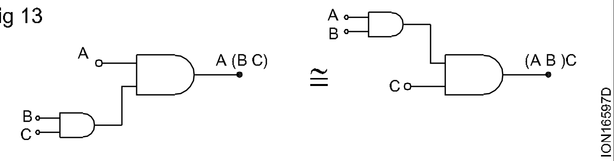
Fig 12



The associative law of multiplication is written as follows for three variables as shown in Fig 13.

A(BC) = (AB)C

Fig 13



This law states that it makes no difference in what order the variables are grouped when ORing/ANDing more than two variables.

Distributive law

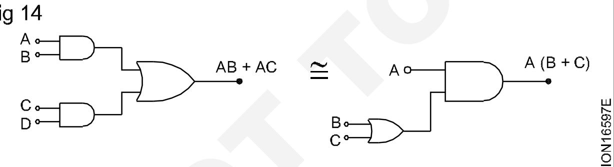
The distributive law is written for three variables as follows.

A(B+C) = AB + AC

This law states that ORing two or more variables and ANDing the result with a single variable is equivalent to ANDing the single variable with each of the two or more variables and then ORing the products as shown in Fig 14. The distributive law also express the process of factoring in which the common variable 'A' is factored out of the product terms.

Ex: AB + AC = A(B+C)

Fig 14



Boolean Algebra Rules

1 $A + 0 = A$

2 $A + 1 = 1$

3 $A + A = A$

4 $A + \overline{A} = 1$

5 $A + AB = A$

6 $A + \overline{A}B = A + B$

7 $A \cdot 0 = 0$

8 $A \cdot 1 = A$

9 $\overline{\overline{A}} = A$

10 $A \cdot A = A$

11 $A \cdot \overline{A} = 0$

12 $(A + B)\ (A + C) = A + BC$

De-Morgans theorem

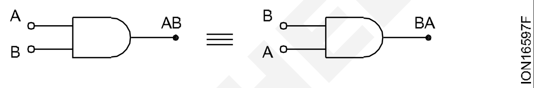
Theorem I

The complement of a product of variables is equal to the sum of the complements of the variables.

$\overline{AB} = \overline{A} + \overline{B}$

The complement of two or more variables ANDed is equivalent to the OR of the complements of the individual variables. The related figure is shown in Fig 15.

Fig 15



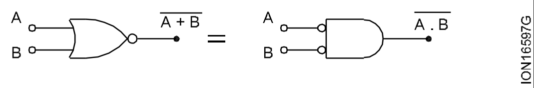
Theorem II

The complement of a sum of variables is equal to the product of the complements of the variables.

$(\overline{A + B} = \overline{A}.\overline{B})$

The complement of two ore more variables ORed is equivalent to the AND of the complements of the individual variables as shown in Fig 16.

Fig 16



Simplify the equation using De-Morgan's theorem

1 $\overline{(A + B + C)D} = \overline{A + B + C}\ \overline{D}$ $\quad (\overline{AB} = \overline{A} + \overline{B})$

$= \overline{A}.\overline{B}.\overline{C}.\overline{D}$ $\quad (\overline{A + B} = \overline{A}.\overline{B})$

2 $\overline{ABC + DEF} = \overline{ABC}.\overline{DEF}$ $(\overline{A + B} = \overline{A}.\overline{B})$

$= (\overline{A} + \overline{B} + \overline{C}).(\overline{D} + \overline{E} + \overline{F})$

Simplification of Boolean equations

Prove that $A + \overline{A}B = A + B$

LHS

$= A + \overline{A}B$

$= (A + AB) + \overline{A}B$

$= AA + AB + \overline{A} \cdot B$

$= AA + AB + \overline{A}B + 0$

$= AA + AB + \overline{A}B + A\overline{A}$

$= A(A + B) + \overline{A}(B + A)$

$= (A + \overline{A})(A + B)$

$= 1.(A + B)$

$= A + B$

Prove that (A+B) (A+C) = A + BC

LHS = (A+B) (A+C)

= AA + AB + AC + BC

= A + AC + AB + BC

= A(1+C) + AB + BC

= A + AB + BC

= A(1+B) + BC

= A + BC

Since

$A = A \,.\, A;$

$A = 0$

$A + \overline{A} = 1$

Simplification of logic circuit using Boolean Equation

AB + A(B+C) + B(B+C)

I Step: Simplify the Boolean equations

AB + AB + AC + BB + BC (Distributive law)

AB + AC + B + BC   Since BB=B

AB + B + AC   (A+ A = A, A.A =A)

B(A + 1) + AC   (1+A=1)

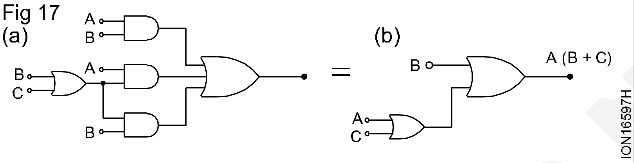
B + AC

II Step write logic diagram for the equations

AB + A(B+C) + B(B+C) = B + AC

Circuit before simplification is shown in Fig 17a. Circuit after simplification is shown in Fig 17b.

Fig 17



The above logic diagram and corresponding Boolean equations show how one can use Boolean Algebra for simplification of logic circuits for the desired logic output.

From the above example it is proved that how the logic circuit gates can be reduced for the same set of output result, using Boolean Algebra. The reduced logic circuit consumes less power and propagation delay time is also reduced, in other words the speed of the circuit increases.

Example

2 Simplify the Boolean expression, and write logic diagram for the given equation and for simplified equation.

$$\overline{A}BC + A\overline{B}\overline{C} + \overline{A}\overline{B}\overline{C} + A\overline{B}C + ABC$$

$$\overline{A}BC + \overline{B}\overline{C}(A + \overline{A}) + AC(\overline{B} + B)$$

$$\overline{A}BC + \overline{B}\overline{C} + AC$$

$$\overline{A}BC + AC + \overline{B}\overline{C}$$

$$C(A + \overline{A}B) + \overline{B}\overline{C}$$

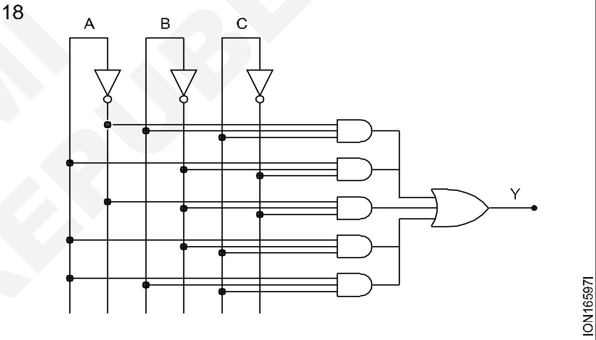
$$C(A + B) + \overline{B}\overline{C}$$

$$AC + BC + \overline{B}\overline{C}$$

[Since A + $\overline{A}$ B = A + B]

Logic diagram for the given equation is shown in Fig 18.

Fig 18



J K Flip-flop circuits

Objectives: At the end of this lesson you shall be able to
- **explain construction of JK flip-flop using NAND gates**
- **state the function of Preset and clear inputs**
- **define the meaning active low and active high**
- **explain the working function of JK master slave flip-flop**
- **explain frequency division using flip flops.**

Operation of J-K flip flop

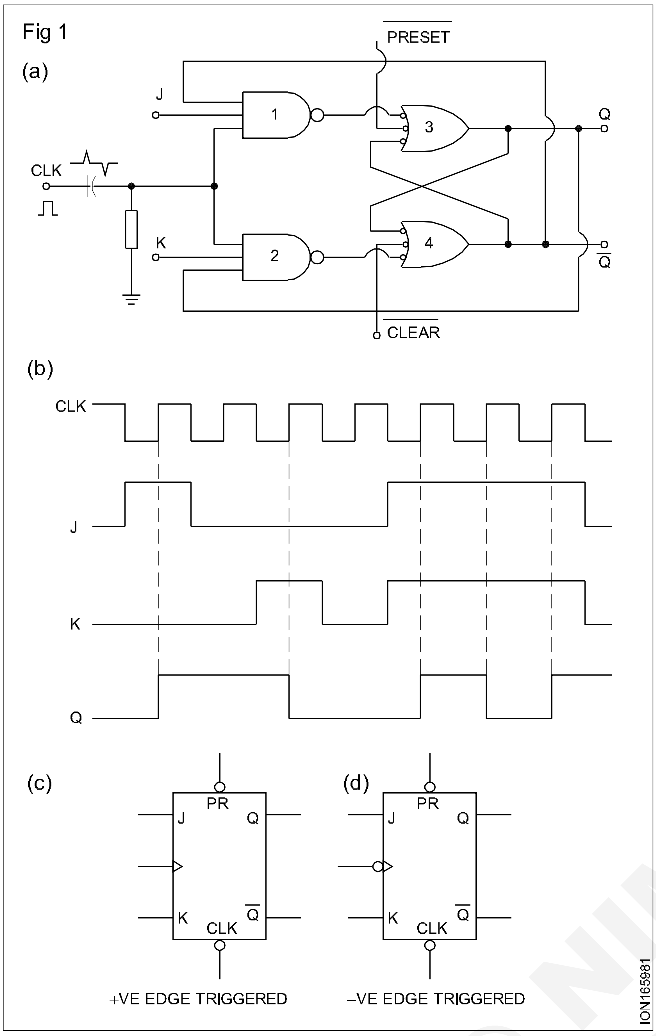
Truth table

CLK	J	K	Q	
0	x	x	NC	
↓	x	x	NC	
↓	x	x	NC	
x	0	0	NC	
↑	0	1	0	Reset
↑	1	0	1	Set
↑	1	1	Toggle	Toggle

The Fig 1 shows one way to build a JK flip-flop. The variables J and K are called control inputs. An R.C circuit with a short time constant, converts the rectangular clock pulse to narrow spikes. Because of the double inversion through the NAND gates, the circuit is +ve edge triggered. In other words, the input gates are enabled only on the rising edge of the clock as shown in truth table.

Reset

When J is low and K is high the upper output gate is disabled. So there is no way to set the flip flop. The only possibility is reset. When Q is high, the lower gate passes a reset trigger as soon as the +ve clock edge arrives. This forces Q to become low. Therefore J=0 and k=1 means that a rising clock edge resets the flip-flop.



Set

When J is high and K is low, the lower output gate is disabled. So it is impossible to reset the flip-flop. But flip-flop can be set, when Q is low, Q is high, the gate 1 passes a set trigger on the positive clock edge. This drives Q into the high state. That is J=1 and K=0 means that the next positive clock edge sets the flip flop.

Toggle

When J and K are both high, it is possible to set or reset the flip flop depending on the current state of the output if Q is high, the lower gate passes a reset trigger on the next positive clock edge on the other hand. When Q is low the upper gate passes a set trigger on the next positive clock edge. Either way Q changes to the complement of the last state. Therefore J=1 and K=1 means that the flip-flop will toggle on the next positive clock edge.

To summarize the operation of the JK.flip-flop, the circuit is inactive when the clock is low, high or on its -ve edge. Likewise the circuit is inactive when J and K are both low. Output changes occur only on the rising edge of the clock as indicated by the last three entries of the table. The o/p either resets, sets or toggles.

Racing

Toggling more than once during a clock cycle is called Racing. Assume that the circuit is level clocked. In other words, assume that RC circuit has been removed and run the clock straight, into the gates, with a high J, high K and high clock, the output toggles. New outputs are then fed

Toggling more than once during a clock cycle is called Racing. Assume that the circuit is level clocked. In other words, assume that RC circuit has been removed and run the clock straight, into the gates, with a high J, high K and high clock, the output toggles. New outputs are then fed back to the input gates. After two propagation times (input and output gates), the output toggles again. And once more new outputs return to the input gates. In this way the output can toggle repeatedly as long as the clock is high.

To overcome this racing problem, JK master slave flip-flop has been developed.

Clear

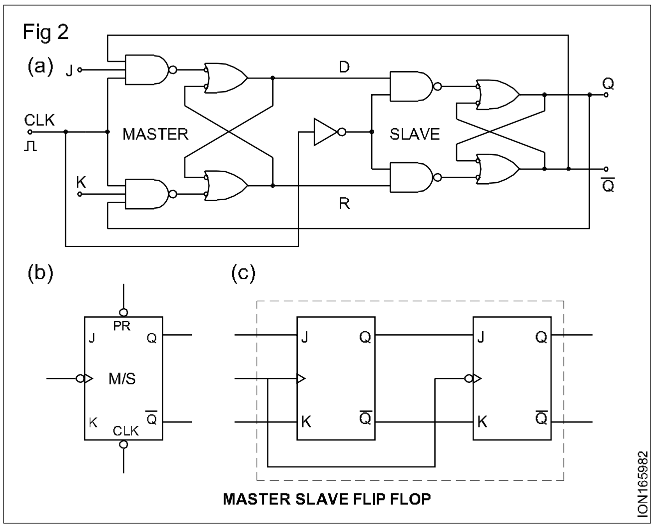
When power is first applied, flip-flops come up in random states. To get some computers started, an operator has to push a master reset button, this sends a clear (reset) signal to all flip-flops, normally clear signal will be active low, (i.e) logic zero should be applied for clear the output. When clear is applied to gate-4 as shown in Fig 1a then the Q will be forced to Logic-0, then automatically $\overline{Q}$ will go to logic-1 condition. This signal, J and K signals have no control over output Q, when clear is set.

Pre-set

Like clear preset is an active low input. This input also independent of CLK, J & K inputs. When preset is made logic-0, the output Q is set to logic one. It is necessary in some digital system to preset the output before the system actually runs.

Master Slave Flip-flop

The Fig 2 shows the JK.Master Slave Flip-flop. It provides another way to avoid racing. A master slave flip-flop is a combination of two clocked flip-flops connected in cascade. Master flip-flop is positive edge triggered, slave flip-flop is negative edge-triggered flip-flop.



- While the clock is high, the master is active and the slave is inactive.

- While the clock is low, the master is inactive and the slave is active.

The J.K master slave flip-flop is used as the main counting device. The popular IC 54LS/74LS76 is a dual JK master slave flip-flop.

Look at the Summarized truth table of J.K master slave flip-flop. A low PR and LOWCLR produces a race condition therefore, PR and CLR are normally kept at a high voltage when inactive. To clear, the flip flop make clear low, to preset the F/F make preset low.

Truth table for positive edge triggered JK flip flop

PR	CLR	CLK	J	K	Q
0	0	X	X	X	Race
0	1	X	X	X	1
1	0	X	X	X	0
1	1	X	0	0	NC
1	1	↑	0	1	0
1	1	↑	1	0	1
1	1	↑	1	1	Toggle

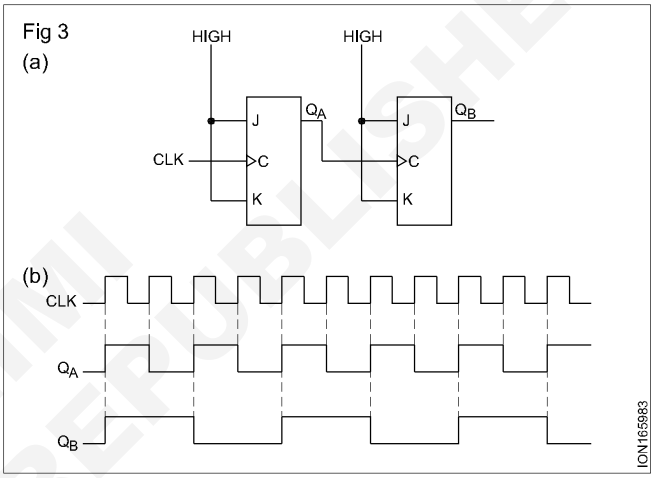
Low J & Low K produces an inactive state regardless of the what the clock is doing. If K goes high by itself, the next clock pulse resets the flip-flop. If J goes high by itself, the next clock pulse sets the flip-flop when J & K are both high, each clock pulse toggle the state of flip flop.

Frequency division using flip flops

Flip-flops are used as frequency dividers of a periodic waveform. When a pulse waveform is applied to the clock input of a J.K flip-flop which is wired for toggle operation, provides square wave output with one half the frequency of the clock input. Thus a single flip-flop can be used for divide by -2 operation as illustrated in Fig 3. The flip-flop changes state on each triggering clock edge. This results in an output which is at half the frequency of the clock waveform.

Further division of clock frequency can be achieved by using the output of one flip-flop as the clock input to a second flip-flop as shown in Fig 3. The frequency of the QA output is divided by 2 by flip-flop B. The QB output is therefore, one fourth the frequency of the original clock input.

By connecting flip-flops in this way, a frequency division of 2^n is achieved, where n is the number of flip-flops. For example, three flip-flops divide the clock frequency by 2^3 = 8. Four flip-flops divide the clock frequency by 2^4 = 16; and so on.



Basic flip flop applications like data storage, data transfer and frequency division

Objectives: At the end of this lesson you shalll be able to
- **state basic types of counters**
- **explain the circuit of a ripple counter**
- **explain a down counter using J-K Flip Flops**
- **explain synchronous and asynchronous decade counters**
- **explain module 10 and module 12 counter circuits.**

Counter

A counter is one of the most useful and versatile subsystems in a digital system. A counter driven by a clock can be used to count the number of clock cycles. Since the clock pulses occur at known intervals, the counter can be used as an instrument for measuring time and therefore period or frequency.

Basically there are two types of counters

1 Synchronous counter

2 Asynchronous counter

Synchronous counter

In this counter every flip-flop is triggered by the clock parallely (synchronously) and thus settling time is simply equal to the delay time of a single flip-flop. The increase in speed is usually obtained at the price of increased hardware.

Asynchronous counter

Asynchronous counters are simple and straight forward in operation and construction and usually requires a minimum of hardware, however have a speed limitation. Each flip-flop is triggered by the previous flip-flop, [i.e., clock is applied serially] and thus the counter has a cumulative settling time. Counters such as these are also called as serial counters or ripple counters.

Serial and parallel counters are used in combination to compromise between speed of operation and hardware count. Serial, parallel or combination counters can be designed such that each clock pulse advances the contents of the counter by one, it is then operating in a count-up mode. The opposite is also possible; the counter then operates in the count-down mode. Furthermore, many counters can be either 'cleared' so that every flip-flop contains a zero, or preset such that the contents of the flip-flops represent any desired binary number.

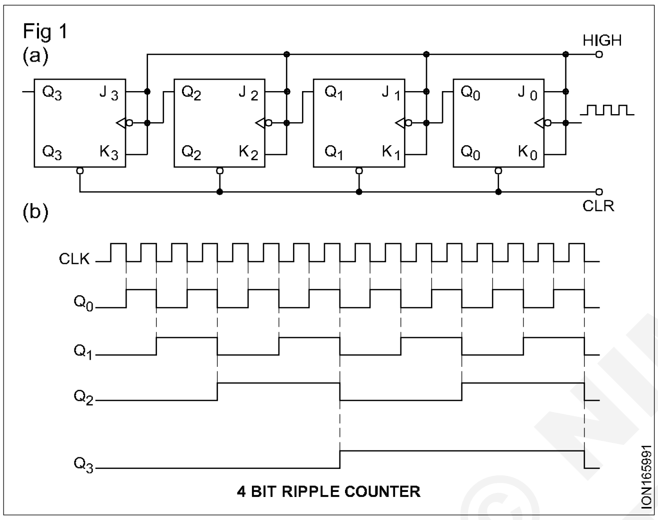
Ripple counter

The Fig 1a shows a counter built with JK flip-flops since the J&K inputs are tied to a high voltage, each flip-flop will toggle, when its clock input receives a negative edge.

Visualize the Q outputs as a binary word.

$Q = Q_3Q_2Q_1Q_0$

Q_3 is the most significant bit (MSB) and Q_0 is the least significant bit (LSB). When CLR goes low, all flip-flops reset, this results in a digital word of Q = 0000.



When clear returns to high, the counter is ready to go, since the LSB flip-flop receives each clock pulse, Q_0 toggles once per negative clock edge, as shown in Fig 1b. The remaining flip-flops toggle less often because they receive their negative edges from the preceding flip-flop outputs(Q). The triggers move through the flip-flops like a ripple in water, that is why this type of counter is called ripple counter.

Counting sequence

When CLR goes from low to high, the Q output of all flip-flops become zeroes.

$Q = Q_3\ Q_2\ Q_1\ Q_0$

Q = 0000

When the first clock pulse triggered the LSB flip-flop, its output Q_0 becomes 1, so the first output word is Q=0001.

When the second clock pulse arrives, Q_0 resets to zero, and this negative falling edge sets next flip-flop output Q_1 to 1 as shown in the timing diagram. Therefore, the next output word is Q=0010.

The third clock pulse advances Q_0 to 1, at this stage Q_0 is having +ve rising edge, so Q_1 output will not change then the counter output is Q=0011.

The fourth clock pulse forces the Q_0 flip-flop to reset and carry. In turn, the Q_1 flip-flop resets and carry, in turn, the Q_1 flip-flop resets and carry.

The resulting output word is Q = 0100.

The fifth clock pulse gives Q = 0101.

The sixth clock pulse gives Q = 0110.

and the seventh pulse gives Q = 0111.

ON the eighth clock pulse Q_0 resets and carrier, Q_1 resets and carrier, Q_2 resets and carry, and Q_3 advances to 1. So the output word becomes Q = 1000.

The ninth clock pulses gives Q = 1001.

The tenth gives Q = 1010 and so on

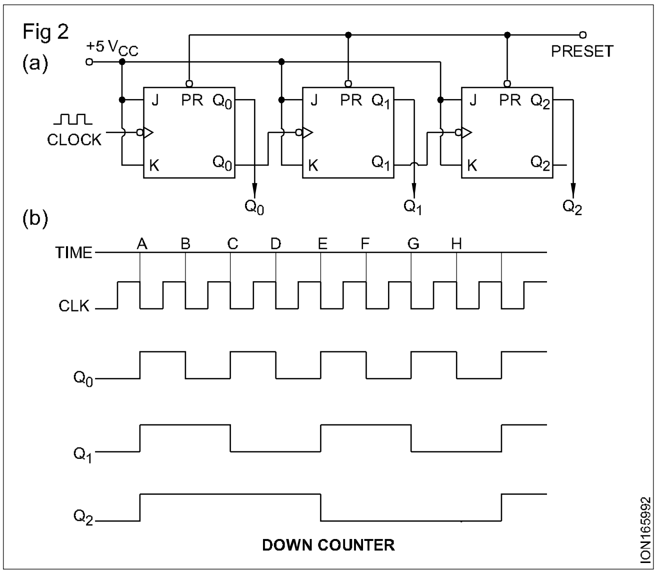
at the 15th clock pulse Q = 1111

The 16th clock pulse resets all flip-flops. Therefore the counter resets to Q = 0000 and the cycle repeats.

By adding more flip-flops to the left end of the counter circuit, the counter length can be extended. Eight flip-flops gives an 8 bit ripple counter, twelve flip-flops result in a 12 bit ripple counter and so on. The timing diagram is shown in Fig 1b.

Down counter

The counter discussed above is an up counter, counts from 0 to 15 [0000 to 1111]. If a counter counts from 1111 to 0000 then it is called DOWN counter. In a down counter Q output as shown in Fig 2 is connected to the clock input of the next flip-flop. Each flip-flop toggles when its clock input goes from 1 to 0. Flip flop Q_0 toggles with each negative clock transition as before. But flip flop Q_1 will toggle each time Q_0 goes high. Notice that each time Q_0 goes high, Q_0 goes low, and it is this negative transition on Q_0 that triggers Q_1. The timing diagram is in Fig 2b.



A low preset signal sets all output, producing an output word of Q = 1111.

When pre goes high, the action starts.

The first clock pulse produces a negative toggle in Q_0, nothing else happens. Q = 1110

The second clock pulse produces a positive toggle in Q_0, which produces a negative toggle in Q_1. Q = 1101

On the third clock pulse Q_0 toggles negatively and Q = 1100

On the fourth clock pulse, Q_0 toggles positively Q_1 toggles positively and Q_2 toggles negatively. Q = 1011.

Likewise counting down from 15-0 takes place, when count reaches 0, i.e.Q=0000, on the next clock pulse, all flip-flops toggles positively to get Q=1111 and the cycle repeats.

Modulo -10 Counter

Asynchronous Decade counters

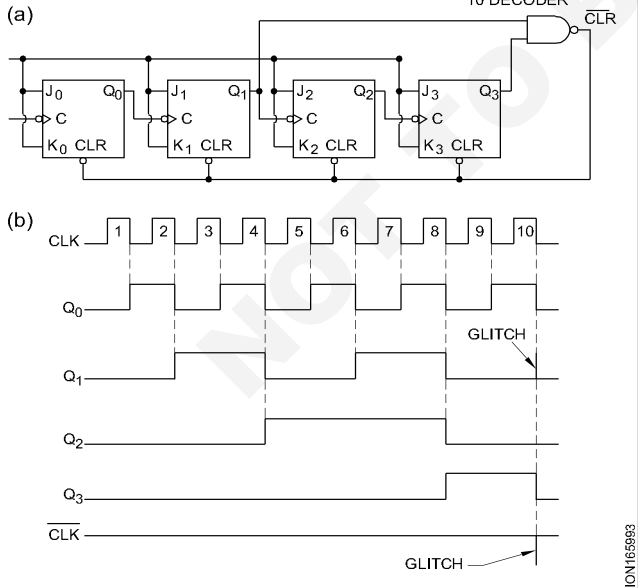
Regular binary counters have a maximum modulus, which means they progress through all of their possible states. The maximum possible number of states (maximum modulus) of a counter is 2^n, where n is the number of flip-flops in the counter.

Counters can also be designed to have a number of states in their sequence that is less than the maximum of 2". The resulting sequence is called a truncated sequence.

One common modulus for counters with truncated sequence is ten. Counters with ten states in their sequence (modulus-10) are called decade counters. A decade counter with a count sequence of zero (0000) through nine (1001) is a BCD decade counter because its ten-state sequence is the BCD code. This type of counter is useful in display applications in which BCD is required for conversion to a decimal readout.

To obtain a truncated sequence, it is necessary to force the counter to recycle before going through all of its normal states. For example, the BCD decade counter must recycle back to the 0000 state after the 1001 state. A decade counter requires four flip-flops (three flip-flops are insufficient because $2^3 = 8$).

Fig 3



We will use a 4-bit asynchronous counter such as the one in Fig 3 and modify its sequence to illustrate the principle of truncated counters. One way to make the counter recycle after the count of nine (1001) is to decode count ten (1010) with a NAND gate and connect the output of the NAND gate to the clear ($\overline{CLR}$) inputs of the flip-flops, as shown in Fig 3.

Notice in Fig 3 that only Q_1 and Q_3 are connected to the NAND gate inputs. This arrangement is an example of partial decoding, in which the two unique states (Q_1=1 and Q_3=1) are sufficient to decode the count of ten, because none of the other states (zero through nine) have both Q_1 and Q_3 HIGH at the same time. When the counter goes into count ten (1010), the decoding gate output goes LOW and asynchronously resets all the flip-flops.

The resulting timing diagram is shown in Fig 3. Notice that there is a glitch on the Q_1 waveform. The reason for this glitch is that Q_1 must first go HIGH before the count of ten can be decoded. Not until several nanoseconds after the counter goes to the count of ten does the output of the decoding gate go LOW (both inputs are HIGH) . Thus, the counter is in the 1010 state for a short time before it is reset to 0000, thus producing the glitch on Q_1 and the resulting glitch on the CLR line which resets the counter.

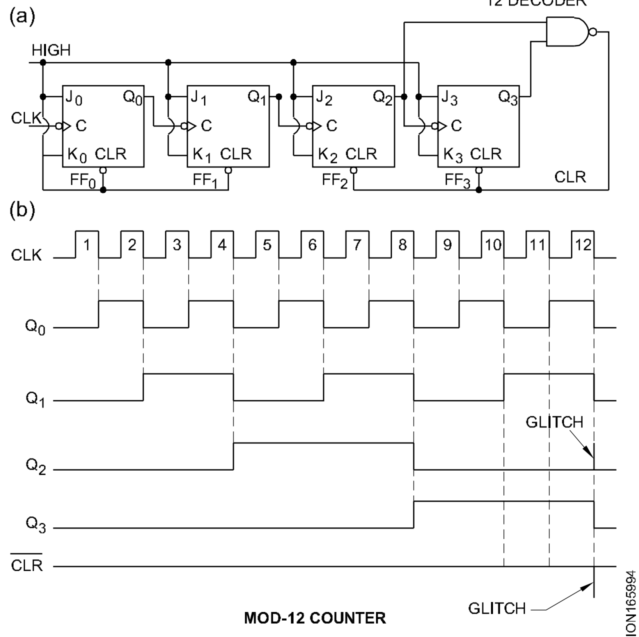
Other truncated sequences can be implemented in a similar way.

Modulo-12 counter

An asynchronous counter can be implemented having a modulus of twelve with a straight binary sequence from 0000 through 1011 as shown in Fig 4a.

Since three flip-flops can produce a maximum of eight states, four flip-flops are required to produce any modulus greater then eight but less than or equal to sixteen.

Fig 4



When the counter gets to its last state, 1011, it must recycle back to 0000 rather than going to its normal next state of 1100, as illustrated in the following sequence chart:

Observe that Q_0 and Q_1 both go to 0 anyway, but Q_2 and Q_3 must be forced to 0 on the twelfth clock pulse. Fig 4a shows the modulus-12 counter. The NAND gate partially decodes count twelve (1100) and resets flip-flop 2 and flip-flop 3. Thus, on the twelfth clock pulse, the counter is forced to recycle from count eleven to count zero, as shown in the timing diagram of Fig 4b. (It is in count twelve for only a few nanoseconds before it is reset by the glitch on CLR)

Chart

Q_3	Q_2	Q_1	Q_0	
0	0	0	0	Recycles
.	.	.	.	
.	.	.	.	
.	.	.	.	
1	0	1	1	
1	1	0	0	Normal next state

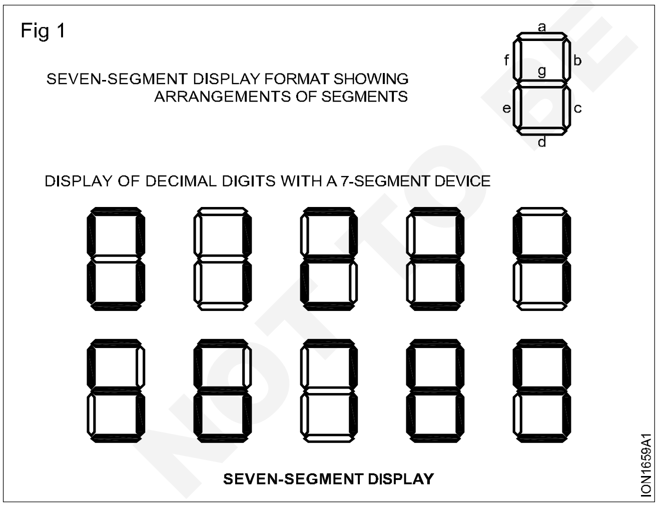
Types of seven segment display

Objectives: At the end of this lesson you shalll be able to
- **explain the constructional details and working of LED type seven segment display**
- **state the need and advantages of multiplexing**
- **explain the process of multiplexing and four digit multiplexed display.**

7-segment display

7 segment displays are used with logic circuits that decode a binary coded decimal (BCD) number and activate the appropriate digits on the display.

The Fig 1 shows a common display format composed of seven elements or segments. Energising certain combinations of these segments can cause each of the ten decimal digits to be displayed. The Fig-b shows the method of digital display for each of the ten digits by using a block segment to represent one that is energized. To produce decimal 'one' on display, segments b and c are energized, to produce 'two' segments a_1,b_1,g_1,e_1 and d_1 are used and so on.

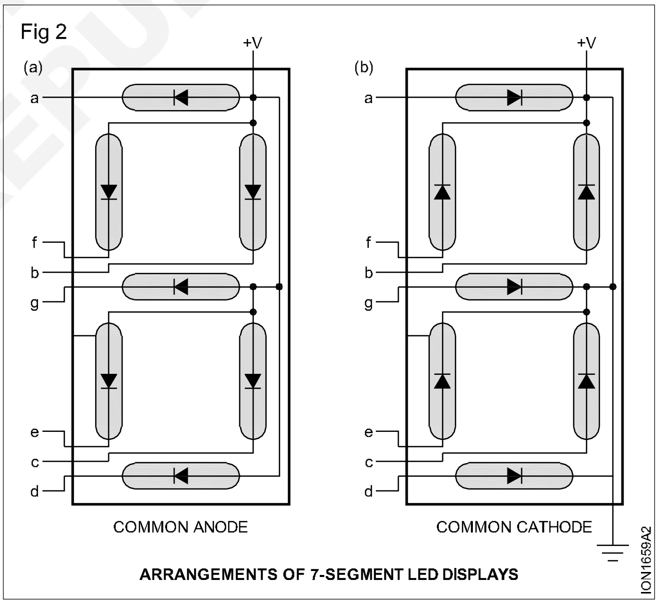


LED display

One common type of 7-segment display consists of light-emitting diodes (LED) arranged as shown in Fig 2. Each segment is an LED that emits light when there is current through it.

The Fig 2 (a) is common anode arrangement requires the driving circuit to provide a low-level voltage in order to activate a given segment, when a low is applied to a segment input, the LED is turned ON and there is current through it.

In Fig 2(b)the common cathode arrangement requires the driver to provide a high level voltage to activate a segment. When a high is applied to a segment input. The LED is turned ON and there is current through it.



LCD display

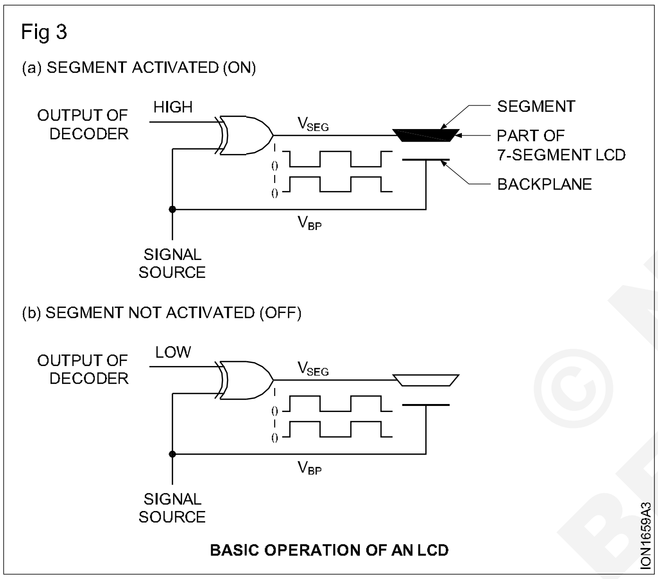
Another common type of 7 segment display is the liquid crystal display (LCD), LCDs operate by polarizing light so that a non activated segment reflects incident light and thus appears invisible against its back ground. An activated segment does not reflect incident light and thus appears dark. LCDs consume much less power than LEDs but can't be seen in the dark, while LEDs can.

LCDs operate from a low frequency signal voltage (30 Hz to 60 Hz) applied between the segment and a common element called the back plane (bp).

The Fig 3 shows a square wave used as the source signal. Each segment in the display is driven by an Ex-OR gate with one input connected to an output of the seven segment decoder/driver and the other input connected to the signal source. When the decoder/driver output is high the Ex-OR output is a square wave that is 180° out of phase with the source signal. The resulting voltage between the LCD segment and back plane is also a square wave because when $V_{seg} = 1$, $V_{bp} = 0$, and vice-versa. The voltage difference turns the segmnet ON.

When the decoder/driver output is low(0), the Ex-OR output is a square wave that is in-phase with the source signal, the resulting voltage difference between the segment and the back plane is 0 because $V_{seg} = V_{bp}$. This condition turns the segment off.

For driving LCDs TTL, is not recommended, because its low-level voltage is typically a few tenths of a volt, thus creating a DC component across the LCD, which degrades its performance. Therefore, CMOS is used in LCD applications.

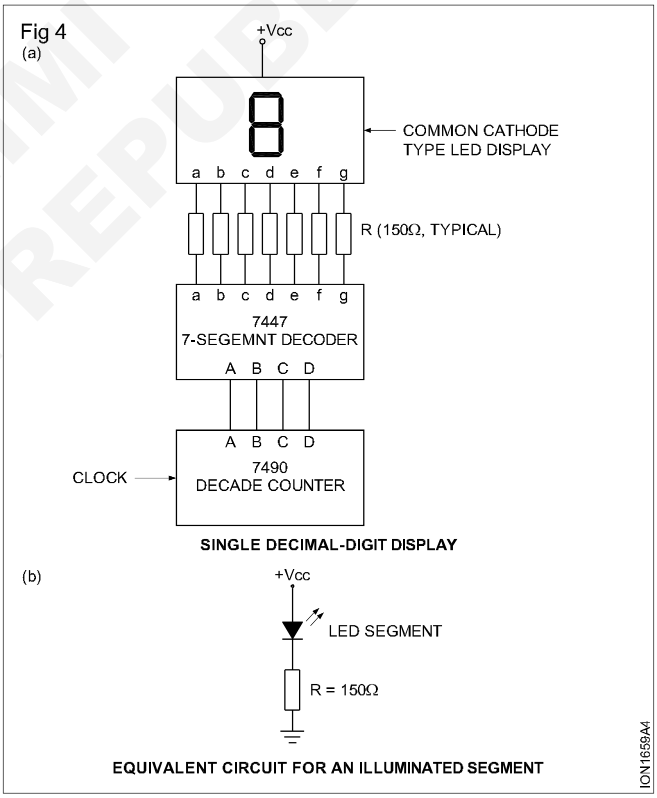


BASIC OPERATION OF AN LCD

In most of the electronic circuits displays are one common integral block. One hardly finds an electronic circuit interacting with real world, not having one kind or the other display module. The decimal outputs of digital instruments such as digital voltmeters(DVMs), frequency counters, event counters and analog parameter indicators are often displayed using seven segment indicators. Such indicators are constructed by using a fluorescent bar, a liquid crystal bar, or a LED bar for each segment. LED type indicators are convenient because they are directly compatible with TTL circuits, do not require the higher voltages used with fluorescents, and are generally brighter than liquid crystals. On the other hand, LEDs do generally require more power than either of the other two types. Multiplexing is a technique used to reduce display power requirements and the complexity of the display interface circuit. The circuit in Fig 1a is a common anode, LED type,seven segment indicator used to display a single decimal digit. The 7447 BCD-to-seven segment decoder is used to drive the indicator, and the four inputs to the 7447 are the four flip-flop outputs of the 7490 decade counter. The 7447 has active low outputs, so the equivalent circuit of an illuminated segment is in Fig1b. The counter counts upward at the rate of the clock input and the equivalent decimal number will appear on the display.

A similar single decimal digit display using a common cathode type LED indicator is possible with seven segment decoder IC 7448 whose outputs are active high. A buffer amplifier is additionally required as the output current capabilities are too small to drive LEDs directly. This is shown in Fig 5. The npn transistors act as switches to connect dc supply to a segment. When an output of the 7448 is high, a transistor is on, and current is supplied to a LED segment. When the output of 7448 is low, the transistor is off, and segment does not illuminate.

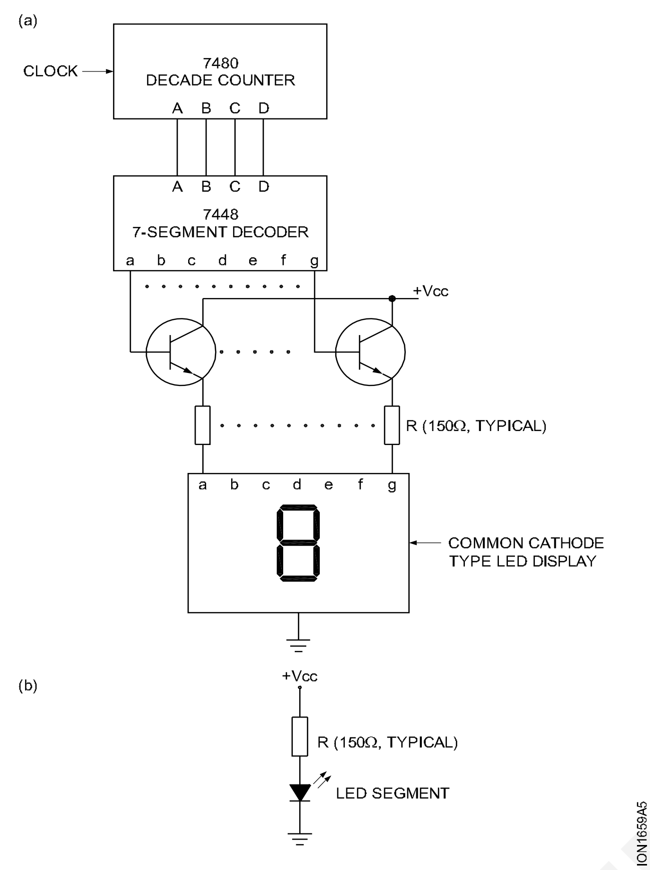
Let us calculate power required for the single digit display of Fig 4. A segment is illuminated when the output of 7447 goes low, causing a 2V drop across it and a current I = (5-2)/150 = 20mA flows through the segment. To display number 8, the indicator require 7x20mA= 140mA. 7447 itself need about 64mA, totalling to 200mA for a single digit display. A digital instrument with four digit decimal display will therefore require 4x200mA = 800mA of current and four such counters and decoders.



EQUIVALENT CIRCUIT FOR AN ILLUMINATED SEGMENT

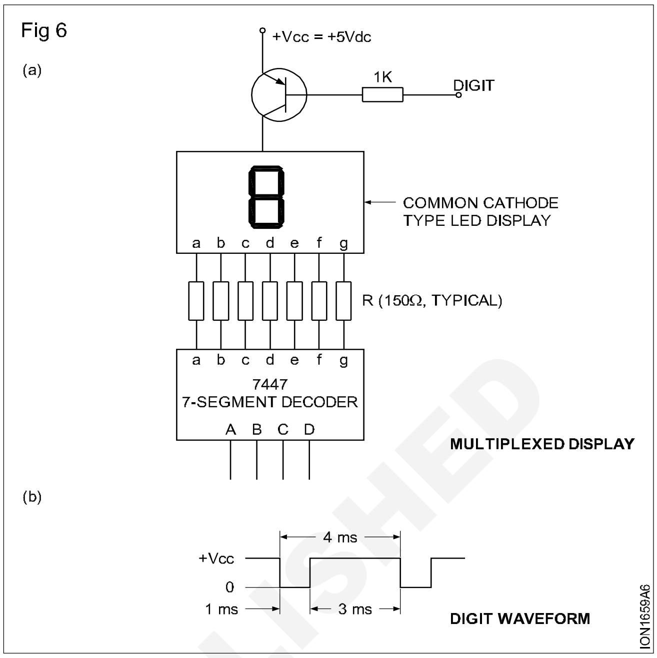
As the no. of digits increase so also the current requirements. These currrent requirements are too much large for small instruments, which can be reduced greatly using a technique known as MULTIPLEXING.Display multiplexing is a process of applying current to each display digit for a very short time interval,but repeatedly. If the pulse repetition rate is sufficiently high, one's eye perceive a steady illumination without any flicker. Indicators illuminated using 50 or 60Hz is reasonably good for flicker free operation.

Fig 5



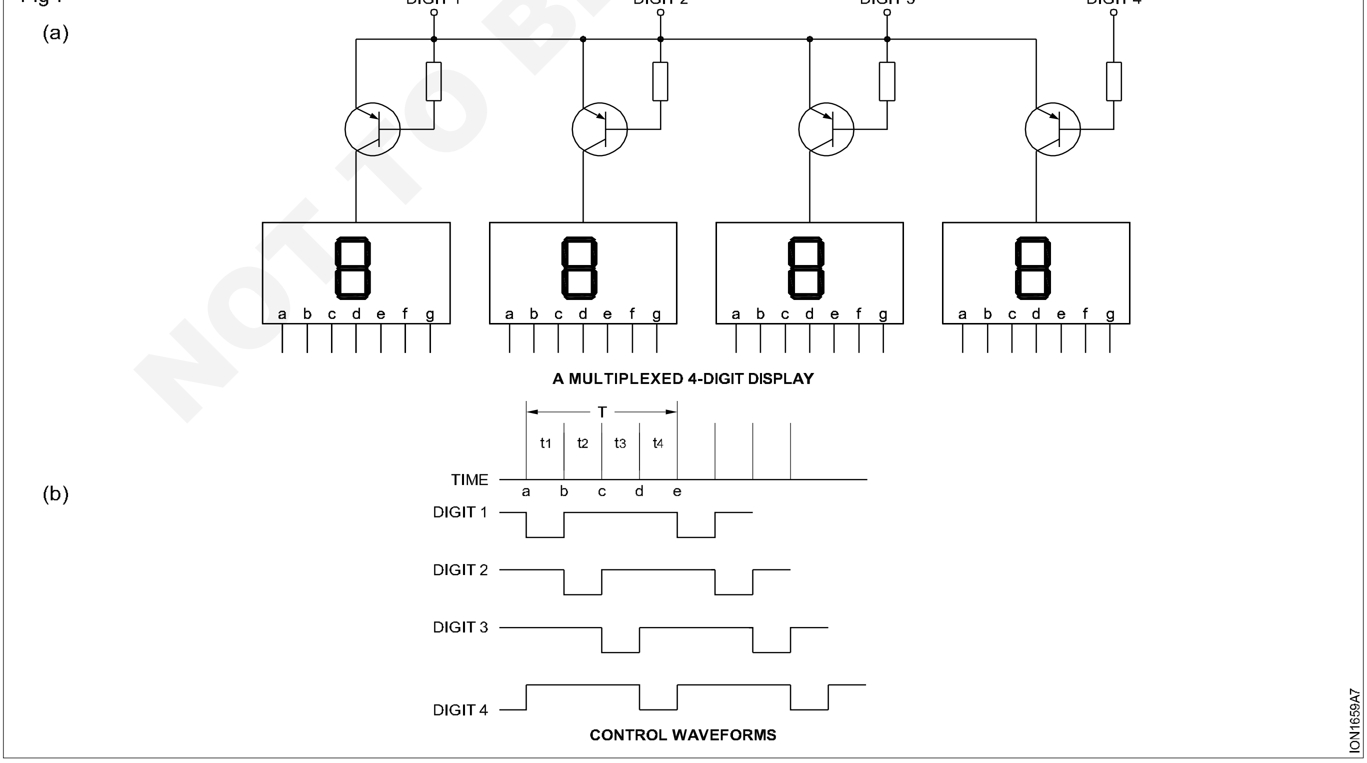
A single digit display shown in Fig 6a can be multiplexed by applying a waveform as shown in Fig 6b. When DIGIT input is high, the transistor is on and a number is displayed. With the waveform as DIGIT input the segment will display a number for only 1 out of every 4 ms. The display is not illuminated for 3 out of 4 ms but to our eyes it looks as if it is continous.with a pulse rate 4ms, the repetition rate would be 1/4ms=250 Hz. The great advantage here is that this single digit display requires only one fourth the current of a continuously illuminated display. This is the great advantage of multiplexing.

Fig 6



Let us discuss how to multiplex the multiple digit display. Fig 7 shows the multiplexing of four digit display, the BCD inputs to each digit are unchanging. If we apply four no's of similar waveforms as in Fig6b to the four DIGIT inputs, each digit will be illuminated for one fourth of the time and extinguished for three fourths of the time.Look at the timing diagram Fig 7b and see that the digit1 is illuminated druing time t1, digit 2 during time t2 and so on. It is very clear from the waveforms that t1=t2=t3=t4T/4. Suppose t1=1ms then T=4ms and repetition rate(RR)=1/0.004=250Hz, this rate is suffiecient for flicker free operation.

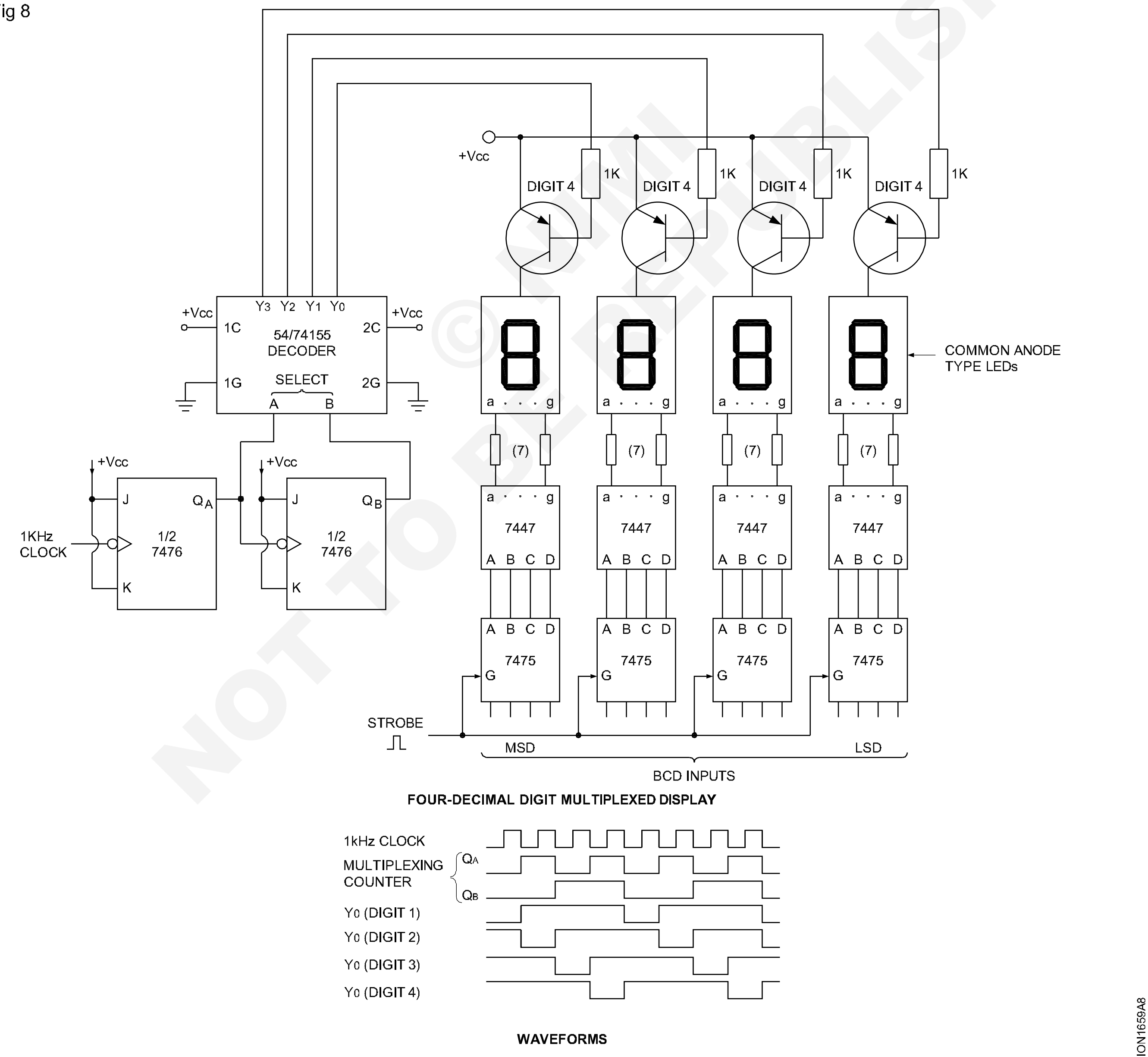
Fig 7



The most important point to be remembered with the multiplexing of displays is that an illuminated digit requires 200mA and since only one digit is illuminated at a time, the current required from the supply is always 200mA. By multiplexing we are illuminating four indicators but using the current required of only a single indicator. Hence multiplexing displays in this way, the power suplly current is simply the current required of a single display, no matter how many displays are being multiplexed.

Now the question is how to generate the DIGIT control waveforms show in Fig 7b. A fulfledged four decimal digit multiplexed display is shown in Fig 8. This circuit is capable of displaying decimal numbers from 0000 to 9999. The 54/74155 is a dual 2-line-to-4 line decoder-demultiplexer and it is driven by a two flip flop binary counter called the multiplexing counter. As this counter counts, only one of the 74155 output lines will go low for each counter state. As a result, the DIGIT control waveforms exactly like those in Fig 7b, will be generated. A savings in components as well as power can be realized if four inputs(ABCD) to the seven segment decoder are multiplexed along with the DIGIT control. The BCD input data is stored in four 7475 D-type latches. Each latch stores a bit and connected to MSD (Most Significant Digit) to LSD(Least Significant Digit). The BCD data can be latched in to the latches by providing a positive going strobe pulse to all the 7475 latches.The BCD input can be applied using thumbwheel switches. The 7476 is a clocked J-K FlipFlop used for generating the address to the SELECT lines. Depending on the address applied at the SELECT input lines, one of the output lines of the decoder 75155 goes low, selecting a specific digt by pulling the base of the transistor to a logical low. If a transistor connected to any of the digits turned on, that particular digit will be illuminated and displays the BCD number connected to it. Similary the next digit can be selected by changing the address input connected at SELECT input. Now the speed of this whole operation can be changed by applying a different clock frequency to the input of the JK FlipFlops CLOCK input pin.

Fig 8



Commercially LSI chips are available that have all the multiplexing accompllished on a single chip. Examples of this are National Semiconductor's MM74C925, 926, 927 & 928. The only external components needed are the seven segment indicators and current limiting resistors.

Zero suppression

This feature is used for multi-digit displays to blank out unnecessary zeros. For example, in a 6-digit display the number 6.4 may be displayed as 006.400 (i.e) the reading zeros are not blanked out. Blanking the zeros at the front of a number is called leading zero suppression and blanking the zeros at the back of the number is called trailling zero suppression. Keep in mind that only non essential zeros are blanked. With zero suppression, the number 030.080 will be displayed as 30.08.

Zero suppression in the 7447 is accomplished using the RBI and BI/RBO functions. RBI is the ripple blanking input and RBO is the ripple blanking output on the 7447. These are used for zero suppression. BI is the blanking input which shares the same pin with RBO, in the other words the BI/RBO pin can be used as an input or an output. When used in BI mode, all segment outputs are high (non active) with BI is low, which over rides all other inputs. The BI function is not part of the zero suppression capability of the device.

All of the segment outputs of the decoder are non active [HIGH] if a zero code (0000) is on its BCD inputs and if its RBI is low. This causes the display to be blank and produce low RBO. The application zero suppression will be dealt in Digital clock.

BCD display and BCD to decimal decoder, BCD to 7 segment display circuits

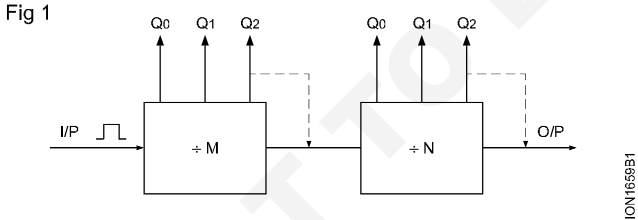
Objectives: At the end of this lesson you shalll be able to
- **define cascaded counter**
- **explain the function I.C 7490 decade counter**
- **explain decoder and its application**
- **explain BCD-to-decimal decoder**
- **explain BCD-to-7 segment decoder driver IC 7447**
- **explain 7 segment display and their types and application.**

Cascaded counters

Counters can be connected in cascade to achieve higher modules of operation, cascading means that the last-stage output of one counter drives the input of the next counter.

The Fig 1 shows the two counters [÷M & ÷N] connected in cascade. The final output of the cascaded counter at output occurs once for every M x N clock pulses. The overall modules of the cascaded counters is (MxN); that is they act as ÷[MN] counter. In general the overall modules of cascaded counters is equal to the product of the individual modules.

Fig 1



DM7490 decade counter

DM7490A is a T.T.L MSI decade counter, contains four master slave flip-flops, a careful examination will reveal that flip-flops Q_B, Q_C and Q_D form a MOD-5 counter, and Q_A a divide-by-two counter.

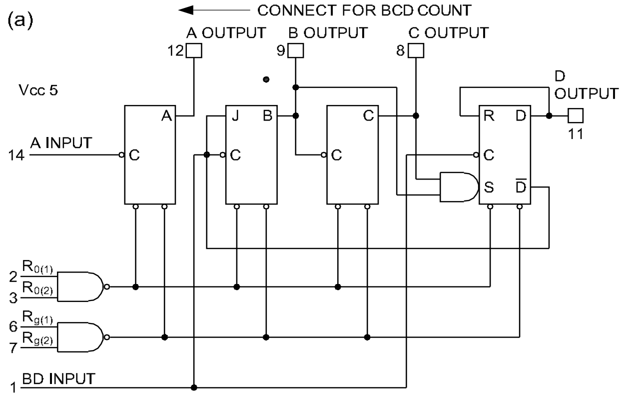
All of these counters have a gated zero reset and the LS-90 also has gated set-to-nine inputs for use in BCD applications. Refer Fig 2 for the detailed internal block diagram.

To use their maximum count length (decade), the output A is connected to the input BD. The input count pulses are applied to input A and the outputs are as described in the appropriate truth table. A symmetrical divided by ten count can be obtained from the LS90 counters by connecting the Q_D output to the 'A' input and applying the input count to the B input which gives a divided-by-ten square wave at output Q_A.

When reset pins [$R_{o(1)}$ and $R_{o(2)}$] are applied with logic high, an outputs Q_A, Q_B, Q_C and Q_D resets to logic zero are shown in reset/count truth table. To keep counter in count mode one of the reset inputs should be in logic 0(low) state.

Fig 2

(a)



(b)

TRUTH TABLES

BCD COUNT SEQUENCE

COUNT	OUTPUT			
	A	B	C	D
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	0	0	1
9	1	0	0	1

GND 10

OUTPUT A CONNECTED TO INPUT BD

RESET/COUNT

RESET INPUTS				COUNT
$R_{0(1)}$	$R_{0(2)}$	$R_{g(1)}$	$R_{g(2)}$	
1	1	0	ϕ	0 0 0 0
1	1	ϕ	0	0 0 0 0
ϕ	ϕ	1	1	1 0 0 1
ϕ	0	ϕ	0	COUNT
0	ϕ	0	ϕ	COUNT
0	ϕ	ϕ	0	COUNT
ϕ	0	0	ϕ	COUNT

ϕ - IMMATERIAL

BCD COUNTER

ION1659B2

The $R_{g(1)}$ and $R_{g(2)}$ inputs are used to preset the counter o/p to BCD nine, to achieve this condition inputs $R_{g(1)}$ and $R_{g(2)}$ should be in logic high state and one of the reset inputs should be in logic 0(low) state. [Ref truth table] During this condition NAND gate o/p will be logic zero and this output is connected to the preset inputs of I[st] and last flip-flop, and sets Q_A and Q_D to logic-1 then the counter reading is 1001.

Decoder

The basic function of a decoder is to detect the presence of a specified combination of bits(code) on its inputs and to indicate the presence of that code by a specified output level. In its general form, a decoder has 'n' input lines to handle 'n' bits and from one to 2^n output lines to indicate the presence of one or more n-bit combinations.

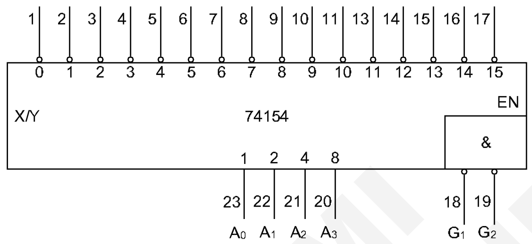
The 4-bit decoder

In order to decode all possible combinations of four bits, sixteen decoding gates are required [2^4 =16]. This type of decoder is commonly called a 4 line to 16 line decoder because there are four inputs and sixteen outputs or a 1-of-16 decoder because for any given code on the inputs, one of the sixteen outputs is activated. The Fig 3 shows the 74154, 4 line to 16 line decoder and the truth table.

BCD-to-Decimal decoder

The BCD-to-decimal decoder converts each BCD code (8421 code) into one of ten possible decimal digit indications. It is frequently referred to as a 4 line to 10 line decoder or a 1-of-10 decoder. The method of implementation is the same as for the 4 line to-16 line decoder, except that only ten decoding gates are required because the BCD code represents only the ten decimal digits 0 through 9.

Fig 3



LOGIC SYMBOL

DECIMAL DIGIT	BINARY INPUTS A_3	A_2	A_1	A_0	DECODING FUNCTION	OUTPUTS 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	$\overline{A}_3\ \overline{A}_2\ \overline{A}_1\ \overline{A}_0$	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	0	0	0	1	$\overline{A}_3\ \overline{A}_2\ \overline{A}_1\ A_0$	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	0	1	0	$\overline{A}_3\ \overline{A}_2\ A_1\ \overline{A}_0$	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	1	1	$\overline{A}_3\ \overline{A}_2\ A_1\ A_0$	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
4	0	1	0	0	$\overline{A}_3\ A_2\ \overline{A}_1\ \overline{A}_0$	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
5	0	1	0	1	$\overline{A}_3\ A_2\ \overline{A}_1\ A_0$	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
6	0	1	1	0	$\overline{A}_3\ A_2\ A_1\ \overline{A}_0$	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
7	0	1	1	1	$\overline{A}_3\ A_2\ A_1\ A_0$	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
8	1	0	0	0	$A_3\ \overline{A}_2\ \overline{A}_1\ \overline{A}_0$	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
9	1	0	0	1	$A_3\ \overline{A}_2\ \overline{A}_1\ A_0$	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
10	1	0	1	0	$A_3\ \overline{A}_2\ A_1\ \overline{A}_0$	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
11	1	0	1	1	$A_3\ \overline{A}_2\ A_1\ A_0$	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
12	1	1	0	0	$A_3\ A_2\ \overline{A}_1\ \overline{A}_0$	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
13	1	1	0	1	$A_3\ A_2\ \overline{A}_1\ A_0$	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
14	1	1	1	0	$A_3\ A_2\ A_1\ \overline{A}_0$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
15	1	1	1	1	$A_3\ A_2\ A_1\ A_0$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0

FUNCTIONS AND TRUTH TABLE FOR A 4 - LINE - TO - 16 - LINE DECODER WITH ACTIVE - LOW OUTPUTS

ION1659B3

7447 BCD-to-7 segment decoder/driver

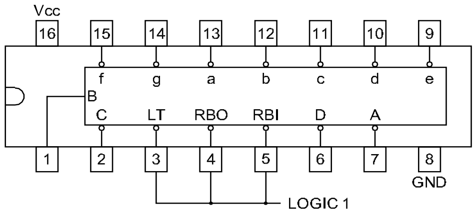
The 7447 [also 74LS47] is an MSI device that decodes a BCD input and drives a 7-segment display. In addition to its decoding and segment drive capability, the 7447 has several additional features as indicated by the LT, RBI and BI/RBO functions in the logic symbol of Fig 4 shown below, as indicated by the bubbles on the logic symbol, all of the outputs (a through g) are active-low as are the LT (lamp test) RBI (ripple blanking input), and BI/RBO [Blanking input (ripple blanking output)] functions. The outputs can drive a common anode 7 segment display directly.

Lamp test

When a low is applied to the LT input and the BI/RBO is high, all of the 7 segments in the display are turned on, lamp test is used to verify that no segments are defective.

Fig 4

(a) PIN LAYOUT



(a) TRUTH TABLE

DECIMAL	INPUTS				OUTPUTS						
0	D	C	B	A	a	b	c	d	e	f	g
0	0	0	0	0	1	1	1	1	1	1	0
1	0	0	0	1	0	1	1	0	0	0	0
2	0	0	1	0	1	1	0	1	1	0	1
3	0	0	1	1	1	1	1	1	0	0	1
4	0	1	0	0	0	1	1	0	0	1	1
5	0	1	0	1	1	0	1	1	0	1	1
6	0	1	1	0	1	0	1	1	1	1	1
7	0	1	1	1	1	1	1	0	0	0	0
8	1	0	0	0	1	1	1	1	1	1	1
9	1	0	0	1	1	1	1	1	0	1	1

BINARY TO 7 - SEGMENT DECODER (7447)

ION1659B4

Basics of register, types and application of registers

Objectives: At the end of this lesson you shalll be able to
- **state the basic functions of a shift register**
- **list and define the different configurations of shift register**
- **explain the function of IC7495 in different configurations.**

Introduction to shift registers

A shift register is a very important digital building block. Registers are often used to momentarily store binary information appearing at the output of an encoding matrix. A register might be used to accept input data from an alphanumeric keyboard and then present this data at the input of a microprocessor chip. Similarly, shift registers are often used to momentarily store binary data at the output of a decoder. For instance, a register could be used to accept output data from a microprocessor chip and then present this data to the circuitry used to drive the display on a CRT screen. Thus registers form a very important link between the main digital system and the input-output channels.

A binary register also forms the basis for some very important arithmetic operations. For example, the operations of complementation, multiplication, and division are frequently implemented by means of a register. A shift register can also be connected to form a number of different types of counters. These counters offer some very distinct advantages.

Types of registers

A register is simply a group of flip-flops that can be used to store a binary number. There must be one flip-flop for each bit in the binary number. For instance, a register used to store an 8-bit binary number must have eight flip-flops. Naturally the flip-flops must be connected such that the binary number can be entered (shifted) into the register and possibly shifted out. A group of flip-flops connected to provide either or both of these functions is called a shift register.

The bits in a binary number (let's call them the data) can be moved form one place to another in either of two ways. The first method involves shifting the data 1 bit at a time in a serial fashion, beginning with either the MSB or the LSB. This technique is referred to as serial shifting. The second method involves shifting all the data bits simultaneously and is referred to as parallel shifting.

There are two ways to shift data into a register (serial or parallel) and similarly two ways to shift the data out of the register. This leads to the construction of four basic register types as shown in Fig 1 -serial in - serial out, serial in - parallel out, parallel in - serial out, and parallel in - parallel out. All of these configurations are commercially available as TTL MSI/LSI circuits. For instance:

Serial in - serial out - 54/74L91, 8 bits

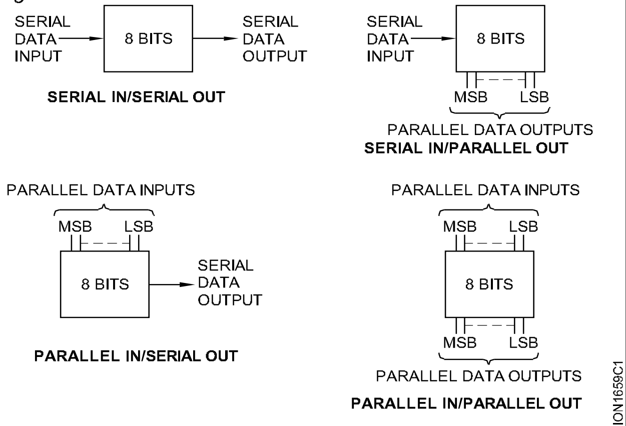
Serial in - parallel out - 54/74164, 8 bits

Parallel in - serial out - 54/75165, 8 bits

Parallel in - parallel out - 54/74194, 4 bits

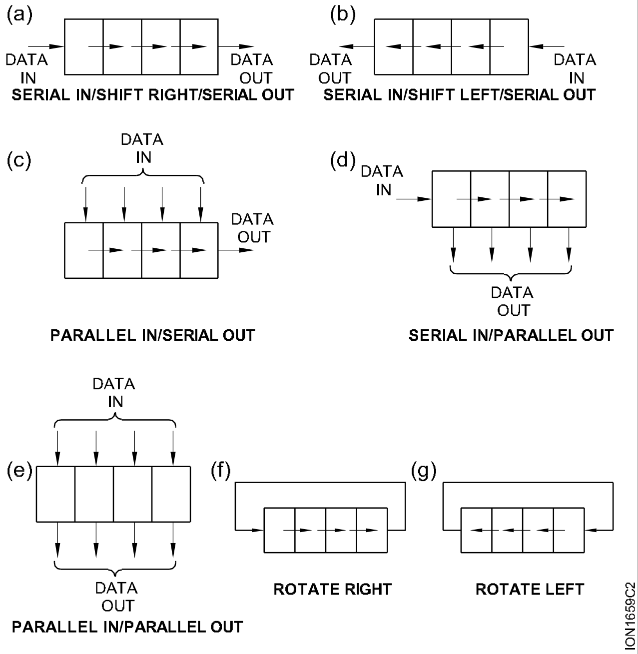
Parallel in - parallel out - 54/74198, 8 bits

Fig 1



The shifting capability of a register permits the movement of data from stage to stage within the register or into or out of the register upon application of clock pulses. Fig 2a to 2g illustrate the types of data movement in shift registers. The block represents any arbitrary 4-bit register and the arrow indicate the direction of data movement.

Fig 2



Serial in - serial out operation

The flip-flops used to construct registers ar usually either JK or D types. So let's begin by summarizing the operation of JK flip-flop.

For a JK flip-flop, the data bit to be shifted into the flip-flop must be present at the J and K inputs when the clock transitions (low or high). Since the data bit is either a 1 or a 0, there are two cases:

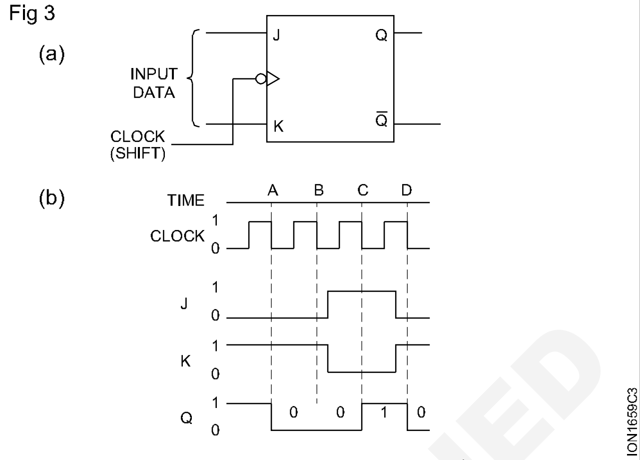
- To shift a 0 into the flip-flop, J=0 and K=1.
- To shift a 1 into the flip-flop, J=1 and K=0.

The important point to note is that the J and K inputs must be controlled to provide the correct input data. The J and K logic levels may be changing while the clock is high (or low), but they must be steady from just before until just after the clock transition (remember, setup time and hold time). For our discussion we shall use JK master-slave flip-flops having clock inputs that are sensitive to negative clock transitions. Incidentally, this negative transition of the clock is frequently referred to as a shift pulse.

The waveforms in Fig 3 illustrate these ideas. At time A, Q is reset low (a 0 is shifted into the flip-flop). At time B, Q does not change since the flip-flop had a 0 in it and another 0 is shifted in. At time C, the flip-flop is set (a 1 is shifted into it). At time D, another 0 is shifted into the flip-flop. In essence, we have shifted 4 data bits into this flip-flop in a time sequence: a 0 at time A, another 0 at time B, a 1 at time C, and a 0 at time D.

Now, consider adding three more flip-flops connected as shown in Fig 4. Let's begin with all the flip-flops reset and then apply the exact same input signals to flip-flop Q as we did in Fig 3. Here's what happens:

Fig 3



At time A: All the flip-flops are reset, so all J inputs are low and all K inputs are high. Then T is reset (the 0 in S is shifted into T). Similarly, the 0 in R is shifted S, the 0 in Q is shifted into R, and the 0 at the data input is shifted into Q. The flip-flop outputs just after time A are QRST = 0000.

At time B: The flip-flops all contain 0s. Thus the 0 in S is shifted into T, the 0 in R shifts into S, the 0 in Q shifts into R, and the 0 at the data input shifted into Q. The flip-flop outputs are QRST = 0000.

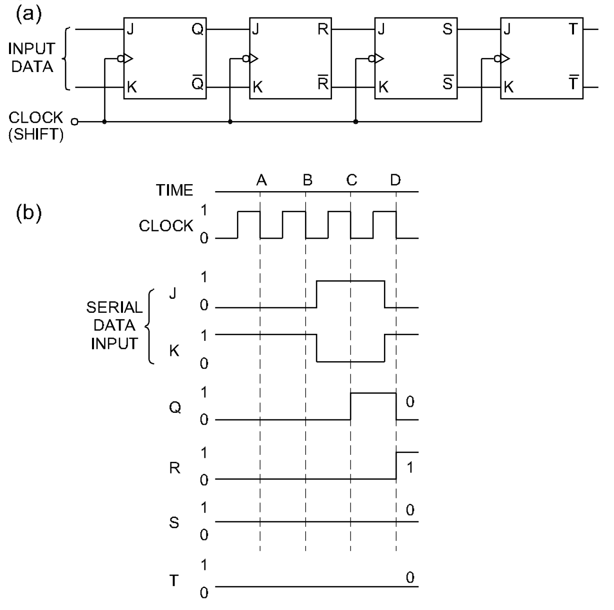
At time C: The flip-flops still all contain 0s. The 0 in S shifts into T, the 0 in R shifts into S, and the 0 in Q shifts into R, but a 1 at the data input now shifts into Q. The flip-flop outputs are QRST = 1000.

At time D: The 0 in S shifts into T, the 0 in R shifts into S, the 1 in Q shifts into R (the J input to R is high and the K input is low), and the 0 at the data input shifts into Q. The flip-flop outputs are QRST = 0100.

To summarize, we have shifted 4 data bits in a serial fashion into four flip-flops. These 4 data bits could represent a 4-bit binary number 0100, assuming that we began shifting with the LSB first. Notice that the LSB is in T and the MSB is in Q. These four flip-flops could be defined as a 4-bit shift register; thus this is the technique used to construct a serial-input shift register.

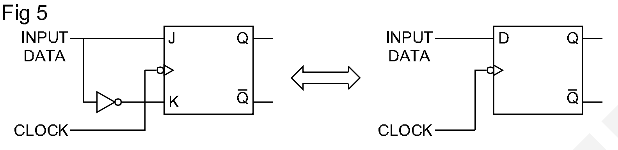
The serial data input for the register shwon in Fig 4 requires two input signals J and K. But look carefully at the waveforms. Clearly, K = J, or J=K. In other words, one signal is always the complement of the other. If we were to connect an inverter between J and K on flip-flop Q with the input at J, therefore, we would need to have only one data input signal - the one required for J. But this is precisely a D-type flip-flop as shown in Fig 5. Remember the rules for a type D flip-flop; on the negative clock transition, the data present at the D input (either a 1 or a 0) will shift into the flip-flop.

Fig 4



Thus the 4-bit serial input shift register shown in Fig 5 can be constructed by replacing the JK flip-flops wth type D flip-flops.

Fig 5



Serial In Parallel Out (SIPO)

Data is entered serially into this type of register, and data bits are taken out of the register parallel from the output of each stage. Once the data bits are stored, each bit appears on its respective output line, and all bits are available simultaneously, rather than on a bit-by-bit basis as with the serial output.

The Fig 6a shows the SIPO shift register using J.K.flip-flops. All the inputs are tied to the compliment of J-inputs. The clock, preset and clear inputs are -ve edge triggered.

Initially all the flip-flops are cleared to logic-0 state by applying logic-0 pulse to the clear inputs.

Fig 6

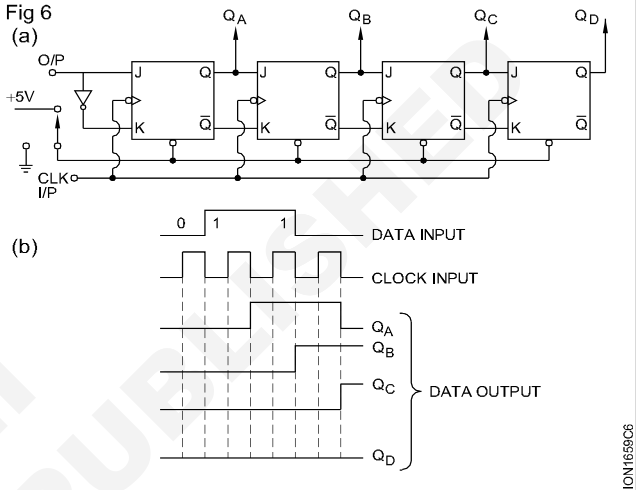
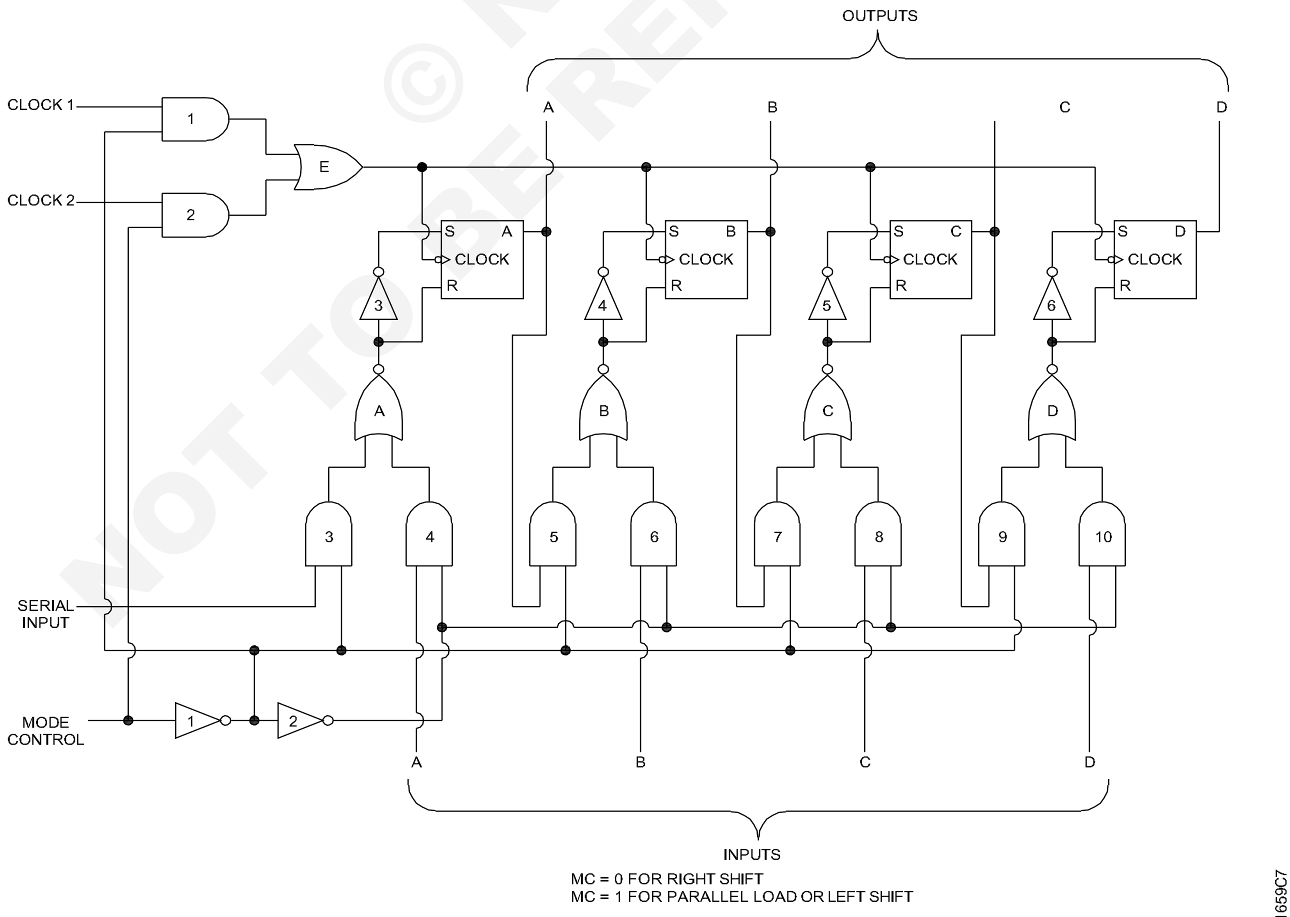


Fig 7



4-BIT RIGHT-SHIFT LEFT-SHIFT REGISTER

The sequence of shifting logic information is shown in Fig 6b which gives waveform diagrams of data input, data output and clock input.

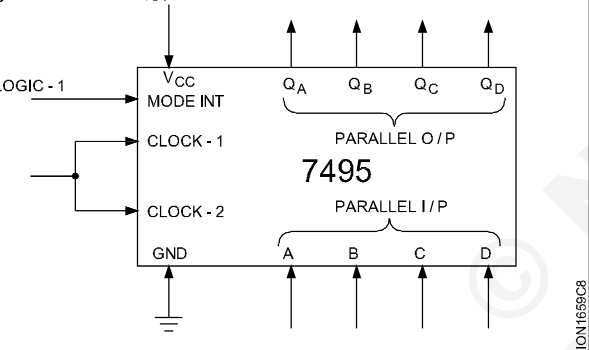
4-bit right-shift left-shift register IC7495

The Fig 7 shows the internal logic diagram of 4 bit shift register with parallel load capability, and with all flip-flop outputs available. This makes it possible to perform the right shift or left shift operation under control of the mode control input. For greater flexibility, the mode control selects clock-1 for the right shift mode and clock 2 for the parallel load (left shift) mode. The clock 1 and clock 2 inputs are tied together if only one clock source is required. Data transfer occurs once the -ve going edge of the clock pulse occurs.

Parallel In Parallel Out (PIPO)

The Fig 8 shows the pins to be used for parallel in parallel out operation in IC7495. For this operation mode control should be kept at logic high. Clock 2 should selected for applying clock pulse, data inputs are to be connected to the A,B,C & D parallel inputs, data output can be taken simultaneously from Q_A, Q_B, Q_C and Q_D.

Fig 8



When mode control is at logic high, inverter 1 output will be at logic-0. Hence AND gates 1,3,5,7 and 9 are disabled because one of the inputs of those gates will be at logic-0. Therefore clock 1 and serial inputs will be disconnected from the flip-flops. At the same time AND gates 2,4,6,8 and 10 are enabled because, both the AND gate inputs of enabled gates will have high inputs simultaneously, when clock is high. Hence only clock 2 and parallel inputs are routed to the flip-flop inputs. Falling edge of the clock pulse, transmits the data information from parallel inputs to parallel outputs, simultaneously.

This type of register requires very less time (i.e one clock pulse) for transfer 1 set of parallel data information.

Serial In Serial Out (SISO)

The Fig 9 shows the pins to be used for SISO operation in IC 7495. When the mode control input is at logic-0 condition inverter 1 (refer functional diagram of 7495 for inter blocks) output will be at logic-1 and that enables AND gates 3,5,7,9 and 1. AND gate-1 selects clock-1 status for triggering flip-flops through OR gate. AND gates 3,5,7,9 selects serial input data. At the same time inverter-2 output will be at logic-0 that disables AND gates 4,6,8,10 thus disconnecting all parallel inputs A,B,C and D reaching flip-flop 4 clock pulses are required to transfer data from input to output of the shift register.

If the outputs are taken from all the outputs Q_A, Q_B, Q_C and Q_D, then this register works like serial in parallel out (shift right) register.

Serial In Parallel Out (shift left)

The Fig 10 shows external wiring diagram for serial in parallel out shift left register. For shift left operation mode control signal level should be logic-1.

Fig 9

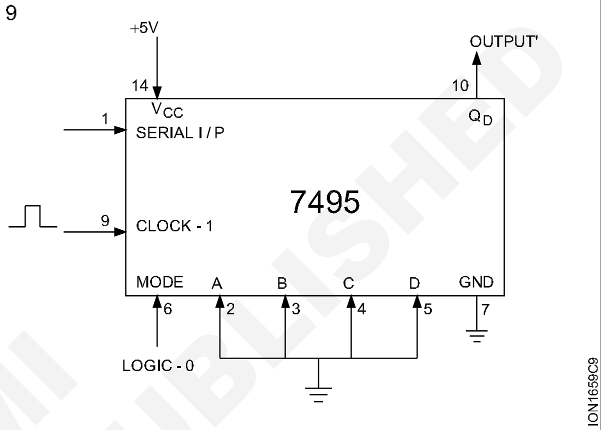
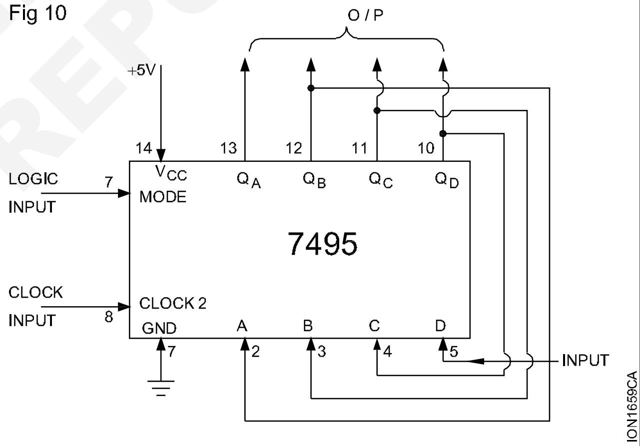


Fig 10



Data input is applied to the parallel input-D remaining parallel inputs A, B and C receives signals from the outputs Q_B, Q_C and Q_D respectively as shown in Fig 10.

When mode control signal is at logic-1 AND gate 2 is enabled and AND gate 1 is disabled. Hence all the flip-flops get triggering pulse from clock 2. At the same time AND gates 3,5,7 and 9 are disabled and AND gates 4,6,8 and 10 are enabled, therefore parallel inputs A,B,C and D routed to the flip-flops inputs, and serial input is disabled from the flip-flops. The data input given at the D input is shifted left as the clock pulse progress. To move data from Q_D to Q_A, 4 clock pulses are required.

Basic blocks of a computer, components of desktop and motherboard

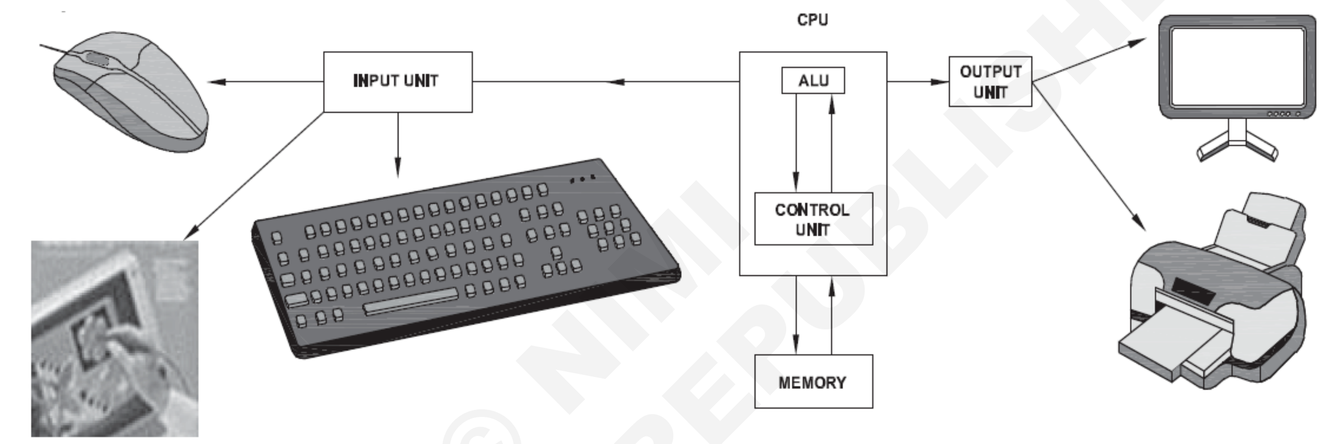
Objectives: At the end of this lesson you shall be able to
- **explain the basics of computer**
- **identify various peripheral devices.**
- **identify and explain computer connection and ports**
- **explain the main components on the mother board**
- **explain the types of cables used in computer**
- **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.

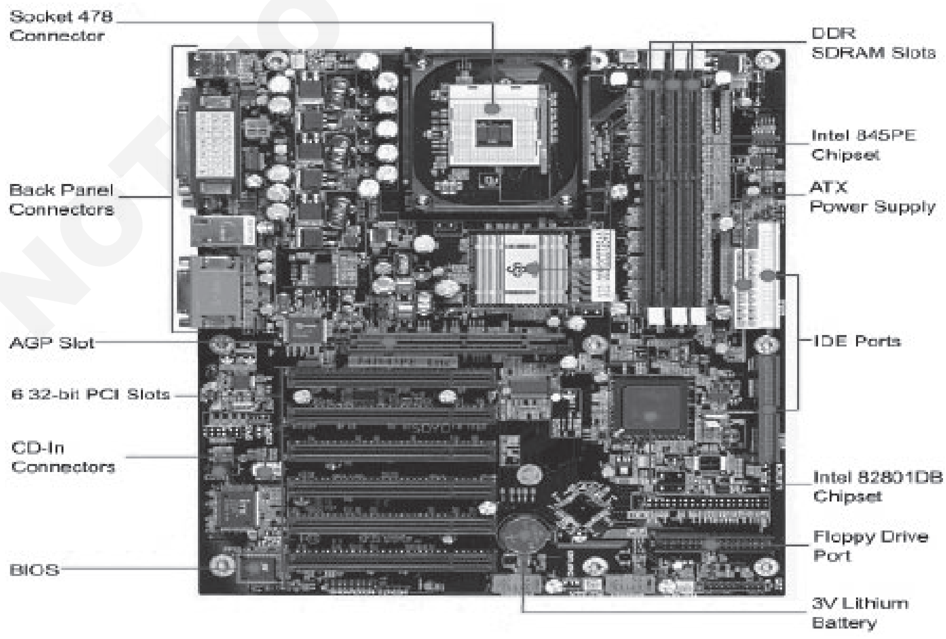
System components

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.

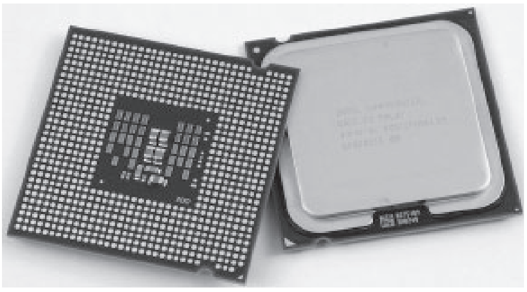
Fig 2



- Processor slot
- Processor voltage regulators
- Motherboard chipset
- Level 2 cache
- Memory SIMM or DIMM sockets
- Bus slots
- ROM BIOS
- Clock / CMOS battery
- 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.

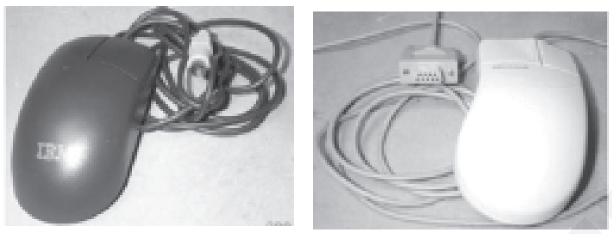
Keyboard

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

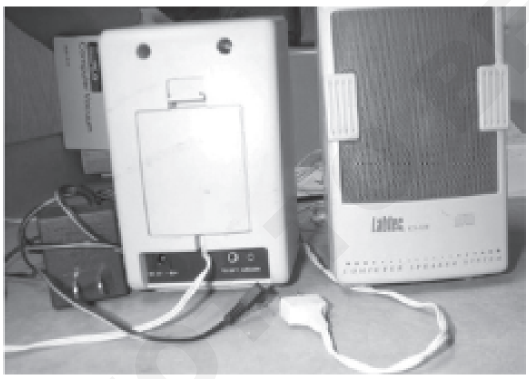
Fig 5



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.

- Position the CPU in the desired location.
- Connect one end of the **network cable** to the back of the CPU (location A**)** and the other to the wall jack.
- Connect the **keyboard** to the back of the CPU (location D).
- Connect the **mouse** to the back of the CPU (location E).
- Connect the **monitor cable** to the back of the CPU (location C).
- Connect the monitor power cable to the power source.
- 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.
- 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.
- 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

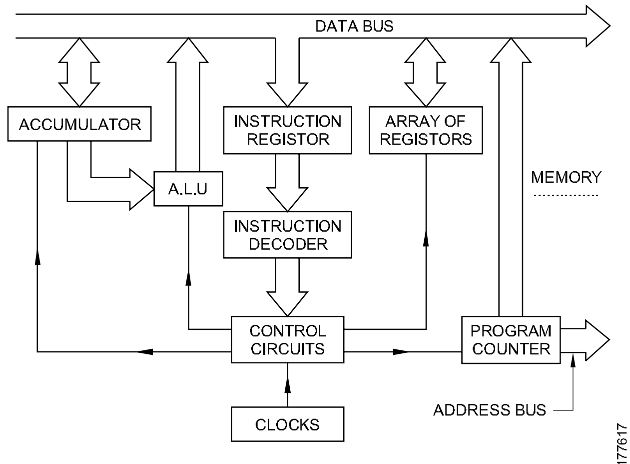
1 **Memory**: This is the area used by the processor to store raw data and instructions

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. (Fig 7)

It contains three units viz.,

1 Memory units (internal , called as registers)

Fig 7



BLOCK DIAGRAM OF A MICROPROCESSOR CHIP

2 Arithmetic Logic Unit (ALU)

3 Control Unit

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.

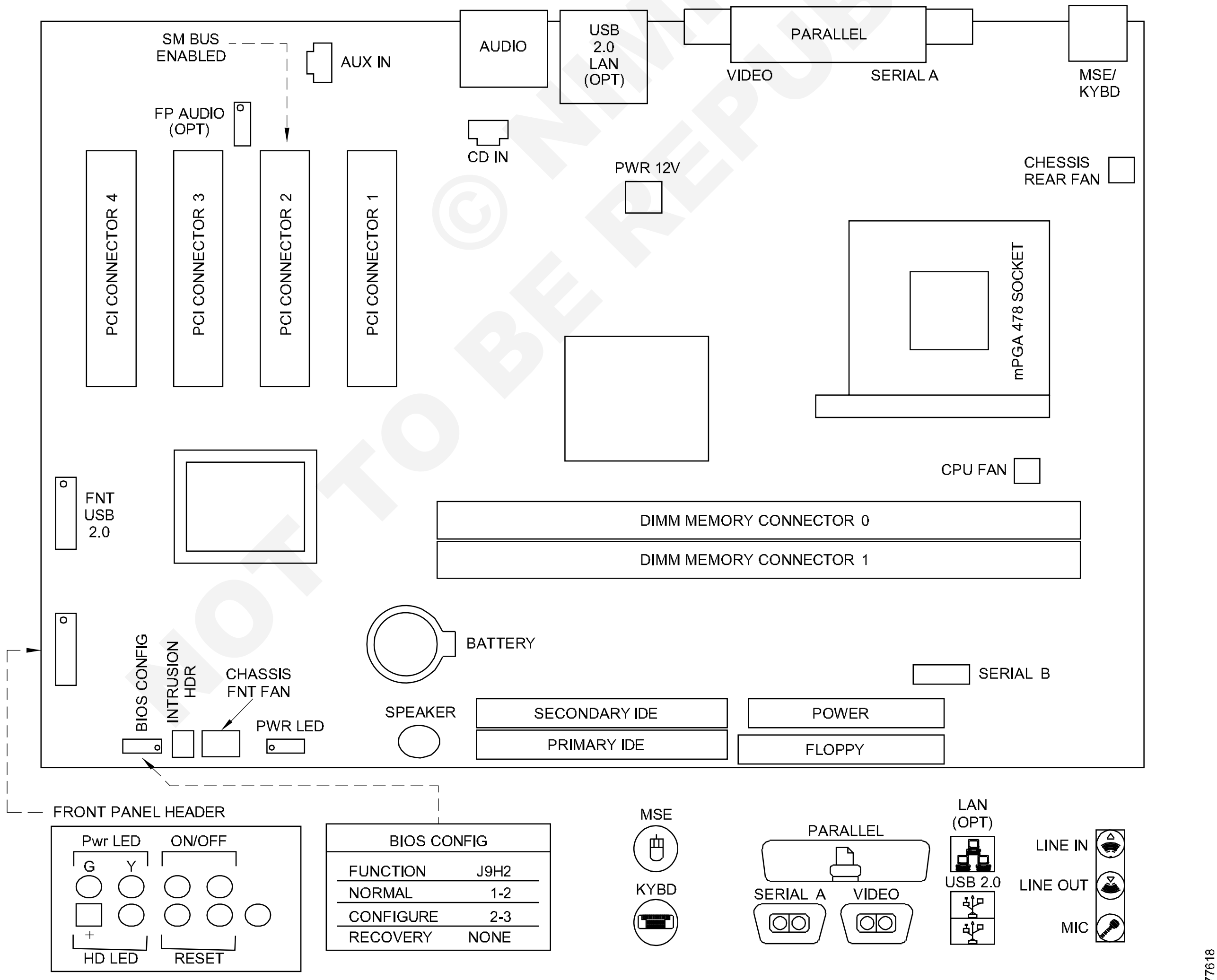
Arithmetic Logic Unit (ALU): This unit does arithmetic calculations and logical operations involved in the program, such as addition, multiplication, comparison etc.,

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

- Put on anti- static wrist strap.
- 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.
- Remove the boards mounting screw which fixes the metal mounting bracket of the add- on card.
- 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.

- Place the card preferably in an antistatic mat such that the components on the card are visible to you.
- Identify and record the jumper settings on the card.
- Identify and record the switch setting if any on the mother board.
- 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.

- The olden type-5 pin –DIN connector
- The more recent type -6 pin P/S -2 connector.
- 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).

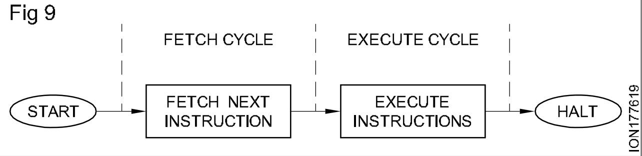
Program Counter (PC): It keeps track of the instruction which is to be executed next, after the execution of an ongoing instruction.

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

- Motherboard varies greatly in supporting various types of components.
- Normally, a motherboard supports a single type of CPU and few types of memories.
- Video Cards, Hard disks, Sound Cards have to compatible with motherboard to function properly.
- Mother boards, cases and power supplies must be compatible to work properly together.

Computer - Memory Units

- It is the amount of data that can be stored in the storage unit.
- The storage capacity are expressed in terms of Bytes.

Computer - Ports

- A computer port is a physical docking point using which an external device can be connected to the computer.
- A computer port can also be programmatic docking point through which information flows from a program to computer or over the internet.

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).

Hard disk drives, DVD

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

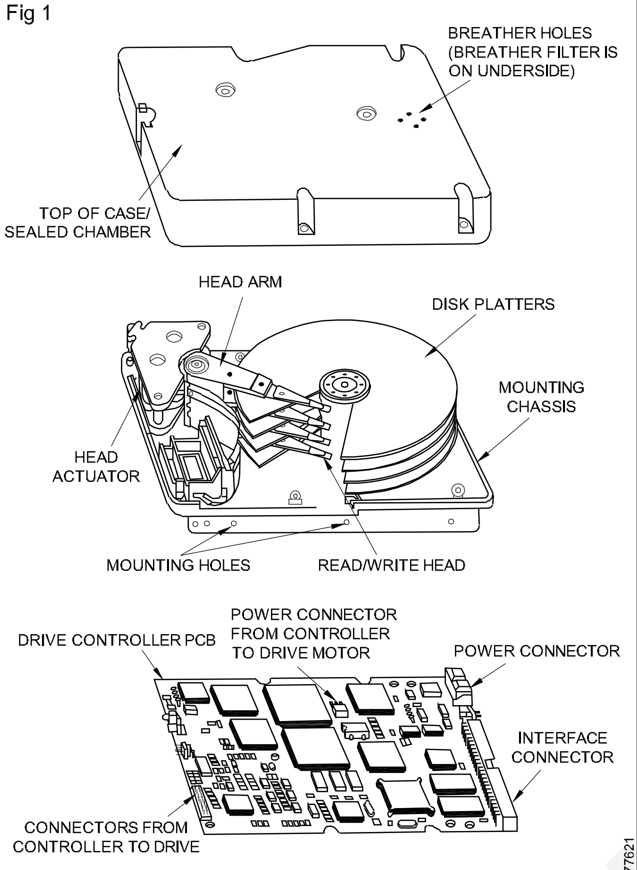
The basic hard disk drive components are as shown in the Fig 1.

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 1



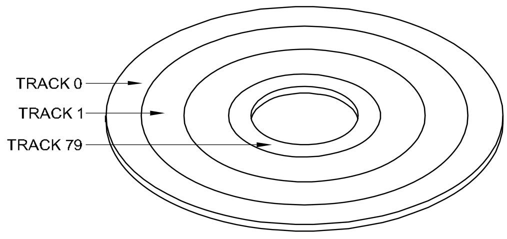
HARD DISK DRIVE COMPONENTS

ION177621

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.

Fig 2



TRACKS ON A PLATTER

ION177622

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.

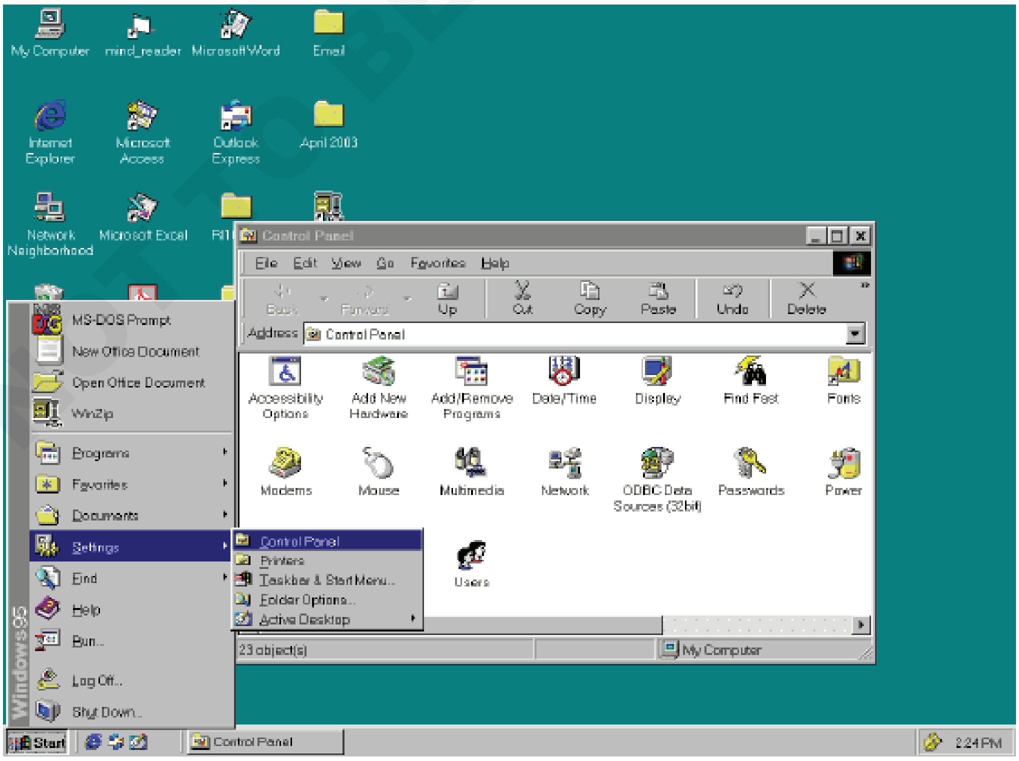
Once operating system is found, the boots trap loader programme loads the operating system components into the memory and hands over the control to the operating system. When the process is complete, the monitor displays A>:/,C:> or windows desktop.

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).

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.

- To set the Windows picture created by the user himself using Paintbrush click on the Browse button.
- Select the file created in the open dialog.
- Observe the preview in the screen within the dialog (as shown).
- 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.

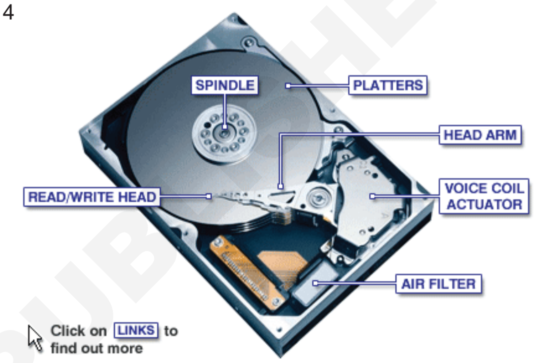
The Currency pages allows you to set some characteristics specific to currency such as the Currency symbol, the Position of currency symbol, the Negative number format, as well as the features just mentioned for use in the Number pages.

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.

- Electrical connections to platter motor.
- Microprocessor chip.
- Programmable flash memory chip.
- Platter motor controller chip.
- S-ATA data connector (the connection between the hard drive and the motherboard).

- 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.

The optic medias

Objectives: At the end of this lesson you shalll be able to
- **descibe about various optical drives**
- **explain the advantages and disadvantages of DVDs.**

CD-ROM and DVD are optic readable media, contrary to hard disks, floppy disks and tapes, which are magnetic.

Fig 1

The optic storage media read with a very thin and very precisely aimed laser beam. They supplement the magnetic media. Data can be packed much more densely in optic media than in magentic media. And they have much longer life span. It is a small plastic disk with a reflecting metal coating, usally aluminum. Myriads of tiny indentations are burned into this coating. These indentations contain the music or data in millions of bits. The CD is organized in tracks. Each track is assigned a number.

In a CD-ROM, the data are stored in sectors, which can be read independently - like from a hard disk.

The CD-ROM has become an important media in the PC world. It can hold 650/700 MB of data, and it is very inexpensive to produce. Today, there are three types of CD drives and DVD drves are available.

Digital video disc

The original acronym came from digital video disc. That DVD, as an international standard, is simply three letters.

How do DVDs work?

DVD digital video disc is a technology based on optical data storage similar to compact disc (CD)... Analog information is converted into digital information, which is then encoded onto the disc from the inside edge out. Digital data are encoded by means of pits on the recording layer of the disc. A single DVD can store 4.7GB of digital data.

What are the different types of DVD?

DVD media comes in several formats; including DVD+R (recordable DVD), DVD-R, DVD=RW (re-writeable DVD), DVD-RW, DVD-RAM (random access memory) and DVD-ROM (read only memory). DVD disc can be played in dedicated DVD players as well as in computers.

Advantages and disadvantages of DVD

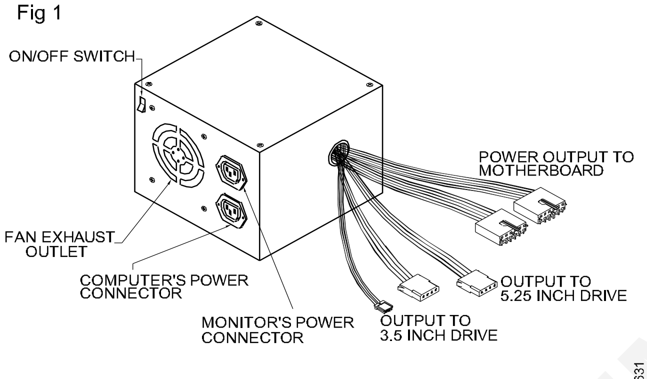
- The important advantage of DVD is the sound and picture quality is excellent, making them ideal for storing films with video and sound.
- And DVDs are now mass produced so they are relatively cheap.
- The disadvantages of DVD is there are several standard followed for DVD system. They can be easily damaged by breaking or scratching.
- The DVD cannot withstand rough handling and can easily be damaged by breaking or scratching.

Working principle of SMPS, its specification

Objectives: At the end of this lesson you shalll 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

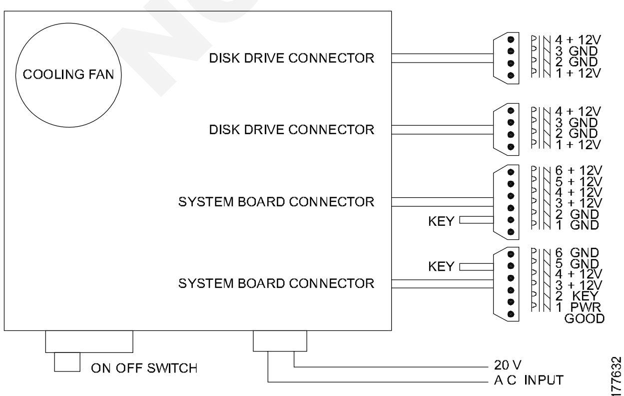
ION177631

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			

Fig 2



INTERFACE CONNECTION

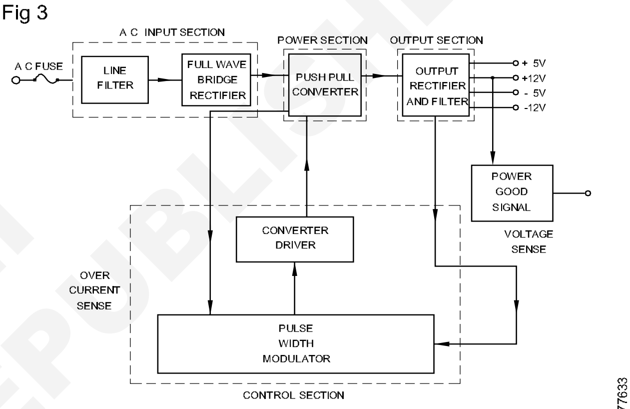
ION177632

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.

Block diagram of SMPS

The block diagram in Fig 3 shows the various functional sections in SMPS.

Fig 3



BLOCK DIAGRAM OF SMPS

ION177633

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.

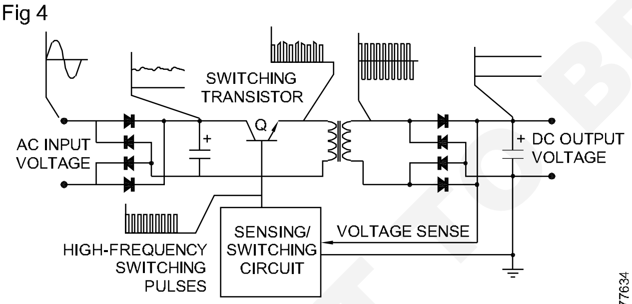
Power good signal section checks for the correct level of DC voltages and gives a power good signal to the motherboard. Power good signal is connected to the reset pin of the processor. Power good signal is given to reset pin after a delay when the voltage levels are correct and satisfactory.

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

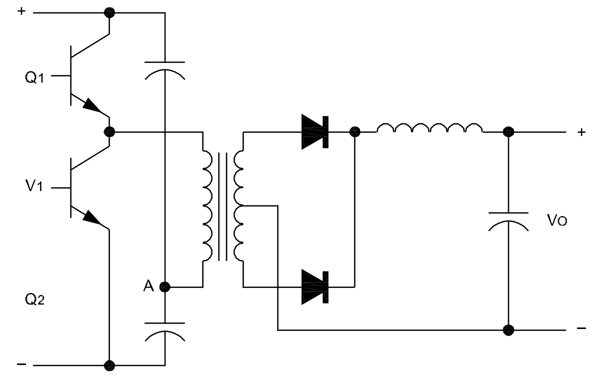


SIMPLIFIED DIAGRAM OF A SWITCHING POWER SUPPLY

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.

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

Fig 5

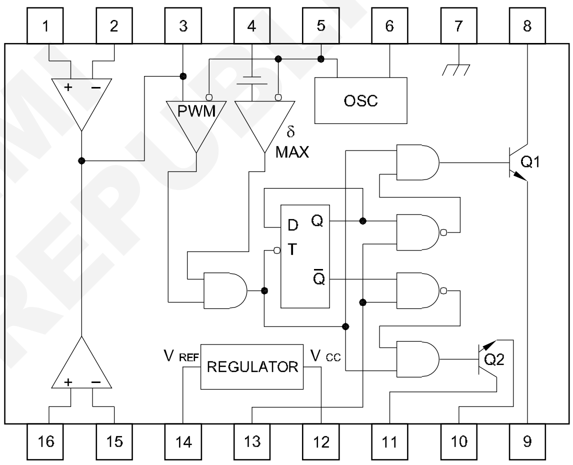


MOST WIDELY USED HALF-BRIDGE CONVERTER CIRCUIT

Pulse width modulation control IC 494

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.

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

ION177636

TL494 BLOCK DIAGRAM AND PIN ASSIGNMENTS

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.

Windows OS MS widows - Starting windows and its operation

Objectives: At the end of this lesson you shalll be able to
- **define microsoft 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.

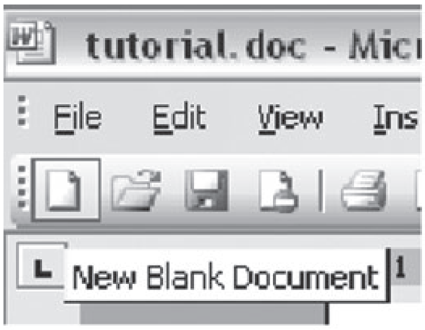
Opening Microsoft Word

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.

- **New Blank Document**

To begin a new document, click on the New Blank Document icon, shaped like a blank sheet of paper.

- **Open**

Clicking on this icon opens up a previously saved document on computer.

- **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.

- **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.

- **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.”

- **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.

- **Spelling and Grammar**

Clicking begins a review of document in search of spelling and grammatical errors that may need to be corrected.

- **Copy**

Copy the current selection to the clipboard, which can then be pasted elsewhere in the document, or into a completely separate program/document.

- **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.

- **Undo Typing**

The Undo Typing button goes back and removes the last addition or change made to document.

- **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.

- **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.

- **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.
- **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.
- **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.
- **Bold:** Places the text in **bold**.
- **Italic:** Places the text in italics.
- **Underline:** Underlines the text.
- **Align Left:** Aligns the selection to the left of the screen/ paper.
- **Center:** Aligns the selection to the center of the screen/ paper.
- **Align Right:** Aligns the selection to the right of the screen/paper.
- **Justify:** Aligns the selection to both the left and right of the screen/paper.
- **Line Spacing:** Adjust the line spacing (single-spaced, double-spaced, etc.)
- **Numbering:** Create a numbered list.
- **Bullets:** Create an unordered, bulleted list.
- **Decrease Indent:** Decreases the indentation of the current selection (to the left).
- **Increase Indent:** Increases the indentation of the current selection (to the right).
- **Outside Border:** Places a border around the current selection; click the drop-down for a wide selection of bordering options.
- **Highlight:** Highlight the current selection; default color is yellow.

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

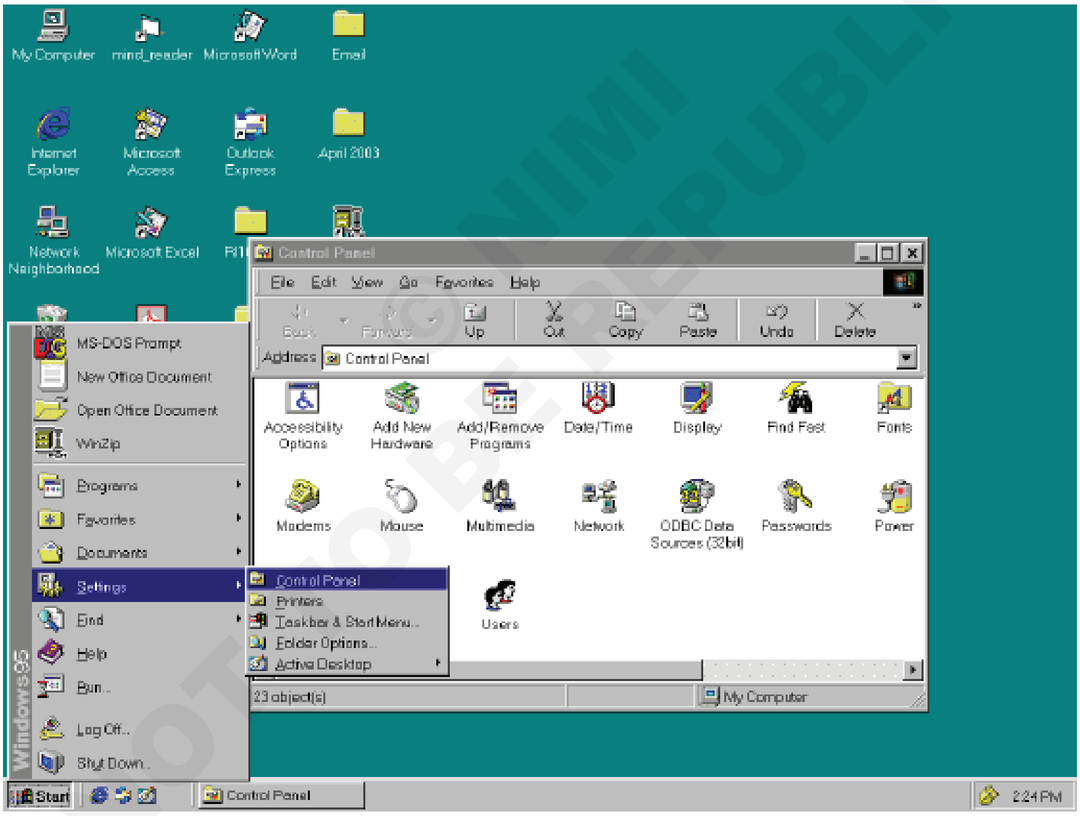
The three basic types of windows installation procedures are as follows:

- 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.

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 2) shows the contents of Control panel.

Fig 2



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).

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.

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

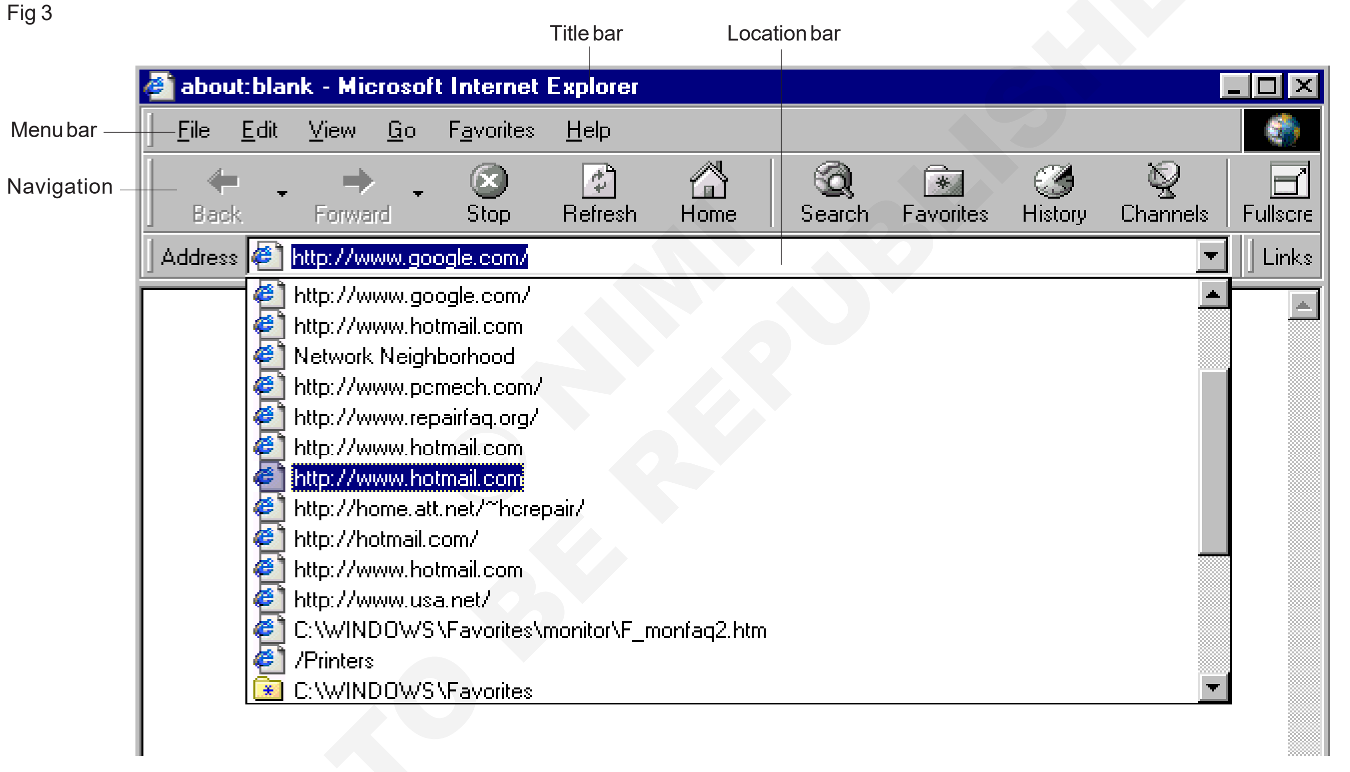
To view the web sites/pages you need a graphical user interface, called a web browser. It is a piece of software, that lets you visit different web sites on the internet and display their pages on your own computer. You can visit the site by supplying the browser with an address or URL.

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.

Fig 3 gives the home page of Microsoft internet explorer.

Fig 3



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.

- Connect your client program/browser to an FTP server.
- Log on as 'anonymous' and give email address as the password.
- Move to the directory on the server that contains the file.
- Specify the directory on computer to store downloaded files.
- Transfer the file from the FTP server to computer.
- 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.

- **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

- **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.

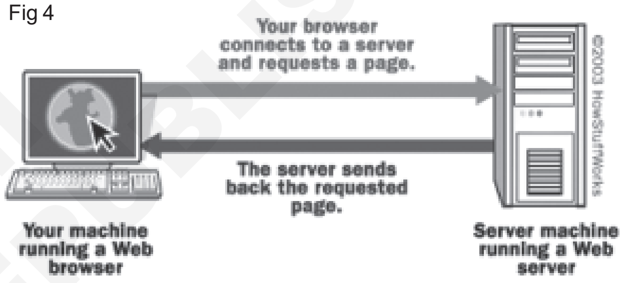
SPAM: Any unwanted and often malicious unsolicited emails. At SHU we try and detect these and mark them appropriately so that they can be deleted by the user without needing to open them.

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 4. Then we will look at the real thing.

Fig 4



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:

- 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.
- 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.
- 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.
- 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:

- Outlook Express connects to the SMTP server at mail.howstuffworks.com using port 25.
- 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.

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.

Specification and standards, types of cables, UTP, STP, coaxial cables

Objective: At the end of this lesson you shalll be able to
- **identify the specification and standards, types of cables, UTP, STP, coaxial cables.**

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

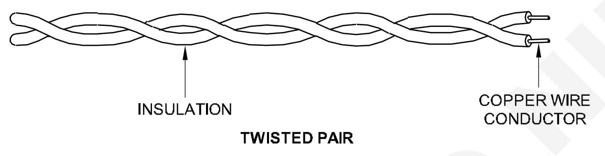
3 Fiber optical cable

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 1. These twisted cables are available in two types.

Fig 1



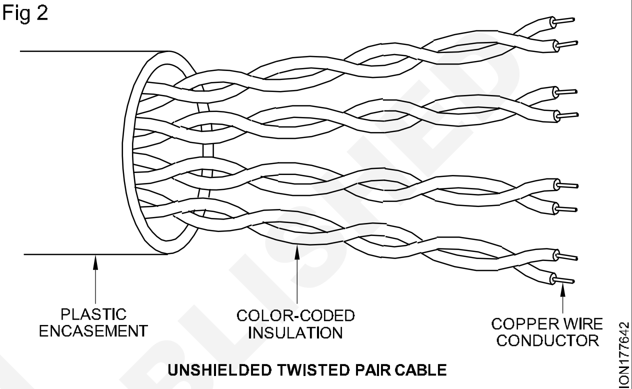
The two types of cables are:

- 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 2.

Fig 2



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 3 shows the STP cable. It is used in places where electromagnetic interference caused by electric motors, power lines and other sources.

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.

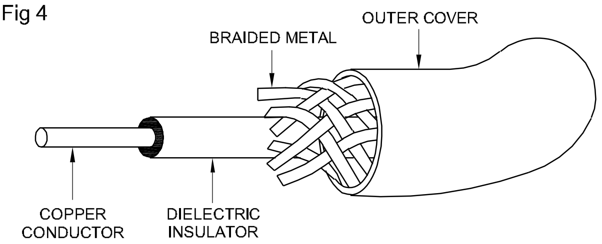
The cabling starts from the Hub or switch which is placed in a Rack centrally. A patch cable (usually 6-10 feet long) connects a port on the hub to a patch panel which is also in the Rack using RJ-45 connectors on each end. On the back side of the patch panel, the UTP cable is hard-wired or crimped to 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 4.

Fig 4



COAXIAL CABLE CROSS-SECTION

ION177644

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.

- 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

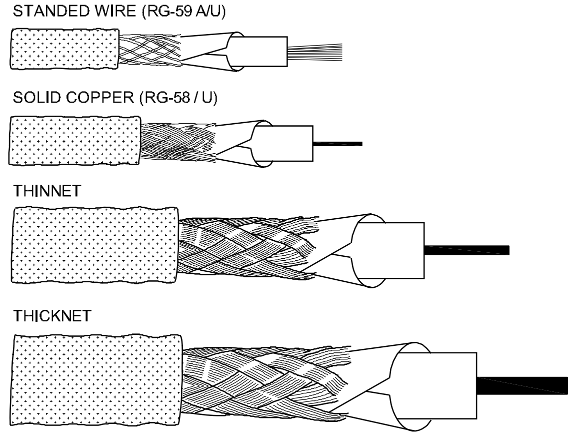
- Thin (Thinnet)
- Thick (Thicknet)

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.

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 5. 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.

Fig 5



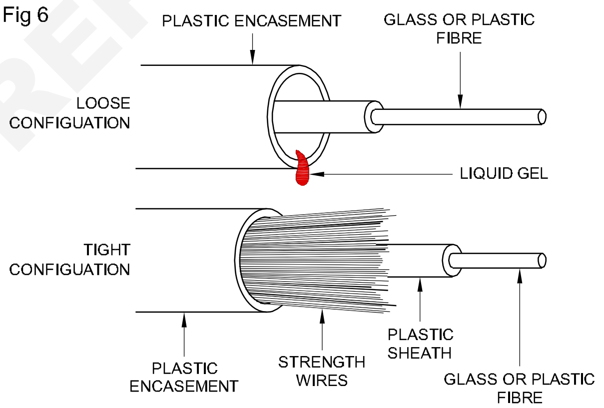
THICKNET CABLE HAS A THICKER CORE THAN THINNET

ION177645

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 6.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.

Fig 6



FIBRE OPTIC CABLE

ION177646

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.

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.

- Repeaters
- Hubs
- Bridges
- Multiplexers
- Transceiver
- 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.

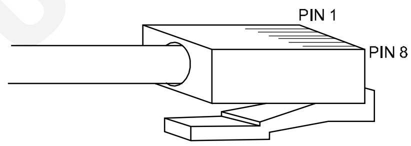
T-connector: A T-shaped co-axial connector that connects two thinnet co-axial cables while supplying an additional connector for a network interface card.

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 7.

Fig 7



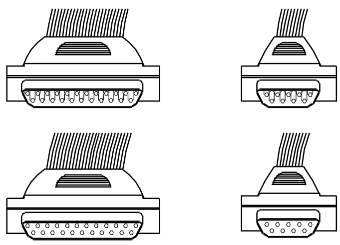
PIN NUMBER	WIRE COLOR
1	WHITE - ORANGE
2	ORANGE
3	WHITE - GREEN
4	BLUE
5	WHITE - BLUE
6	GREEN
7	WHITE - BROWN
8	BROWN

MODULAR CONNECTOR

ION177647

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 8 and 9.

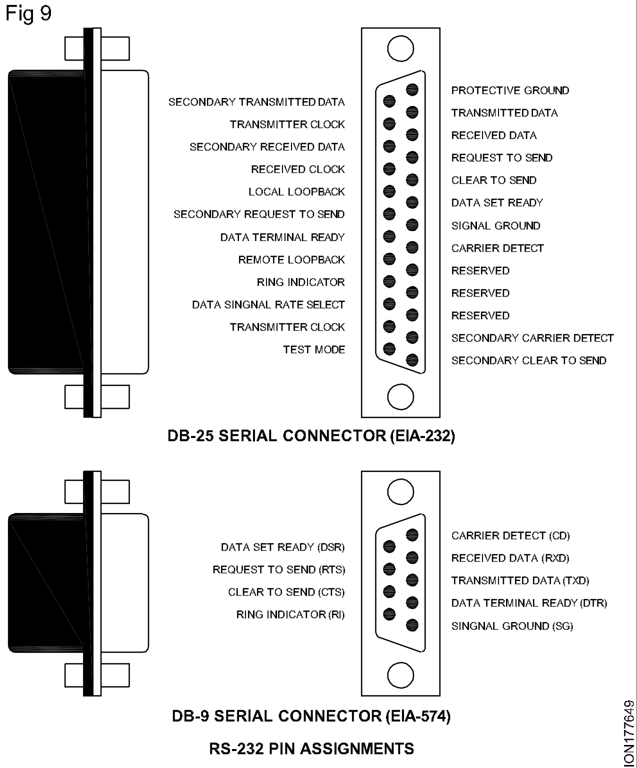
Fig 8



INDUSTRY STANDARD FOR SERIAL COMMUNICATION

ION177648

Fig 9



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.

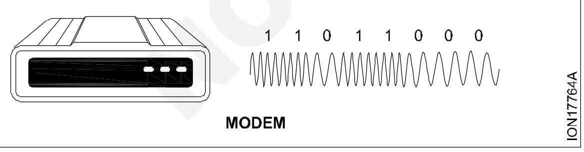
Network interface cards

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 10 shows modem.

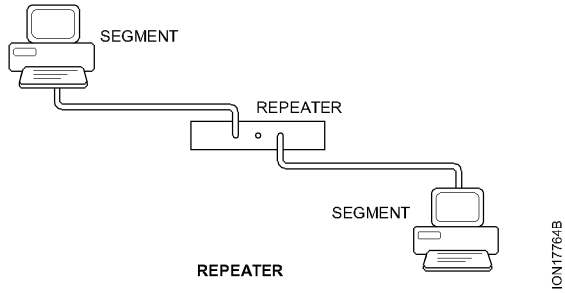
Fig 10



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.

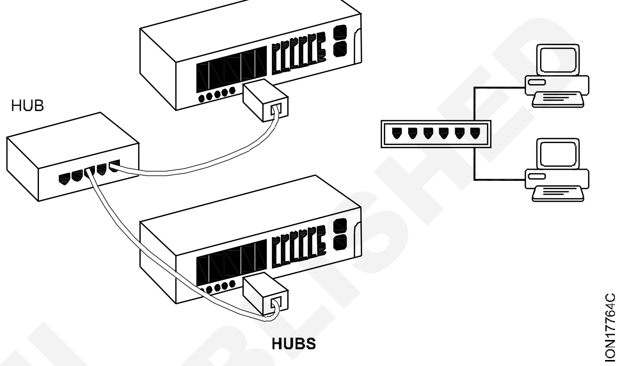
Repeaters: Electro magnetic waves become weaker as they pass through transmission medium. Each transmission medium can only be used for a certain distance. One can exceed the physical mediums maximum effective distance by using an amplification device called repeater. Repeater is shown in Fig 11.

Fig 11



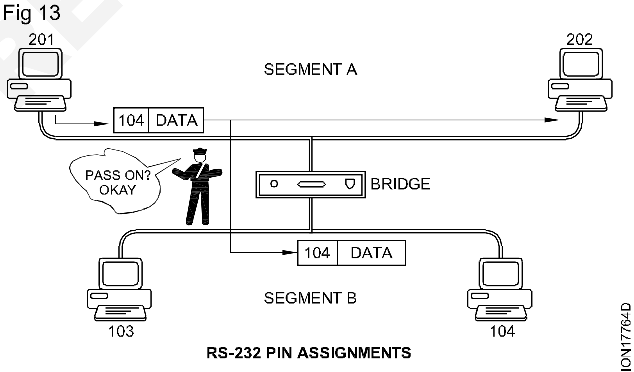
Hubs: Some networks require a central point of connection between media segments. These central points are referred to as hubs is shown in Fig 12.

Fig 12



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 13.

Fig 13



The above figure explains that

- Receive all signals sent on segment A.
- Discard signals addressed to other nodes on segment A.
- 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.

Study the library components available in the circuit simulation software, various resources of the software

Objectives: At the end of this lesson you shalll be able to
- **define electronic simulation software**
- **build a circuit with simulation software**
- **virtual instrumentation testing.**

Electronic Simulation Software

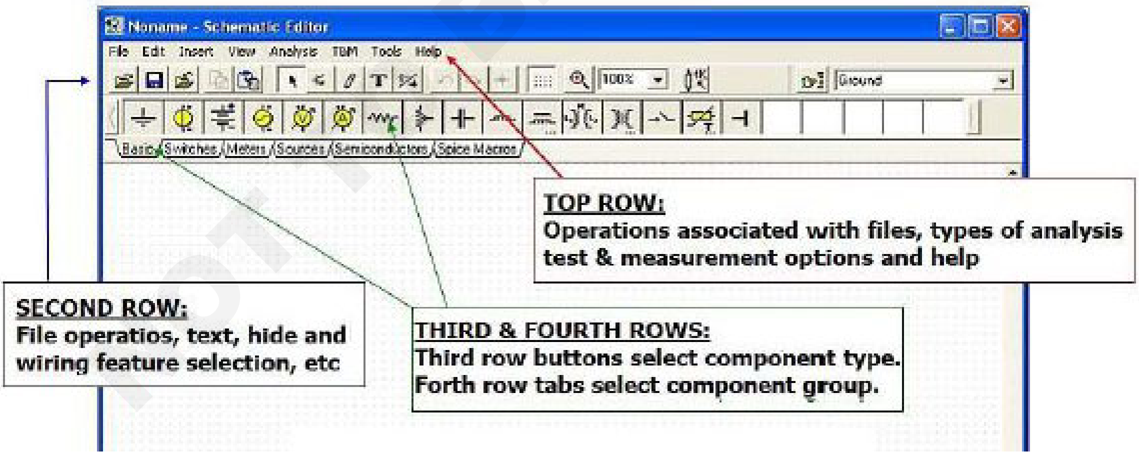
Introduction

- Electronic Circuit simulation is a preparatory software tool designed to create, test and analyse various analog and digital circuits.
- Simulation software allows for modelling of simple to complex circuit operation and is an invaluable analysis tool.
- Electronics simulation software engages the user by integrating them into the learning experience.
- A great collection of most of the electronic components such as passive to active devices are used for circuit drawing, circuit design and analysis.
- There are several free version of electronic circuit simulation softwares available in internet. Also tutorial video guides the user to make use of the application of these simulation softwares.

Free and open source circuit simulation software:

- The list of well - structured free circuit simulation software's window based simulator are given below:
  - NgSpice
  - MultiSim
  - QUCS
  - MacSpice
  - Xspice
  - LTSpice
  - PECS
  - TINA-TI
- Circuit Logix ,etc.
- In the following paragraphs how one of the free version of electronic circuit simulation software can be installed into the computer system after downloaded from the internet and made use of this application software tool for creating, testing virtually using electronic testing & measuring instruments are explained in a step by step manner.
- TINA - TI is a powerful circuit design and simulation tool. IT is ideal for designing,testing,and troubleshooting a broad variety of basic and advanced electronic circuits.

Fig 1



The schematic editor window

- The tool is ideal for helping designers and engineers to develop and test circuit ideas.
- It is a software program developed by both **Texas Instruments** and **DesignSoft,Inc.**

Requirement of PC Configuration:

- The minimum hardware and software requirements for the currently released TINA-TI version are :

  i IBM PC - compatible computer running Microsoft windows 98/ME/NT/2000/XP ii Pentium or equivalent processor

iii 64MB of RAM

iv Hard disk drive with at least 100MB free space

v Mouse

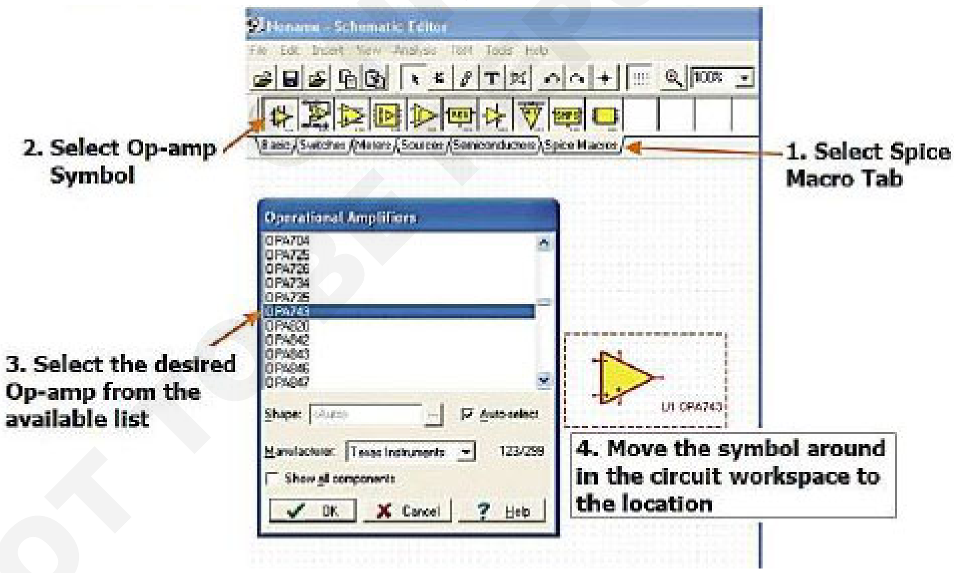
vi VGA adapter card and monitor

- Once the free version of software is downloaded to the system, we can select the program through the windows start menu or by clicking the simulation software Icon on the desktop that was created during the installation.
- The first screen appears as shown in figure 1 is the schematic editor layout.
- The empty workspace on the sheet is the design window where the test circuit is to be created.
- Below the schematic Editor title bar is an operational menu row with selections such as file operations, analytical operations, test and measurement equipment selection, etc.
- Located just below the menu row is a row of icons associated with different file and TINA tasks.
- The final row of icons allows selecting a specific component group. These component groups contain basic passive components, semiconductors, and even sophisticated device macro models. These groups are accessed to build the circuit schematic.

Building a circuit using the electronic circuit simulator:

- For building a circuit using simulator, select the required active and passive components and arrange the components and wire the components as per the circuit diagram.
- A search throug a circuit application handbook provides a number of op-amp based designs. A texas instruments 'OPA743 12V CMOS Op- amp is selected for the circuit application.
- This amplifier is well - suited for this design, and provides very good DC and AC performance.
- It operates with supplies of 3.5V to 12V; our example requires 5V (10V).
- The step- by- step procedure is as follows:
- Select the spice macros tab and then the op-amp symbol to access the OPA743 macro model. When the Op-amp model list appears, scroll down and click on the OPA743
- Then click OK. The op-amp symbol appears in teh circuit workspace. With the mouse clicked drag the symbol into position on the workspace as shown in Fig 2.
- It is locked into position on the circuit workspace by clicking the left mouse button.

Fig 2

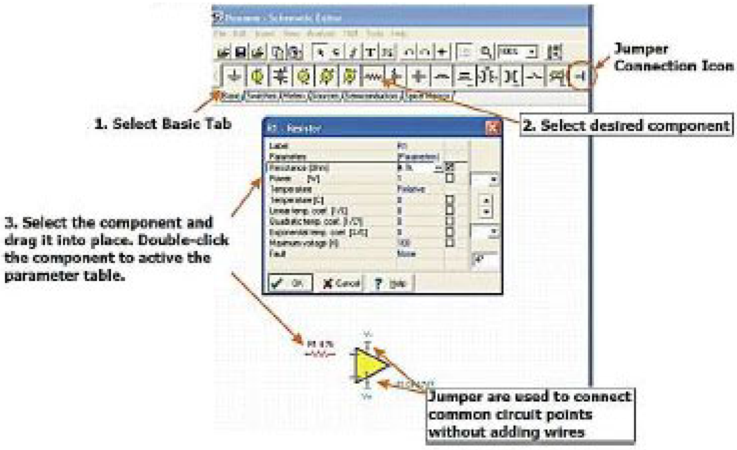


Building a circuit with Op-Amp IC

Adding passive and Active Components:

- Component selection is easily accomplished by clicking on a component group from the lower row of tabs: Basic, switches, Meters, etc.
- These tabs provide a wide variety of passive components, sources, meters, relays, semiconductors, and the previously-mentioned circuit macros.
- Click on the scematic symbol for a particular component and drag it into position in the circuit workspace. A left mouse button click lock it into place.
- In our example, select a resistor from the basic group, and then position it next to the Op-amp symbol.
- The resistor value and other component characteristics may be altered by selecting the individual parameter boxes and changing the respective values. Select the component parameter box and highlight the value you wish to change. Use the key board, enter a new value by typing over the value that is shown in Fig 3.
- Similar parametric tables are available for passive devices, sources, semiconductors, and other component tyes.

Fig 3

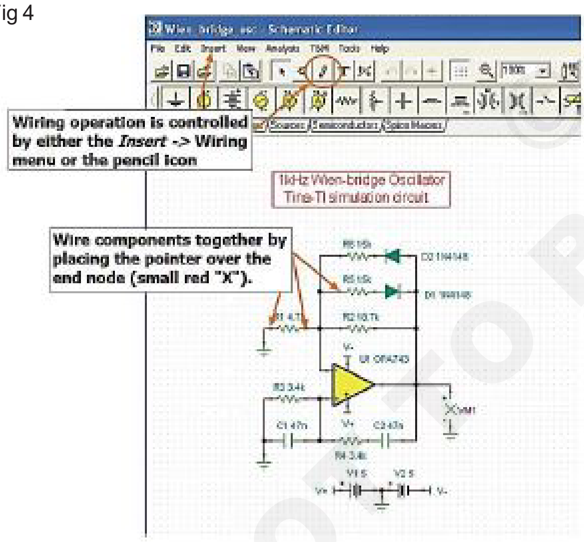


Active and passive component selection

Arranging and wiring components:

- Once all components are selected and properly positioned,they can be wired together.Each component has nodes where circuit connections are needed.
- These nodes with a small red x.(The x looks more like two small lines at the wiring node than the alpha character).
- Wiring components to each other is easilydone as shown in Fig 4 by placing the mouse pointer over a node connection and holding the left mouse button down.

Fig 4



Wiring components together

- A wire is drawn as the mouse is moved along the circuit space grid.Release the mouse button when the wire reaches the intended end connection point.
- The wiring function also may be accessed from the insert menu,or the icon that looks like a small pencil.

Analysis Capabilities:

- When the circuit schematic entry is complete, the circuit is nearly ready for simulation.The analysis process begins by selecting the Analysis menu.
- A list of different types of analysis-such as AC,DC, Transient, or Noise-appears.
- The first option uder the Analysis menu is an **Error Rules Check (ERC)**.Selecting this feature runs this check on the circuit ; a pop -up window then lists any circuit errors.
- If an error is lited in the window,clicking on that error line highlights the error point in the schematic.The error window also lists types of circuit errors that are found during the analysis.
- Even if the ERC is not selected, the software automatically performs a check at the start of a simulation.
- Upon selecting one type of analysis to perform, another window appears that displays different setting selections that are associated with that particular analysis.
- Nominal settings are initally provided; these parameters may be set as needed for the desired output.

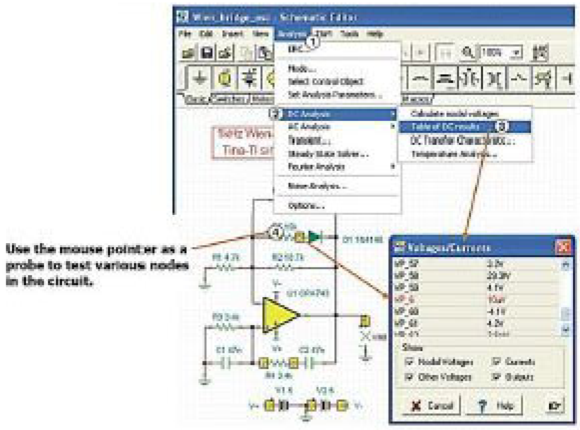
DC Analysis:

- Follow these steps -(illustrated in Fig 5) to perform a DC analysis.
  - Click on the Analysis menu.
  - Select DC Analysis.
  - Click on Table of DC Results.The Voltages/Currents table appears.
  - Use the mouse pointer as a probe to test the circuit nodes.
- The probed node and measured value are displayed in red in the Voltages/Currents table, as shown in Fig 5.

Transient Analysis:

- The transient analysis performed on the example Wien-bridge oscillator circuit is shown in Fig 6.
- It illustrates the Wien-bridge oscillator strat-up and steady-state performance.

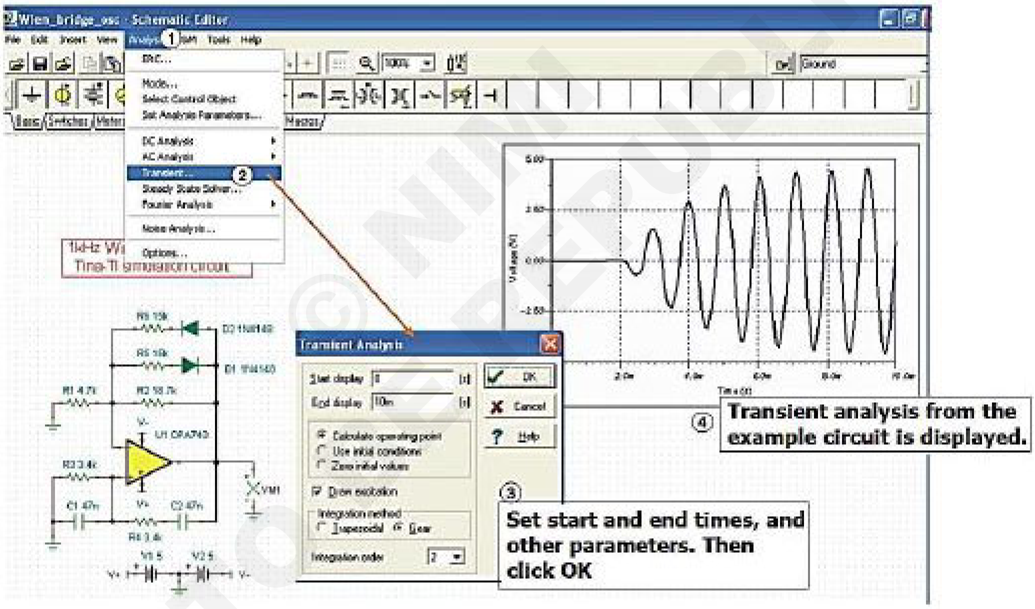
Fig 5



DC Analysis with Voltages/current table

- The display in the actual window may be edited with axis labelling, scales, background grid colour, and ect, all set as desired by the individula user.
- Follow these steps (marked in Fig 6) to perform a transient analysis.
- Click on the analysis menu.
- Select Transient.
- The Transient Analysis dialog box appears.Enter start and end times, and other parameters as desired.
- Click OK to run the analysis.

Fig 6



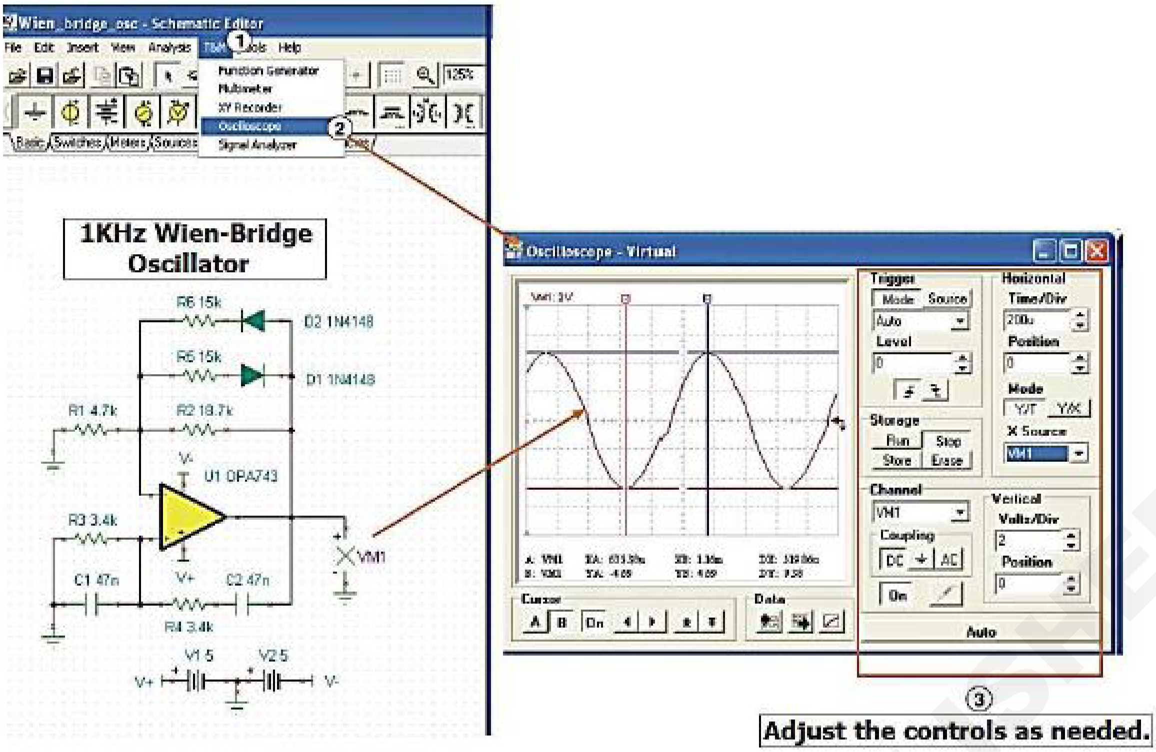
Transient analysis on wein-bridge oscillator

Test and Measurement:

- The Simulation software generates post- simulation result in tables and plots,depending on the type of analysis performed.
- A virtual oscilloscope as shown in Fig 7 is used to observe the steady - state output of the Wien- bridge oscillator circuit. In the same way, a virtual signal analyzer can also be used together with an amplifier circuit so that the harmonic performance of a simulation can be observed.
- To access the virtual oscillosocope, select T&M (step 1 in Figure), and then osilloscope (step 2).Place the cursor at the output of the simulated circuit, and adjust the controls in the virtual oscilloscope dialog box as needed.
- The T&M selection options also include a virtual AC/DC multi-meter, function generator, and an X-Y recorder.
- The function generator may be adjusted in combination with a virtual oscilloscope or analyser.

Thus , the electronic simulation software can be effectively utilized to design,construct,test and analyse various operational parameters using the required electronic components from simple resistor to sophisticated integrated circuits available in the library of resources.After completion of constructing the circuit,required DC power supply, signal generators,digital multimeter even the oscillosope like instruments are simply clicked and connected virtually to make measurements of voltage, current or waveform observation with the ease of clicking the mouse and keyboard.

Fig 7



Virtual instrumentation testing

Sensors, transducers and applications

Objectives: At the end of this lesson you shalll be able to
- **state semsors and their classification**
- **state the type of sensors.**

Sensors

Sensors are devices that are frequently used to detect and respond to electrical or optical signals. A Sensor converts the physical parameter (for example: temperature, blood pressure, humidity, speed, etc.) into a signal which can be measured electrically. For example the temperature sensor. The mercury in the glass thermometer expands and contracts the liquid to convert the measured temperature which can be read by a viewer on the calibrated glass tube.

Criteria to choose a Sensor

There are certain features which have to be considered when we choose a sensor. They are as given below:

1 **Accuracy**

2 **Environmental condition -** Usually has limits for temperature/ humidity

3 **Range -** Measurement limit of sensor

4 **Calibration -** Essential for most of the measuring devices as the readings changes with time

5 **Resolution -** Smallest increment detected by the sensor

6 **Cost**

7 **Repeatability -** The reading that varies is repeatedly measured under the same environment

Classification of Sensors

The sensors are classified into the following criteria:

1 Primary Input quantity

2 Transduction principles (Using physical and chemical effects)

3 Material and Technology

4 Property

5 Application

Transduction principle is the fundamental criteria which are followed for an efficient approach. Usually, material and technology criteria are chosen by the development engineering group.

Classification based on property is as given below:

- **Temperature -** Thermistors, thermocouples, RTD's, IC and many more.
- **Pressure -** Fibre optic, vacuum, elastic liquid based manometers, LVDT, electronic.
- **Flow -** Electromagnetic, differential pressure, positional displacement, thermal mass, etc.
- **Level Sensors -** Differential pressure, ultrasonic radio frequency, radar, thermal displacement, etc.
- **Proximity and displacement -** LVDT, photoelectric, capacitive, magnetic, ultrasonic.
- **Biosensors -** Resonant mirror, electrochemical, surface Plasmon resonance, Light addressable potentio-metric.
- **Image -** Charge coupled devices, CMOS
- **Gas and chemical -** Semiconductor, Infrared, Conductance, Electrochemical.
- **Acceleration -** Gyroscopes, Accelerometers.
- **Others -** Moisture, humidity sensor, Speed sensor, mass, Tilt sensor, force, viscosity.

The Bio-sensors group are the new optical technology based sensors. CMOS Image sensors have low resolution as compared to charge coupled devices. CMOS has the advantages of small size, cheap, less power consumption and hence are better substitutes for Charge coupled devices. Accelerometers are independently grouped because of their vital role in future applications like aircraft, automobiles, etc and in fields of videogames, toys, etc.

Classification based on Application is as given below:

- Industrial process control, measurement and automation
- **Non-industrial use -** Aircraft, Medical products, Automobiles, Consumer electronics, other type of sensors.

Classified based on power or energy supply requirement of the sensors

- **Active Sensor -** Sensors that require power supply are called as Active Sensors. Example: LiDAR (Light detection and ranging), photoconductive cell.
- **Passive Sensor -** Sensors that do not require power supply are called as Passive Sensors. Example: Radiometers, film photography.
- In the current and future applications, sensors can be classified into groups as follows:
- **Accelerometers -** These are based on the Micro Electro Mechanical sensor technology. They are used for patient monitoring which includes pace makers and vehicle dynamic systems.

- **Biosensors -** These are based on the electrochemical technology. They are used for food testing, medical care device, water testing, and biological warfare agent detection.
- **Image Sensors -** These are based on the CMOS technology. They are used in consumer electronics, biometrics, traffic and security surveillance and PC imaging.
- **Motion Detectors -** These are based on the Infra Red, Ultrasonic, and Microwave / radar technology. They are used in videogames and simulations, light activation and security detection.

Classification of transducers (Passive & Active)

Passive transducers

Passive transducer require an external power supply to operate, called an excitation signal which is used by the sensor to produce the output signal.

Active transducers

Active transducers are self-generating devices because their own properties change in response to an external effect.

1 Passive Type Transducers

a Resistance Variation Type

Resistance Strain Gauge - The change in value of resistance of metal semi-conductor due to elongation or compression is known by the measurement of torque, displacement or force.

Resistance Thermometer / Resistance Temperature Detector (RTD) - The change in resistance of metal wire due to the change in temperature known by the measurement of temperature

Resistance Hygrometer - The change in the resistance of conductive strip due to the change of moisture content is known by the value of its corresponding humidity.

Hot Wire Meter - The change in resistance of a heating element due to convection cooling of a flow of gas is known by its corresponding gas flow or pressure.

Photoconductive Cell - The change in resistance of a cell due to a corresponding change in light flux is known by its corresponding light intensity.

Thermistor - The change in resistance of a semi-conductor that has a negative co-efficient of resistance is known by its corresponding measure of temperature.

Potentiometer Type - The change in resistance of a potentiometer reading due to the movement of the slider as a part of an external force applied is known by its corresponding pressure or displacement.

b Capacitance Variation Type

Variable Capacitance Pressure Gauge - The change in capacitance due to the change of distance between two parallel plates caused by an external force is known by its corresponding displacement or pressure.

Dielectric Gauge - The change in capacitance due to a change in the dielectric is known by its corresponding liquid level or thickness.

Capacitor Microphone - The change in capacitance due to the variation in sound pressure on a movable diaphragm is known by its corresponding sound.

c Inductance Variation Type

Eddy Current Transducer - The change in inductance of a coil due to the proximity of an eddy current plate is known by its corresponding displacement or thickness.

Variable Reluctance Type - The variation in reluctance of a magnetic circuit that occurs due to the change in position of the iron core or coil is known by its corresponding displacement or pressure.

Proximity Inductance Type - The inductance change of an alternating current excited coil due to the change in the magnetic circuit is known by its corresponding pressure or displacement.

Differential Transformer - The change in differential voltage of 2 secondary windings of a transformer because of the change in position of the magnetic core is known by its corresponding force, pressure or displacement.

Magnetostrictive Transducer - The change in magnetic properties due to change in pressure and stress is known by its corresponding sound value, pressure or force.

d Voltage and Current Type

Photo-emissive Cell - Electron emission due to light incidence on photo-emissive surface is known by its corresponding light flux value.

Hall Effect - The voltage generated due to magnetic flux across a semi-conductor plate with a movement of current through it is known by its corresponding value of magnetic flux or current.

Ionisation Chamber - The electron flow variation due to the ionisation of gas caused by radio-active radiation is known by its corresponding radiation value.

2 Active Type

Photo-voltaic Cell - The voltage change that occurs across the p-n junction due to light radiation is known by its corresponding solar cell value or light intensity.

Thermocouple - The voltage change developed across a junction of two dissimilar metals is known by its corresponding value of temperature, heat or flow.

Piezoelectric Type - When an external force is applied on to a quartz crystal, there will be a change in the voltage generated across the surface. This change is measured by its corresponding value of sound or vibration.

Moving Coil Type - The change in voltage generated in a magnetic field can be measured using its corresponding value of vibration or velocity.

Selection of Transducer

Selection of a transducer is one of the most important factors which help in obtaining accurate results. Some of the main parameters are given below.

- Selection depends on the physical quantity to be measured.
- Depends on the best transducer principle for the given physical input.
- Depends on the order of accuracy to be obtained.
- Based on whether the transducer is active or passive.

Characteristic of transducer

All transducers, irrespective of their measurement requirements, exhibit the same characteristics such as range, span, etc.

Thermistors / thermocouples - Basic principle, salient features, operating range, composition, advantages and disadvantages

Objectives: At the end of this lesson you shalll be able to
- **define thermistor and its types**
- **define construction and working principle, salient features of the thermistor**
- **describe the application, advantages & disadvantages.**

Thermistor

A thermistor is a resistance thermometer, or a resistor whose resistance is dependent on temperature. The term is a combination of "thermal" and "resistor". It is made of metallic oxides, pressed into a bead, disk, or cylindrical shape and then encapsulated with an impermeable material such as epoxy or glass.

A thermistor is a temperature sensor constructed of semiconductor material that exhibits a large modification in resistance in proportion to a tiny low modification in temperature. Thermistor is inexpensive, rugged, and reliable and responds quickly. Because of these qualities thermistors are used to measure simple temperature measurements, but not for high temperatures. Thermistor is easy to use, cheap, and durable and responds predictably to a change in temperature. Thermistors are mostly used in digital thermometers and home appliances such as refrigerator, ovens, and so on. Stability, sensitivity and time constant are the final properties of thermistor that create these thermistors sturdy, portable, cost-efficient, sensitive and best to measure single-point temperature. Thermistors are available in different shapes like rod, disc, bead, washer, etc. This article gives an overview of thermistor working principle and applications.

Types of thermistor:

There are a number of ways in which thermistors can be categorised into the different thermistor types. The first is dependent upon the way they react to heat. Some increase their resistance with increasing temperature, while others exhibit a fall in resistance.

It is possible to use a very simplified equation for the curve of a thermistor to expand this idea:

$$\Delta R = k \times \Delta T$$

Where

ΔR = change in resistance.

ΔT = change in temperature.

k = first-order temperature coefficient of resistance.

In most cases the relationship between temperature and resistance is non-linear, but over small changes a linear relationship can be assumed.

There are two types of thermistor

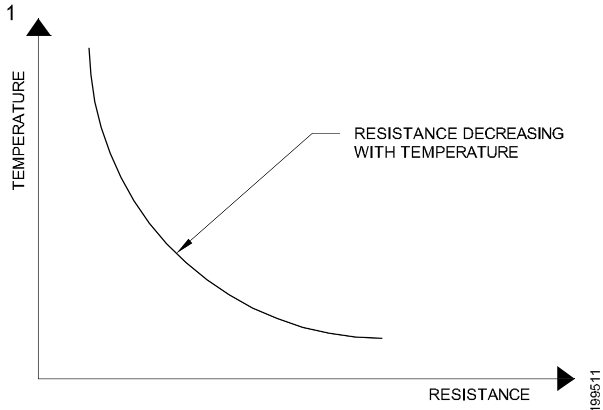
1 Negative Temperature Coefficient (NTC)

2 Positive Temperature Coefficient (PTC)

Negative Temperature Coefficient (NTC):

Negative Temperature Coefficient (NTC) thermistor, when the temperature increases, resistance decreases. Conversely, when temperature decreases, resistance increases as shown in the Fig 1. This type of thermistor is used the most.

Fig 1



NTC TEMPERATURE VS RESISTANCE CURVE

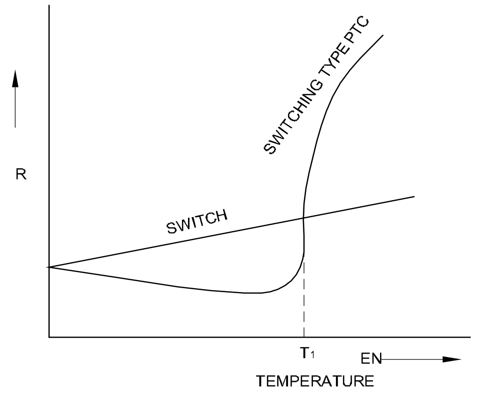
Positive Temperature coefficient (PTC):

A PTC thermistor works a little differently. When temperature increases, the resistance increases, and when temperature decreases, resistance decreases as shown in the Fig 2.This type of thermistor is generally used as a fuse.

Construction

The device is manufactured from materials like sintered mixtures of oxides of metals such as manganese, nickel, cobalt, and iron. Their resistances range from 0.4 ohms to 75 mega-ohms and they may be fabricated in wide variety of shapes and sizes. Smaller thermistors are in the form of beads of diameter from 0.15 millimeters to 1.5 millimeters. Such a bead may be sealed in the tip of solid glass rod to form probe which is easier to mount than bead. Alternatively thermistor may be in the form of disks and washers made by pressing thermistor material under high pressure into flat cylindrical shapes with diameter from 3 millimeters to 25 millimeters. Washers may be stacked and placed in series or parallel to increase power disciplining capability. As shown in Fig 3.

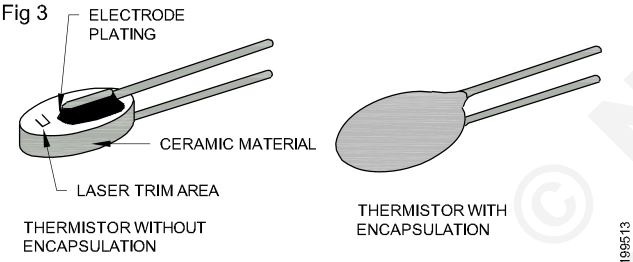
Fig 2



R - T CHARACTERISTICS OF PTC THERMISTORS

PTC TEMPERATURE VS RESISTANCE

Fig 3

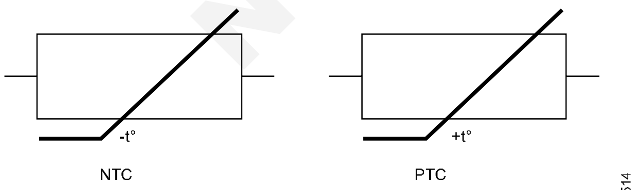


CONSTRUCTION OF THERMISTORS

Working Principle

A thermistor is an inexpensive and easily obtainable temperature sensitive resistor, thermistor working principle is, its resistance is depending upon temperature. When temperature changes, the resistance of the thermistor changes in a predictable way, the benefits of using a thermistor are accuracy and stability, There are two types of termistors available as NTC and PTC, their symbols are shown in Fig 4.

Fig 4



THERMISTORS SYMBOL

Salient features of thermistor

- Thermistors are compact, rugged and inexpensive.
- It exhibit high stability.
- The response time of thermistor can vary from a fraction of second to minutes, depending on the characteristics and contraction of the thermistor.
- The response time varies inversely with the dissipation factor.
- The dissipation factor varies with the degree of thermal isolation of the thermistor.
- The upper temperature limits is depending on physical changes in the material and the contact materials
- A low current must be allowed through the thermistor to avoid self heating.

Application

- Temperature control of air conditioner and refrigerator.
- Room temperature monitoring
- Surge Suppression in power lines in SMPS.
- This device is used to measure the temperature of incubators.
- NTC thermistors are used to measure and monitor batteries while they are kept for charging.
- They are used to know the temperature of oil and coolant used inside automotive engines.

Advantages of Thermistor

- When the resistors are connected in the electrical circuit, heat is dissipated in the circuit due to flow of current. This heat tends to increase the temperature of the resistor due to which their resistance changes. For the thermistor the definite value of the resistance is reached at the given ambient conditions due to which the effect of this heat is reduced.
- In certain cases even the ambient conditions keep on changing, this is compensated by the negative temperature characteristics of the thermistor. This is quite convenient against the materials that have positive resistance characteristics for the temperature.
- The thermistors are used not only for the measurement of temperature for the measurement of power etc.
- They are also used as the controls, overload protectors, giving warnings etc.
- The size of the thermistors is very small and they are very low in cost. However, since their size is small they have to be operated at lower current levels.

Disadvantages

- The high resistivity of thermistors is a significant advantage, since it leads to very small errors, which could be even hundred time smaller compared to measurement errors of RTDs.
- In general, thermistors are more fragile than RTDs and thermocouples and therefore require delicate handling and mounting. Another drawback of them is that because they consist of semiconductors, they are more prone to permanent de-calibration (drifting out of their specified tolerance). Contrary to applicability of

RTDs and thermocouples, use of thermistors is generally limited to a temperature range of few hundred degrees Celsius.

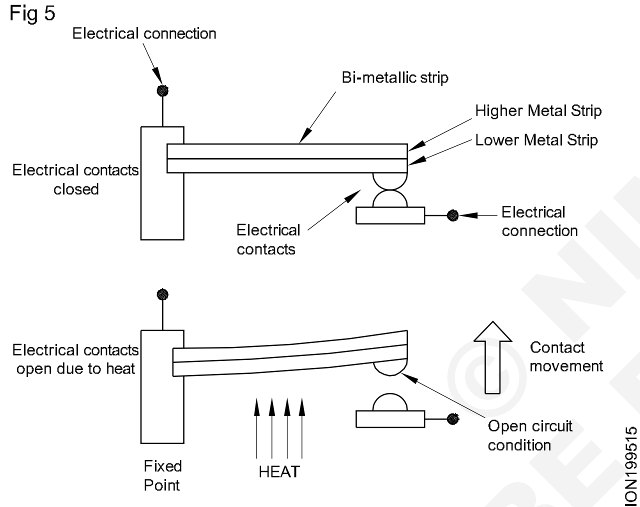
- Small mass of thermistors also makes them susceptible to self-heating errors.

The Theromostat

The thermostat is a contant type electro-mechanical temperature sensor or switch, that basically consists of two diffrent metals such as nickel, copper, tungsten or aluminium etc, that are bonded together to form a Bi-metalllic strip. The different linear expansion rates of the two dissimilar metals produces a mechanical bending movement when the strip is subjected to heat.

The bi-metallic strip can be used itself as an electrical switch or as a mechanical way of operating an electrical switch in thermostatic controls and are used extensively to control hot water heating elements in boilers, furnaces, hot water storage tanks as well as in vehicle radiator cooling systems. The Bi-metallic Thermostat in shown in Fig 5.

Fig 5



The thermostat consists of two thermally different metals stuck together back to back. When it is at normal temperature closed and current passes through the thermostat. When it has heated up, one metal expands more than the other and the bonded bi-metallic strip bends up (or down) opening the contacts preventing the current from flowing.

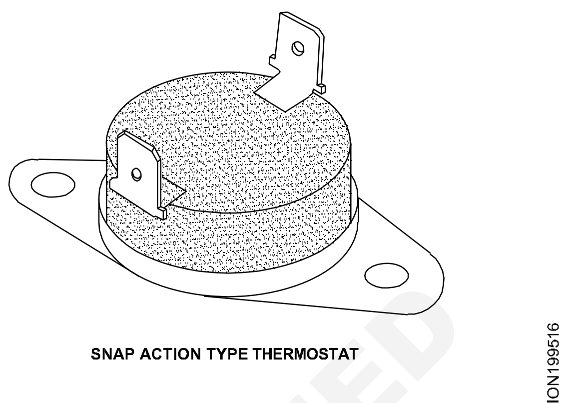
On/Off thermostat

There are two main types of bi-metallic strips based mainly upon their movement when subjected to temperature changes. There are the 'snap-action' types that produce an instantaneous "ON/OFF" or "OFF/ON" type action on the electrical contacts at a set temperature point, and the slower 'creep-action' types that gradually change their position as the temperature changes.

Snap-action type thermostat is shown in Fig 6 It is commonly used in our homes for controlling the temperature set point of ovens, irons, immersion hot water tanks and they can also be found on walls to control the domestic heating system.

Creeper types generally consist of a bi-metallic coil or sprial that slowly unwinds or coils-up as the temperature changes. Generally, creeper type bi-metallic strips are more sensitive to temperature changes than the temperature gauges and dials etc.

Fig 6



SNAP ACTION TYPE THERMOSTAT

Although snap-action type thermostats are very cheap and are available over a wide opeating range, one main disadvantage of the standard snap-action type thermostat is when used as a temperature sensor, they have a large hysteresis range from when electrical contacts open until when they close again for example it may be set 20°C but may not open until 22°C or close again until 18°C.

Commercially available bi-metallic thermostats for home use do have temperature adjustment screws that allow for a more precise desired temperature set-point and hysteresis level to be pre-set.

Temperature sensor ICs

A silicon temperature sensor is an integrated circuit, include extensive signal processing circuitry within the same package as the sensor. There is n need to add compensation circuit for temperature sensor ICs. Some of these are analogue circuits with either voltage or current output. Other combine analogue sensing circuits with voltage comparators to provide alerts functions. Some other sensor ICs combine analogue-sensing circuitry with digital input/output and control registers, making them an ideal solution for microprocessor-based systems.

There are a wide variety of temperature sensor ICs that are available to simplify the broadest possible range of temperature monitoring

Tempeature sensor ICs are classified into different types like voltage output, current ouput, digital output, resistance output silicon and Diode temperature sensors. Modern semiconductor temperature sensors offer high accuracy and high linearity over an operating range of about 55°C to +150°C. Internal amplifiers can scale the output to convient values, such as 10mV/°C. As an example the LM 35 temperature sensor outline diagram is shown in the Fig 7 a and b.

Feature of LM35 Temperature Sensor:

- Calibrated directly in Celsius.
- Rated for full -55°C to +150°C range

- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operated from 4 to 30 volts
- Low self-heating
- ±1/4°C of typical nonlinearity

Fig 7(a)

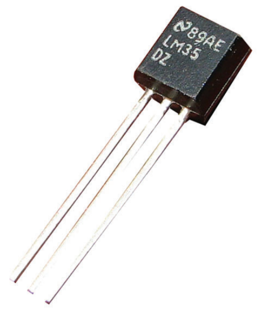
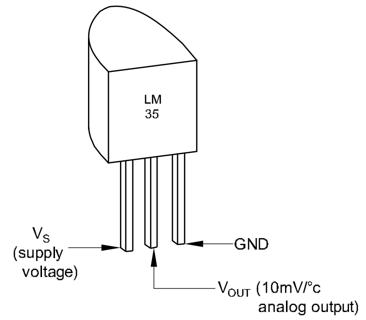


Fig 7

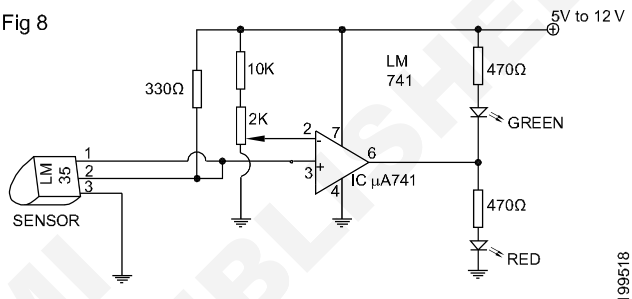


The Above temperature sensor has three terminals. This of sensor consists of a material that performs the operation according to temperature to vary the resistance. This change of resistance is sensed by the circuit and it calculate temperature. When the voltage increases then temperature also rises.

Temperature sensors directly connected to microprocessor input and thus capable of direct and reliable communication with microprocessors. The sensor unit can communicate effectively with low-cost processors without the need of A/D converters.

A practical circuit using temperatue sensor IC LM 35 is shown in Fig 8, in which the sensor output is connected to the non-investing input of the Op-Amp IC 741. On reaching the predetermined temperature the circuit produces the output changes the status of LED indicator.

Fig 8



TEMPERATURE SENSOR USING IC LM35

Thermocouple

Objectives: At the end of this lesson you shall be able to
- **define thermocouple and its working principle**
- **explain the various type of thermocouple .**
- **describe the application, advantages & disadvantages**
- **explain the characteristics curve graph of mV Vs temperature measured.**

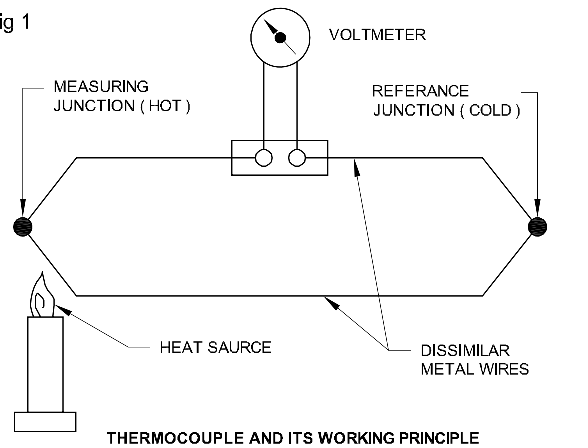
Thermocouple and its working principle

Thermocouple is a device consisting of two dissimilar conductors or semiconductors that contact each other at one or more points as shown in fig.1. A thermocouple produces a voltage when the temperature of one of the contact points differs from the temperature of another, in a process known as the thermoelectric effect. Thermocouples are a widely used type of temperature sensor for measurement and control and can also convert a temperature gradient into electricity.

Type of thermocouples

Characteristic functions for thermocouples that reach intermediate temperatures, as covered by nickel alloy thermocouple types E,J,K,M,N,T. Also shown are the noble metal alloy type P, and the pure noble metal combinations gold-platinum and platinum-palladium.

Fig 1



THERMOCOUPLE AND ITS WORKING PRINCIPLE

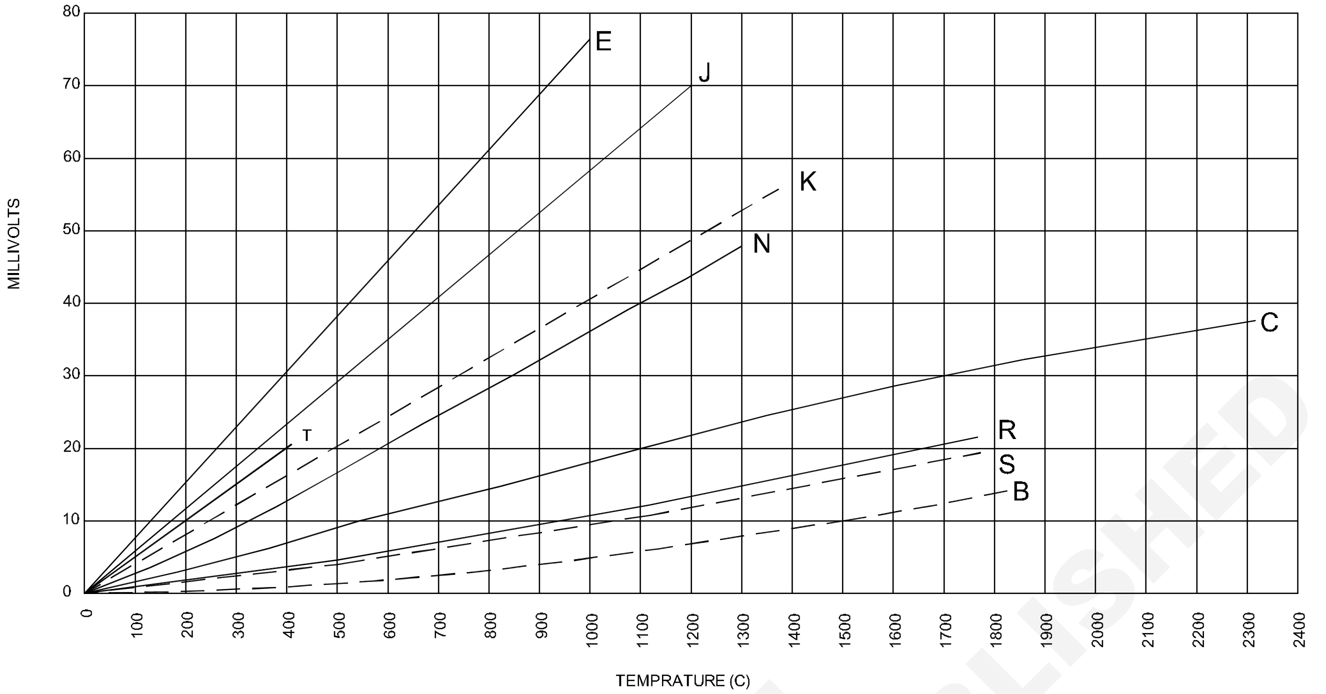
The table 1 showing the different type to thermocouple and its range.

Thermocouple Characteristics Table 1

ANSI/ ASTM	Symbol Single	Generic Names	Colour Coding		Magnetic	Environment (Bare Wire)
			Individual Conductor	Overall jacket extension grade wire		
T	TP TN	Copper Constantan, Nominal Composition: 55% Cu, 45% Ni	Blue Red	Blue	X X	Mild Oxidizing, Reducing Vacuum or Inert, Good where moisture is present.
J	JP JN	Iron Constantan, Nominal Composition: 55% Cu, 45% Ni	White Red	Black	X X	Reducing Vacuum, Insert Limited use in oxidizing at High Temperatures, Not recommended for low temps.
E	EP EN	Chromel &, Nominal Composition: 90% Ni, 10% Cr, Constantan, Nominal Composition: 55% Cu, 45% Ni	Purple Red	Purple	X	Oxidizing or Inert, Limited use in Vacuum or Reducing.
K	KP KN	Chromel, Nominal Composition: 90% Ni, 10% Cr, Alumel*, Nominal Composition: 95% Ni, 2% Mn, 2% Al	Yellow Red	Yellow	X X	Clean Oxidizing and Insert Limited use in Vacuum or Reducing.
N	NP NN	Nicrosil*, Nominal Compositions: 84, 6%Ni, 14.2%, Cr, 1.4% Si Nisil*, Nominal Composition: 95.5%, Ni, 4.4% Si, 1% Mg	Orange Red	Orange	X X	Clean Oxidizing and Insert Limited use in Vacuum or Reducing
S	SP SN	Platinum 10% Rhodium Pure Platinum	Black Red	Green	X X	Oxidizing or Inert Atmospheres, Do not Insert in metal tubes. Beware of contamination.
R	RP RN	Platinum 10% Rhodium Pure Platinum	Black Red	Green	X X	Oxidizing in Inert Atmospheres. Do not insert in metal tubes. Beware of contamination.
B	BP BN	Platinum 30% Rhodium Platinum 6% Rhodium	Gray Red	Gray	X X	Oxidizing or Inert Atmospheres. Do not insert in metal tubes. Beware of contamination.
C	P N	Tungsten 5% Rhenium Tungsten 26% Rhenium	Green Red	Red	X X	Vacuum, Inert, Hydrogen Atmospheres, Beware of Embrittlement.

Temperature Vs mV graph for various type of Thermocouples (Fig 2)

Fig 2



TEMPERATURE Vs mV GRAPH FOR VARIOUS TYPE OF THERMOCOUPLES

Applications

1 Temperature measurement for kilns, gas turbine exhaust, diesel engines.

2 Temperature measurement of industrial processes and fog machines.

3 For process temperature measurement of Steel, Cement , Petro chemical etc.,

Advantage

1 Thermocouples are suitable for measuring over a large temperature range, from - 270 up to 3000 °C (for a short time, in inert atmosphere).

2 They are less suitable for applications where smaller temperature differences need to be measured with high accuracy, for example the range 0-100 °C with 0.1 °C accuracy.

Disadvantage

1 Thermocouples measure their own temperature.

2 Thermocouples can error in reading their own temperature, especially after being used for a while, or if the insulation between the wires loses its resistance due to moisture or thermal conditions

3 Beware of electrical hazards using thermocouples, they are electrical conductors. RTD's are less sensitive to electrical noise.

4 Thermocouples DO NOT MEASURE AT THE JUNCTIONS! They can't, it is physically impossible to have a temperature gradient at a point.

5 The distance between thermocouple and heater element will generate a thermal lag which can be compensated by the temperature controller.

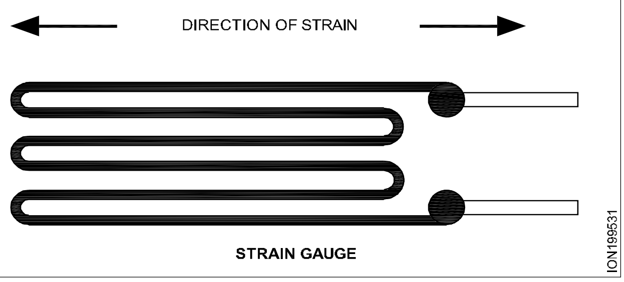
Strain gauges/ Load cell – principle, gauge factor, types of strain gauges

Objectives: At the end of this lesson you shalll be able to
- **explain the strain gauges and its types**
- **define construction and working principle & gauge factor**
- **explain the load cell and strain gauge load cell**
- **describe the application, advantages and disadvantages.**

Strain Gauges

A strain gauge (or strain gage) is a device used to measure strain on an object. The most common type of strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge is attached to the object by a suitable adhesive, such as cyanoacrylate. As the object is deformed, the foil is deformed, causing its electrical resistance to change. This resistance change, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the gauge factor. as shown in Fig 1.

Fig 1



STRAIN GAUGE

Types of strain gauges

There are four main types of strain gauges: mechanical, hydraulic, electrical resistance, and piezoelectric.

1 Mechanical

2 Hydraulic

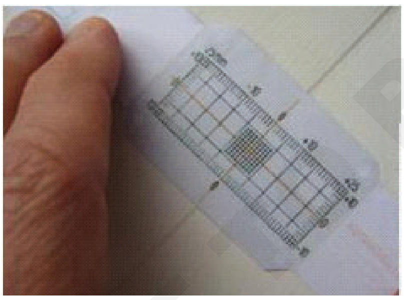
3 Electrical Resistance

4 Piezoelectric

Mechanical strain Gauge

Suppose you have a crack forming in a wall of your home because of subsidence and you want to know if it's getting any worse. Call in the building inspectors and they'll probably glue a piece of tough, plexiglass plastic, ruled with lines and a scale, directly over the crack. Sometimes known as a crack monitor, you'll find it's actually made up of two separate plastic layers. The bottom layer has a ruled scale on it and the top layer has a red arrow or pointer. You glue one layer to one side of the crack and one layer to the other so, as the crack opens, the layers slide very slowly past one another and you can see the pointer moving over the scale. Mechanical strain gauges as shown in Fig 2.

Fig 2

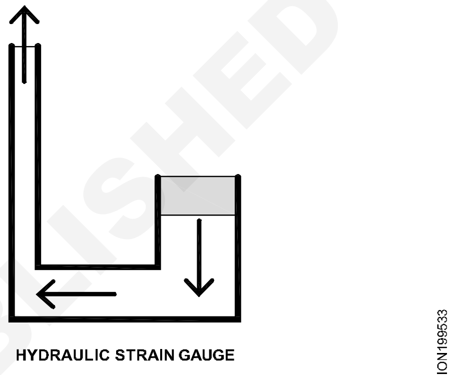


MECHANICAL STRAIN GAUGE

Hydraulic strain Gauge

One of the problems with strain gauges is detecting very small strains. You can imagine, for example, a situation where your house is slowly subsiding but the amount of movement is so small that it won't show up-perhaps until the damage is done. With a simple crack detector such as the ones described above, it takes 1mm of building movement to produce 1mm of movement on the surface of the crack detector. But what if we want to detect movements smaller than this that doesn't show up on a scale? In this case, what we really need is a strain gauge with leverage that amplifies the strain, so even a tiny movement of the detecting element produces a very large and easily measurable movement of a pointer over a scale. Hydraulic detectors offer a solution and work much like simple syringes. Syringes are essentially hydraulic pistons where a small movement of fluid in a large piston (the part you press with your finger) produces a much larger movement of fluid in a small piston attached to it (the needle where the fluid comes out). It's easy to see how this can be used in a strain gauge: you simply connect your large piston to whatever it is that's producing the strain and use a smaller piston in a smaller tube, marked with a scale, to indicate how much movement has occurred. The relative size of the pistons determines how much the movement you're trying to detect is scaled up. Typically, hydraulic strain gauges like this multiply movement by a factor of 10 or so and are commonly used in geology and Earth science. As shown in Fig 3.

Fig 3



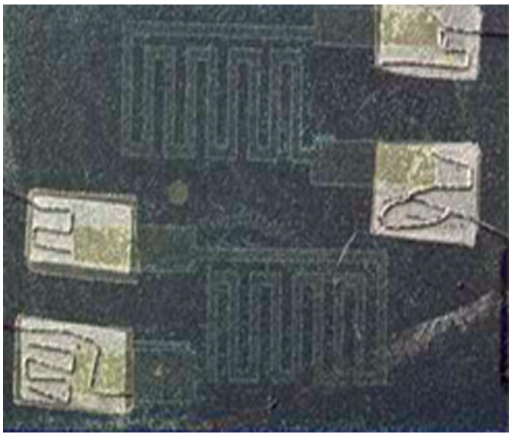
HYDRAULIC STRAIN GAUGE

Electrical Resistance strain gauge

If you're designing something like an airplane wing, typically you need to make far more sophisticated measurements (and many more of them) than a simple mechanical strain gauge will allow. You might want to measure the strain during takeoff, for example, when the engines are producing maximum thrust. You can't go sticking little plastic strain gauges onto the wing and walk out to measure them during a flight! But you can use electrical strain gauges to do much the same thing from a flight recorder in the cockpit.

The most common electrical strain gauges are thin, rectangular-shaped strips of foil with maze-like wiring patterns on them leading to a couple of electrical cables. You stick the foil onto the material you want to measure and wire the cables up to your computer or monitoring circuit. When the material you're studying is strained, the foil strip is very slightly bent out of shape and the maze-like wires are either pulled apart (so their wires are stretched slightly thinner) or pushed together (so the wires are pushed together and become slightly thicker). Changing the width of a metal wire changes its electrical resistance, because it's harder for electrons to carry electric currents down narrower wires. So all you have to do is measure the resistance and, with a bit of calculation, you can calculate the strain. If the forces involved are small, the deformation is elastic and the strain gauge eventually returns to its original shape-so you can keep making measurements over a period of time, such as during the test flight of a prototype plane as shown in Fig 4.

Fig 4



ELECTRICAL RESISTANCE STRAIN GAUGE

Piezoelectric Strain Gauge

Some types of materials, including quartz crystals and various types of ceramics, are effectively "natural" strain gauges. If you push and pull them, they generate tiny electrical voltages between their opposite faces. This phenomenon is called piezoelectricity (pronounced pee-ay-zo electricity) and it's probably best known as a way of generating the timekeeping signal in quartz watches. Measure the voltage from a piezoelectric sensor and you can calculate the strain very simply. Piezoelectric strain gauges are among the most sensitive and reliable and can withstand years of repeated use as shown in Fig 5.

Fig 5

PIEZOELECTRIC STRAIN GAUGE

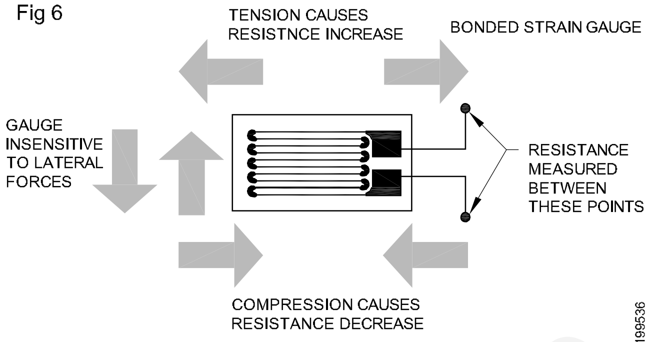
Principle of Working - Strain Gauges

When force is applied to any metallic wire its length increases due to the strain. The more is the applied force, more is the strain and more is the increase in length of the wire. If L_1 is the initial length of the wire and L_2 is the final length after application of the force, the strain is given as:

$\in = (L_2 - L_1)/L_1$

Further, as the length of the stretched wire increases, its diameter decreases. Now, we know that resistance of the conductor is the inverse function of the length. As the length of the conductor increases its resistance decreases. This change in resistance of the conductor can be measured easily and calibrated against the applied force. Thus strain gauges can be used to measure force and related parameters like displacement and stress. The input and output relationship of the strain gauges can be expressed by the term gauge factor or gauge gradient, which is defined as the change in resistance R for the given value of applied strain $\in$. As shown in Fig 6 working principle of strain gauge.

Fig 6



STRAIN GAUGES WORKING PRINCIPLE

Gauge factor

The gauge factor GF is defined as:

Where

is the change in resistance caused by strain,

is the resistance of the unreformed gauge, and

is strain.

For metallic foil gauges, the gauge factor is usually a little over 2. For a single active gauge and three dummy resistors in a Wheatstone bridge configuration, the output from the bridge is:

$$GF = \frac{\Delta R / R_G}{\varepsilon}$$

where

ΔR is the change in resistance caused by strain,

R_G is the resistance of the unreformed gauge, and

ε is strain.

For metallic foil gauges, the gauge factor is usually a little over 2. For a single active gauge and three dummy resistors in a Wheatstone bridge configuration, the output ν from the bridge is:

$$\nu = \frac{BV.GF.\varepsilon}{4}$$

where

BV is the bridge excitation voltage.

Foil gauges typically have active areas of about 2-10 mm^2 in size. With careful installation, the correct gauge, and the correct adhesive, strains up to at least 10% can be measured. Gauge factor(G.F)=1+2μ whereμ=poisson's ratio.

Load cell:

A load cell is a device that is used to convert a force into electrical signal. Strain gauge load cells are the most common types of load cells. There are other types of load cells such as hydraulic (or hydrostatic), Pneumatic Load Cells, Piezoelectric load cells, Capacitive load cells, Piezoresistive load cells.etc.

Load cells are used for quick and precise measurements. Compared with other sensors, load cells are relatively more affordable and have a longer life span as shown in Fig 7.

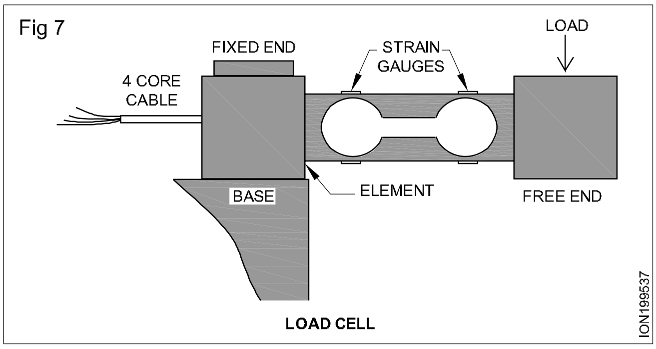


Fig 7 LOAD CELL

Uses of Load Cells

Load cells are used in several types of measuring instruments such as laboratory balances, industrial scales, platform scales and universal testing machines. Installed load cells in glass fiber nests to weigh albatross chicks. Load Cells are used in a wide variety of items such as the seven-post shaker which is often used to setup race cars.

Strain gauge load cell

Through a mechanical construction, the force being sensed deforms a strain gauge as shown in the Fig 8. The strain gauge measures the deformation (strain) as a change in electrical resistance, which is a measure of the strain and hence the applied forces. A load cell usually consists of four strain gauges in a Wheatstone bridge configuration. Load cells of one strain gauge (Quarter Bridge) or two strain gauges (half bridge) are also available. The electrical signal output is typically in the order of a few millivolts and requires amplification by an instrumentation amplifier before it can be used. The output of the transducer can be scaled to calculate the force applied to the transducer.

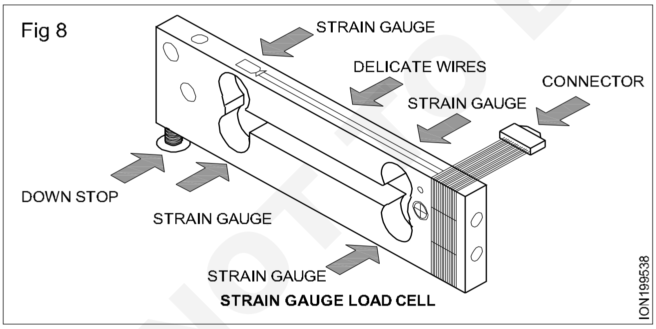


Fig 8 STRAIN GAUGE LOAD CELL

Strain gauge load cells are the most common in industry. These load cells are particularly stiff, have very good resonance values, and tend to have long life cycles in application. Strain gauge load cells work on the principle that the strain gauge (a planar resistor) deforms/stretches/contracts when the material of the load cells deforms appropriately. These values are extremely small and are relational to the stress and/or strain that the material load cell is undergoing at the time. The change in resistance of the strain gauge provides an electrical value change that is calibrated to the load placed on the load cell.

Strain gauge load cells convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. In most cases, four strain gauges are used to obtain maximum sensitivity and temperature compensation. Two of the gauges are usually in tension, and two in compression, and are wired with compensation adjustments. The strain gauge load cell is fundamentally a spring optimized for strain measurement. Gauges are mounted in areas that exhibit strain in compression or tension. The gauges are mounted in a differential bridge to enhance measurement accuracy. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load. Other load cells are fading into obscurity, as strain gauge load cells continue to increase their accuracy and lower their unit costs.

Advantages of strain Gauge

- There is no moving part.
- It is small and inexpensive.

Disadvantages of strain Gauge

- It is non-linear.
- It needs to be calibrated.

Application of Strain gauge

- Residual stress .
- Vibration measurement.
- Torque measurement.
- Bending and deflection measurement.
- Compression and tension measurement.
- Strain measurement.

Advantages of load cells

- Rugged and compact construction.
- No moving parts.
- Can be used for static and dynamic loading.
- Highly Accurate.
- Wide range of measurement.
- Can be used for static and dynamic loading.

Disadvantages of load cells

- Calibration is a tedious procedure.

Inductive/ capacitive transducers - Principle of operation, advantages and disadvantages

Objectives: At the end of this lesson you shalll be able to
- **define proximity switches**
- **explain the different types of proximity switches**
- **describe the selection, advantages and disadvantages.**

Proximity sensors

Proximity sensors detect the presence of objects without physical contact.It detects the presence or absence of objects using electromagnetic fields, light, and sound. There are many types, each suited to specific applications and environments.

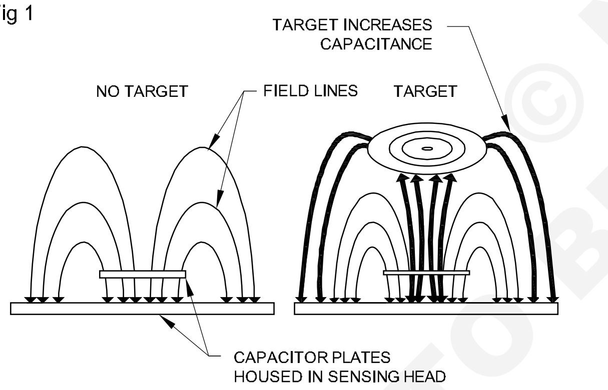
Types of proximity

- Capacitive
- Inductive
- Photo electric

Capacitive Transducers

It is important to know the basics of a parallel plate capacitor. Being the simplest form of a capacitor, it has two parallel conducting plates that are separated to each other by a dielectric or insulator with a permittivity of E (for air). Other than paper, vacuum, and semi-conductor depletion region, the most commonly used dielectric is air. as shown in Fig 1.

Fig 1



CAPACITIVE SENSING

Due to a potential difference across the conductors, an electric field develops across the insulator. This causes the positive charges to accumulate on one plate and the negative charges to accumulate on the other. The capacitor value is usually denoted by its capacitance, which is measured in Farads. It can be defined as the ratio of the electric charge on each conductor to the voltage difference between them.

The capacitance is denoted by C. In a parallel plate capacitor, $C = [A*\epsilon_r*9.85*10^{12}\ F/M]/d$

A - Area of each plate (m)

d - Distance between both the plates (m)

ϵ_r - Relative Dielectric Constant

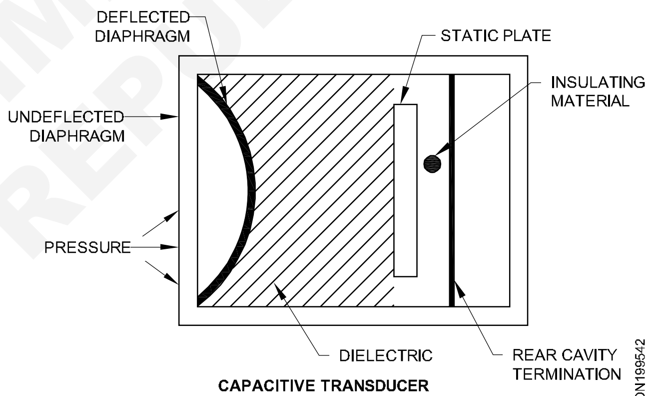
The value $9.85*10^{12}$ F/M is a constant denoted by ϵ_0 and is called the dielectric constant of free space.

From the equation it is clear that the value of capacitance C and the distance between the parallel plates,d are inversely proportional to each other. An increase of distance between the parallel plates will decrease the capacitance value correspondingly. The same theory is used in a capacitive transducer. This transducer is used to convert the value of displacement or change in pressure in terms of frequency.

Parts of Capacitance Transducer (Fig 2)

As shown in the Figure 2, a capacitive transducer has a static plate and a deflected flexible diaphragm with a dielectric in between. When a force is exerted to the outer side of the diaphragm the distance between the diaphragm and the static plate changes. This produces a capacitance which is measured using an alternating current bridge or a tank circuit.

Fig 2 CAPACITIVE TRANDUCER



CAPACITIVE TRANSDUCER

A tank circuit is more preferred because it produces a change in frequency according to the change in capacitance. This value of frequency will be corresponding to the displacement or force given to the input.

Advantages

- It produces an accurate frequency response to both static and dynamic measurements.

Disadvantages

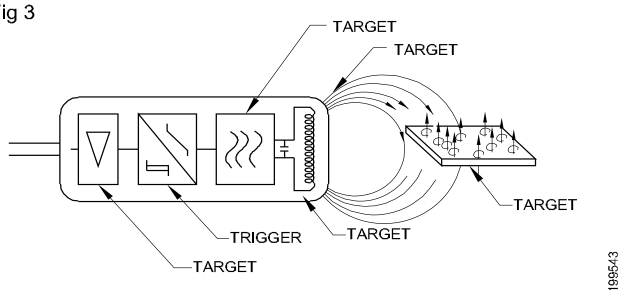
- An increase or decrease in temperature to a high level will change the accuracy of the device.
- As the lead is lengthy it can cause errors or distortion in signals.

Inductance Type Inductive Transducers

The inductance type of the inductive transducers simple single coil is used as the transducer. When the mechanical element whose displacement is to be measured is moved, it changes the permeance of the flux path generated by the circuit, which changes the inductance of the circuit and the corresponding output. The output from the circuit is calibrated directly against the value of the input, thus it directly gives the valve of the parameter to be measured.

The Fig 3 shows the single coil inductive circuit. Here the magnetic material is connected to the electric circuit and it is excited by the alternating current. At the bottom there is another magnetic material that acts as the armature. As the armature is moved, the air gap between the two magnetic material changes and the permeance of the flux generated by the circuit changes that changes the inductance of the circuit and its output. The output meter directly gives the valve of the input mechanical quantity.

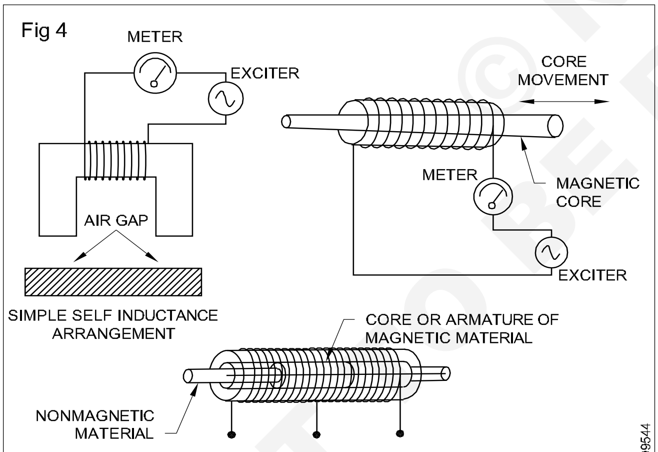
Fig 3



INDUCTANCE TYPE INDUCTIVE TRANSDUCERS

In the Fig 4, coil is wound around the round hollow magnetic material and there is magnetic core that moves inside hollow magnetic material. In the above circuits the change in the air gap or the change in the amount of the magnetic material in the circuit can be used to produce the output proportional to the input.

Fig 4



INDUCTANCE TYPE INDUCTIVE TRANSDUCERS

Another arrangement of the coils is shown in Fig 3, where two coils are used. In this circuit the movement of the core changes the relative inductance of the two coils and over all inductance of the circuit. This system is used in the devices along with the inductive bridge circuit. In this circuit the change in the induction ratio of the two coils provides the output proportional to the mechanical input.

In the above arrangements the supply of the current and the output is obtained from the same coil or circuit.

Advantages

- Non contact type
- Maintenance free
- pnp or npn type
- 360°- viewable output indicators for easy operation and maintenance.
- Electrical protections against short circuits, overload, transient noise, false pulses and reverse polarity (DC models) to help reduce downtime and maintenance costs.

Disadvantages

Virtually nil but following may be noted:

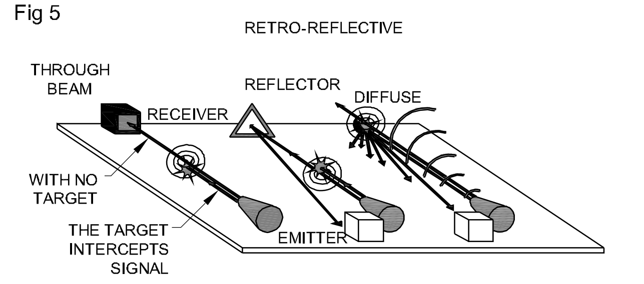
- Cannot be repaired
- Must be free from oil and dust
- Cable connections to be checked regularly

Photoelectric sensors

Photoelectric sensors are so versatile that they solve the bulk of problems put to industrial sensing. Because photoelectric technology has so rapidly advanced, they now commonly detect targets less than 1 mm in diameter, or from 60 m away. Classified by the method in which light is emitted and delivered to the receiver, many photoelectric configurations are available. However, all photoelectric sensors consist of a few of basic components: each has an emitter light source (Light Emitting Diode, laser diode), a photodiode or phototransistor receiver to detect emitted light, and supporting electronics designed to amplify the receiver signal. The emitter, sometimes called the sender, transmits a beam of either visible or infrared light to the detecting receiver.

All photoelectric sensors operate under similar principles as shown in Fig 5 Identifying their output is thus made easy; dark-on and light-on classifications refer to light reception and sensor output activity. If output is produced when no light is received, the sensor is dark-on. Output from light received, and it's light-on. Either way, deciding on light-on or dark-on prior to purchasing is required unless the sensor is user adjustable. (In that case, output style can be specified during installation by flipping a switch or wiring the sensor accordingly.)

Fig 5



LASERS OF SOUND WAVES SERVE AS THE SIGNAL IN THREE SETUPS. IN THROUGH BEAM AND RETRO-REFLECTIVE, THE SIGNAL SHOOTS FROM THE EMITTER TO RECEIVER UNTIL THE TARGET CUTS IT OFF. IN DIFFUSE SENSING, THE SIGNAL DIVERGES UNTIL A TARGET MOVES IN AND REFLECTS SOME BACK TO THE RECEIVER.

PHOTOELECTRIC / ULTRASONIC SENSING SETUPS

Through-beam

The most reliable photoelectric sensing is with through-beam sensors. Separated from the receiver by a separate housing, the emitter provides a constant beam of light; detection occurs when an object passing between the two breaks the beam. Despite its reliability, through-beam is the least popular photoelectric setup. The purchase, installation, and alignment of the emitter and receiver in two opposing locations, which may be quite a distance apart, are costly and laborious. With newly developed designs, through-beam photoelectric sensors typically offer the longest sensing distance of photoelectric sensors - 25 m and over is now commonplace. New laser diode emitter models can transmit a well-collimated beam 60 m for increased accuracy and detection. At these distances, some through-beam laser sensors are capable of detecting an object the size of a fly; at close range, that becomes 0.01 mm. But while these laser sensors increase precision, response speed is the same as with non-laser sensors - typically around 500 Hz.

One ability unique to through-beam photoelectric sensors is effective sensing in the presence of thick airborne contaminants. If pollutants build up directly on the emitter or receiver, there is a higher probability of false triggering. However, some manufacturers now incorporate alarm outputs into the sensor's circuitry that monitor the amount of light hitting the receiver. If detected light decreases to a specified level without a target in place, the sensor sends a warning by means of a builtin LED or output wire.

Through-beam photoelectric sensors have commercial and industrial applications. At home, for example, they detect obstructions in the path of garage doors; the sensors have saved many a bicycle and car from being smashed. Objects on industrial conveyors, on the other hand, can be detected anywhere between the emitter and receiver, as long as there are gaps between the monitored objects, and sensor light does not "burn through" them. (Burn-through might happen with thin or lightly colored objects that allow emitted light to pass through to the receiver.)

Application and selection of proximity sensor:

Proximity Sensor comparison Table 1

Technology	Sensing Range	Applications	Target Materials
Inductive 	<4-40 mm	Any close - range detection of ferrous material	Iron Steel Aluminum Copper etc. 
Capacitive 	<3-60 mm	Close - range detection of non - ferrous material	Liquids Wood Granulates Plastic Glass etc. 
Photoelectric 	<1mm - 60 mm	Long - range small or large target detection	Silicon Plastic Paper Metal etc. 
Ultrasonic 	<30 mm - 3 mm	Long - range detection of targets with difficult surface properties. Color/ reflectivity insensitive.	Cellophane Foam Glass liquid Powder etc 

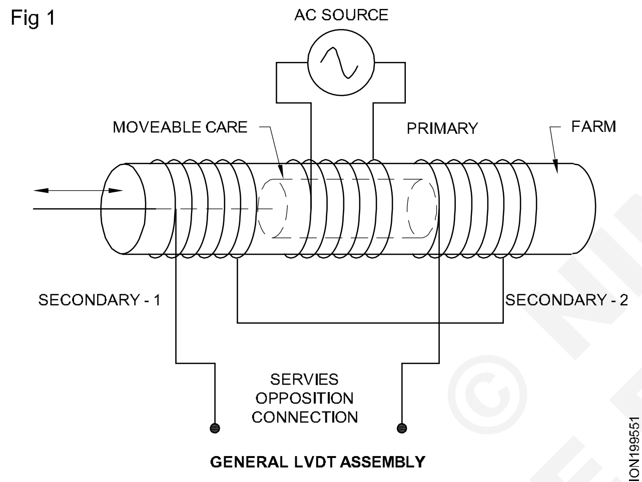
Principle of operation of LVDT, advantages and disadvantages

Objectives: At the end of this lesson you shalll be able to
- **define LVDT**
- **explain the working principle and operation of LVDT**
- **state the advantages, disadvantages and application of LVDT.**

Details of LVDT and its construction

Linear variable differential transformers (LVDT) are used to measure displacement. LVDTs operate on the principle of a transformer. As shown in Figure 1, an LVDT consists of a coil assembly and a core. The coil assembly is typically mounted to a stationary form, while the core is secured to the object whose position is being measured. The coil assembly consists of three coils of wire wound on the hollow form. A core of permeable material can slide freely through the center of the form. The inner coil is the primary, which is excited by an AC source as shown. Magnetic flux produced by the primary is coupled to the two secondary coils, inducing an AC voltage in each coil.

Fig 1



GENERAL LVDT ASSEMBLY

LVDTs Working principle

The LVDT or Linear Variable Differential Transformer is a well established transducer design which has been used throughout many decades for the accurate measurement of displacement and within closed loops for the control of positioning. So, how does an LVDT work? In its simplest form, the design consists of a cylindrical array of a primary and secondary windings with a separate cylindrical core which passes through the centre. (Fig 2a).

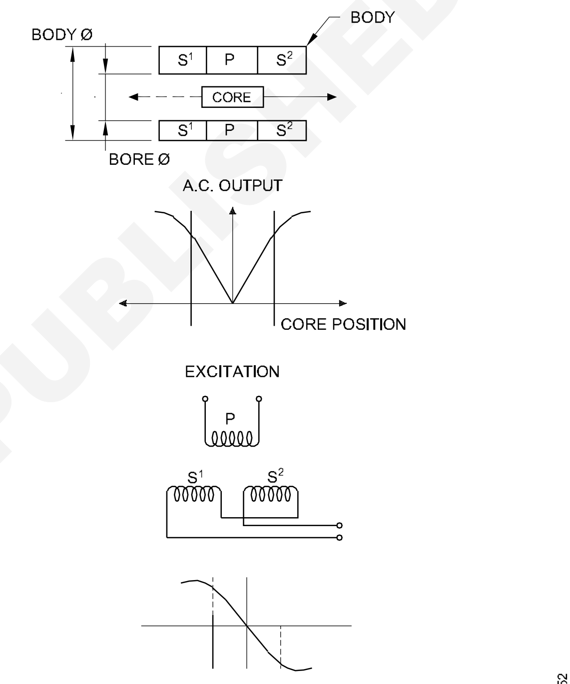
The primary windings (P) are energized with a constant amplitude A.C. supply at a frequency of 1 to 10 kHz. This produces an alternating magnetic field in the centre of the transducer which induces a signal into the secondary windings (S &S) depending on the position of the core.

Movement of the core within this area causes the secondary signal to change (Fig 2b). As the two secondary windings are positioned and connected in a set arrangement (push-pull mode), when the core is positioned at the centre, a zero signal is derived.

Movement of the core from this point in either direction causes the signal to increase (Fig 2c). As the windings are wound in a particular precise manner, the signal output has a linear relationship with the actual mechanical movement of the core.

The secondary output signal is then processed by a phase-sensitive demodulator which is switched at the same frequency as the primary energising supply. This results in a final output which, after rectification and filtering, gives D.C. or 4-20mA output proportional to the core movement and also indicates its direction, positive or negative from the central zero point (Fig 2d).

Fig 2



LVDTs WORKING PRINCIPLE

Advantage

The distinct advantage of using an LVDT displacement transducer is that the moving core does not make contact with other electrical components of the assembly, as with resistive types, as so offers high reliability and long life. Further, the core can be so aligned that an air gap exists around it, ideal for applications where minimum mechanical friction is required.

The LVDT design lends itself for easy modification to fulfill a whole range of different applications in both research and industry.

Disadvantages of LVDT

- Very high displacement is required for generating high voltages.
- Shielding is required since it is sensitive to magnetic field.
- The performance of the transducer gets affected by vibrations.

- Its is greatly affected by temperature changes.
- Internally non contact but externally has to be connected where the measurement has to be made.
- Not feasible for very long range measurements.

Applications of LVDT

LVDT is used to measure displacement ranging from fraction millimeter to centimeter.

Acting as a secondary transducer, LVDT can be used as a device to measure force, weight and pressure, etc..

Operational amplifiers and their applications

Objectives : At the end of this lesson you shall be able to
- **state the base material used in making ICs**
- **state the most important considerations in designing ICs**
- **state the meaning of operational amplifier**
- **state the two basic modes of operation of Op- Amps**
- **list ideal and typical characteristics of Op-Amps**
- **explain a simple summing and difference amplifier**
- **state the meaning of slew rate and its importance.**

Integrated circuits

An integrated circuit (IC), as its name implies, is an integrated (put together) form of several components of a circuit on a single chip or wafer of a semiconductor material, generally silicon. ICs may have hundreds of active components (transistors, diodes) and passive components (resistors, capacitors etc.,).

The active and passive components are deposited or diffused on this minute sized silicon substrate. The substrate is then mounted on a ceramic or a insulated metal base called header as shown in Fig 1. Aluminum or gold wires of about one-third thickness of a human hair are bonded between the IC contacts called pads and the header leads. The package is then sealed. The most common types of IC packages are shown in Fig 2.

Fig 1

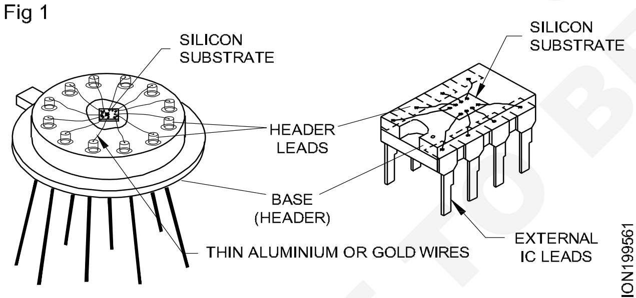
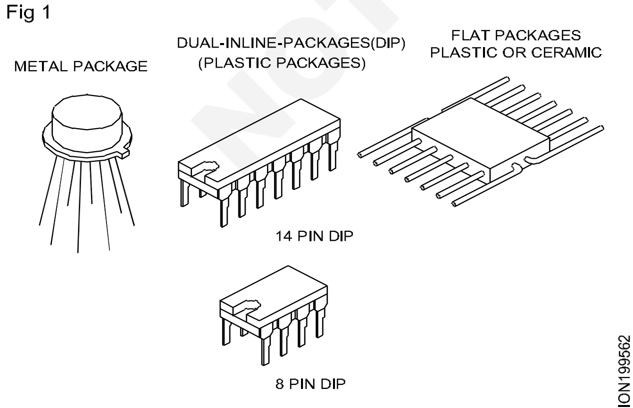


Fig 1



ICs are made by a complex photographic process on a very small sized surface. This process is known as micro photolithographic process This process is known as micro photolithographic process. The base material of ICs is a highly refined silicon chip (also known as substrate) as shown in Fig 1. Generally the size of the silicon substrate is of the size of a pin head.

The number of pins each IC has depends on the complexity of the circuit built into the IC. However, any IC will have minuimum of 3 pins as in any voltage regulator ICs, to more than 64 pins in computer ICs.

In ICs, fabrication of active components such as transistors and diodes take much less space on the chip than resistors and capacitors. Also, because of the limited space on the chip, resistors and capacitor values then can be made on the IC limited. For this reason direct coupling between transistor stages are used in ICs. Also transistors are used as resistors instead of fabricating resistors themselves. Components like chokes, coils and transformers cannot be fabricated in ICs because of its physical bulkiness. Therefore, wherever inductors are necessary for a circuit leads are brought out of the ICs such that, inductors can be connected external to the IC.

One very important consideration in the design of ICs is its flexibility in application. Most ICs are designed to be used for more than one application by making small changes in external circuitry. For example, an IC may be used as an amplifier or as an oscillator and so on. The commonly used OP-AMP ICs are μA741-single op-amp and LM 324 - having four op-amp. They come in DIP and having larger input voltage range no latch up, high gain short circuit protection, no frequency compensation required input voltage range from -15v to +15v while common mode input is from -12v to +12v supply current is 1.7mA power consumption is 50 mV. The leading IC manufactures are signetics, texas instruments, fair child and national semi conductors limited.

Advantages of integrated circuits

- Although the circuit inside an IC is complex consisting of a large number of components, the overall physical size of the IC is extremely small resulting in miniaturization of the electronic gadgets size.

- Drastic decrease in the overall weight of the gadget due to miniaturised size of the circuit.
- Low power requirement.
- Increased reliability due to less number of solder connections.
- Greater flexibility in use of the same IC for different circuit configurations.
- Better functioning under wide range of temperatures.
- Low cost per IC due to large scale production of ICs.

Limitation of integrated circuits

- Large value capacitors and resistors cannot be fabricated.
- Chokes, inductors and transformers cannot be fabricated.
- If any one stage inside the IC circuit becomes defective, the complete IC has to be discarded.
- Handling is very delicate.

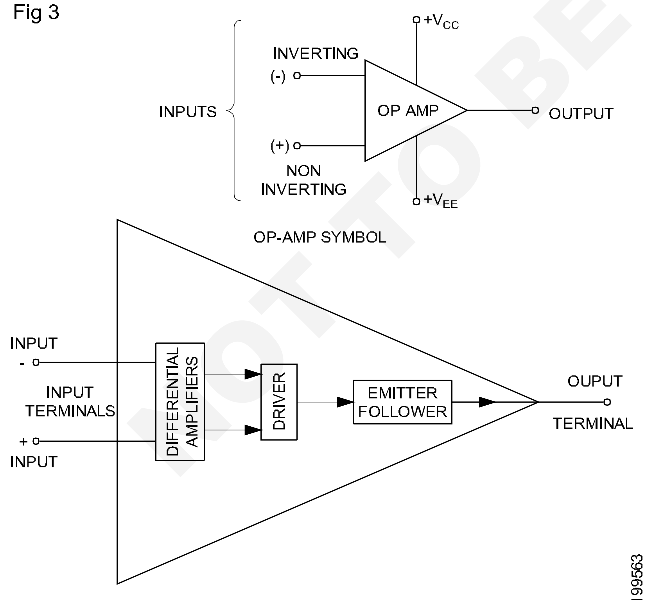
Basic linear integrated circuit-'Operational Amplifiers' (OP Amps)

An operational amplifier, often referred as op-Amp, is a high gain, direct coupled differential amplifier, designed to amplify both DC and AC signals.

The term operational is used with these amplifiers because, in early days these amplifiers were used in analog computers to perform mathematical operations such as addition, multiplication etc.,

Symbol used to represent an Op-Amp and the functional blocks inside it are shown in Fig 3.

Fig 3

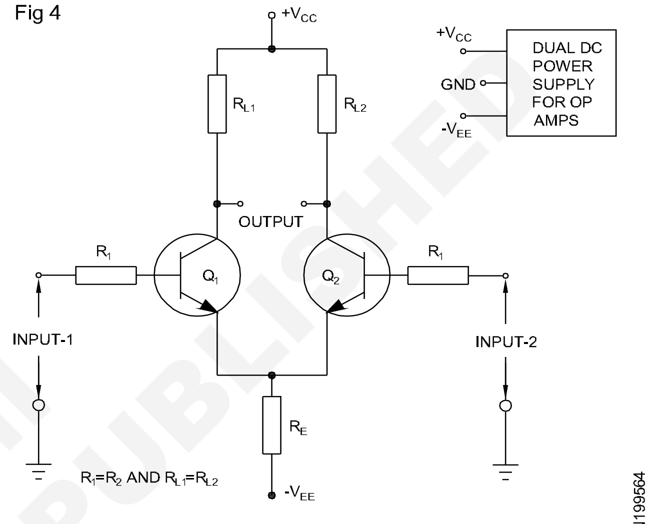


BLOCK DIAGRAM OF CIRCUITS IN AN OPERATIONAL AMPLIFIERS

As can be seen from Fig 3, operational amplifiers will have two inputs and one output. The reason for having two input points is that Op Amps have a special type of amplifier configuration known as Differential amplifier as its first stage.

A typical differential amplifier stage is shown in Fig. 4. A differential amplifier stage consists of two transistors with an input to each transistor. The output is taken between the collectors of the transistors as shown in Fig. 4. The most important point to note is, both the transistors have identical characteristics, load resistors, input resistors and a single emitter resistor. Dual power supply(+ve,-ve and Gnd) is required for differential amplifiers (single supply can also be used with a few extra components). If a dual supply is used and if the amplifier is properly balanced (symmetrical values), the output voltage across the collectors will be equal to the difference of the two input voltages. Hence, this amplifier is called differential amplifier.

Fig 4



DIFFERENTIAL AMPLIFIER

Modes of operation of differential amplifiers

Any operational amplifier can be operated in two modes. They are,

- Common-mode operation
- Differential-mode operation.

Common-mode operation

In Fig 5, since both sides of the differential amplifier circuit are identical, if an identical signal (same level and phase) is applied to both the inputs(transistors), the same output signal results from both collectors. If a meter is connected across the outputs the voltage difference will be zero. Thus, the output is equal to the gain times the difference between the input voltages. Mathematically, this is expressed as,

$$V_{out\ (com)} = A(V_1\ V_2)$$

Where,

A is the grain of each transistor

V_1 and V_2 are the base input voltages measured to ground.

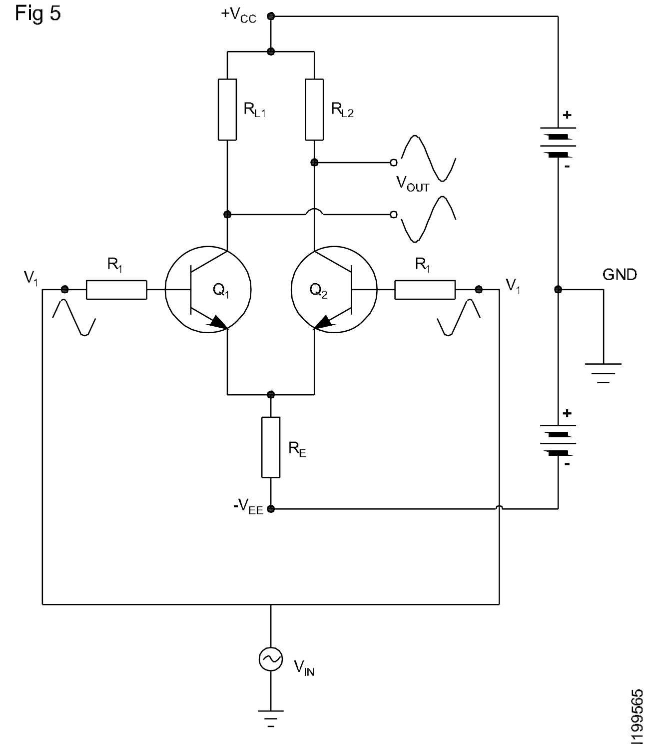
This mode of operation is called *Common-mode operation.*

In common-mode operation, a differential amplifier theoretically rejects the common mode signals (signal that is identical at each input) and hence the output will be zero as shown below,

If both the magnitude and phase of V_1 and V_2 are the same, then,

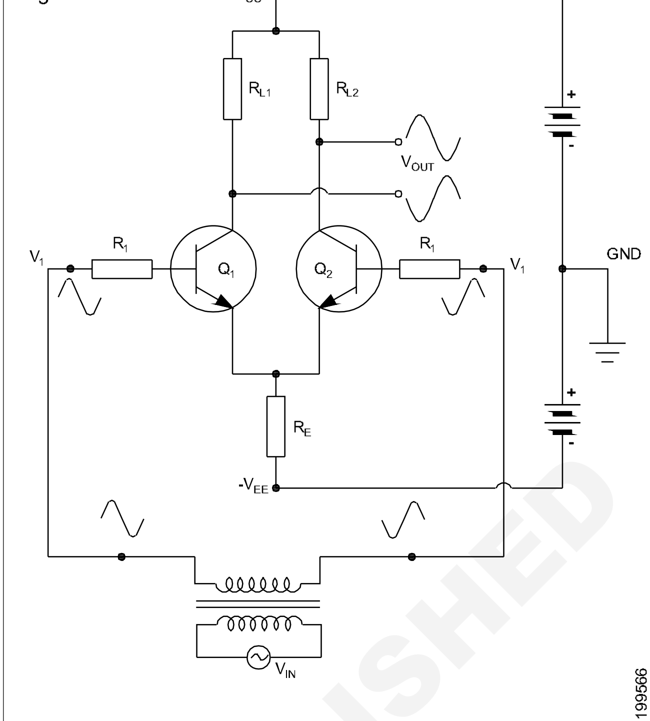
$$V_{out} = A(V_1\ V_2) = A\ (V_1 - V_1) = A\ (0)$$

Fig 5



COMMON MODE OF OPERATION

Fig 6



DIFFERENTIAL-MODE OF OPERATION

In practice, since the two halves of the circuit cannot be perfectly identical, instead of zero output there will be a very small output. For example, a differential amplifier with a 0.5 V common-mode input signal may give an output of 0.025 V instead of zero. This 0.025V is because of the slight mismatch between the two half of the differential amplifier circuit.

Differential-mode operation

Fig 6 shows the differential-mode operation. When the two input signals are out of phase by 180°, the amplifier amplifies the difference of the input signals. Since the input signals are of equal in amplitude, but out of phase by 1 80° the output signal is equal to, twice the gain times the input signal. This can be mathematically written as,If magnitude of $V_1 = V_2$ then,

$$V_{out\ (Dif)} = A [V_1 - (- V_2)] = A [(2V_1)] = ..2A (V_1)$$

Common-mode rejection ratio

The common-mode rejection ratio (CMRR) of a differential amplifier (or other device) is the rejection by the device of unwanted input signals common to both input leads, relative to the wanted difference signal. An ideal differential amplifier would have infinite CMRR; this is not achievable in practice. A high CMRR is required when a differential signal must be amplified in the presence of a possibly large common-mode input. An example is audio transmission over balanced lines.

Ideally, a differential amplifier takes the voltages, V_+ and V_- on its two inputs and produces an output voltage $V=A_d(V_+-V_-)$ where A_d is the differential gain. However, the output of a real differential amplifier is better described as,

$$V_o = A_d(V_+-V_-)+{}_{1/2}A_{cm}(V_+-V_-),$$

Where is the common-mode gain, which is typically much smaller than the differential gain.

The CMRR is defined as the ratio of the powers of the differential gain over the common-mode gain, measured in positive decibels (thus using the 20 log rule):

As differential gain should exceed common-mode gain, this will be a positive number, and the higher the better.

The CMRR is a very important specification, as it indicates how much of the common-mode signal will appear in your measurement. The value of the CMRR often depends on signal frequency as well, and must be specified as a function thereof.

It is often important in reducing noise on transmission lines. For example, when measuring the resistance of a thermocouple in a noisy environment, the noise from the environment appears as an offset on both input leads, making it a common-mode voltage signal. The CMRR of the measurement instrument determines the attenuation applied to the offset or noise.

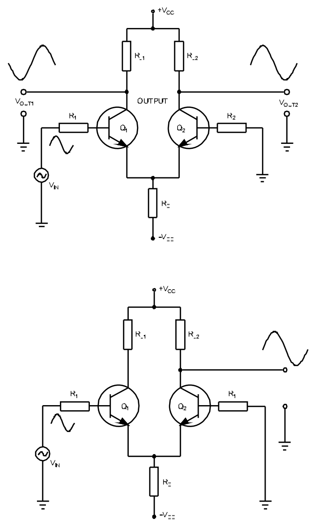
Methods of giving input and taking output in differential amplifiers.

A differential amplifier is normally used with a double ended input and double ended output. But this is not a compulsion. A differential amplifier can also be used as single ended input and with single ended output.

Single-ended input: The input signal is applied to only one input and the other input is grounded as shown in Fig 7a.

Single-ended output: The output signal from the ampli-fier is taken from the collector to ground instead of across the collectors as shown in Fig 7a. The output can betaken from the collector of Q1 to Gnd or Q2 to Gnd or from both collectors to ground as shown in Fig 7b. when the output is taken from both collectors to Gnd the two signals provide a push-pull output as shown in Fig 7b.

Fig 7



DIFFERENTIAL AMPLIFIER

ION199567

Recall that the two transistors of a push-pull amplifiers need signal of some amplitude but out-of-phase by 180°.

Differential input:

The two inputs given are signals having opposite polarity(180° out of phase). The input is similar to input to a push-pull amplifier.

Differential output: The output is taken across the two collectors which is nothing but the difference between the two collector voltages. The difference will be zero when the input voltages are equal and are of the same polarity. The input signals add up if they have opposite polarities.

Practical Op-Amps and applications

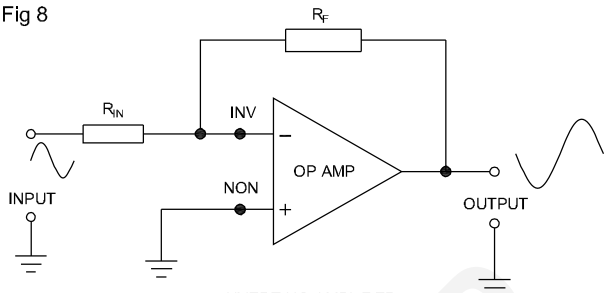
In an Op-Amps as shown in Fig 3, apart from the first differential stage, the subsequent stages are the driver and emitter-follower stage which are already discussed in earlier lessons. Most of the commercially available Op-Amp ICs will usually have two input terminals and only one output terminal as shown in Fig 3. The two inputs of the Op-Amp are called, INVERTING(-) and NON-IN-VERTING(+) inputs. This is because, a signal applied to the inverting(-) input, produces output which will be 180° out of phase with the input. Whereas a signal applied, to the NON-INVERTING (+) input produces an output which will be in-phase with the input.

Gain of Op-Amps

The gain and other characteristics of the operational amplifier depends upon the external components connected external to the Op-Amp.

The theoretical gain of Op-Amps is very high, of the order of 100,000 or more. In practical amplifiers using Op-Amp, a resistor is used to provide an external negative feed back to the Op-Amp. The negative feedback resistor is generally connected between the output terminal to either of the input terminals as shown in Fig 8. Although the negative feed back reduces the gain of the amplifier drastically (10 to 1000), the negative feed back makes the amplifier stable, prevents it from going into oscilla-tions and increases the frequency response range of the amplifiers.

Fig 8



INVERTING AMPLIFIER

ION199568

The gain of Op-Amp without negative feedback is referred to as OPEN LOOP GAIN whereas, the again of Op-Amp with feed back is referred to as CLOSED LOOP GAIN.

Op-Amp as inverting amplifier

Fig 8 shows a typical inverting amplifier using an Op-Amp. In this inverting amplifier, the input signal is applied to the INVERTING (INV)terminal. The NON-INVERTING (NON) terminal which is grounded the input signal is applied at the INV terminal, the output of the amplifier will be an amplified signal of opposite polarity. The resistor R_F be-tween the output and input provides necessary negative feedback. The amount of negative feedback provided de-pends on the values of resistors R_F and R_{In}.

$$\text{Inverting Amplifier Gian } \left(A_{inv}\right) = -\frac{R_F}{R_1}$$

Negative sing indicates inverting of output signal generally, amplifier gain can also be written as

$$A = \frac{Vo}{V_{in}}$$

As an example, let us calculate the closed-loop voltage gain, for the inverting amplifier at Fig 8. Assume values of R_F = 470 KΩ and R_{in} = 47 KΩ. Assume an input signal voltage of 0.5V.

The closed-loop gain of an inverting amplifier is given by,

$$A_{inv} = \frac{R_F}{R_{in}}$$

$$A_{inv} = \frac{-470K}{47K} = -10$$

Since $R_F/R_{in} = A_{(inv)}$, equation can also be written as,

The out put voltage of the non – inverting amplifier is given by,

$$V_{out(inv)} = A_{(inv)} \cdot V_{in}$$

in the given example,

$$V_{OUT\,(NON)} = 10x0.5\ v$$
$$= 5.0\ \text{Volts}$$

OP Amp non inverting amplifier

In the Fig. 9 shows a typical amplifier using OP-Amp. In this non-inverting amplifier, the input signal is applied to the non-inverting (NON) terminal. The output signal of amplifier is same polarity (inphase) of applied input signal. The resistor R_F between output and input providing necessary feedback. The amount of feedback provided by amplifier depends on value of R_F and R_{in}.

$$\text{For gain } A_{(NON)} = \frac{V_{out}}{V_{in}} = \frac{R_{in} + R_F}{R_{in}} = 1 + \frac{R_F}{R_{in}}$$

Gain-bandwidth product(GBP)

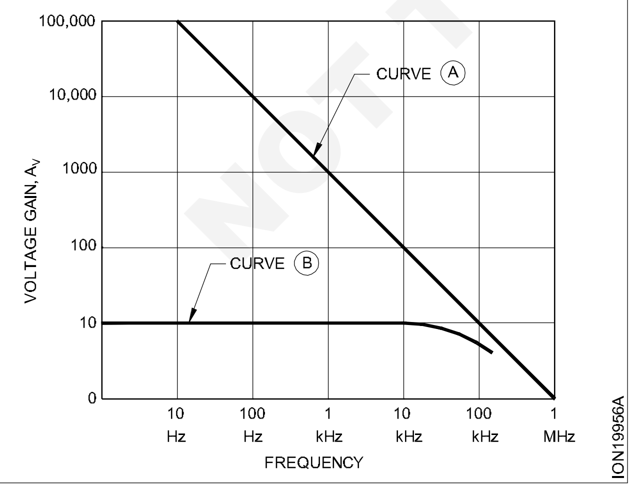
Typical frequency response of an Op-Amp is from direct current, or 0 Hz, to more than 1 MHz. However, because of internal shunt capacitances, the amplifier gain drops off sharply as the frequency is increased Therefore to specify the gain of an Op-Amp at different frequencies, a term called as Gain-Bandwidth-Product(GBP) is speci-fied. For example, if the GBP of an Op-Amp is given as 1MHz, it means that the gain of the Op-Amp becomes unity at an input signal of 1 MHz. It is always useful to know the gain-bandwidth product (GBP), of the Op-Amp being used.

Example: The GBP of an Op-Amp is specified as 1 MHz. What is the maximum gain that can be obtained using this Op- Amp at 1 KHZ GBP of 1 MHZ means, gain = 1 at 1 MHZ. Therefore, at 1 KHZ more gain will be,

$$\text{Gain at1khz} = \frac{GEP}{1KHz} = \frac{1MHz}{1KHz} = 1000$$

This means, at 1 KHz an Op-Amp with GPB of 1 MHz provides a maximum gain of 1000. This is shown in curve A of Fig 10.

Fig 10



Curve A of Fig 10 shows the open loop frequency response of an Op-Amp with a constant GBP of 1 MHz. As can be seen from curve A, for the same Op-Amp, the gain is 100 at 10 KHz, 10 at 100 KHz and becomes unity at 1 MHz.: This huge variation in open loop gain $A_{(OPEN)}$, can be made almost constant using negative feedback.

As shown in curve B of Fig 10, using suitable value of resistor R_F and R_{in}, if the closed loop gain $A_{(CUOSED)}$ of the Op-Amp is set at say 10, then the frequency response of the Op-Amp becomes almost flat upto 100KMz. This is one of the major advantages of negative feed back in Op-Amps.

TIP: The lower you set the gain of the amplifier, the higher will be the bandwidth of the amplifier.

Characteristics of Op-Amps

An ideal operational amplifier will have the following characteristics:

Voltage gain $A_V = \infty$

Bandwidth BW = ∞

Input resistance $R_{in} = \infty$

Output resistance $R_0 = 0$.

In practice such ideal characteristics cannot be achieved. However, in many practical situations, Op-Amps come close to these characteristics. Typical specifications of an Op-Amp is given below:

Voltage gain, $A_V \leq 100,000$

Bandwidth, BW $\approx$ 1 MHz (unity gain)

Input resistance, R_{in} 2 MΩ

Output resistance $R_0 \leq 50\ \Omega$

Typical Op-Amp applications

Application of Op-Amps are innumerable. This is because, of the flexibility that is built into the internal circuit of the Op-Amp. In addition to its basic function of ampli-fication, Op-Amp are used as comparators, adders, subtracters, differentiator, integrators and so on.

Application of Op-Amp as a summing amplifier

Fig 11 is the circuit of a Op-Amp summing amplifier or in simple terms an adder. Here, the Op-Amp is used as an inverting amplifier to do the summing operation. In Fig 11, three input signals are applied to the INV terminal of the Op-Amp through resistors R_1 R_2 and R_3. The amount of negative feedback given to the Op-Amp is dependent on the value of R_F divided by each resistor in the feedback path. As a result, the output voltage of the Op-Amp is given by,

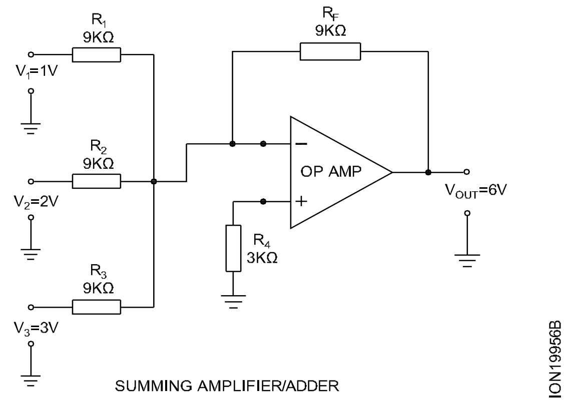
$$V_{out} = \left[\left(\frac{R_f}{R_1} xV_1\right)\right] + \left(\frac{R_f}{R_1} xV_2\right) + \left(\frac{R_f}{R_1} xV_3\right)$$

If, $R_1 = R_2 = R_3 = R_F$, then R_F/R becomes 1 in each signal path.

Then, the output is given by,

$$V_{out} = V_1 + V_2 + V_3$$
$$V_{out} = (1x1V) + (1x2V) + (1x3V)$$
$$V_{out} = 1V + 2V + 3V = 6Volts$$

Fig 11



The output of 6V is equal to the sum of the three input voltages. Note that the value of resistor R_4 (3KQ) at the NON terminal of Op-Amp is made equal to the parallel combination of three 9 K resistors at the INV terminal. This resistor is required to balance the inputs of the differential amplifier in the Op-Amp.

Slew'rate in Op-Amps

Slew rate is an important characteristic of Op-Amps. The term slew refers to, the *rate of change of the output voltage.* As an example, a slew rate of 1 volt per microsecond (V/µs) means, the amplitude of output voltage can change by a maximum of 1 V in 1µs. Fast slew rate or high slew rate is desirable for high frequency amplifiers, especially those with non-sinusoidal input signal wave shapes.

DC supply voltage for Op–Amps

Op-Amps generally need dual (±) DC supply. Typical values of DC supply voltages are ± 9 V ± 15 V and ± 22V. Note that both positive and negative voltages of same amplitude is required for Op-Amps. The V^+ is used as the collector voltage, and the V^- is used as the emitter supply voltage of the first differential amplifier stage of the Op Amp as shown in Fig.4

The DC load current drawn from the power supply for an Op-Amp is generally less than a few milliamps. Typical power rating of Op-Amps is around 500 mW.

Commercial Op-Amp ICs

The earliest and most popular commercial Op-Amp is the 741 IC. This Op-Amp IC is manufactured by several manufacturers, and hence, carries along with it tags such as uA 741(Fairchild), LM 741 (National semiconductor) and so on. Commercially several other types of Op-Amp ICs having different type numbers are available in the market. Some IC packages may consist of more than one Op-Amp built-in a single package. For instance, LM324 (National semiconductors) is a quad-operational ampli-fier. The term quad means it has four Op-Amp in one package. Some of the popular Op-Amps and its specifi-cations manufactured by National Semiconductors).

Op-Amp Applications - differential & instrumentation amplifiers

Objectives: At the end of this lesson you shall be able to
- **describe the working of differential amplifier**
- **describe the operation of instrumentation amplifier.**

Differential amplifier:

The easiest way to construct fully-differential circuit is to think of the inverting op-amp feedback topology. In fully-differential op-amp circuits, there are two inverting feedback paths:

1 Inverting input to noninverting output

2 Noninverting input to inverting output

Both feedback paths must be closed for the fully - differential op-amp to operate properly.

The differential amplifier has a unique feature that many circuits don't have - two inputs. This circuit amplifies the difference between its input terminals. Other circuits with one input actually have another input – the ground potential. But, in cases where a signal source (like a sensor) has both of its terminals biased at several volts above ground, you need to amplify the difference between the terminals. What about noise that adds an unwanted voltage equally to both terminals of a sensor? The differential amplifier reject the noise and rescue the signal.

A new pin

Fully-differential op-amps have an extra input pin (V_{COM}). The purpose of this pin is to provide a place to input a potentially noisy signal that will appear simultaneously on both inputs – i.e. common mode noise. The fully-differential op-amp can then reject the common mode noise.

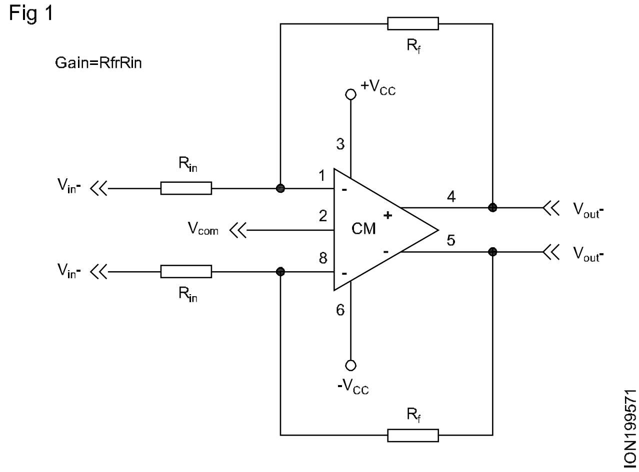
The V_{COM} pin can be connected to a data converter reference voltage pin to achieve tight tracking between the op-amp common mode voltage and the data converter common mode voltage. In this application, the data converter also provides a free dc level conversion for single supply circuits. The common mode voltage of the data converter is also the dc operating point of the single-supply circuit. The designer should take care, however, that the dc operating point of the circuit is within the common mode range of the op-amp + and – inputs. This can most easily be achieved by summing a dc level into the inputs equal or close to the common mode voltage.

Gain

A gain stage is a basic op-amp circuit. Nothing has really changed from the single-ended design, except that two feedback pathways have been closed. The differential gain is still Rf /Rin a familier concept to analog designers. fig 1 shows the differential amplifier circuit.

This circuit can be converted to a single-ended input by connecting either of the signal inputs to ground. The gain equation remains unchanged, because the gain is the differential gain.

Fig 1



Instrumentation amplifier:

An instrumentation system is used to measure the output singal produced by a transducer. The input stage is composed of a transducer, depending on the physical quantity to be measured.

The output stage may use devices such as meters, oscilloscopes and display circuits. The signal source of instrumentation amplifier is the output of the transducer. To amplify the low level output signal of the transducer, instrumentation amplifier is used in the middle. It is nothing but a differential amplifier using 3 op-amps and mainly used in instrumentation system.

Instrumentatiion amplifier is differencial OP-Amp circuit which providing high input impedence with simple gain adjustment.

The differential input single-ended output istrumentation amplifier is one of the most versatile signal processing amplifiers available. It is used for precision amplification of differential dc or ac signals while rejecting large values of common mode noise. By using integrated circuits, a high level of performance is obtained at minimum cost.Fig.2 shows a basic instrumentation amplifier which provides a 10 volt output for 100 mW input, while rejecting common mode noise. To obtain good input characteristics, two voltage followers buffer the input signal. The LM102 is specifically designed for voltage follower usage and has 10,000 MΩ input impedance with 3 nA input currents. This high input impedance provides two benefits: it allows the instrumentation amplifier to be used with high source resistances and still have low error; and it allows the source resistances to be unbalanced by over 10,000X with no degradation in common mode rejection.

The followers drive a balanced differential amplifier, as shown in Fig 2, which provides gain and rejects the common mode voltage. The gain is set by the ratio of R4 to R2 and R5 to R3. With the values shown, the gain for differential signals is 100.

To obtain good common mode rejection ratios, it is necessary that the ratio of R4 to R2 match the ratio of R5 to R3.For example, if the resistors in circuit shown in Figure 1 had a total mismatch of 0.1%, the common mode rejection would be 60 dB times the closed loop gain, or 100 dB. The circuit shown in Fig 3 would have constant common mode rejection of 60 dB, independent of gain.

Fig 2

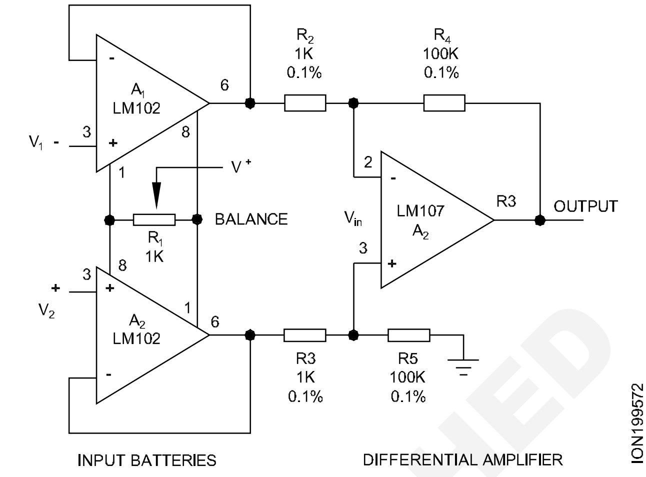
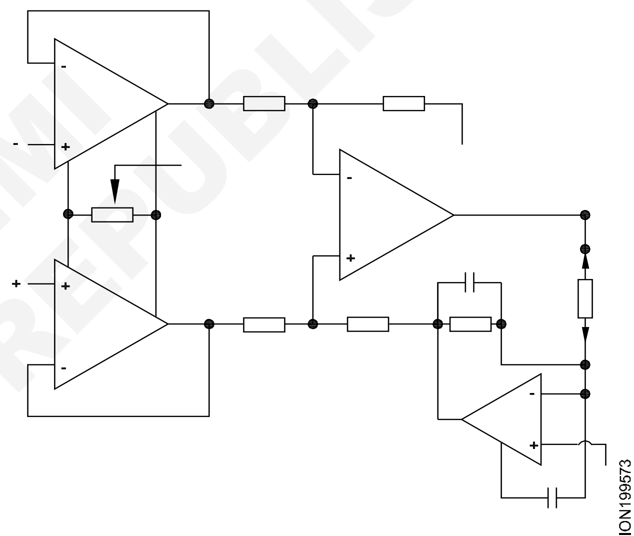


Fig 3



The important features of instrumentation amplifier are

a High gain accuracy

b High CMRR

c Low dc offset

d High input impedance

e Low output impedance

f Low noise

In either circuit,it is possible to trim any one of the resistors to obtain common mode rejection ratios in excess of 100 dB.

For optimum performance, several items should be considered during construction. R1 is used for zeroing the output.It should be a high resolution, mechanically stable potentiometer to avoid a zero shift from occuring with mechanical disturbances. Since there are several ICs operating in close proximity, the power supplies should be bypassed with 0.01 µF disc capacitors to insure stability. The resistors should be of the same type to have the same temperature coefficient.

A high I/P impedance instrumentation amplifier is shown below.

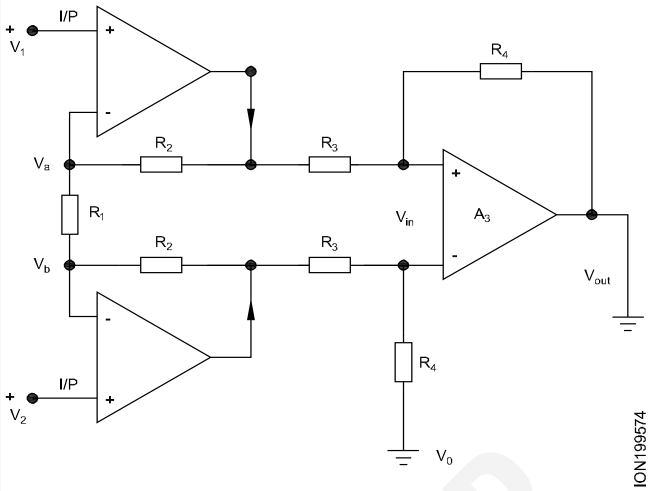
This circuit consisting two buffer circuits with '3' new resistors (R_2,R_1,R_2) linking them. The gain of amplifier can change by sinply adjusting 'R_1' value.

$$\text{Voltage gain (AV)} = \frac{V_O}{(V_1 - V_2)}$$

$$= \left(1 + \frac{2R_2}{R_1}\right) x \frac{R_4}{R_3}$$

If need variable gain, simply replace a 'R_1' with potentiometer.

Fig 4



Voltage-to-current & current-to-voltage converter using OP AMP

Objective: At the end of this lesson you shall be able to
- **explain voltage-to-current converter and current-to-voltage converter.**

Voltage-to-current converter

Figure 1 shows a feedback circuit. Since the returning voltage opposes the input voltage the feedback is negative, from Fig 1.

$I_{out} = V_{in}/R$ ...... (1)

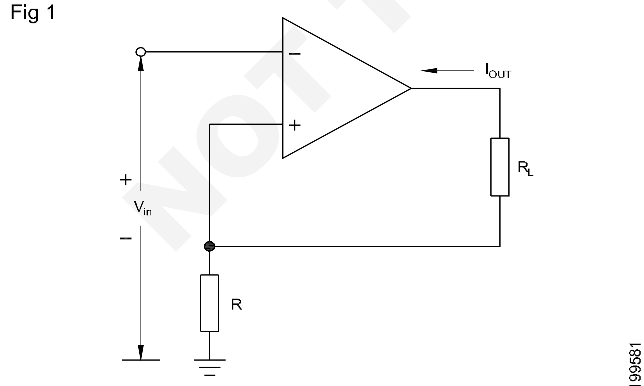
$Z_{in} = \infty$ ...... (2)

$Z_{out} = \infty$ ...... (3)

In a perfect voltage-to-current convertor, the output current depends only on the input voltage and the value of R.

The infinite input impedance means the voltage-to-current converter will not load down the circuit driving it. Also, the infinite output impedence implies the circuit acts like a current source. A voltage-to-current converter has a high input impedence and a high output impedence. One of the application of voltage-to-current converter is in building an electronic voltmeter.

Fig 1



VOLTAGE - TO - CURRENT CONVERTER

Application

In instrumentation most of transducers produces voltage easily, but current is not producing easily. So for converting voltage to current using OP-Amp based circuits.

Current to voltage converter

Figure 2 shows current-to-voltage converter of negative feedback. From Fig 2.

$V_{out} = R \times I_{in}$ ...... (1)

$Z_{in} = \infty$ ...... (2)

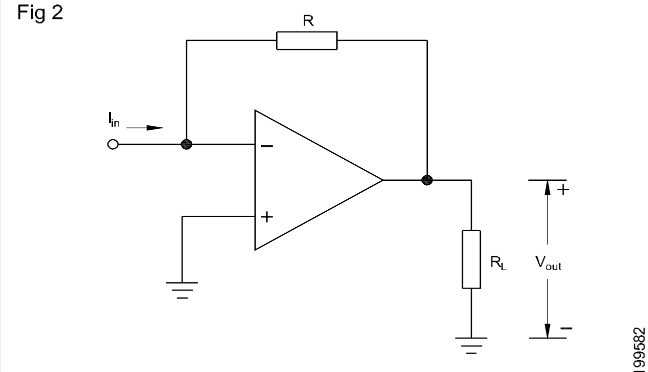
$Z_{out} = 0$ ...... (3)

In a perfect current-to-voltage converter the output voltage depends only on the input current and the value of R.

The zero input impedence means the converter looks like a perfect current sink (ground). A current-to-voltage converter will not load down the circuit driving it and also its output voltage is unaffected by small load resistance.

A current-to-voltage converter has a high input impedance and a low output impedance. One of the application of the current -to-voltage converter is in building an electronic ammeter.

Fig 2



CURRENT - TO - VOLTAGE CONVERTER

Applications

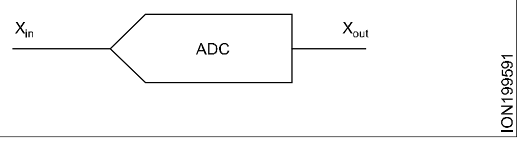
The transmitter outputs are mostly in current. But where as the display systems are required voltage input for this purpose, current to voltage converters are using.

Introduction to ADC and DAC, schematic diagram, features and characteristic with the applications

Objectives: At the end of this lesson you shalll be able to
- **explain the function of A to D converter and its types**
- **explain successive-approximation method of A/D converter**
- **state the characteristic of ADC 0809 IC**
- **list the application of ADC.**

In electronics there are several circuit designed according to requirements. An analog-to-digital converter is a circuit that converts an analog signal from a microphone or a digital camera, into a digital signal.The schematic representation of ADC is shown in Fig 1.

Fig 1



This electronic circuit directly converts the continuous form of signal to discrete form is also expressed as A/D or A-to-D or ADC .

Analog to digital conversion is necessary when measured quantities must be in digital form for processing in a computer for display or storage. This A/D converter is a linkage between the analog (linear) world of transducers measuring parameter like temperature, pressure, vibration etc into equivalent digital signals for discrete world of processing the signal and handling the data.

The major factors that determine the quality performance of A/D converter are resolution, sampling rate, speed and linearity. The resolution is the smallest change in voltage that can be detected by the system and that can produce a change in the digital code.

The speed of a A/D converter is determined by the time it takes to perform the conversion process. Analog signal can be converted to digital codes by many methods of which successive approximation and flash A/D conversion methods are most common

Types of Analog to Digital Converter

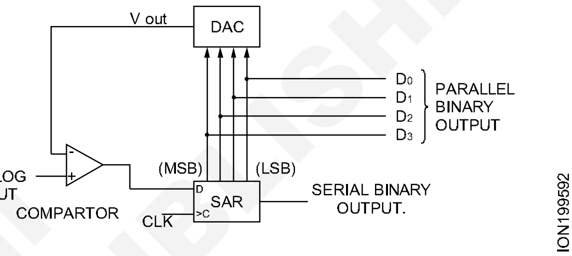
- Successive Approximation ADC: This converter compares the input signal with the output of an internal DAC at each successive step. It is the most expensive type.
- Dual Slope ADC: It has high accuracy but very slow in operation.
- Pipeline ADC: It is same as that of two step Flash ADC.
- Delta-Sigma ADC: It has high resolution but slow due to over sampling.
- Flash ADC: It is the fastest ADC but very expensive.
- Other: Staircase ramp, Voltage-to-Frequency, Switched capacitor, tracking, Charge balancing, and resolver.

Successive-approximation A/D converter

Successive approximation is perhaps the most widely used method of A/D conversion. It has a much shorter conversion time, it also has fixed conversion time that is the same for any value of the analog input.

The Fig 2 shows basic block diagram of a 4 bit successive approximation ADC. It consists of a DAC, a successive-approximation register (SAR), and a comparator.

Fig 2



The basic operation is as follows:

The input bits of the DAC are enabled (made equal to logic-1) one at a time, starting with MSB, as each bit is enabled, the comparator produces an output that indicates whether the analog input voltage is greater or less than the output of the DAC for the corresponding I/p. If the DAC output is greater than the analog input, the comparator's output is low, causing the bit in the register to RESET. If the DAC output is less than the analog input the '1' bit is retained in the SAR register. The system does this with the MSB first, then the next most significant bit, then the next and so on. After all the bits of the DAC have been tried, the conversion cycle is complete.

Fig 3 illustrates the step-by-step conversion of a constant analog input voltage (5V in this case). Let us assume that the DAC has the following output characteristic: V_{out} = 8V for the 2^3 bit (MSB), V_{out} = 4V for the 2^2 bit, V_{out} = 2V for the 2^1 bit and V_{out} = 1V for the 2^0 bit (LSB).

Fig 3a shows the first step in the conversion cycle with the MSB=1, the output of the DAC=8V. Since this is greater than the analog input of 5V, the output of the DAC is 8V. Since this is greater than the analog input of 5V, the output of the comparator is low, causing the MSB in the SAR to be reset to a logic-0.

Fig 3b shows the second step in the conversion cycle with the 2^2 bit equal to a logic-1. The output of the DAC is 4V, since this is less than the analog input of 5V, the output of the comparator switches to a HIGH, causing this bit to be retained in the SAR.

Fig 3c shows the third step in the conversion cycle with the 2^1 bit equal to a logic-1. The output of the DAC is 6 volts because there is a logic-1 on the 2^2 bit input and on the 2^1 bit input 4V+2V=6V, since this is greater than the analog input of 5V, the output of the comparator. Switches to a LOW, causing this bit to be RESET to a logic-0.

Fig 3

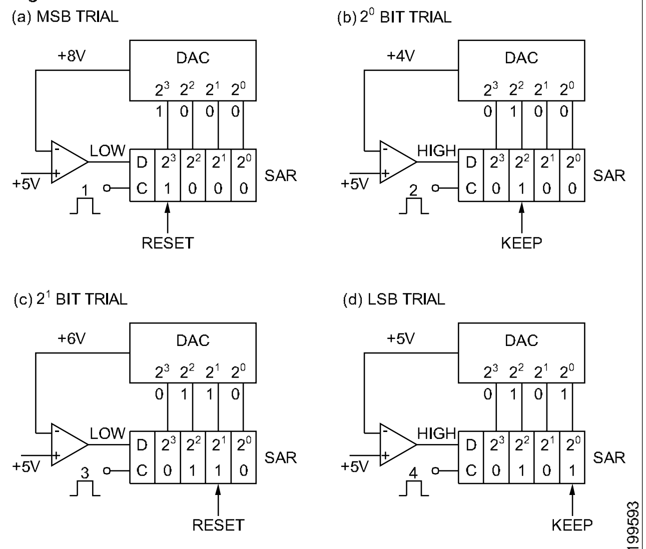


ILLUSTRATION OF SUCCESSIVE-APPROXIMATION CONVERSION PROCESS

Fig 3d shows the fourth and final step in the conversion cycle with the 2^0 bit equal to a logic-1. The output of the DAC is 5V because there is a logic-1 on the 2^2 bit input and on the 2^0 bit input 4V+1V=5V.

The four bits have all been tried, thus completing the conversion cycle. At this point the binary code in the register is 0101, which is the binary value of the analog input of 5V. Another conversion cycle now begins and the basic process is repeated. The SAR is cleared at the beginning of each cycle.

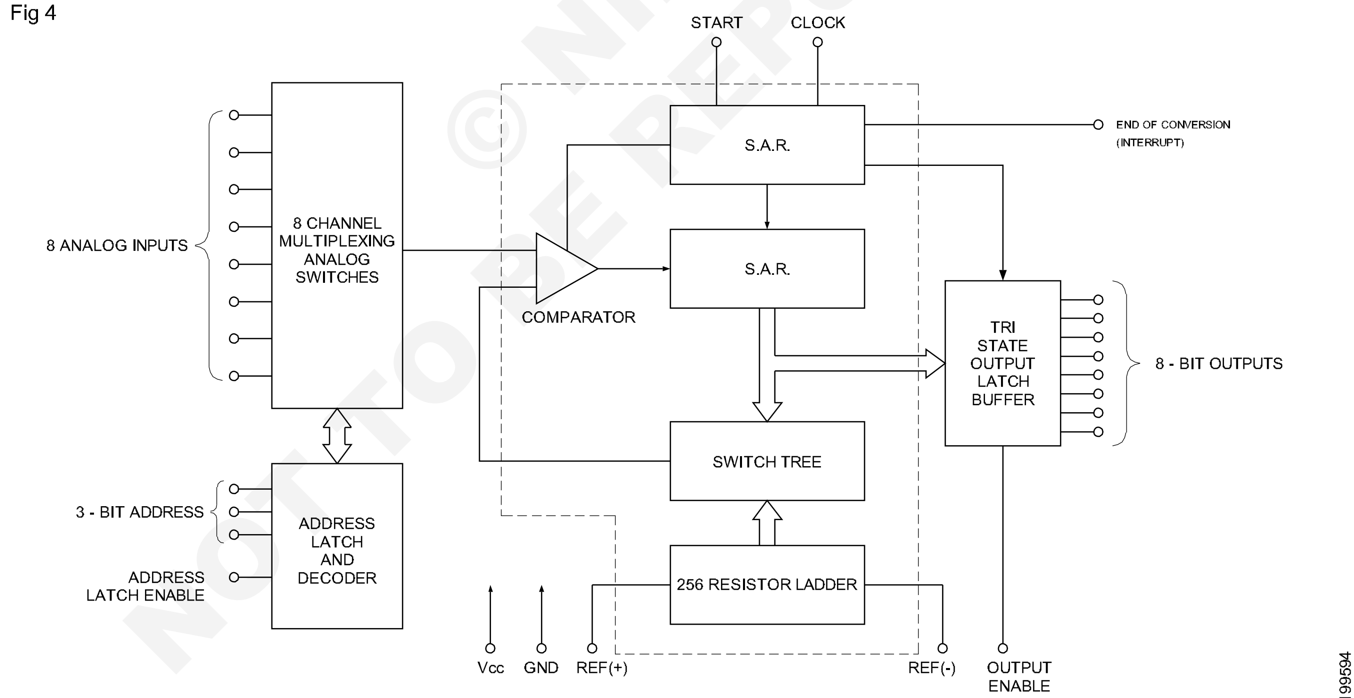
Analogue to digital converter ADC0808/0809 8 bit microprocessor compatible A/D converter

The ADC0808/0809 data acquisition device implement on a single chip most the elements of the standard data acquisition system. They contain an 8-bit A/D converter, 8 channel multiplexer with an address input latch and associated control logic. These device provide most of the logic to interface to a variety of microprocessors with the addition of a minimum number of parts.

Functional description

The ADC0808/0809 shown in the above Fig 4 can be functionally divided into 2 basic sub circuits. These two sub circuits are an analog multiplexer and an A/D converter. The multiplexer uses 8-standard CMOS analog switches to provide for upto 8 analog inputs, the switches are selectively turned on, depending on the data latched into 3-bit multiplexer address register.

Fig 4



BLOCK DIAGRAM OF 8 - BIT MICROPROCESSOR COMPATIBLE ANALOG TO DIGITAL CONVERTERS

The second function block, the successive approximation A/D converter transforms the analog output of the multiplexer to an 8 bit digital word, the output of the multiplexer goes to one of two comparator inputs. The other input is derived from a 256R resistor ladder, which is tapped by a MOSFET transistor switch tree. The converter control logic controls the switch tree, funneling a particular tap voltage to the comparator, based on the result of this comparison, the control logic and the successive approximation register (SAR) will decide whether the next tap to be selected should be higher or lower than the present tap on the resistor ladder, this algorithm is executed 8 times per conversion, once every 8 clock periods, yielding a total conversion time 64 clock period.

When the conversion cycle is complete the resulting data is loaded into the tri-state output latch can then be read by the host system any time before the end of the next conversion. The try state capability of the latch allows easy interface to bus oriented systems.

Application of ADC

- Used together with the transducer.
- Used in computer to convert the analog signal to digital signal.
- Used in cell phones.
- Used in microcontrollers.
- Used in digital signal processing.
- Used in digital storage oscilloscopes.
- Used in scientific instruments.
- Used in music reproduction technology etc.

Digital - to - Analog converter

Objective: At the end of this lesson you shall be able to
- **explain the function of digital to analog converter.**

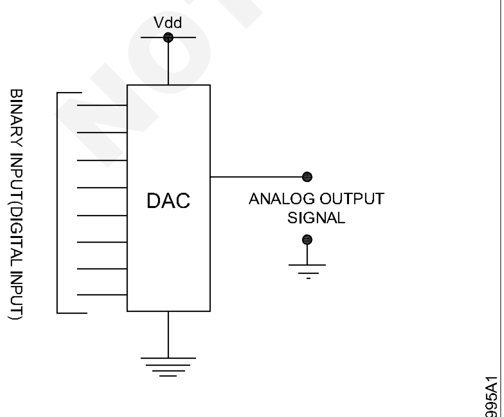
Digital to Analog Converter (DAC) is a device that transforms digital data into an analog signal. A DAC can reconstruct sampled data into an analog signal with precision. The digital data may be produced from a microprocessor, Application Specific Integrated Circuit (ASIC), or Field Programmable Gate Array (FPGA), but ultimately the data requires the conversion to an analog signal in order to interact with the real world. The block diagram of Basic Digital to Analog Converter is shown in Fig 1.

D/A Converter Architectures: There are two methods commonly used for digital to analog conversion: Weighted Resistors method and the other one is using the R-2R ladder network method.

DAC 0808 Digital to Analog converter

The DAC 0808 series is an 8 bit monolithic digital-to-analog converter (DAC) featuring a full scale output current setting time of 150ns while dissipating only 33mw with ±5V supplies. No reference current (I_{ref}) trimming is required for most applications since the full scale output current is typically ±1 LSB of 255 I_{ref}/256. Relative accuracies of better than ±0.19% assure 8-bit monotonicity and linearity, while zero level output current of less than 4μA provides 8-bit zero accuracy for I_{ref} = 2mA, the power supply currents of the DAC 0808 series are independent of bit codes and exhibits essentially constant device characteristics over the entire supply voltage range.

Fig 1



BLOCK DIAGRAM OF DAC

The DAC 0808 will interface directly with popular TTL, DTL or CMOS logic levels, and is a direct replacement for the MC1508/MC1408.

The Fig 1 shows the data bits of a DAC0808 connected to port 22H of minimum system. Pin 2 of the DAC0808 is grounded, and a 15pF compensating capacitor is between pins 16 and 3, +5V supply sets up a reference current for the R-2R ladder, pin 14 is connected to a positive supply through a resistor (trimmer) R_{14} allows you to adjust this to 2mA and pin 15 is grounded through a resistor R_{15} is the same size as R_{14}; this compensates for drift in the input stage of the converter. Notice that I_{out} drives the inverting input of an op-amp; therefore the final output ranges from 0 to +2V. Pin 1 is unused, pin 2 is chip ground, pin 3 (V_{EE}) is -5V, pin 4 is the ground return for the current out of the ladder; this pin usually connects to an op-amp, pin 5 to 12 are for the 8 bits of input data, Pin 13(V_{CC}) is +5V. Finally a capacitor between pin 16 and pin 3 frequency-compensates the device.

Grounding and bypassing

D/A and A/D converter IC(s) require correct grounding and capacitive bypassing in order to operate according to performance specifications. The digital signals can severely impair analog signals to contact the electromagnetic interference caused by the digital signals, the analog and digital grounds should be kept separate and should have only one common point on the circuit board. Bypass capacitors are required at the power connections to the IC, the reference signal inputs and the analog inputs to minimize noise that is induced by the digital signals. Manufacturer specifies the recommended bypass capacitor locations and values in the data sheet.

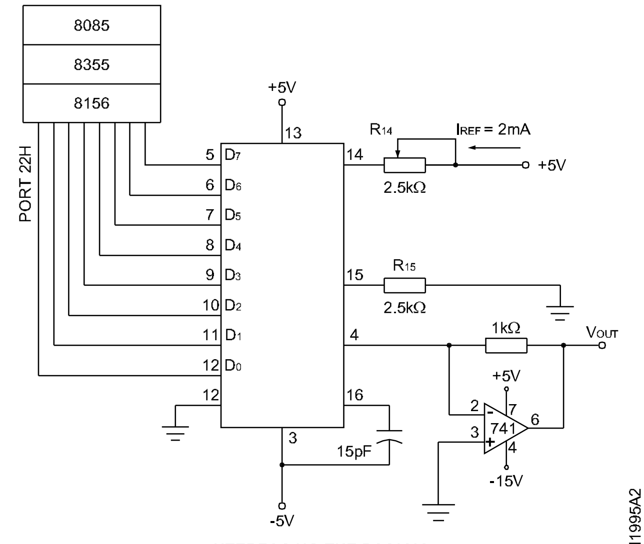
The typical DAC 0808 Digital to Analog converter is shown in Fig 2 and its working is explained below:

Applications of Digital to Analog Converter

DACs are used in many digital signal processing applications and many more applications. Some of the important applications are discussed below.

- **Audio Amplifier** DACs are used to produce DC voltage gain with Microcontroller commands. Often, the DAC will be incorporated into an entire audio codec which includes signal processing features.

Fig 2



INTERFACING THE DAC0808

- **Video Encoder** the video encoder system will process a video signal and send digital signals to a variety of DACs to produce analog video signals of various formats, along with optimizing of output levels. As with audio codecs, these ICs may have integrated DACs.
- **Display Electronics** the graphic controller will typically use a lookup table to generate data signals sent to a video DAC for analog outputs such as Red, Green, Blue (RGB) signals to drive a display.
- **Data Acquisition Systems** data to be measured is digitized by an Analog-to-Digital Converter (ADC) and then sent to a processor. The data acquisition will also include a process control end, in which the processor sends feedback data to a DAC for converting to analog signals.
- **Calibration** the DAC provides dynamic calibration for gain and voltage offset for accuracy in test and measurement systems.
- **Motor Control** many motor controls require **voltage control signals,** and a DAC is ideal for this application which may be driven by a processor or controller.
- **Digital Potentiometer** almost all digital potentiometers are based on the string DAC architecture. With some reorganization of the resistor/ switch array, and the addition of an I2C compatible interface, a fully digital potentiometer can be implemented.

Frequency selective filters

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

- **state the meaning of frequency selective filters**
- **define an electronic filter**
- **state different types of filters**
- **define a low pass filter**
- **define cut-off frequency**
- **define a high pass filter**
- **applications of high pass filter**
- **define a band pass filter**
- **applications of band pass filter**
- **explain roll-off rate**
- **list a few applications of LPFs.**

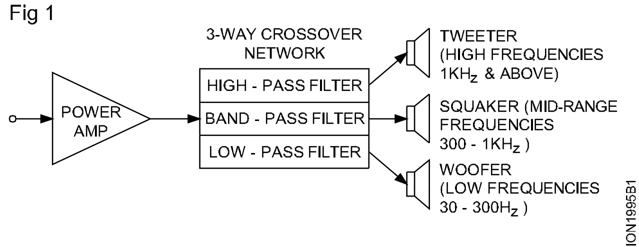
Filters

The term to filter, in general, means to selectively remove. For example, water filters are used to remove dust, dirt and disease causing germs from water. This means, the water filter selectively removes or blocks dust, dirt and disease causing germs but allows or passes purified water. In a o similar way, in electronics, signals may consist of more than one frequency component. Then filters which selectively remove or allow a band of frequencies are used. Such filters are called Frequency selective filters. These filters are common in electronic circuits.

Frequency selective filters are electronic circuits comprising of electronic components such as resistors, capacitors, inductors, and sometimes active devices such as transistors, IC's etc., These circuits are designed to allow or to block (filter) a band of frequencies as shown in Fig 1. Filters may also be designed to allow or block a particular frequency component.

In all the subsequent discussions, the term Filter refers to frequency selective filters only.

Fig 1



Filters constructed using only passive components such as resistors, capacitors and/or inductors are called passive filters.

Filters constructed using active devices such as transistors or op-amps in addition to passive components are called active filters.

Types of FILTERS

Referring to Fig 1, filters may be classified as,

Low pass filters - Passes or allow low frequencies (for example: 30 to 300 Hz)

High pass filters - Passes or allows high frequencies (for example: 1 KHz and above)

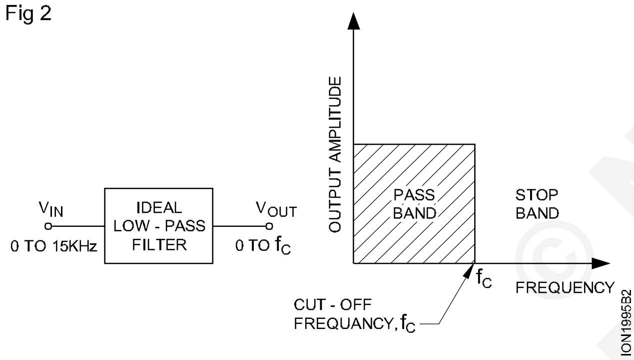
Band pass filters - Passes or allows a particular band of frequencies (for example: 300 Hz to 1 KHz)

Low Pass Filter (LPF)

An ideal low pass filter is a circuit which passes all frequency signals from 0-Hz to a particular frequency called the cut-off frequency. This also means that, a low pass filter stops all signals having frequency beyond the cut off frequency as shown in Fig 2.

The frequency response of an ideal low pass filter as shown in Fig 2 will be constant in the pass band up to the cut off frequency f_c. Beyond f_c , called as the stop band the output of the filter is zero.

Fig 2

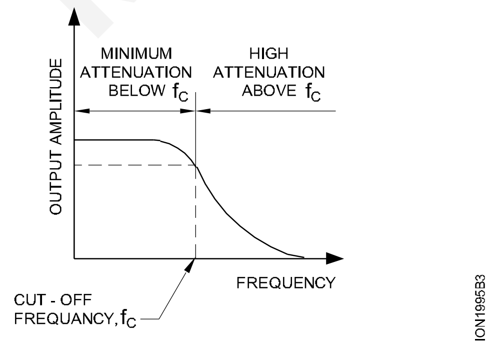


However, in practice it is not possible to design a LPF having ideal characteristics as in Fig 2.

A practical low pass filter can be defined as a circuit which allows all frequencies below a particularfrequency called cut off frequency and attenuates heavily all frequencies above the cut off frequency as shown in Fig 3.

Attenuation means reducing the amplitude/ mag-nitude of the signal.

Fig 3



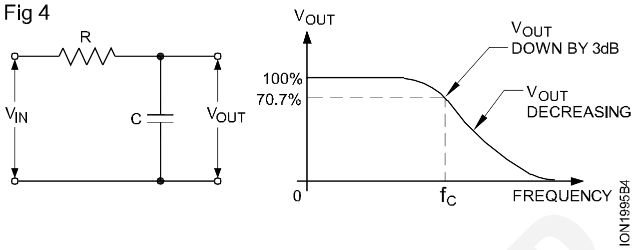
Low pass filters can be constructed using,

- Resistors and capacitors - referred to as RC-filters
- Inductors and capacitors - referred to as LC-filters.

Passive RC-low pass filter

A typical RC low pass filter and its frequency response is shown in Fig 4.

Fig 4



The output of the RC low pass filter is taken across capacitor C.

When input V_{in} is DC (0 Hz), capacitor C behaves practically as open circuit. At low frequencies, reactance of C (X_c = 1/2pf_c) is very high. Hence, at low frequencies capacitor behaves almost as open circuit. Therefore, at low frequencies output of filter is same as the input.

When input signal frequency increases, the capacitive reactance X_c decreases(X_c is inversely proportional to frequency).

Therefore, capacitor C gives a low resistance path for the high frequency signals to ground. Hence, as the input signal frequency increases the output of the filter decreases. This is shown in Fig 4. At a particular high frequency, capacitor C acts as a short circuit grounding all the input. When this happens, V_{out} = 0 volt.

Definition of cut-off frequency

The cut-off frequency, f_c is defined as the frequency at which the power output of the filter is one half of the input power. In terms of voltage, at cut-off frequency f_c, the output amplitude will be 70.7% of the input amplitude as shown in Fig 4.

Cut off frequency fc of a RC low pass filter can be calculated using the formula,

$$f_c = \frac{1}{2\pi RC}$$

where, R = Resistance in ohms
C = Capacitance in farad
f_c = Cut off frequency in Hz.

A low pass filter constructed using one resistor and one capacitor as shown in Fig 4 is known as a single stage LPF. This is also called a single pole LPF Since the output of a LPF lags from input, LPFs are also referred to as Lag networks.

Measurement of gain in DECIBEL (dB)

Gain of a LPF is given by,

Gain in dB = 20 log V_{out} / V_{in}

At cut-off frequency, since the output voltage will be 70.7% of the input ,

Gain of a LPF at cut-off frequency f_c = 20 log (0.707)

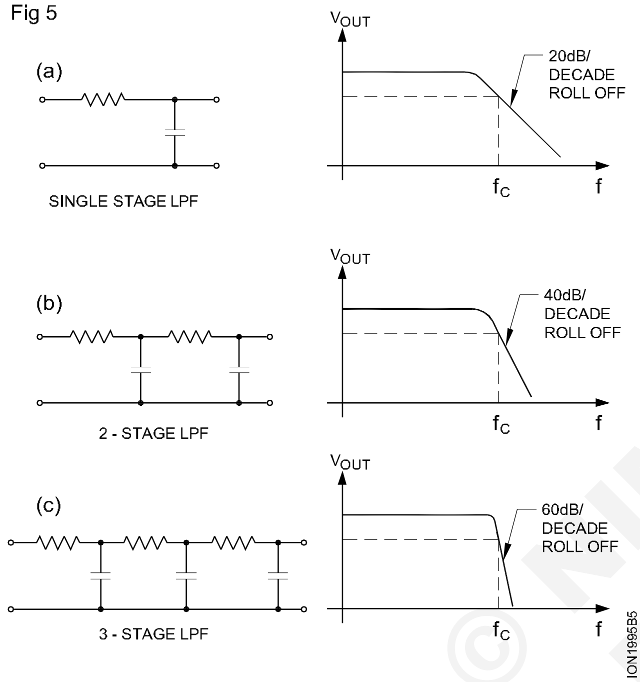
= - 3dB

Hence, in a LPF, f_c is also called the 3dB frequency of the filter.

ROLL-OFF

The rate at which the output level of LPF decreases depends on the number of stages in the LPF as shown in Fig 5.

Fig 5



The rate of decrease in output level, or rate of increase in attenuation after the cut off frequency fc is called roll-off. Roll-off of a filter is expressed in decibels-per-decade (dB/decade) ordecibels-per-octave (dB/octave).

The higher the number of stages in a LPF, the higher will be the roll-off rate and better will be the performance of the LPF as shown in Fig 5.

The disadvantage of cascading more number of filter stages is, the attenuation to the input signal is the pass-band increases as more number of resistors come in series between the input and output.

In general, a n-pole (n-stage) LPF will have 20 x n dB/decade roll off.

Passive LC Low Pass Filter

Low pass filter can be constructed using an inductor (L) and a capacitor (C). A typical L-C low pass filter designed for fc = 1 KHz is shown in Fig 6.

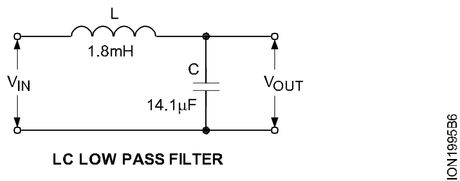
The frequency response of LC low pass filter and RC low pass filter will have the same shape. The cut-off frequency in LC low pass filter is given by,

$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

where, L = inductance value in henry

C = capacitance value in farad.

Fig 6



In audio frequency circuits, LC low pass filters are not preferred as the physical size of the indicator will be large. However, in radio frequency applications(r.f), LCfilters are popular as the inductor size will be small at such high frequencies.

Applications of Low Pass Filter

Low pass filters are used in wide variety of applications. A few such applications are;

1 in DC power supplies as ripple filter to block AC ripples from reaching the output.

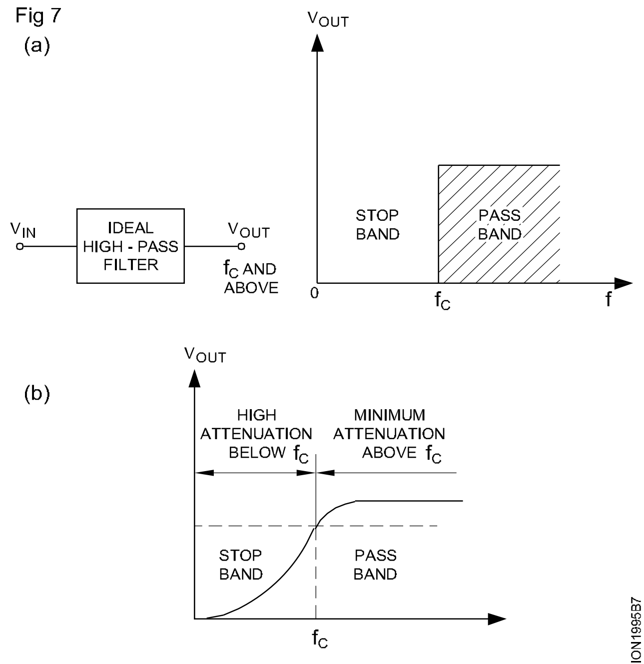
2 in tone control circuit of amplifiers, tape recorder amplifiers etc., to separate low frequencies (Bass o signals).

3 in cross over networks (shown in Fig 1) in speaker boxes.

High Pass Filters (HPF)

A High pass filter is a circuit that only allows signals above a particular frequency called cut-off frequency to pass through it. An ideal HPF blocks signals whose frequency is below the cut off frequency fc as shown in Fig 7a. The frequency response of a practical HPF is shown in Fig 7b.

Fig 7



Applications of High Pass Filters

High pass filters are used in wide variety of applications. A few such applications are;

- in tape recorders and amplifier tone control network
- in loud speaker cross over network
- in scratch filters
- in communication transmitters and receivers.

Band Pass Filters (BPF)

A band pass filter is a circuit that allows all the signals whose frequency is between two frequency limits called lower cut off frequency (f_L) and upper cut off frequency (f_U). Band pass filter heavily attenuates signals whose frequency is less than the lower cut off frequency or more than the upper cut off frequency as shown in Fig 8.

Applications of Band Pass Filters

Band pass filters are used in wide variety of applications. A few such applications are;

- in cross over network
- as voice filters in amplifiers
- in graphic equalizer networks
- in communication transmitters and receivers.

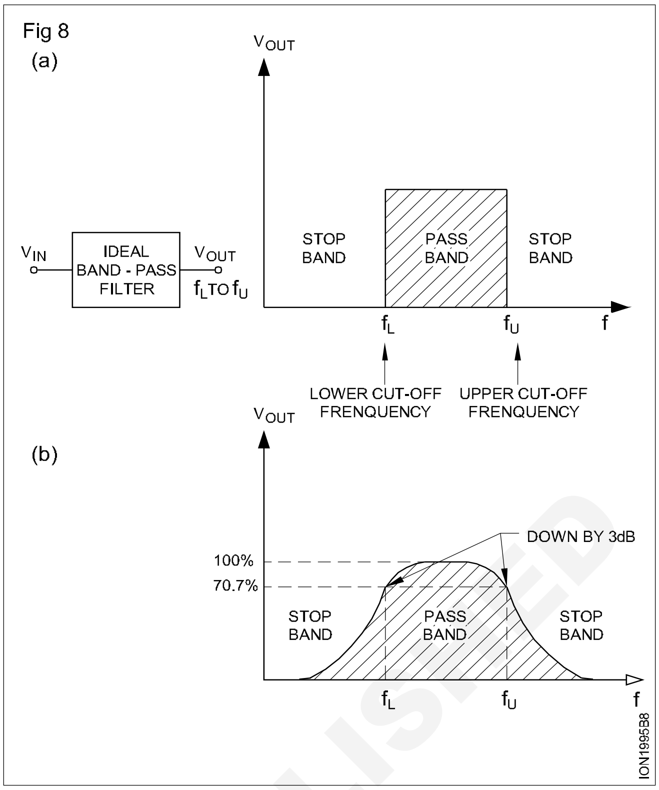


Fig 8

Active filters using OP AMPs

Objective: At the end of this lesson you shall be able to
- **explain the working of active filters using OP AMPs.**

Active filters

In the RC passive filter tutorials, we saw how a basic first-order filter circuits, such as the low pass and the high pass filters can be made using just a single resistor in series with a non-polarized capacitor connected across a sinusoidal input signal.

We also noticed that the main disadvantage of passive filters is that the amplitude of the output signal is less than that of the input signal, ie, the gain is never greater than unity and that the load impedance affects the filters characteristics.

With passive filter circuits containing multiple stages, this loss in signal amplitude called “Attenuation” can become quiet severe. One way of restoring or controlling this loss of signal is by using amplification through the use of Active Filters.

As their name implies, Active Filters contain active components such as operational amplifiers, transistors or FET’s within their circuit design. They draw their power from an external power source and use it to boost or amplify the output signal.

Filter amplification can also be used to either shape or alter the frequency response of the filter circuit by producing a more selective output response, making the output bandwidth of the filter more narrower or even wider. Then the main difference between a “passive filter” and an “active filter” is amplification.

An active filter generally uses an operational amplifier (op-amp) within its design and in the operational amplifier tutorial we saw that an Op-amp has a high input impedance, a low output impedance and a voltage gain determined by the resistor network within its feedback loop.

Unlike a passive high pass filter which has in theory an infinite high frequency response, the maximum frequency response of an active filter is limited to the Gain/Bandwidth product (or open loop gain) of the operational amplifier being used. Still, active filters are generally more easier to design than passive filters, they produce good performance characteristics, very good accuracy with a steep roll-off and low noise when used with a good circuit design.

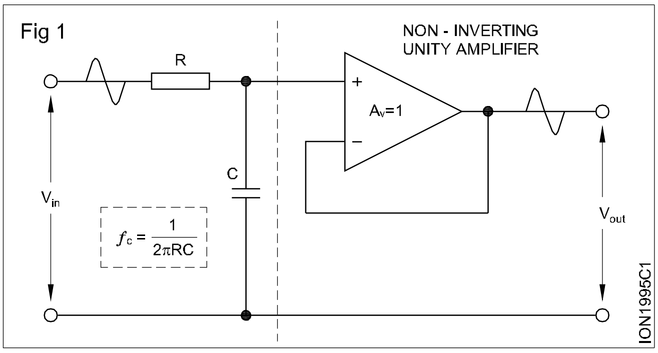
Active low pass filter

The most common and easily understood active filter is the Active Low Pass Filter. Its principle of operation and frequency response is exactly the same as those for the previously seen passive filter, the only difference this time is that it uses an op-amp for amplification and gain control. The simplest form of a low pass active filter is to connect an inverting or non-inverting amplifier, the same as those discussed in the Op-amp, to the basic RC low pass filter circuit as shown.

First order active low pass filter

This first-order low pass active filter, consists simply of a passive RC filter stage providing a low frequency path to the input of a non-inverting operational amplifier. The amplifier is configured as a voltage-follower (Buffer) giving it a DC gain of one, Av = +1 or unity gain as opposed to the previous passive RC filter which has a DC gain of less than unity.

Fig 1



The advantage of this configuration is that the op-amps high input impedance prevents excessive loading on the filters output while its low output impedance prevents the filters cut-off frequency point from being affected by changes in the impedance of the load.

While this configuration provides good stability to the filter, its main disadvantage is that it has no voltage gain above one. However, although the voltage gain is unity the power gain is very high as its output impedance is much lower than its input impedance. If a voltage gain greater than one is required we can use the following filter circuit.

Active low pass filter with amplification

The frequency response of the circuit will be the same as that for the passive RC filter, except that the amplitude of the output is increased by the pass band gain, A_F of the amplifier. For a non-inverting amplifier circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R_2) divided by its corresponding input resistor (R_1) value and is given as:

$$\text{DC Gain} = \left(1 + \frac{R_2}{R_1}\right)$$

Therefore, the gain of an active low pass filter as a function of frequency will be:

$$\text{Voltage Gain, (Av)} = \frac{V_{out}}{V_{in}} = \frac{AF}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}}$$

Gain of a first-order low pass filter

Where

- A_F = the pass band gain of the filter, (1 + R2/R1)
- f = the frequency of the input signal in Hertz, (Hz)
- fc = the cut-off frequency in Hertz, (Hz)

Thus, the operation of a low pass active filter can be verified from the frequency gain equation above as:

1 At very low frequencies, $f < fc \quad \frac{V_{out}}{V_{in}} \approx A_f$

2 At the cut-off frequency, $f = fc \quad \frac{V_{out}}{V_{in}} = \frac{A_f}{\sqrt{2}} = 0.707A$

3 At very high frequencies, $f > fc \quad \frac{V_{out}}{V_{in}}$

Thus, the Active Low Pass Filter has a constant gain A_F from 0Hz to the high frequency cut-off point, f_C. At f_C the gain is $0.707A_F$, and after f_C it decreases at a constant rate as the frequency increases. That is, when the frequency is increased tenfold (one decade), the voltage gain is divided by 10.

In other words, the gain decreases 20dB (= 20 log10) each time the frequency is increased by 10. When dealing with filter circuits the magnitude of the pass band gain of the circuit is generally expressed in *decibels* or *dB* as a function of the voltage gain, and this is defined as:

Magnitude of Voltage Gain in (dB)

$$Av(dB) = 20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$$

$$-3dB = 20\log_{10}\left(0.707\frac{V_{out}}{V_{in}}\right)$$

Active low pass filter example no1

Design a non-inverting active low pass filter circuit that has a gain of ten at low frequencies, a high frequency cut-off or corner frequency of 159Hz and an input impedance of 10K.

The voltage gain of a non-inverting operational amplifier is given as:

$$AF = 1 + \frac{R_2}{R_1} = 10$$

R2 = (10-1) x R = 9 x 1KΩ = 9KΩ

Assume a value for resistor R1 of 1KW rearranging the formula above gives a value for R2 of then, for a voltage gain of 10, R1 = 1KW and R2 = 9KW. However, a 9KW resistor does not exist so the next

Gain in dB = 20 log A = 20 log 10 = 20 dB

preferred value of 9kW is used instead. Converting this voltage gain to a decibel dB value gives:

Gain in dB = 20 log A = 20 log 10 = 20 dB

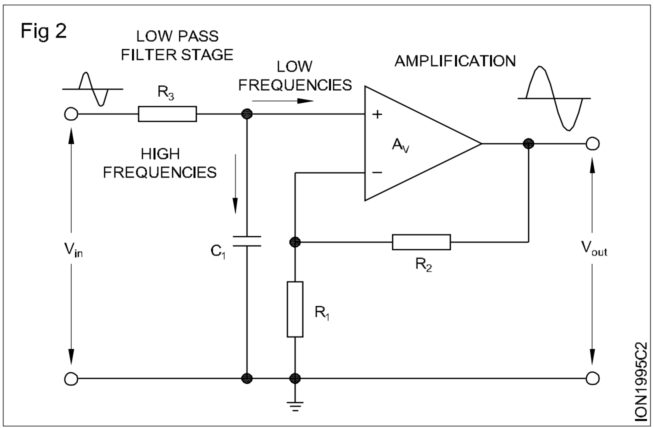
The cut-off or corner frequency (fc) is given as being 159Hz with an input impedance of 10KW. This cut-off frequency can be found by using the formula:

where f_c = 159Hz and R = 10KW.

$$C = \frac{1}{2\Pi fcR} = \frac{1}{2\,\Pi\,x159x10k\,\Omega} = 100nF$$

then, by rearranging the above formula we can find the value for capacitor C as:

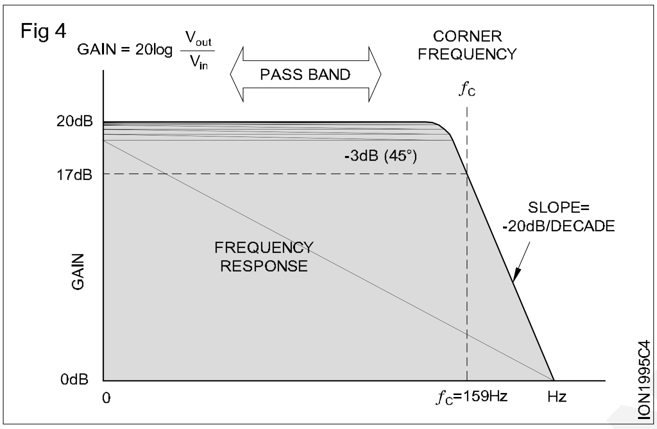
Fig 2



Then the final circuit along with its frequency response is given below as:

Low pass filter circuit (Fig 3)

Fig 4



Frequency response curve

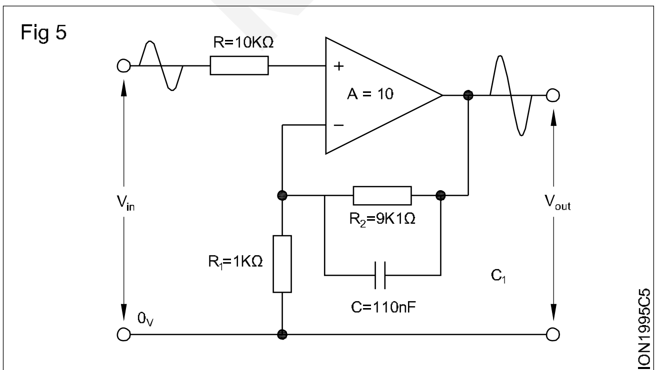
If the external impedance connected to the input of the circuit changes, this change will also affect the corner frequency of the filter (components connected in series or parallel). One way of avoiding this is to place the capacitor in parallel with the feedback resistor R2.

The value of the capacitor will change slightly from being 100nF to 110nF to take account of the 9k1O resistor and the formula used to calculate the cut-off corner frequency is the same as that used for the RC passive low pass filter.

$$fc = \frac{1}{2\Pi CR_2} \text{Hertz}$$

An example of the new Active Low Pass Filter circuit is given as.

Fig 5

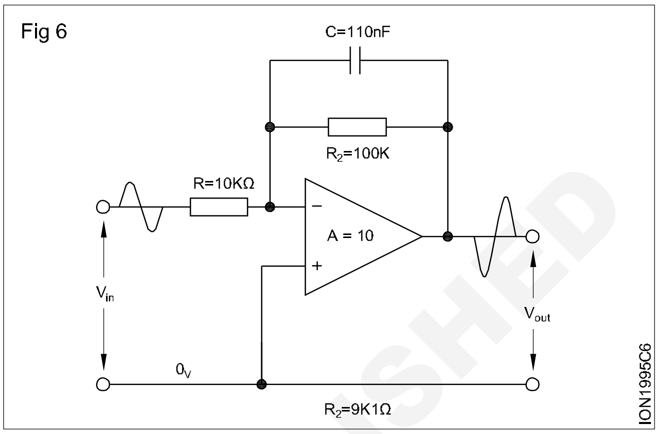


Simplified non-inverting amplifier filter circuit

Equivalent inverting amplifier filter circuit

Applications of Active Low Pass Filters are in audio amplifiers, equalizers or speaker systems to direct the lower frequency bass signals to the larger bass speakers or to reduce any high frequency noise or "hiss" type distortion. When used like this in audio applications the active low pass filter is sometimes called a "Bass Boost" filter. (Fig 6)

Fig 6

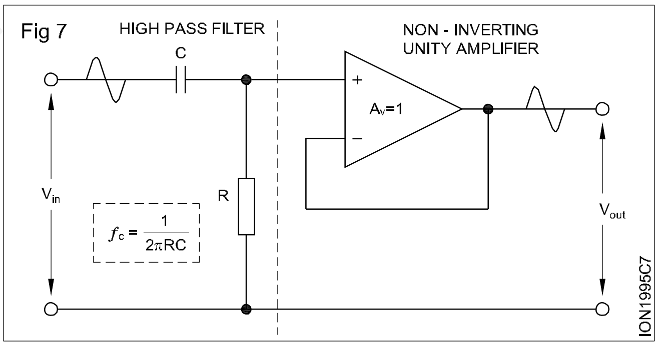


Active high pass filters

The basic electrical operation of an Active High Pass Filter (HPF) is exactly the same as we saw for its equivalent RC passive high pass filter circuit, except this time the circuit has an operational amplifier or op-amp included within its filter design providing amplification and gain control.

Like the previous active low pass filter circuit, the simplest form of an active high pass filter is to connect a standard inverting or non-inverting operational amplifier to the basic RC high pass passive filter circuit as shown in Fig 7.

Fig 7



First order active high pass filter

Technically, there is no such thing as an active high pass filter. Unlike Passive High Pass Filters which have an "infinite" frequency response, the maximum pass band frequency response of an Active High Pass Filter is limited by the open-loop characteristics or bandwidth of the operational amplifier being used, making them appear as if they are band pass filters with a high frequency cut-off determined by the selection of op-amp and gain.

In the Operational Amplifier tutorial we saw that the maximum frequency response of an op-amp is limited to the Gain/Bandwidth product or open loop voltage gain (A V) of the operational amplifier being used giving it a bandwidth limitation, where the closed loop response of the op amp intersects the open loop response.

A commonly available operational amplifier such as the uA741 has a typical "open-loop" (without any feedback) DC voltage gain of about 100dB maximum reducing at a roll off rate of -20dB/Decade (-6db/Octave) as the input frequency increases. The gain of the uA741 reduces until it reaches unity gain, (0dB) or its "transition frequency" (ft) which is about 1MHz. This causes the op-amp to have a frequency response curve very similar to that of a first-order low pass filter and this is shown below.

Specification and working of analog sensor inputs as well as analog control outputs

Objectives: At the end of this lesson you shalll be able to
- **define the transducers, sensors and basics of passive & active transducers**
- **explain thermistor, its types and construction details**
- **describe the working principle, features, applications, advantage & disadvantages.**

Transducers and sensors

Transducer

A transducer is a device that is used to convert a physical quantity into its corresponding electrical signal or vice versa. In most of the electrical systems, the input signal will not be an electrical signal, but a non-electrical signal. This will have to be converted into its corresponding electrical signal if its value is to be measured using electrical methods.

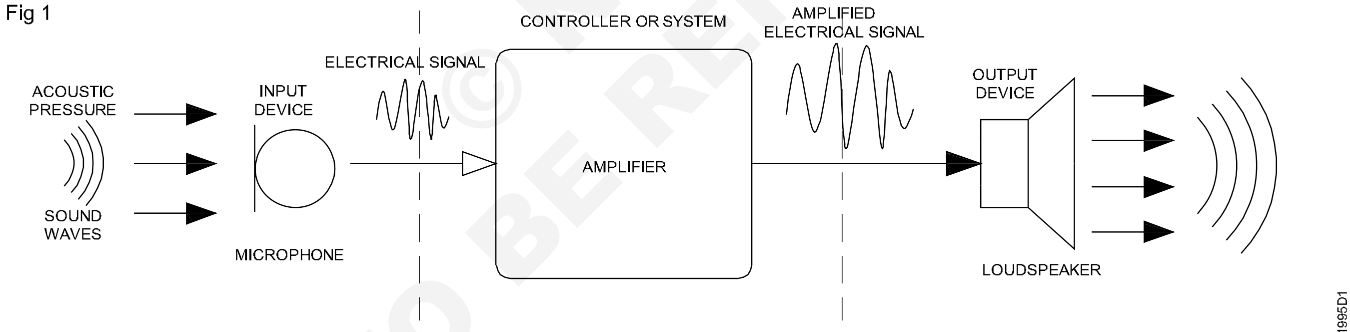
Sensor: Devices which perform an "Input" function are commonly called Sensors because they "sense" a physical change in some characteristic that changes in response to some excitation, for example heat or force is converted into an electrical signal.

There are different types of Sensors and Transducers, both analogue & digital and input & output available to choose from. The type of input or output transducer being used, really depends upon the type of signal or process being "Sensed" or "Controlled" but we can define a sensor and transducers as devices that converts one physical quantity into another.

Simple Input/Output System using Sound Transducers as shown in Fig 1

There are different types of sensors and transducers available in the market, and the choice of which one to use really depends upon the quantity being measured or controlled. The more common types given in the Table 1.

Fig 1



INPUT/OUTPUT SYSTEM USING SOUND TRANSDUCERS

Table 1

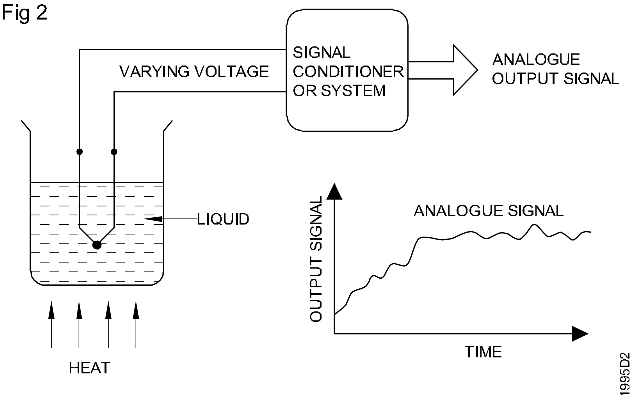
Physical quantity being measured by the sensor	Input Device (Sensor)	Output Device (Actuator)
Light Level	Light Dependant Resistor (LDR) Photodiode, Photo-transistor Solar Cell	Lights & Lamps, LED's & Displays, Fibre Optics
Temperature	Thermocouple, Thermistor, Thermostat, Resistive Temperature Detectors	Heater, Fan
Force/Pressure	Strain Gauge, Pressure Switch Load Cells	Lifts & Jacks Electromagnet, Vibration
Position	Potentiometer, Encoders Reflective/Slotted Opto-switch LVDT	Motor, Solenoid Panel Meters
Speed	Tacho-generator, Reflective/Slotted Opto-coupler, Doppler Effect Sensors	AC and DC Motors Stepper Motor, Brake
Sound	Carbon Microphone, Piezo-electric Crystal	Bell Buzzer, Loudspeaker

Analogue and Digital Sensors

Analogue Sensors

Analogue Sensors produce a continuous output signal or voltage which is generally proportional to the quantity being measured. Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc are all analogue quantities as they tend to be continuous in nature. For example, the temperature of a liquid can be measured using a thermometer or thermocouple which continuously responds to temperature changes as the liquid is heated up or cooled down as shown in Fig 2.

Fig 2



THERMOCOUPLE USED TO PRODUCE AN ANALOGUE SIGNAL

Thermocouple used to produce an Analogue Signal

Analogue sensors tend to produce output signals that are changing smoothly and continuously over time. These signals tend to be very small in value from a few mico-volts (uV) to several milli-volts (mV), so some form of amplification is required. Then circuits which measure analogue signals usually have a slow response and/or low accuracy. Also analogue signals can be easily converted into digital type signals for use in microcontroller systems by the use of analogue-to-digital converters (ADCs).

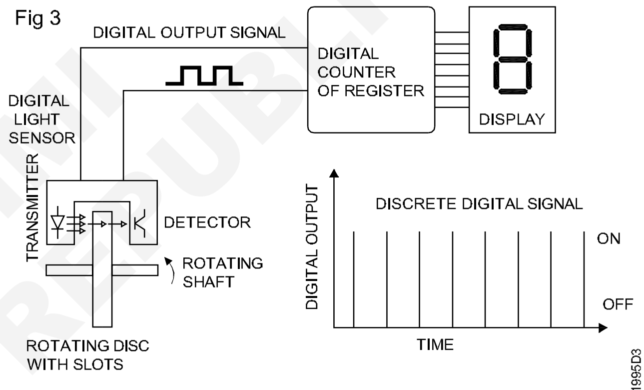
Digital Sensors

As its name implies, **Digital Sensors** produce a discrete digital output signals or voltages that are a digital representation of the quantity being measured. Digital sensors produce a **Binary** output signal in the form of a logic "1" or a logic "0", ("ON" or "OFF"). This means then that a digital signal only produces discrete (non-continuous) values which may be outputted as a single "bit", (serial transmission) or by combining the bits to produce a single "byte" output (parallel transmission).

Light Sensor used to produce an Digital Signal

In our simple example as shown fig.3 the speed of the rotating shaft is measured by using a digital LED/Opto-detector sensor. The disc which is fixed to a rotating shaft (for example, from a motor or robot wheels), has a number of transparent slots within its design, As the disc rotates with the speed of the shaft, each slot passes by the sensor in turn producing an output pulse representing a logic "1" or logic "0" level.

Fig 3



LIGHT SENSOR USED TO PRODUCE AN DIGITAL SIGNAL

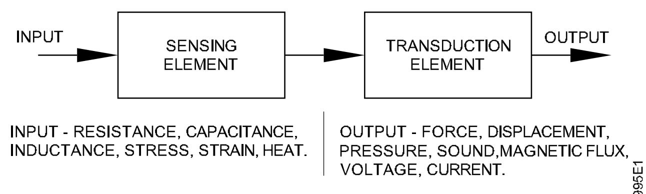
Basics of passive and active transducers

Objectives: At the end of this lesson you shall be able to
- **define the classification of the transducers**
- **explain the various type of passive and active transducers**
- **describe the procedure for selection of transducers.**

A transducer is a device that is used to convert a physical quantity into its corresponding electrical signal. In most of the electrical systems, the input signal will not be an electrical signal, but a non-electrical signal. This will have to be converted into its corresponding electrical signal if its value is to be measured using electrical methods.

A transducer will have basically two main components. They are as shown in Fig 1.

Fig 1



TRANSDUCTION BLOCK DIAGRAM

Sensing Element: The physical quantity or its rate of change is sensed and responded to by this part of the transistor.

Transduction Element: The output of the sensing element is passed on to the transduction element. This element is responsible for converting the non-electrical signal into its proportional electrical signal.

There may be cases when the transduction element performs the action of both transduction and sensing.

Diffrent Types of Level Sensors and their Workings

A level sensor is one kind of device used to determine the liquid level that flows in an open system or closed system

The level measurements can be available in two types namely continous measurements and point level measurements. The continuous level sensor is used to measure the levels to a precise limit whereas point level sensors used to determine the level of liquid wheather that is high or low. (Fig 2)

Fig 2

LEVEL SENSORS

Generally these sensors are connected to an output unit for sending out the results to a monitoring system The present technologies use wireless transmission of information to the monitoring system, which is very useful in imprtant and hazardous locations that cannot be simply accessed by common workers.

Classification of Level sensors

Ultrasonic Level sensors

Level sensors are classified according to their working principle and their applications.

Ultrasonic level sensors are used to detect the levels of sticky liquid substances and bulkiness materials as well. They are worked by producing audio waves at the range of frequency from 20 to 200 kHz. These waves are then replicated back to a transducer The ultrasonic level sensors are used to control the liquid level, fine-grained solids within mining and powders, food and beverage industries and chemical processing

Capacitance Level Sensors

These sensors are used to detect the liquid levels like slurries and aqueous liquids They are operated by using a probe for checking level changes. These level changes are transformed into analong signals. The probes are generally made of conducting wire by PTFE insulation But stainless steel probes are extermely responce and hence they are appropriate for measuring non-conductive subsance granular or materials with low dielectric constant. These types of sensors are very simple to use and clean as they do not have any moving components.

They are commonly used in applications like Tank level monitoring in chemical, water treatment, food, battery industries and involving high pressure and temperature

Optical Level Sensors

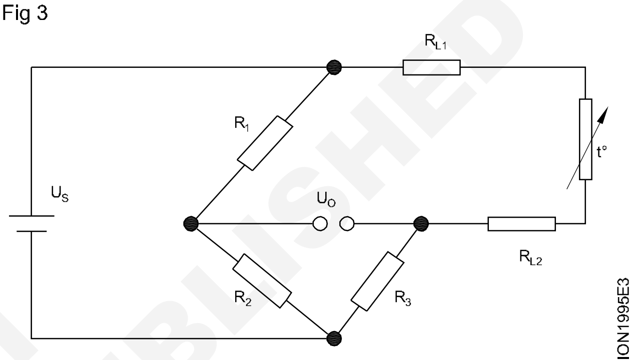
Optical level sensors are used to detect liquid including poised materials, interface between two immiscible liquids and the occurrence of sediments. They are working based on the changes of transmission in infrared light emitted from an IR LED. The interference from the produced light can be reduced by using a high energy IR diode and pulse modulation methods.

Continuous optical level sensors, on the other hand, use the highly internse laser light that can infuse dusty enviroments and notice liquid substances. They are commonly used in applications like leak detection and tank level measurement.

RTD Configuration

An RTD can be connected in a two, three or four-wire configuration. The two-wire configuration is the simplest and also the most error prone. In this setup, the RTD is connected by two wires to a Wheatstone bridge circuit and the two output voltage is measured. The disadvntage of this circuit is that the two connecting lead wire resistances add directly two RTD's resistance and error is incurred.

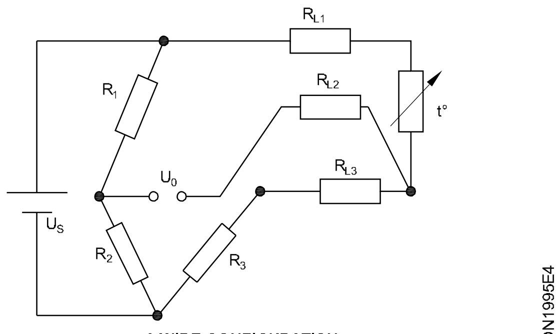
Fig 3



2-Wire Configuration

The four-wire configuration consists of two current leads and two potential leads that measure the voltage drop across the RTD. The two potential leads are high resistance to negate the effect of the voltage drop due to current flowing during the measurement.

Fig 4



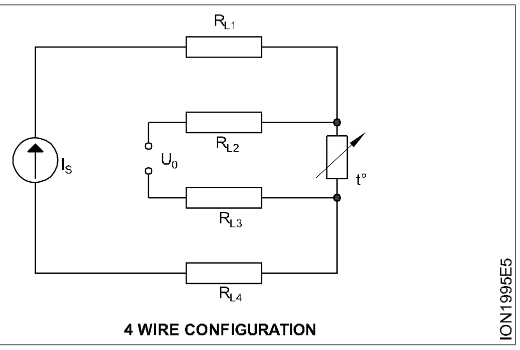
3 WIRE CONFIGURATION

This configuration is ideal for canceling the lead wire resistance in the circuit as well as eliminating the effects of different lead resistance, Which was possible problem with the three-wire configuration. The four-wire configuration is commonly used when a highly accurate measurement is requried for the application.

Float Switch

Liquid Level sensors or float switches are used to monitor liquid levels in tanks or other vessels and are designed to react according to react according to predefined high or low levels. They are connected to the pump motor in series with the supply.

Fig 5

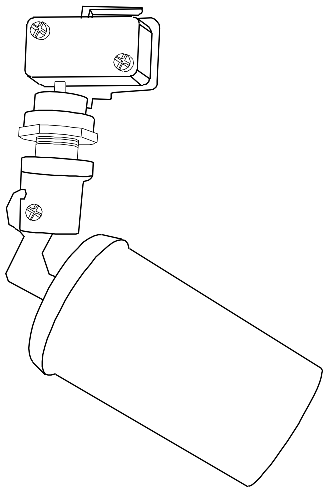


4 WIRE CONFIGURATION

The folat switch is shown in Fig 6. It consists of a micro switch attached to a assembly with a hollow cylinderical sealed float hinged to move up and down

The micro switch is N/C type and connects power supply to motor for pumping water into tank.

Fig 6



FLOAT SWITCH

When the water raises the float raises and the attached, lever pushes the knob of micro switch open/disconnect the electrical circuit. Thus the pump motor is switched OFF.

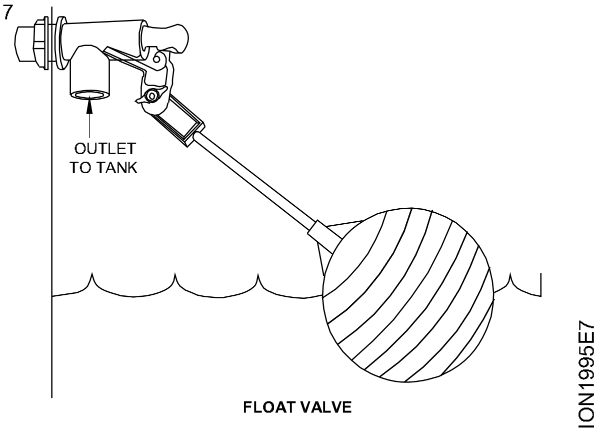
Whenever the water level decreases the float comes down, there by the micro switch is automatically connect power to the motor.

Float Value

A float valve is used to shut off the flow of liquids, normally water, at a predetermined level. when adjusted and working properly a float value is very accurate and extremely reliable. Float values are found in nearly every over head water tank at home as well as in many industrial applications. The concepts of the float value is very simple, Which accounts for its reliability and wide spread use.The float value is shown in Fig 7.

It consists of a value connected to a hollowball sealed float rises with it: once it rises to a pre-set level, the mechanism forces the lever to close the valve and shut off the water flow.

Fig 7



FLOAT VALVE

Classification of transducers (Passive & Active)

Passive transducers

Passive transducer require an external power supply to operate, called an excitation signal which is used by the sensor to produce the output signal.

Active transducers

Active transducers are self-generating devices because their own properties change in response to an external effect.

1 Passive Type Transducers

a Resistance Variation Type

Resistance Strain Gauge - The change in value of resistance of metal semi-conductor due to elongation or compression is known by the measurement of torque, displacement or force.

Resistance Thermometer / Resistance Temperature Detector (RTD) - The change in resistance of metal wire due to the change in temperature known by the measurement of temperature

Resistance Hygrometer - The change in the resistance of conductive strip due to the change of moisture content is known by the value of its corresponding humidity.

Hot Wire Meter - The change in resistance of a heating element due to convection cooling of a flow of gas is known by its corresponding gas flow or pressure.

Photoconductive Cell - The change in resistance of a cell due to a corresponding change in light flux is known by its corresponding light intensity.

Thermistor - The change in resistance of a semi-conductor that has a negative co-efficient of resistance is known by its corresponding measure of temperature.

Potentiometer Type - The change in resistance of a potentiometer reading due to the movement of the slider as a part of an external force applied is known by its corresponding pressure or displacement.

b Capacitance Variation Type

Variable Capacitance Pressure Gauge - The change in capacitance due to the change of distance between two parallel plates caused by an external force is known by its corresponding displacement or pressure.

Dielectric Gauge - The change in capacitance due to a change in the dielectric is known by its corresponding liquid level or thickness.

Capacitor Microphone - The change in capacitance due to the variation in sound pressure on a movable diaphragm is known by its corresponding sound.

c Inductance Variation Type

Eddy Current Transducer - The change in inductance of a coil due to the proximity of an eddy current plate is known by its corresponding displacement or thickness.

Variable Reluctance Type - The variation in reluctance of a magnetic circuit that occurs due to the change in position of the iron core or coil is known by its corresponding displacement or pressure.

Proximity Inductance Type - The inductance change of an alternating current excited coil due to the change in the magnetic circuit is known by its corresponding pressure or displacement.

Differential Transformer - The change in differential voltage of 2 secondary windings of a transformer because of the change in position of the magnetic core is known by its corresponding force, pressure or displacement.

Magnetostrictive Transducer - The change in magnetic properties due to change in pressure and stress is known by its corresponding sound value, pressure or force.

d Voltage and Current Type

Photo-emissive Cell - Electron emission due to light incidence on photo-emissive surface is known by its corresponding light flux value.

Hall Effect - The voltage generated due to magnetic flux across a semi-conductor plate with a movement of current through it is known by its corresponding value of magnetic flux or current.

Ionisation Chamber - The electron flow variation due to the ionisation of gas caused by radio-active radiation is known by its corresponding radiation value.

2 Active Type

Photo-voltaic Cell - The voltage change that occurs across the p-n junction due to light radiation is known by its corresponding solar cell value or light intensity.

Thermocouple - The voltage change developed across a junction of two dissimilar metals is known by its corresponding value of temperature, heat or flow.

Piezoelectric Type - When an external force is applied on to a quartz crystal, there will be a change in the voltage generated across the surface. This change is measured by its corresponding value of sound or vibration.

Moving Coil Type - The change in voltage generated in a magnetic field can be measured using its corresponding value of vibration or velocity.

Selection of Transducer

Selection of a transducer is one of the most important factors which help in obtaining accurate results. Some of the main parameters are given below.

- Selection depends on the physical quantity to be measured.
- Depends on the best transducer principle for the given physical input.
- Depends on the order of accuracy to be obtained.
- Based on whether the transducer is active or passive.

Characteristic of transducer

All transducers, irrespective of their measurement requirements, exhibit the same characteristics such as range, span, etc.

Introduction microprocessor & 8051 microcontroller, architecture, pin details & the bus system

Objectives: At the end of this lesson you shalll be able to
- **understand the architecture of 8051 microcontroller**
- **differetiate between microprocessor and microcontroller**
- **observe advantages of microcontroller.**

Microprocessor 8085

Introduction

The microprocessor is a programmable device that contains the arithmetic, logic, and control circuitry required to perform the functions of a computer's central processing unit.

The data processing logic and control circuits are included on a single integrated circuit, or a small number of integrated circuits. It is an important part of a computer architecture without which you will not be able to perform anything on your computer.

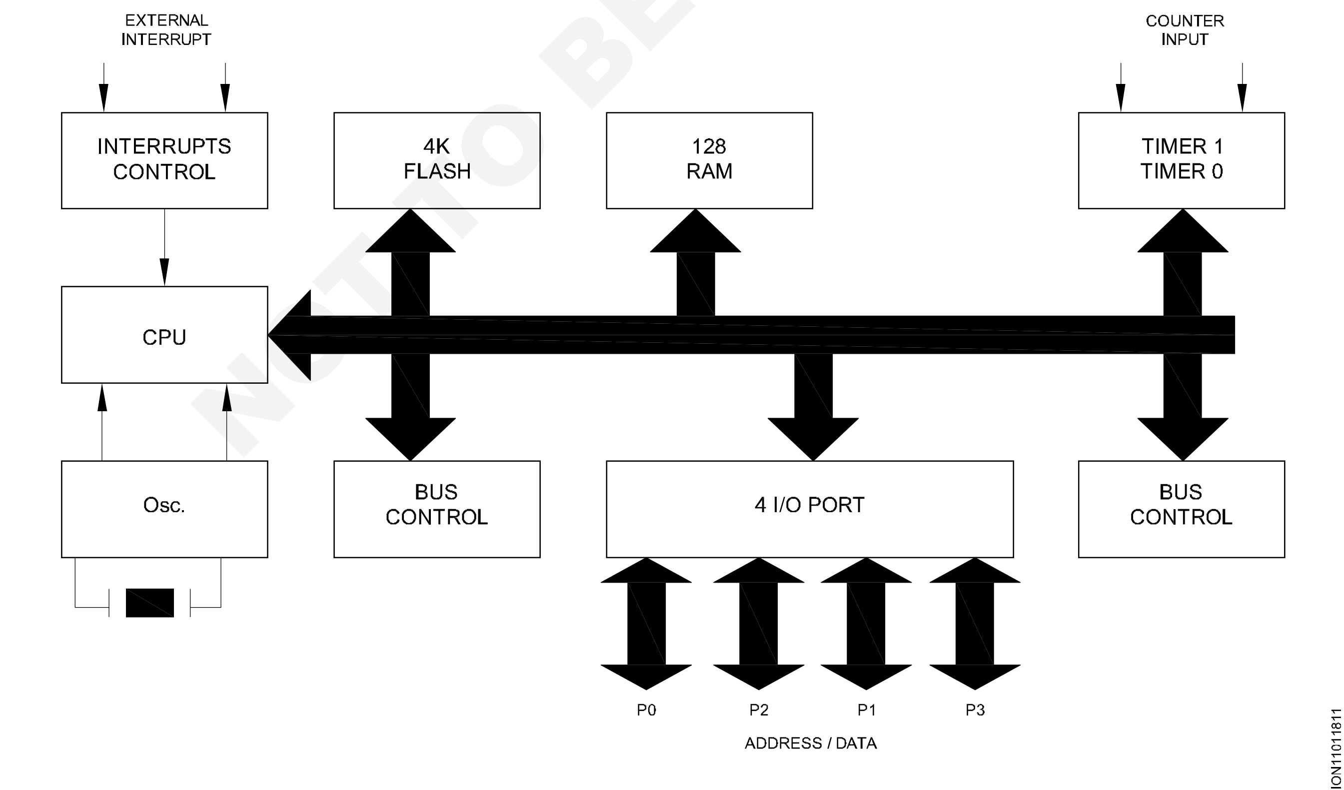
It is the brain of computer, which does all the work. It is a computer processor that incorporates all the functions of CPU (Central Processing Unit) on a single IC (Integrated Circuit).There are three types of microprocessors namely, CISC, RISC, and EPIC.

The microprocessor follows a sequence: Fetch, Decode, and then Execute. The microprocessor fetches those instructions from the memory, then decodes it and executes those instructions till STOP instruction is reached. Later, it sends the result in binary form to the output port.

Microcontroller

The main reason for the development of microcontroller is to overcome the drawback of the microprocessor. Even though microprocessors are powerful devices, they require external chips like RAM, ROM input/output ports and other components in order to design a complete working system. This made it economically difficult to develop computerized consumer applicances on a large scale as the system cost is very high. Microcontrollers are the devices that actually fit the profile "Computer - on - a chip" as it consists of a main processing unit or processor along with some other components that are necessary to make it a complete computer. The components that are present on a typical microcontroller IC are CPU, memory, input / ouput ports and timers. The block diagram of a microcontroller is shown below in Fig 1.

Fig 1



Microcontrollers are basically used in embedded systems. Microcontrollers can be classified based on bus width, memory structure and instruction set. Bus width indicates a the size of the data bus.

Microcontrollers can be classified as 8-bit, 16- bit or 32-bit based on the bus width. Higher bus widths often result in better performance. Microcontrollers can be divided into two types based on their memory structures ; Embedded memory and external memory. In case of embedded memory microcontrollers, the required data and program memory is embedded into the IC. Whereas external memory microcontrollers do not have program memory embedded on them and require an external chip for the same. Now a day, all microcontrollers are embedded memory microcontrollers. The classification based on instruction set is similar to that of a microprocessor. They can be either CISC (complex instruction set computer) or RISC (Reduced instruction set computer. Majority of microcontrollers follow CISC architecture with over 80 instructions. Microcontrollers can also be divided based on their computer architecture into von neumann and harvard.

Functions of different ICs used in the microcontroller kit

1 **EPROM : 27256 (32k x 8 EPROM)**

The micro -51 EB LCD has a standard EPROM configuration of 32KB. The address for the monitor EPROM is 0000-3FFF. EPROM expansion is C000-FFFF.

2 **RAM : 61256 (256K x 16 BIT SRAM)**

The micro - 51 EB LCD has 32 KB of read /write program / data memory using one 61256 whose addres is from 4000 to BFFFF. The micro - 51 EB LCD has one more 32KB of read/write data memory using one 61256 whose address is 0000-3FFF and C000-FEFF.

3 **Parallel I/O interface : 8255 PPI (Programmable pheripheral interface)**

Intel 8255 programmble pheripheral interface 24 programmbable I/O lines configured as three 8 bit ports direct bit set / reset capability. Three modes of operation namely basic I/O, strobed I/O and bidirectional bus.

4 **RS485 Drivers and RS232 drivers : ICL 232 (RS232) and 74LBC184D (RS485)**

8051 is used for serial communication with associated diver for interface immunity and overcoming attenuation.

5 **Address Latch : (74LS273)**

It is used to latch the address (A0-A7) from AD lines (AD0-AD7). The latch stores the number output by the 8051 from the databus. So that the LED can be lit with any 8 bit binary number.

6 **Data bus buffer : (72LS244)**

It connect 8 bit of input data to I/O pheripheral devices.

7 **LCD interface and LCD module : (IC74174)**

The LCD is diaplay is driven by both address latch and data bus buffer.

The following table 1 shows some of the difference between microprocessors and microcontrollers.

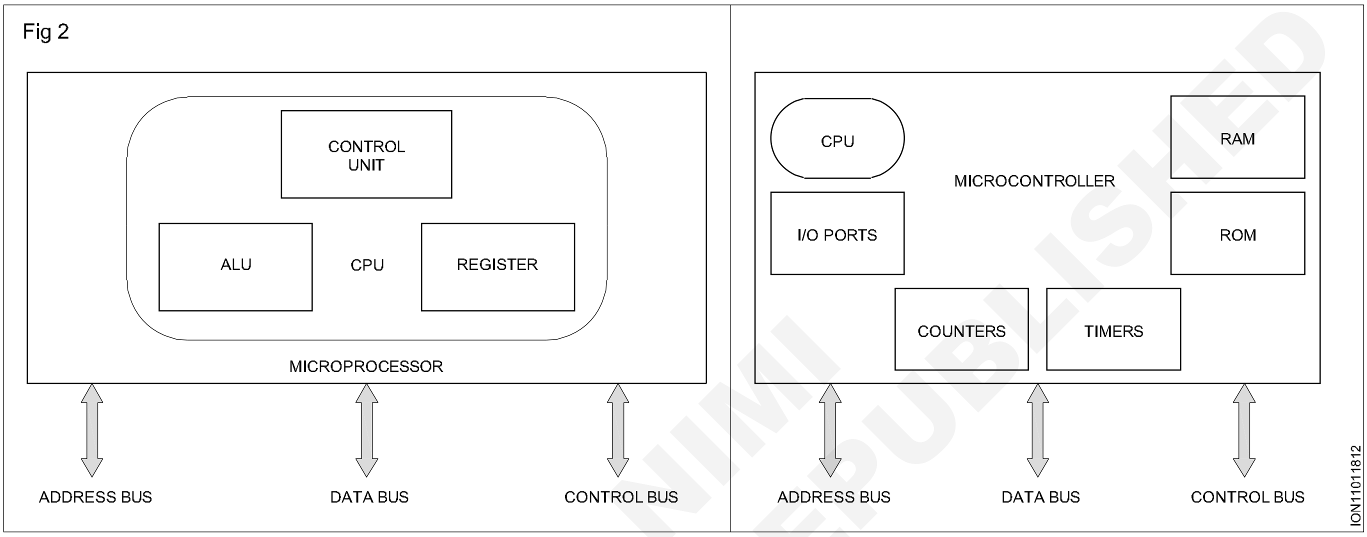
Table 1

Micropocessor	Microcontroller
Microprocessor assimilates the function of a central processing unit (CPU) on to a single integrated circuit (IC).	Microcontroller can be considered as a small computer which has a processor and some other components order to make it a micro computer chip.
Microprocessors are mainly used in designing general purpose systems from small to large and complex systems like super computers.	Microcontrollers are used in automatically controlled devices.
Microprocessors are basic components of personal computers.	Microcontrollers are generally used in embedded system.
A microprocessor based system can perform numerous tasks.	A microcontroller based system can perform single of very few tasks.
The main task of microprocessor is to perform the instruction cycle repeatedly. This includes fetch, decode and execute.	In addition to performing the tasks of fetch, decode and execute, a microcontroller also controls its environment based on the output of the instruction cycle.
In order to build or design a system (Computer, a microprocessor has to be connected externally to some other components like memory (RAM and ROM) and input output ports.	The IC of a microcontroller has memory (both RAM, ROM) integrated on it along with some other components like I/O devices and timers.

Micropocessor	Microcontroller
The overall cost of a sytem built using a microprocessor is high. This is because of the requirement of external components.	Cost of a system built using a microcontroller is less, all the components are readily available.
Generally power consumption and dissipation is high because of the external devices. Hence it requires external cooling system.	Power consumption is less.
The clock frequency is very high usually in the order of Giga Hertz.	Clock frequency is less usually in the order of Mega Hertz.

Advantages of microcontroller : As the microcontroller is having on - chip I/O ports, timer/counters, code and data memory (limited) which reduces the program exeuction time. (Fig 2)

Fig 2



Comparative study of 8051 and 8052.

Although the 8051 microcontroller was introduced first with 8 bit capacity the enhanced version of 8051 been developed later which is called 8052 micro controller. The 8052 microcontroller is technically designed with certain additional features. The common features of these microcontrollers are given in Table 2 and the diffrences are given in Table 3 below:

Table 2

Commom features of 8051 and 8052

SI.No.	Parameter	8051	8052
1	Clocks instruction cycle	12	12
2	UARTs/serial ports	1	1
3	Maximum program size without external logic	64K	64K
4	Maximum PIO	32	32
5	Size	8 Bit	8 Bit

Table 3

Diffrences between 8051 and 8052

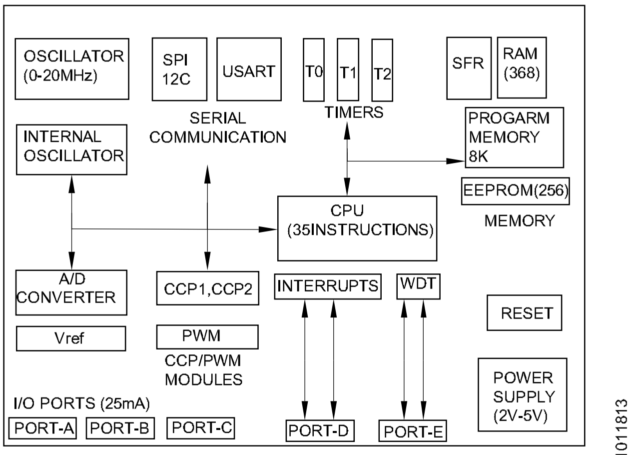
PARAMETERS	8051	8052
Internal RAM (DATA Memory)	128byte	256 Bye
Internal ROM (Code Memory)	4Kb	8Kb
Timer/Counter	2	3
No.of interrupt	5	6

Peripheral Interface Controller

Peripheral Interface Controller (PIC) is the world's smallest and very fast microcontroller that can be programmed to execute a vast range of tasks compare with other controllers. These programming and the simulated process of this microcontroller can be done by a circuit-wizard software. PIC microcontroller is an IC and its architecture comprises of CPU, RAM, ROM, timers, counters and protocols like SPI, UART, CAN which are used for interfacing with other peripherals. Microcontrollers are used for industrial purpose also the advantages of using this microcontroller includes low power consumption, high performance, supports hardware and software tools such as simulators, compilers, and debuggers.

The block diagram of PIC microcontroller architecture is shown in (Fig 3) comprises of central processing unit (CPU), I/O ports, A/D converter, memory organization, timers/ counters, serial communication, interrupts, oscillator and CCP module that are discussed in given below:

Fig 3



ARCHITECTURE OF PIC MICROCONTROLLER

Architecture of PIC Microcontroller

Central Processing Unit (CPU)

PIC microcontroller's CPU is not different like other microcontroller CPU, which includes the ALU, controller unit, the memory unit, and accumulator. ALU is mainly used for arithmetic and logical operations. The memory unit is used to store the commands after processing. The control unit is used to control the internal & external peripherals, and the accumulator is used to store the final results and further processes.

Memory Organization

The memory module of the PIC microcontroller architecture consists of Random Access Memory (RAM) Read Only Memory (ROM) and STACK.

Memory Organization

Random Access Memory (RAM)

(RAM) The Random access memory is used to store the information temporarily in its registers. It is categorized into two banks, each bank has so many registers. The RAM registers are categorized into two types, namely Special Function Registers (SFR) General Purpose Registers (GPR).

General Purpose Registers (GPR)

As the name implies, These registers are used for general purpose only. For instance, if we want to multiply any two numbers by using this microcontroller. Usually, registers are used for multiplying and storing in other registers. So, GPR registers don't have any superior function,- CPU can simply access the data in the registers.

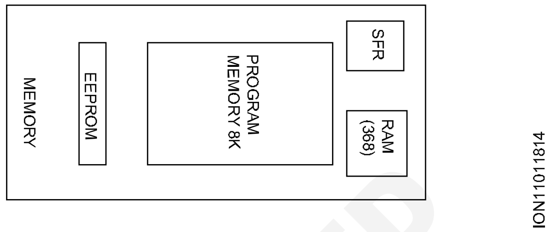
Special Function Registers (SFR)

As the name implies, SFRs are used only for special purposes. These registers work based on the function assigned to them, and these registers cannot work as a normal register. For instance, if you cannot use the STATUS register for storing the information, SFRs are used for viewing the status of the program. So, the user cannot change the SFR's function; the function is given by the manufacturer at the time of built-up.

Memory Organization

The memory organization of Peripheral Interface Controller (PIC) is shown in Fig 4 which includes the following:

Fig 4



- Read Only Memory (ROM)
- Electrically Erasable Programmable Read Only Memory (EEPROM)
- Flash Memory
- Stack

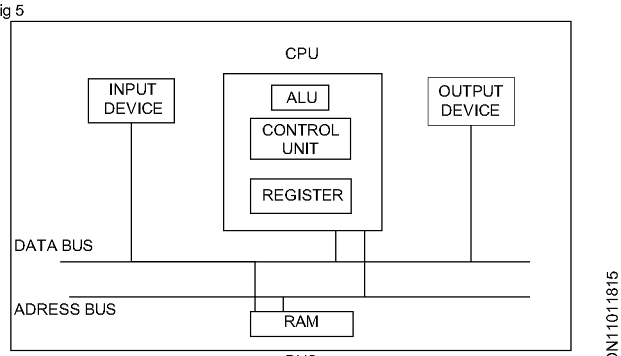
Input Output (I/O) Ports

The PIC microcontroller consists of 5-ports, namely Port-A, Port-B, Port-C, Port-D and Port-E.

BUS

BUS is used to transfer and receive the data from one peripheral to another as shown in Fig 5. It is categorized into two types as data bus and address bus.The Data Bus is used to transfer or receive the data.

Fig 5

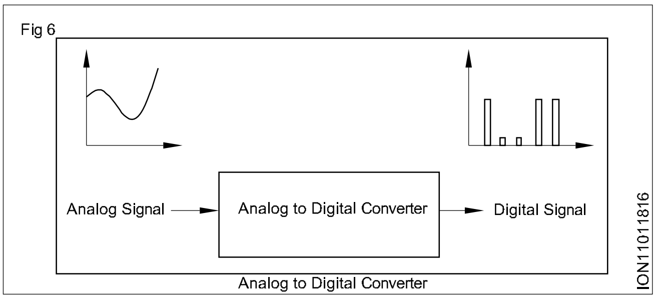


BUS

The address bus is used to transfer the memory address from the peripherals to the Central Processing Unit(CPU).Input /Output pins are used to interface the exterior peripherals; both the UART and USART are serial communication protocols, used to interface with serial devices such as GPS, GSM, IR, Bluetooth, etc.

Analog to Digital (A/D) Converter

A/D converter is shown in Fig 6. It is used to convert analog voltage values to digital voltage values. An A/D module in PIC Microcontroller Controller comprises of 5-inputs for 28-pin devices and 8-inputs for 40-pin devices. The operation of the A/D converter is controlled by special registers like ADCON0 & ADCON1. The upper and lower bits of the converter are stored in registers like ADRESH and ADRESL. In this process, it needs 5V of an analog reference voltage.



Timer/Counters

PIC microcontroller has four-timer/counters wherein the one 8-bit timer and the remaining timers have the choice to select 8 or 16-bit mode. Timers are used for generating accuracy actions, for example, creating specific time delays between two operations.

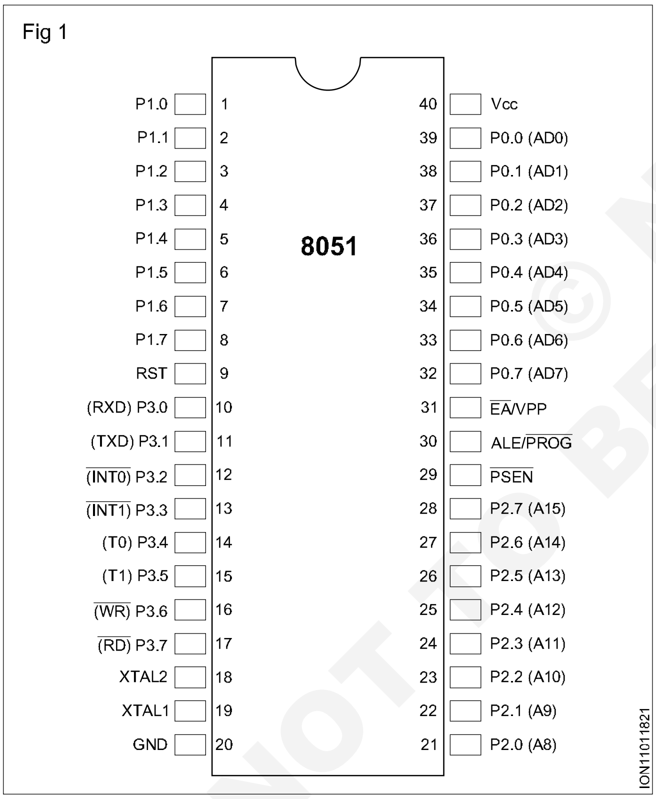
Interrupts

PIC microcontroller consists of 20 internal and 3-external interrupt sources which are allied with different peripherals like USART, ADC, Timers, and so on.

Pin details of 8051, Internal data memory, SFR and on-chip features

Objectives: At the end of this lesson you shall be able to
- **pin diagram of 8051**
- **data memory and special function registers**
- **utilization of on - chip resources such as ADC.**

The pin diagram of 8051: 8051 is a 40 pin microcontroller with I/O ports (Ref.Fig 1)



There are 4 ports in 8051 IC (Port 0, Port 1, Port 2 and Port 3) 32 pins are function as I/O port lines and 24 of these lines are dual purpose (P0, P1, P3). Each can operate as I/O, or as a control line or part of the address or data bus. Eight lines in each port can be used in interfacing to parallel devices like printers, DAC etc., or each line the port can be used in interfacing to single bit devices like LED's, switches, transistors, solenoid, motors and loudspeakers.

PORT 0 (32-39 Pins)

It is a dual purpose port (P0.0-P0.7). For simple design it is used as I/O ports. For larger design with external memory, it is used as multiplexed address and data bus (AD0-AD7)

PORT 1(1-8 Pins)

It is a dedicated I/O port (P1.0-P1.7). It is used only to inferface with the external devices.

PORT 2 (21-28 Pins)

It is a dual purpose port (P2.0-P2.7). It is used as I/O port or higher byte of address bus (A8-A15).

PORT 3 (10-17 Pins)

It is a dual purpose port (P3.0- P3.7) It is used as I/O port, or used to special features of 8051 (Table 1).

Table 1

BIT	Name	BIT Address	Alternate function
P 3.0	RXD	B0H	Receive data for serial port
P 3.1	TXD	B1H	Transmit data for serial port
P 3.2	INT0	B2H	External interrupt 0
P 3.3	INT1	B3H	External interrupt 1
P 3.4	T0	B4H	Timer /counter 0 external input

BIT	Name	BIT Address	Alternate function
P 3.5	T1	B5H	Timer/counter 1 external input
P 3.6	WR	B6H	External data memory write stroke
P 3.7	RD	B7H	External data memory read stroke
P 1.0	T2	90H	Timer/ Counter 2 external input
P 1.1	T2EX	91 H	Timer /Counter 2 capacture / reload

RST (9 Pin No)

It is a master reset input pin. It should be kept high to start - up 8051.

On- chip oscillator (18-19 Pins)

It is a crystal oscillator with stabilizing capacitor connected to pin number 18 and 19. The normal crystal frequency is 12 MHz.

Power connection (20,40 Pins)

The 8051 operates at +5V DC. Pin No. 40 is Vcc. Pin No. 20 is Vss (GND)

PSEN (Program store enable) (29 Pin No)

PSEN is an output and control signal to enable the external memory.

ALE (Address Latch Enable) (30 Pin No)

ALE is an ouput signal to control demultiplexing the address and data bus. ALE signal oscillates at 2 MHz.

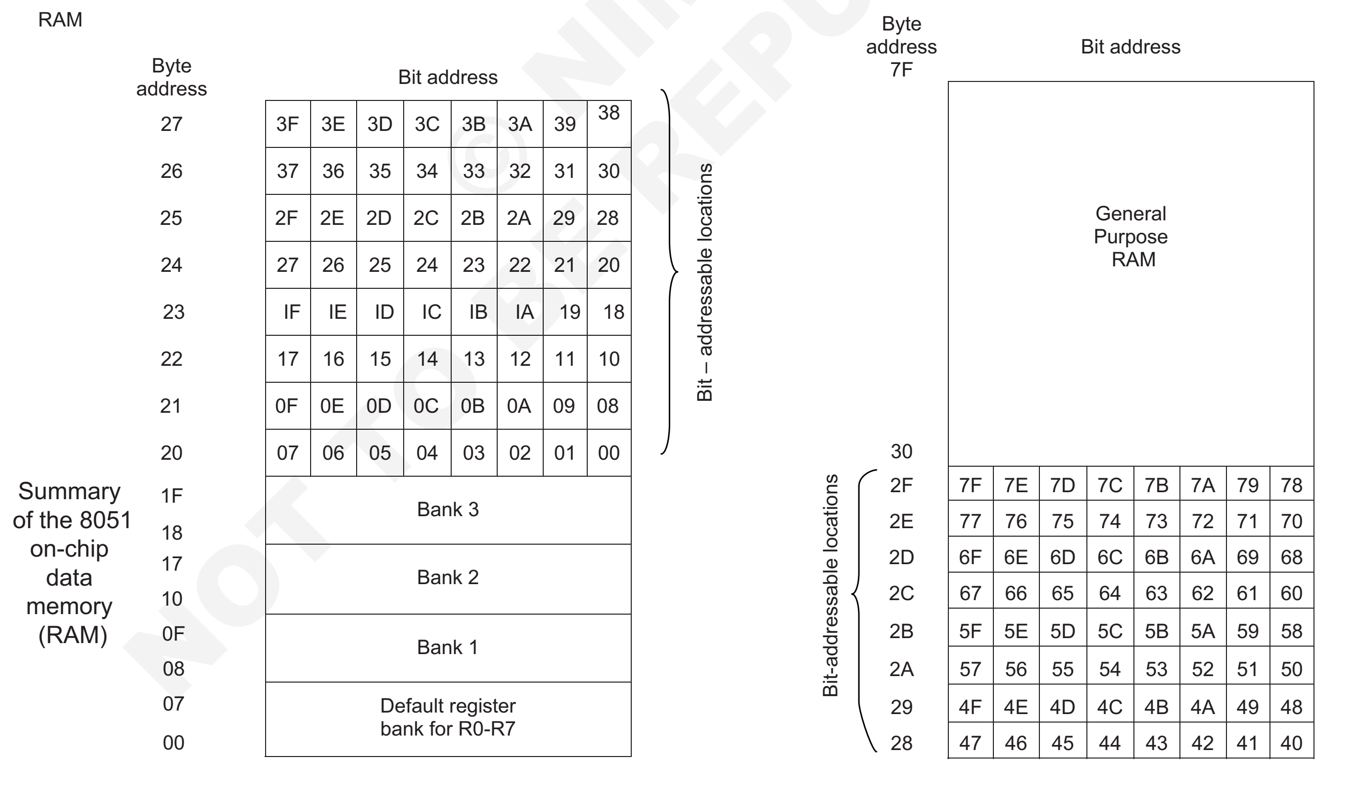
EA (External access) (31 Pin No)

It is an input signal is generally kept high (+5VDC) or low (GND). If EA is high 8051 executes program from internal ROM. If EA is low it executes program from external memory.

Internal data memory

128 Bytes of internal data memory is divided in to two parts, Part I is RAM (00- 7FH) Part II is special function registers (SFR) (80-FFH) (Fig 2).

Fig 2



RAM

i Register Bank (00H-1FH) 4 banks (Bank 0,1,2,3) Each bank consisting of 8 register (R0-R7).

ii Bit addressable RAM (20 H-2FH).

iii General purpose RAM (30 H-7FH).

i Register banks

The bottom 32 locations of internal memory contain the register banks. The 8051 instruction set supports of 8 registers R0 through R7, and by default these registers are addresses 00H-07H.

ii Bit addressable RAM

There are 128 general - purpose bit addressable locations at byte addresses 20 H through 2FH (8 bits /byte X 16 bytes = 128 bits). These addresses are accessed as bytes or as bits, depending on the instruction.

For example, to set bit 67H, the following instruction could be used.

Set B 67H

Note that "Bit address 67H" is the most significant bit at "byte address 2CH".

iii General purpose RAM

General purpose RAM consisting of address location(30H-7FH) which is byte addressable available to programmer to store data /programs.

21 SFRs are available, out of 21, 11 are bit addressable and 10 are byte addressable

P0 (80 H)	: Port 0, bit addressable
SP (81 H)	: Stack pointer
DPL (82 H)	: Data pointer low byte
DPH (83 H)	: Data pointer high byte
PCON (87H)	: Power control register
TCON (88H)	: Timer control register, bit addressable
TMOD (89H)	: Timer mode register
TL0 (8AH)	: Timer 0 low byte
TL1 (8BH)	: Timer 1 low byte
TH0 (8CH)	: Timer 0 high byte
TH1 (8DH)	: Timer 1 high byte
P1 (90H)	: Port 1, bit addressable
SCON (98H)	: Serial port control register, bit addressable
SBUF (99H)	: Serial data buffer, byte addressable
P2 (A0H)	: Port 2, bit addressable
IE (A8H)	: Interrupt enable, bit addressable
P3 (B0H)	:Port 3, bit addressable
IP (B8H)	: Interrupt priority, bit addressable
PSW (D0H)	: Program status word, bit addressable
ACC (E0H)	: Accumulator, bit addressable

On-chip features of 8051 philips microcontroller

The derivative of 8051 philips microcontroller is most powerful 8 bit microcontroller. It has got an 8 bit CPU optimized for control application. 64 K program memory space, 64K data memory space, 4K bytes of on - chip program memory. 128 bytes of on - chip data memory, 32 bi-directional and individually addressable I/O lines, two 16 bit timer / counters, one full duplex serial port and 6 source /5- vector interruput with two priority level on - chip.

Utilization of on - chip resources such as ADC

The PCF 8591 is a single - chip, single - supply low - power 8 bit CMOS data acquisition, device with four analog inputs, one analog output and a serial I2C - bus interface. The functions of the device include analog input multiplexing, on- chip track and hold function, 8 bit analog-to-digital conversion and an 8- bit digital - to analog conversion. The maximum conversion rate is given by the maximum speed of the I2C- bus.

Features and benefits

- Single power supply
- Operating supply voltage 2.5V to 6.0V
- Low standby current
- Serial input and output via I2C- bus
- I2C address selection by 3 hardware address pins
- Max sampling ratte given by I2C- bus speed
- 4 Analog inputs configurable as single ended or differential inputs
- Auto- incremented channel selection
- Analog voltage range from VSS to VDD
- On - chip track and hold circuit
- 8-bit successive approximation A/D conversion
- Multiplying DAC with one analog output.

Applications

- Supply monitoring
- Reference setting

Arduino development board, pin diagram, functional diagram, hardware familiarization and operating instructions

Objectives: At the end of this lesson you shalll be able to
- **to understand the usage, pin layout of arduino board**
- **to familiarize with the bard components and its operational steps.**

1 Arduino

Arduino provides open-source electronics prototyping platforms based on flexible, easy-to-use hardware and software. Arduino prototyping platforms are intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino's prototyping platforms can sense the environment by receiving input from a variety of sensors and can affect their surroundings by controlling lights, motors, and other actuators. Arduino projects can be stand-alone or they can communicate with software running on a computer. Arduino also simplifies the process of working with microcontrollers. and its advantages are :

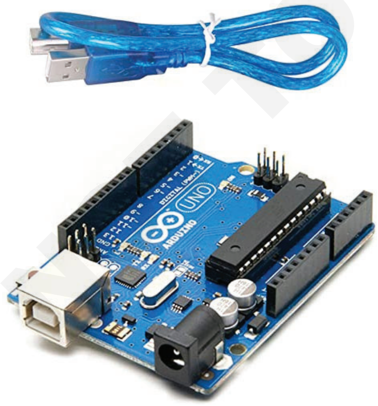
- The Arduino boards are very easy to get started.
- The Arduino boards are used in the automatic room light control.
- On the Arduino, both software, hardware, and IDE are open source.
- The Arduino boards are used in the real-time application.

1.1 Types of Arduino Boards

1.1.1 Arduino UNO (R3):

Arduino Uno allows faster transfer rate & more memory.

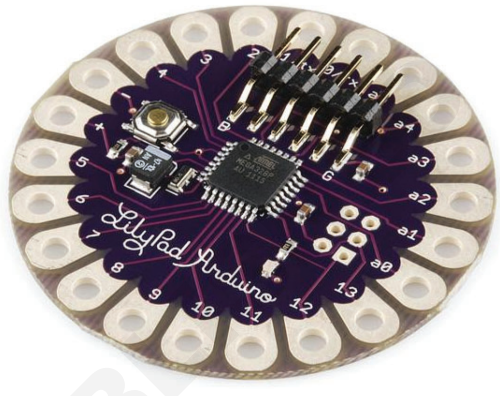
Fig 1



1.1.2. LilyPad Arduino

This is designed to integrate easily into an e-textiles & wearable projects. designed to have large connecting pads to allow them to be sewn into clothing. There is an available of various input, output, and sensor boards and they are washable.

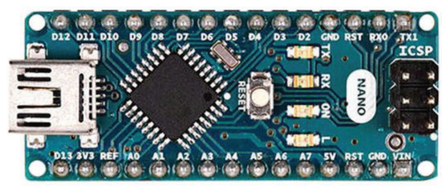
Fig 2



1.1.3. Arduino Nano development Board

Arduino Nano 3.0 is a small, complete, and breadboard friendly surface mount embedded version of Arduino with integrated USB, which is based on the ATmega328.

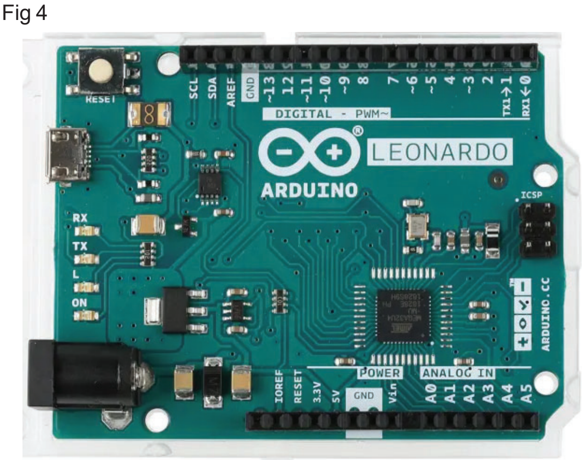
Fig 3



1.1.4. Arduino Leonardo

The Leonardo differs from all preceding boards in that the ATmega32u4 has built-in USB communication, eliminating the need for a secondary processor.

Fig 4

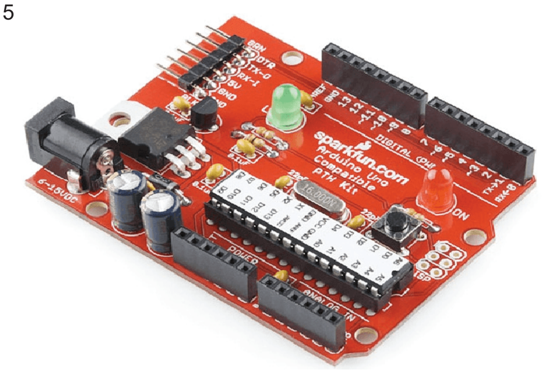


1.1.5. Arduino Red Board

The Arduino red board is programmed by using the USB cable of mini-B with the help of Arduino IDE software. Without any modifications in the security system there, it will work in Windows8 OS. The Arduino red board is more constant because USB and FTDI chips are used and they are flat on the back.

Among these boards Arduino Uno is commonly used and throughout this week Arduino Uno will be discussed in detail.

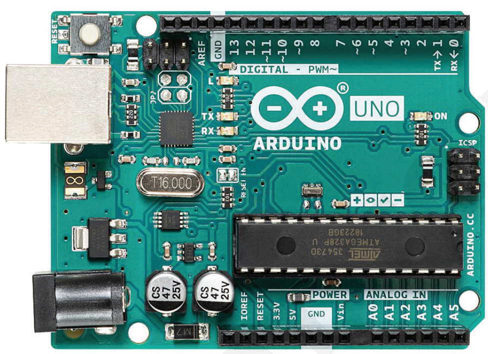
Fig 5



1.2 Arduino uno R3 development board

The Arduino UNO R3 is frequently used microcontroller board in the family of an Arduino. This is the latest third version of an Arduino board and released in the year 2011. The main features of this board mainly include, it is available in DIP (dual-inline-package), detachable and ATmega328 microcontroller. The programming of this board can easily be loaded by using an Arduino computer program.

Fig 6



1.2.1 Arduino Uno R3 Specifications

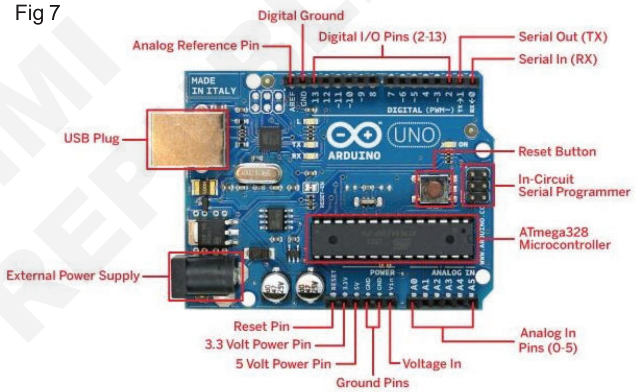
The Arduino Uno R3 board includes the following specifications.

- It is an ATmega328P based Microcontroller
- The Operating Voltage of the Arduino is 5V
- The recommended input voltage ranges from 7V to 12V
- The i/p voltage (limit) is 6V to 20V
- Digital input and output pins-14
- Digital input & output pins (PWM)-6
- Analog i/p pins are 6
- DC Current for each I/O Pin is 20 mA
- DC Current used for 3.3V Pin is 50 mA
- Flash Memory -32 KB, and 0.5 KB memory is used by the boot loader
- SRAM is 2 KB
- EEPROM is 1 KB
- The speed of the CLK is 16 MHz
- In Built LED
- Length and width of the Arduino are 68.6 mm X 53.4 mm
- The weight of the Arduino board is 25 g

1.3 Arduino Uno R3 Pin, Functional Diagram and Hardware Familiarization

The Arduino Uno R3 pin diagram comprises of 14-digit I/O pins. From these pins, 6-pins can be utilized like PWM(Pulse Width Modulation) outputs. This board includes 14 digital input/output pins, Analog inputs-6, a USB connection, quartz crystal-16 MHz, a power jack, resonator-16Mhz, a power jack, an ICSP header an RST button.

Fig 7



1.3.1 Power Supply

The power supply of the Arduino can be done with the help of an exterior power supply otherwise USB connection. The exterior power supply (6 to 20 volts) mainly includes a battery or an AC to DC adapter. The connection of an adapter can be done by plugging a center-positive plug (2.1mm) into the power jack on the board. The battery terminals can be placed in the pins of Vin as well as GND. The power pins of an Arduino board include the following.

Vin: The input voltage or Vin to the Arduino while it is using an exterior power supply opposite to volts from the connection of USB or else RPS (regulated power supply). By using this pin, one can supply the voltage.

5 Volts: The RPS can be used to give the power supply to the microcontroller as well as components which are used on the Arduino board. This can approach from the input voltage through a regulator.

3V3: A 3.3 supply voltage can be generated with the onboard regulator, and the highest draw current will be 50 mA.

GND: GND (ground) pins

1.3.2 Memory

The memory of an ATmega328 microcontroller includes 32 KB and 0.5 KB memory is utilized for the Boot loader), and also it includes SRAM-2 KB as well as EEPROM-1KB.

1.3.3 Input and Output

Uno R3 includes 14-digital pins which can be used as an input otherwise output by using the functions like pin Mode (), digital Read(), and digital Write(). These pins can operate with 5V, and every digital pin can give or receive 20mA, & includes a 20k to 50k ohm pull up resistor. The maximum current on any pin is 40mA which cannot surpass for avoiding the microcontroller from the damage. Additionally, some of the pins of an Arduino include specific functions.

Serial Pins

The serial pins of an Arduino board are TX (1) and RX (0) pins and these pins can be used to transfer the TTL serial data. The connection of these pins can be done with the equivalent pins of the ATmega8 U2 USB to TTL chip.

External Interrupt Pins

The external interrupt pins of the board are 2 & 3, and these pins can be arranged to activate an interrupt on a rising otherwise falling edge, a low-value otherwise a modify in value

PWM Pins

The PWM pins of an Arduino are 3, 5, 6, 9, 10, & 11, and gives an output of an 8-bit PWM with the function analog Write ().

SPI (Serial Peripheral Interface) Pins

The SPI pins are 10, 11, 12, 13 namely SS, MOSI, MISO, SCK, and these will maintain the SPI communication with the help of the SPI library.

LED Pin

An arguing board is inbuilt with a LED using digital pin-13. Whenever the digital pin is high, the LED will glow otherwise it will not glow.

TWI (2-Wire Interface) Pins

The TWI pins are SDA or A4, & SCL or A5, which can support the communication of TWI with the help of Wire library.

AREF (Analog Reference) Pin

An analog reference pin is the reference voltage to the inputs of an analog i/ps using the function like analog Reference().

Reset (RST) Pin

This pin brings a low line for resetting the microcontroller, and it is very useful for using an RST button toward shields which can block the one over the Arduino R3 board.

1.3.4 Communication

The communication protocols of an Arduino Uno include SPI, I2C, and UART serial communication.

UART

An Arduino Uno uses the two functions like the transmitter digital pin1 and the receiver digital pin0. These pins are mainly used in UART TTL serial communication.

I2C

An Arduino UNO board employs SDA pin otherwise A4 pin & A5 pin otherwise SCL pin is used for I2C communication with wire library. In this, both the SCL and SDA are CLK signal and data signal.

SPI Pins

The SPI communication includes MOSI, MISO, and SCK.

MOSI (Pin11)

This is the master out slave in the pin, used to transmit the data to the devices

MISO (Pin12)

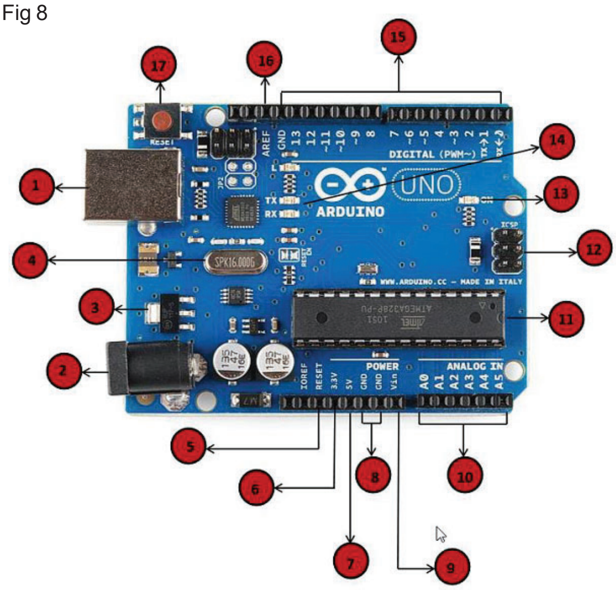
This pin is a serial CLK, and the CLK pulse will synchronize the transmission of which is produced by the master.

SCK (Pin13)

The CLK pulse synchronizes data transmission that is generated by the master. Equivalent pins with the SPI library is employed for the communication of SPI. ICSP (in-circuit serial programming) headers can be utilized for programming ATmega microcontroller directly with the boot loader.

1.4 Hardware Familiarization

Fig 8



1	**Power USB** Arduino board can be powered by using the USB cable from ther computer.Connect the USB cable to the USB connection (1).
2	Power (Barrel Jack)Arduino boards can be powered directly from the AC mains power supply by connecting it to the Barrel Jack (2).
3	Voltage RegulatorThe function of the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements.
4	Crystal OscillatorThe crystal oscillator helps Arduino in dealing with time issues. Arduino calculate time using the crystal oscillator. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz.
5,17	Arduino ResetTo reset the Arduino board, i.e., start the program from the beginning. Resetting the UNO board in two ways. First, by using the reset button (17) on the board. Second, connect an external reset button to the Arduino pin labeled RESET (5).
6,7 8,9	Pins (3.3, 5, GND, Vin)· 3.3V (6) " Supply 3.3 output volt· 5V (7) " Supply 5 output volt· Most of the components used with Arduino board works fine with 3.3 volt and 5 volt.· GND (8)(Ground) " There are several GND pins on the Arduino, any of which can be used to ground your circuit.· Vin (9) " This pin also can be used to power the Arduino board from an external power source, like AC mains power supply.
10	Analog pinsThe Arduino UNO board has six analog input pins A0 through A5. These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.
11	Main microcontrollerEach Arduino board has its own microcontroller (11). It as the brain of your board. The main IC (integrated circuit) on the Arduino is slightly different from board to board. The microcontrollers are usually of the ATMEL Company.
12	ICSP pinMostly, ICSP (12) is an AVR, a tiny programming header for the Arduino consisting of MOSI, MISO, SCK, RESET, VCC, and GND. It is often referred to as an SPI (Serial Peripheral Interface), which could be considered as an "expansion" of the output. It is slaving the output device to the master of the SPI bus.
13	Power LED indicatorThis LED should light up when Arduino is plugged into a power source to indicate that your board is powered up correctly. If this light does not turn on, then there is something wrong with the connection.
14	TX and RX LEDsOn the board two labels: TX (transmit) and RX (receive) will be available. They appear in two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TX and RX led (13). The TX led flashes with different speed while sending the serial data. The speed of flashing depends on the baud rate used by the board. RX flashes during the receiving process.

15	Digital I/OThe Arduino UNO board has 14 digital I/O pins (15) (of which 6 provide PWM (Pulse Width Modulation) output. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled "~" can be used to generate PWM.
16	AREFAREF stands for Analog Reference. It is sometimes, used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

1.4 Operating Instructions

To make Arduino into a Operating process, the need for the working system are:

- Arduino Uno board
- USB programming cable (A to B)
- 9V battery or external power supply (for stand-alone operation)
- Solderless breadboard for external circuits, and 22 g solid wire for connections
- Host PC running the Arduino development environment. Versions exist for Windows, Mac and Linux