TEXTILE MECHATRONICS

NSQF LEVEL - 4

1st Year

TRADE THEORY

SECTOR: CAPITAL GOODS & MANUFACTURING

(As per revised syllabus July 2022 - 1200Hrs)

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Directorate General of Training

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

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

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Trade : **Textile Mechatronics - 1st Year Trade Theory - NSQF Level - 4 (Revised 2022)**

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, 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 **Textile Mechatronics 1st Year Trade Theory** in **CG & M Sector** under **Yearly Pattern.** The NSQF Level - 4 (Revised 2022) Trade Practical 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 - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (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 Director General, Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

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ATUL KUMAR TIWARI, *I.A.S*
Secretary
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Government of India.

September 2024
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 Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi under the Craftsman and Apprenticeship Training Schemes.

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

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

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

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

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

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

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

Chennai - 600 032 **EXECUTIVE DIRECTOR**

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ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this Instructional Material **(Trade Theory)** for the trade of **Textile Mechatronics 1st Year NSQF Level - 4 (Revised 2022)** under **Capital Goods & Manufacturing** Sector for ITIs.

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

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

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

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INTRODUCTION

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 - 4 (Revised 2022) syllabus are covered.

The manual is divided into Seven modules

Module 1	**Safety Precautions and Basic Electrical Practice**
Module 2	**Building and Testing Basic Electrical Circuits**
Module 3	**Basics of Electrical Machines**
Module 4	**Electronics**
Module 5	**Basic Workshop Operations and Training**
Module 6	**Basic Electrical Wiring and Winding Methods**
Module 7	**Feedback and Control Elements**

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.

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **Textile Mechatronics 1st Year NSQF Level - 4 (Revised 2022)** in **CG & M**. The contents are sequenced according to the practical exercise contained in NSQF Level - 4 (Revised 2022) 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.

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.

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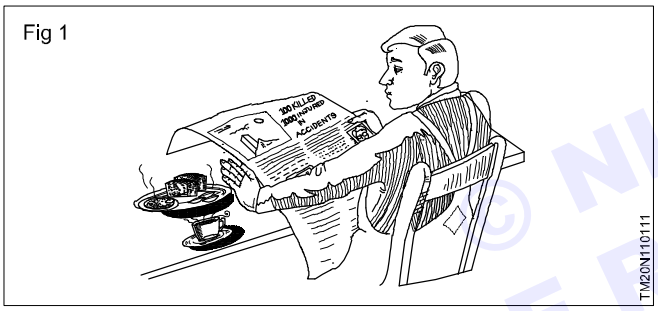
Safety workshop practice - Firefighting practice

Objectives: At the end of this lesson you shall be able to
- **state about an accident**
- **state the causes for accidents in general terms**
- **state the is safety attitude**
- **list the four basic categories of safety signs.**

What is an accident?

Nobody deliberately has an accident; accidents occur due to causes which are not foreseen. Sometimes nothing can be done to prevent them from happening. For example, a part of a machine fails when nobody has any reason to think there is anything wrong with it, or the driver of a vehicle collapses at the wheel. Most accidents however occur as a result of human error, of ignorance or neglect, forgetfulness or recklessness. These accidents can be prevented. If people had acted differently at some point, the event which we call an 'accident' would not have occurred. (Fig 1)

Fig 1



Lots of accidents still happen every year killing a lot of people. Although most people are alarmed and horrified by this state of affairs, accidents continue to happen, costing the industry millions of rupees every year. Older workers who have come to terms with the dangers, young workers who may be reckless, employers who turn a blind eye to the possibility of things going wrong - because they want to get the job done, all these factors contribute to this senseless waste. Fortunately there are many who do not take this view. They have a different attitude to safety - and 'attitude' is an all-important factor in the chain of events which leads to someone causing, being involved in, or becoming the victim of an 'accident'.

Causes for accidents: Normally accidents do not just happen. They are caused. (Fig 2)

Causes for accidents are many. Some of the important causes are listed below. (Fig 3)

- Unawareness of danger
- Disregard for safety
- Negligence
- Lack of understanding of proper safety procedures

Fig 2

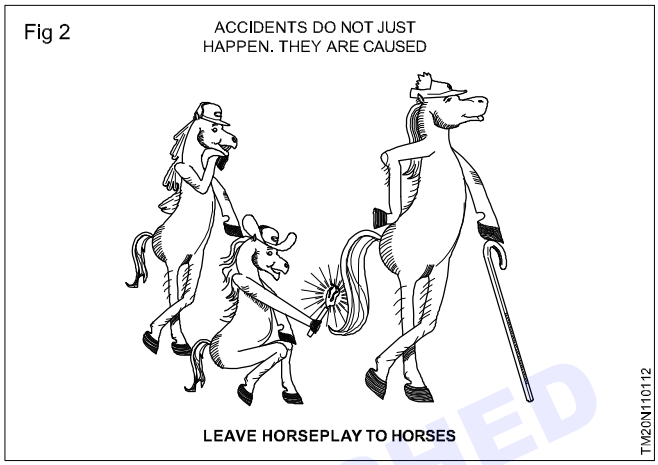


Fig 3



- Untidy condition of workplace
- Inadequate light and ventilation
- Improper use of tools
- Unsafe conditions

Safe attitudes: People's attitudes govern what they do or fail to do. In most cases where someone is working with unsafe equipment or in an unsafe situation, somebody has allowed that state of affairs to come about by something they have done or failed to do. (Fig 4)

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Fig 4



Most accidents don't just happen; they are caused by people who (for example) damage equipment or see it is faulty but don't report it, or leave tools and equipment lying about for other people to trip over. Anybody who sees a hazard and does nothing about it is also contributing to the possibility of an accident. A worker doesn't necessarily need to do anything to help bring about an accident; just going mindlessly about his work may be enough to ensure a work-mate being crippled for life. He didn't do it - but by proper and timely thinking and acting, he could have prevented it.

Responsibilities: Safety doesn't just happen - it has to be organised and achieved like the work-process of which it forms a part. The law states that both an employer and his employees have a responsibility in this behalf.

Employer's responsibililties: The effort a firm puts into planning and organising work, into training people, into engaging skilled and competent workers, maintaining plant and equipment, and checking, inspecting and keeping records - all of this contributes to the safety in the workplace.

The employer will be responsible for the equipment provided, the working conditions, what employees are asked to do, and the training given.

Employee's responsibilities: You will be responsible for the way you use the equipment, how you do your job, the use you make of your training, and your general attitude to safety.

A great deal is done by employers and other people to make your working life safer; but always remember you are responsible for your own actions and the effect they have on others. You must not take that responsibility lightly.

Rules and procedures at work: What you must do, by law, is often included in the various rules and procedures laid down by your employer. They may be written down, but more often than not, are just the way a firm does things - you will learn these from other workers as you do your job. They may govern the issue and use of tools, protective clothing and equipment, reporting procedures, emergency drills, access to restricted areas, and many other matters. Such rules are essential; they contribute to the efficiency and safety of the job.

Safety signs: As you go about your work on a construction site you will see a variety of signs and notices. Some of these will be familiar to you - a 'no smoking' sign for example; others you may not have seen before. It is up to you to learn what they mean - and to take notice of them. They warn of the possible danger, and must not be ignored.

Safety signs fall into four separate categories. These can be recognised by their shape and colour. Sometimes they may be just a symbol; other signs may include letters or figures and provide extra information such as the clearance height of an obstacle or the safe working load of a crane.

The four basic categories of signs are as follows.

- prohibition signs
- mandatory signs
- warning signs
- information signs

Prohibition signs



Shape	Circular.
Colour	Red border and cross bar. Black symbol on white background.
Meaning	Shows it must not be done.
Example	No smoking.

Mandatory signs



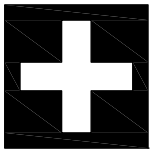
Shape	Circular.
Colour	White symbol on blue background.
Meaning	Shows what must be done.
Example	Wear hand protection.

Warning signs



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

Information signs



Shape	Square or oblong.
Colour	White symbols on green background.
Meaning	Indicates or gives information of safety provision.
Example	First aid point.

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Prohibition signs (Fig 5)

Fig 5



Mandatory signs (Fig 6)



Warning signs (Fig 7)

Fig 7



Questions about your safety

Do you know the general safety rules that cover your place of work?

Are you familiar with the safety laws that cover your particular job?

Do you know how to do your work without causing danger to yourself, your workmates and the general public?

Are the plant, machinery and tools that you use really safe? Do you know how to use them safely and keep them in a safe condition?

Do you wear all the right protective clothing, and have you been issued with all the necessary safety equipment?

Have you been given all the necessary safety information about the materials used?

Have you been given training and instruction to enable you to do your job safely?

Do you know who is responsible for safety at your place of work?

Do you know who are the appointed `Safety Representatives'?

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Lifting and handling loads

Objectives: At the end of this lesson you shall be able to
- **state the types of injury caused while lifting and carrying loads, and how to prevent them**
- **state the six points to be noted in the kinetic method of lifting.**

Many of the accidents reported involve injuries caused while lifting and carrying loads. An electrician may need to install a heavy electric motor in a restricted space and make the correct wiring connections. Wrong lifting techniques can result in injury. A load need not necessarily be very heavy to cause injury.

What causes an injury more frequently -

a very heavy load or a wrong way of lifting?

A wrong way of lifting something too heavy causes injury. The muscles and joints are strained. This is especially true in the case of injury to the back. The most common type of injury due to a wrong way of lifting is injury to the back.

Are the injuries caused as a result of strain only?

No. Injuries during lifting and carrying may be caused by tripping over an object and falling, or striking an object with a load.

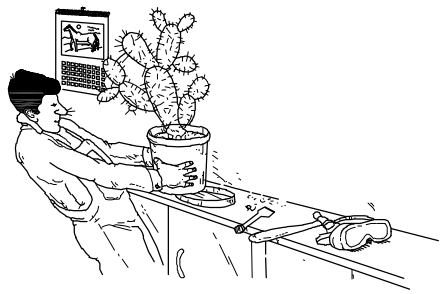
Types of injury and how to prevent them

Cuts and abrasions: Cuts and abrasions are caused:

– by rough surfaces and jagged edges

– by splinters and sharp or pointed projections. (Fig 1)

Fig 1



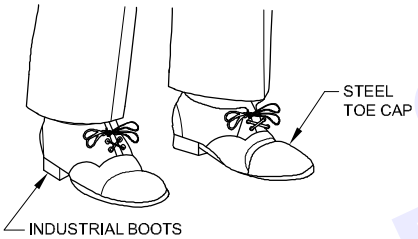
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Leather gloves will usually be sufficient for protection, but the load should be checked to make sure of this, since large or heavy loads may involve body contact as well.

Crushing of feet or hands: Feet or hands should be positioned so that they cannot be trapped by the load. Timber wedges can be used when raising and lowering heavy loads to ensure that the fingers and hands are not caught and crushed.

Safety shoes with steel toe caps will protect the feet. (Fig 2)

Fig 2



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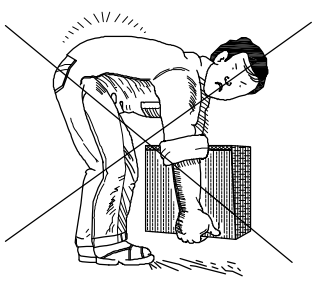
Strains to muscles and joints: Strains to muscles and joints may be the result of:

– lifting a load which is too heavy or

– lifting incorrectly.

Sudden and awkward movements such as twisting or jerking during a lift can put severe strain on muscles. Injury to the back is most often caused by lifting loads which are too heavy or by employing wrong methods. 'Stoop lifting' - lifting from a standing position with the back rounded (Fig 3) increases the risk of a back injury.

Fig 3

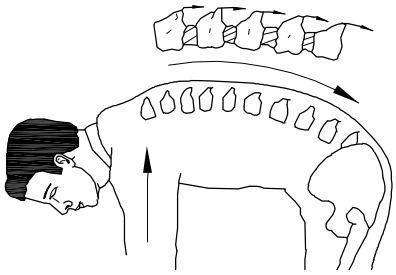


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The human spine is not an efficient weight lifting machine, and can be easily damaged if incorrect techniques are used.

The stress on a rounded back can be up to six times greater than if the spine is kept straight. Fig 4 shows an example of stoop-lifting.

Fig 4



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Preparing to lift: What preparation should you have to make before lifting?

Before lifting or handling any load ask yourself the following questions.

What has to be moved?

Where from and where to?

Will assistance be required?

A load which seems light enough to carry at first will become progressively heavier, the farther you have to carry it.

Before lifting and carrying, make sure the route is clear of obstacles and the place where the load is to be deposited is not obstructed.

The person carrying the load should always be able to see over or around it.

The weight, a person can lift will vary according to:

– age

– physique and

– condition such as other health factors.

It will also depend on whether one is used to lifting and handling heavy loads.

What makes an object difficult to lift and carry?

– Weight is not the only factor which makes it difficult to lift and carry.

– The size and shape can make an object awkward to handle.

– Loads, which require the arms to be extended in front of the body, place more strain on the back and stomach than do compact objects carried close to the body.

– The absence of hand-holds or natural handling points can make it difficult to raise and carry the object.

The kinetic method of lifting: It enables the worker to make full use of the body's own weight to initiate the lift.

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The natural shape of the spine is maintained throughout (although the body may be bent forward, the spine should remain straight), and the lift is powered by the strong muscles in the legs and thighs.

It is important to begin with the right posture, that is, the various parts of the body should be correctly positioned before beginning the lift. The following six points should be noted.

– The Feet are placed about 18 inches(45cms) wide apart, with one foot slightly forward, in the direction of movement. This gives a good balance and provides a secure basis for the lift.

– The Knees should be slightly bent (but not fully bent as in a squat).

– The Back must be straight, although the body may be inclined forward as shown in the illustration.

– The Arms should be as close to the body as possible. The farther the arms are extended the greater the strain. Elbows too should be kept in.

– The Grip must be firm and secure.

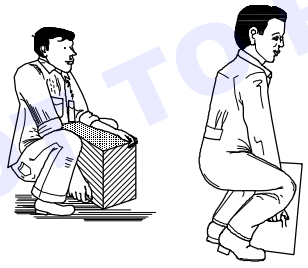
– The Head should be erect with the chin in.

Correct manual lifting techniques

– Approach the load squarely, facing the direction of travel.

– The lift should start with the lifter in a balanced squatting position, with the legs slightly apart and the load to be lifted held close to the body. Ensure that a safe secure hand grip is obtained. Before the weight is taken, the back should be straightened and held as near the vertical position as possible. (Fig 5)

Fig 5



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– To raise the load, first straighten the legs. This ensures that the lifting strain is being correctly transmitted and is being taken by the powerful thigh muscles and bones. Look directly ahead, not down at the load while straightening up, and keep the back straight; this will ensure a smooth, natural movement without jerking or straining. (Fig 6)

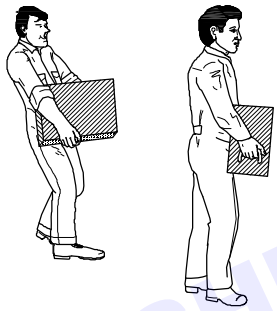
Fig 6



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– To complete the lift, raise the upper part of the body to the vertical position. When a load is near to an individual's maximum lifting capacity, it will be necessary to lean back on the hips slightly (to counterbalance the load) before straightening up. (Fig 7)

Fig 7

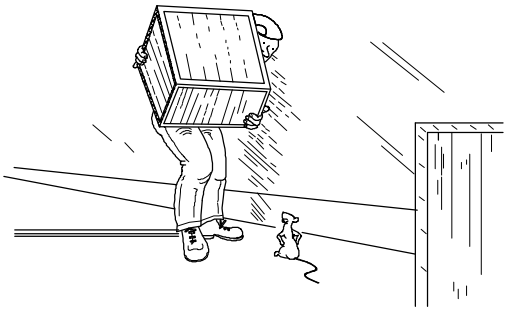


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– Keeping the load well into the body, carry it to the place where it is to be set down. When turning, avoid twisting from the waist-turn the whole body in one movement.

Lowering the load: Make sure the area is clear of obstructions. (Fig 8)

Fig 8



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Bend at the knees to a semi-squatting position; keep the back and head erect by looking straight ahead, not down at the load. It may be helpful to rest the elbows on the thighs during the final stage of lowering.

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Moving heavy equipment

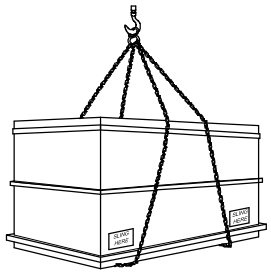
Objectives: At the end of this lesson you shall be able to
- **name the methods followed in industry to move heavy equipment**
- **describe the procedure to be followed for moving heavy equipment on layers and rollers**
- **list the safety considerations while raising a load and moving a load.**

Heavy equipment is moved in industry using any of the following

- Cranes and slings
- Winches
- Machine moving platforms
- Layers and rollers.

Cranes and slings: This method is used whenever loads are to be lifted and moved. (Fig 1) Examine the slings for cuts, abrasion, wear, fraying or corrosion.

Fig 1

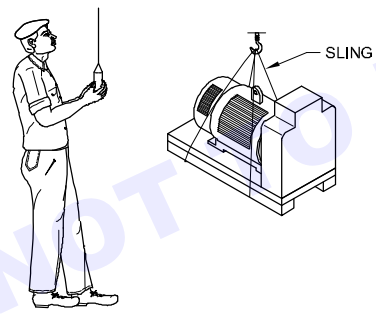


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Damaged slings must not be used.

Distribute the weight as evenly as possible between the slings when using more than one sling. (Fig 2)

Fig 2



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Keep the slings as near to vertical as possible.

Winches: Winches are used to pull heavy loads along the ground.

Cranes and slings may be power-driven (Fig 3) or hand-operated. (Fig 4)

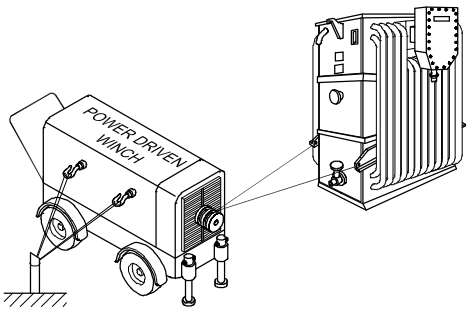
Ensure that the safe working load (SWL) of the winch is adequate for the task.

Secure the winch to a structure which is strong enough to withstand the pull.

On open ground, drive long stakes into the ground and secure the winch to them.

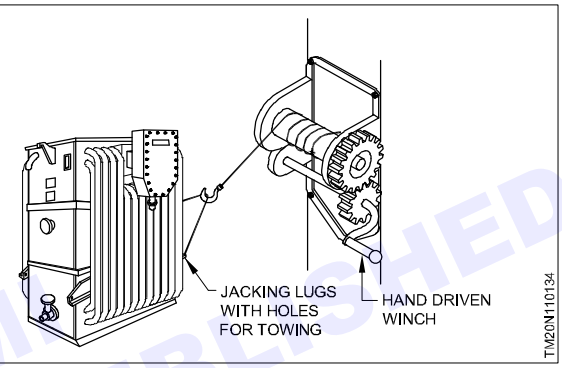
Choose a suitable sling and pass it around the base of the load. Secure it to the hook of the winch.

Fig 3



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Fig 4



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Some heavy items have special lugs welded to them for jacking and towing purposes.

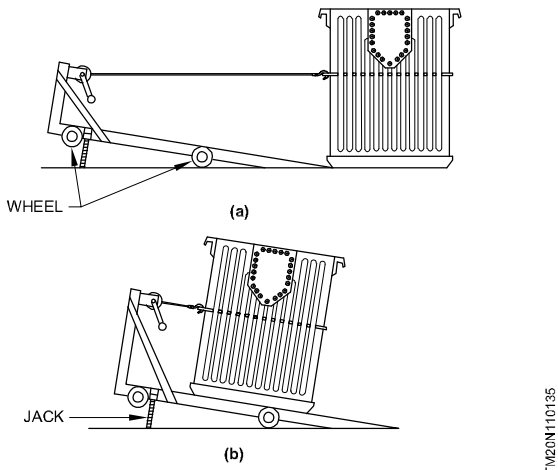
Safety considerations: Before using any winch, check that the brake or ratchet mechanism is in working order. You should know how to control it.

Keep hands and fingers well away from the gear wheels.

Keep bearings and gears oiled or greased.

Machine moving platforms: This is a special device made to move heavy equipment in industry. Fig 5a and 5b show the method of loading the equipment.

Fig 5



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Pass a suitable sling round the load at a convenient height.

Attach the sling to the hook of the winch and draw the load on the platform until its centre of gravity lies between the front and rear wheels.

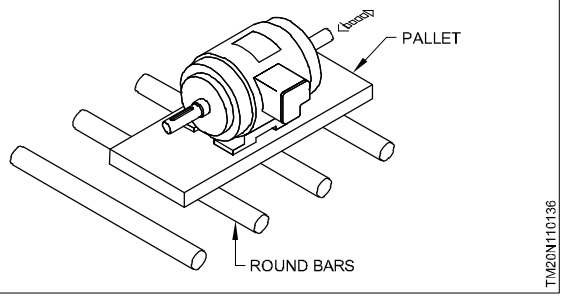
Lower the jacks so that the platform rests on its wheels.

For unloading follow the procedure in the reverse order.

Using layers and rollers: Sometimes a load cannot be moved along the ground because of the irregular shape of its base or because it is not rigid enough.

Place such a load on a flat-bottomed pallet or 'layer' resting on round bars. (Fig 6)

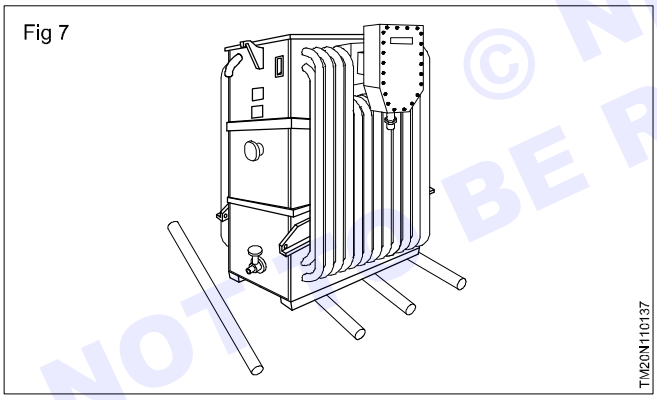
Fig 6



Ensure the bars (rollers) are long enough to project at each side of the load, for ease of handling.

They should be large enough to roll easily over any unevenness along the route but should be small enough to be handled easily. (Fig 7)

Fig 7



Two or three bars of equal diameter are sufficient for most loads but if four or more bars are used the load may be moved faster as there is no delay when moving the rear bar to the front. (Fig 7)

Move the load by using a crowbar. (Fig 8)

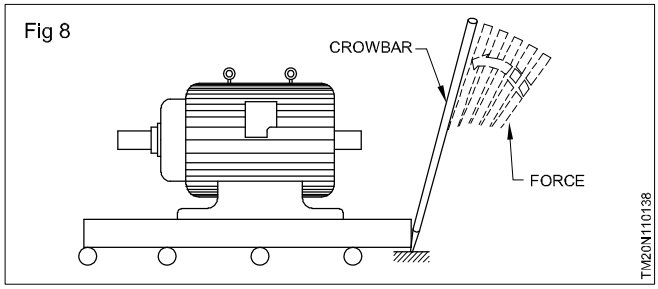
When a load is on rollers, only shallow slopes can be negotiated.

Hold the load in check all the time it is on the slope.

Use a winch with an effective brake for this operation.

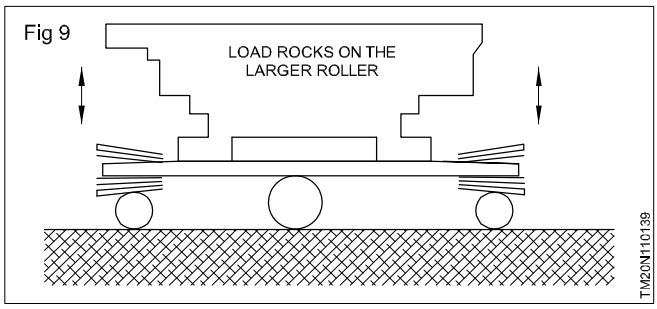
To negotiate a corner on rollers: For a moderate load, insert one roller a little larger than the others as the corner is approached.

Fig 8



When this roller is under the centre of gravity of the load, the load can be rocked to and fro on the roller and swivelled around sideways. (Fig 9)

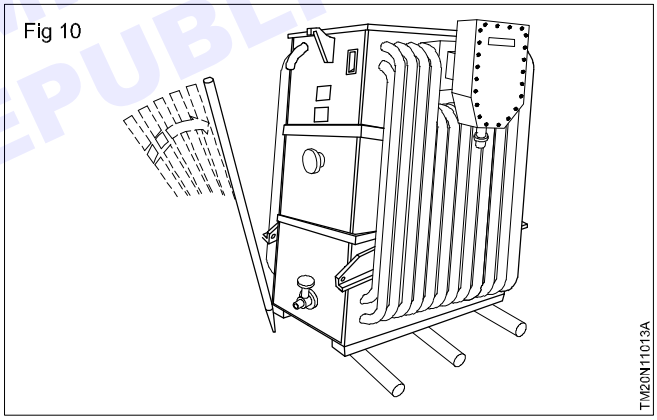
Fig 9



For heavier loads: Stop the load at the beginning of the corner.

Twist the load round on the rollers by pushing the sides with a crowbar until the load is just over the ends of the rollers. (Fig 10)

Fig 10



Place some rollers at an angle to the front of the load.

Push the load forward on to these rollers.

Twist the load further round and place the freed rollers in front of and at an angle to the load. (Fig 11)

Continue until the load is pointing in the desired direction.

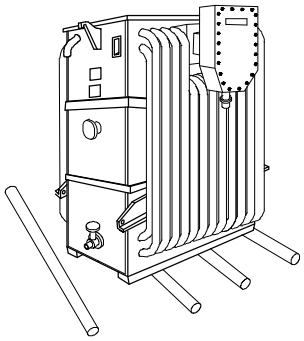
Safety considerations

Moving heavy loads with crowbars or jacks: Make sure hands are clear of the load before lowering it on to packing or rollers.

Do not use hands underneath the packing when positioning it. Use a push block.

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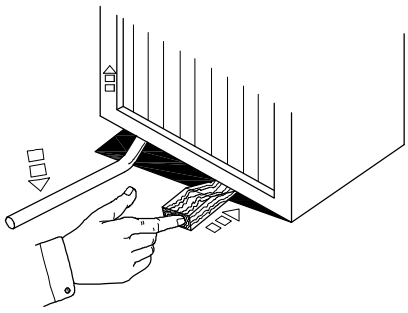
Fig 11



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Place the packing on the floor and push it under the load. (Fig 12)

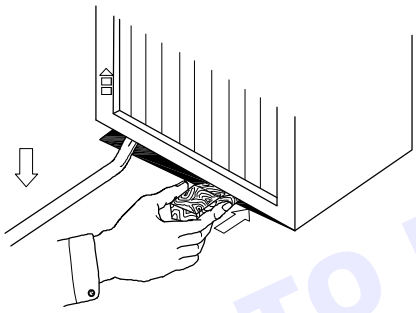
Fig 12



TM20N11013C

Hold it by its side faces keeping the fingers well away from the lower edge of the load and from the floor. (Fig 13)

Fig 13



TM20N11013D

Raising a load: Check that the slings are correctly secured to the load and to the hook. Ensure they are not twisted or caught on a projecting part of the load.

If you cannot see an assistant on the far side of the load, verify that he is ready before starting to lift and ensure that his hands are clear of the slings.

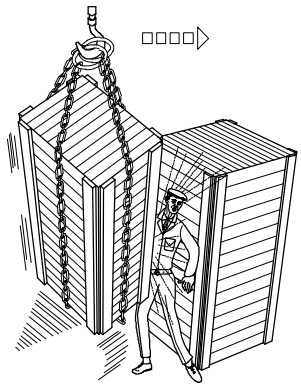
Warn nearby workers that the lift is about to begin.

Lift slowly!

Take care to avoid being crushed against other objects as the load rises. It may swing or rotate as it leaves the ground. (Fig 14)

Minimise such movement by locating the hooks as accurately as possible above the centre of gravity of the load.

Fig 14

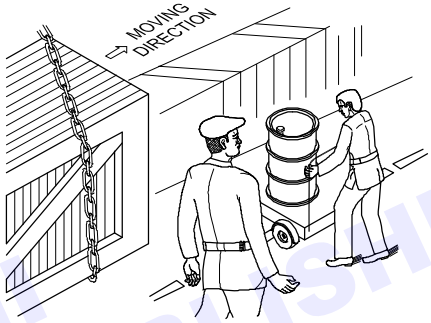


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Keep the floor clear of unnecessary objects.

Moving a load: Check that there are no obstacles in the way of the crane and the load. (Fig 15)

Fig 15



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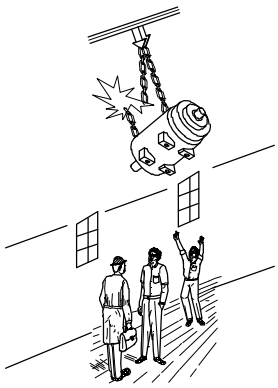
Stand clear of the load and move it steadily.

Be prepared to stop the load quickly, if somebody moves into its path.

Allow for the natural swing of the load when changing speed or direction.

Ensure that the load will not pass over the heads of other people. (Fig 16)

Fig 16



TM20N11013G

The tackle may fail or slip.

Warn them to stand clear before an accident is caused.

Accidents do not happen. They are caused.

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Safety practice - Fire extinguishers

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

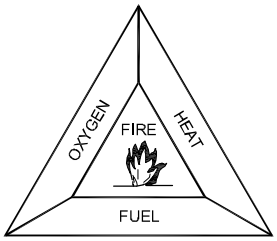
- **state the effects of a fire break out**
- **state the causes for fire in a workshop**
- **state the conditions required for combustion relevant to fire prevention**
- **state the general precautionary measures to be taken for prevention of fire.**

Fire is the burning of combustible material. A fire in an unwanted place and on an unwanted occasion and in uncontrollable quantity can cause damage or destroy property and materials. It might injure people, and sometimes cause loss of life as well. Hence, every effort must be made to prevent fire. When a fire outbreak is discovered, it must be controlled and extinguished by immediate corrective action.

Is it possible to prevent fire? Yes, fire can be prevented by eliminating anyone of the three factors that causes fire.

The following are the three factors that must be present in combination for a fire to continue to burn. (Fig 1)

Fig 1



Fuel: Any substance, liquid, solid or gas will burn, if there is oxygen and high enough temperatures.

Heat: Every fuel will begin to burn at a certain temperature. It varies and depends on the fuel. Solids and liquids give off vapour when heated, and it is this vapour which ignites. Some liquids do not have to be heated as they give off vapour at normal room temperature say 15^0C, *eg.* petrol.

Oxygen: Usually exists in sufficient quantity in air to keep a fire burning.

Extinguishing of fire: Isolating or removing any of these factors from the combination will extinguish the fire. There are three basic ways of achieving this.

– **Starving** the fire of fuel removes this element.

– **Smothering** - ie. isolate the fire from the supply of oxygen by blanketing it with foam, sand etc.

– **Cooling** - use water to lower the temperature.

Removing any one of these factors will extinguish the fire.

Preventing fires: The majority of fires begin with small outbreaks which burn unnoticed until they have a secure hold. Most fires could be prevented with more care and by following some simple common sense rules.

Accumulation of combustible refuse (cotton waste soaked with oil, scrap wood, paper, etc.) in odd corners are a fire risk. Refuse should be removed to collection points.

The cause of fire in electrical equipment is misuse or neglect. Loose connections, wrongly rated fuses, overloaded circuits cause overheating which may in turn lead to a fire. Damage to insulation between conductors in cables causes fire.

Clothing and anything else which might catch fire should be kept well away from heaters. Make sure that the heater is shut off at the end of the working day.

Highly flammable liquids and petroleum mixtures (thinner, adhesive solutions, solvents, kerosene, spirit, LPG gas etc.) should be stored in the flammable material storage area.

Blowlamps and torches must not be left burning when they are not in use.

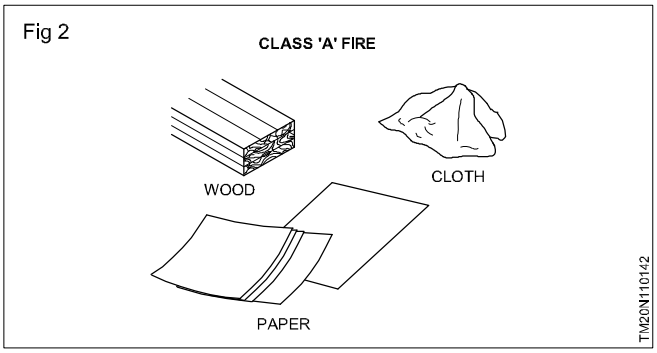
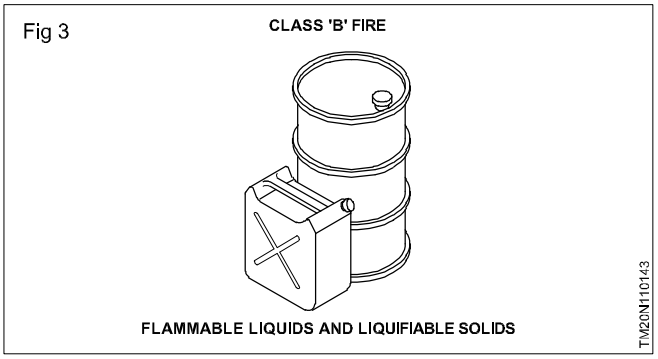
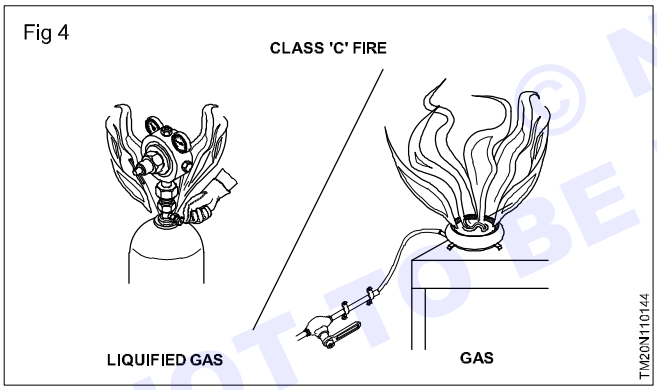
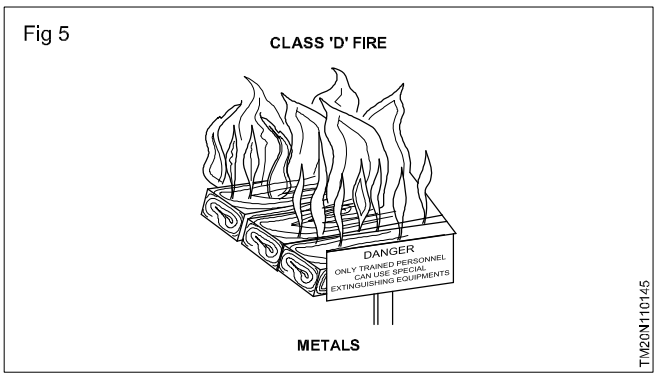
Extinguishing fires: Fires are classified into four types in terms of the nature of fuel.

Different types of fire have to be dealt with in different ways and with different extinguishing agents.

An extinguishing agent is the material or substance used to put out the fire, and is usually (but not always) contained in a fire extinguisher with a release mechanism for spraying into the fire.

It is important to know the right type of agent for extinguishing a particular type of fire; using a wrong agent can make things worse. There is no classification for 'electrical fires' as such, since these are only fires in materials where electricity is present.

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Fuel	Extinguishing
Fig 2  	Most effective ie. cooling with water. Jets of water should be sprayed on the base of the fire and then gradually upwards.
Fig 3  	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.
Fig 4  	Extreme caution is necessary in dealing with liquefied 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 powder extinguishers are used on this type of fire. Special powders have now been developed which are capable of controlling and/or extinguishing this type of fire. The standard range of fire extinguishing agents is inadequate or dangerous when dealing with metal fires.
Fig 5  	Fire on electrical equipment. Halon, Carbon dioxide, 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 under any circumstances.

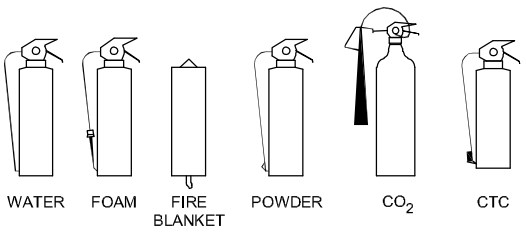
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Types of fire extinguishers

Objectives: At the end of this lesson you shall be able to
- **distinguish different types of fire extinguishers**
- **determine the correct type of fire extinguisher to be used based on the class of fire**
- **describe the general procedure to be adopted in the event of a fire.**

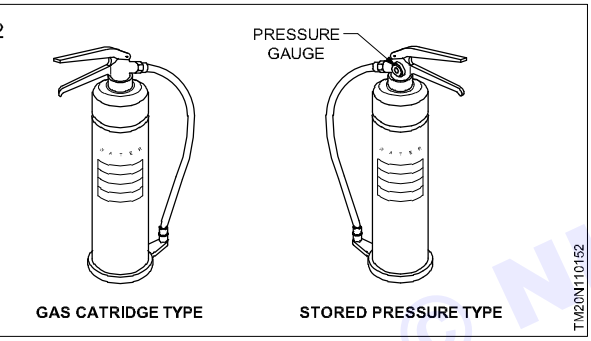
Many types of fire extinguishers are available with different extinguishing 'agents' to deal with different classes of fires. (Fig 1)

Fig 1



Water-filled extinguishers: There are two methods of operation. (Fig 2)

Fig 2



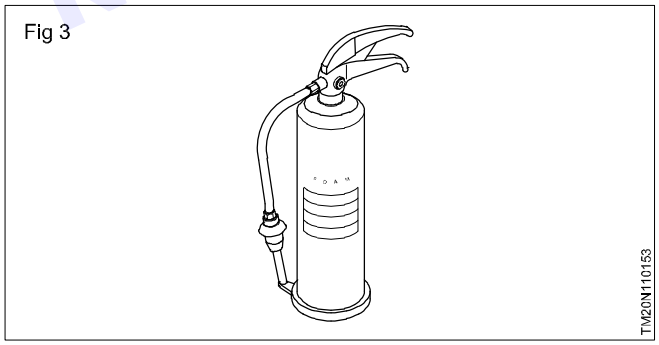
– Gas cartridge type

– Stored pressure type

With both methods of operation the discharge can be interrupted as required, conserving the contents and preventing unnecessary water damage.

Foam extinguishers (Fig 3):These may be of stored pressure or gas cartridge types. Always check the operating instructions on the extinguisher before use.

Fig 3



Most suitable for

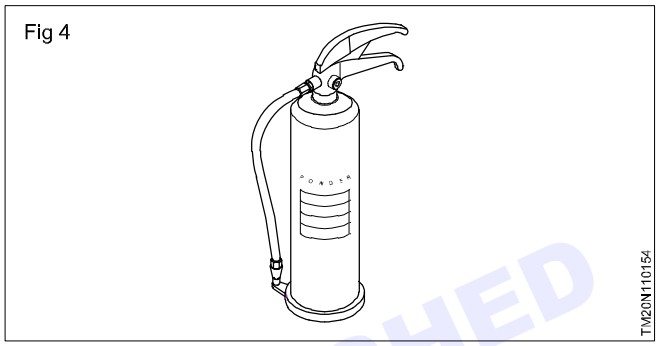
– flammable liquid fires

– running liquid fires.

Must not be used on fires where electrical equipment is involved.

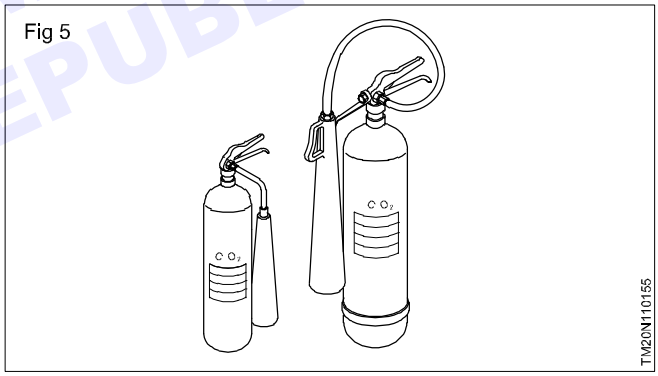
Dry powder extinguishers (Fig 4): Extinguishers fitted with dry powder may be of the gas cartridge or stored pressure type. Appearance and method of operation is the same as that of the water-filled one. The main distinguishing feature is the fork shaped nozzle. Powders have been developed to deal with class D fires.

Fig 4



Carbon dioxide (CO_2): This type is easily distinguished by the distinctively shaped discharge horn. (Fig 5).

Fig 5



Suitable for Class B fires. Best suited where contamination by deposits must be avoided. Not generally effective in open air.

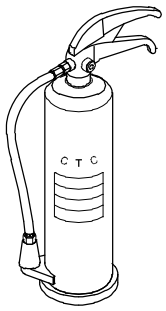
Always check the operating instructions on the container before use. Available with different gadgets of operation such as - plunger, lever, trigger etc.

Halon extinguishers (Fig 6)**:** These extinguishers may be filled with carbon-tetrachloride and Bromochlorodifluoro methane (BCF). They may be either gas cartridge or stored pressure type.

They are more effective in extinguishing small fires involving pouring liquids. These extinguishers are particularly suitable and safe to use on electrical equipment as the chemicals are electrically non-conductive.

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Fig 6



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

The general procedure in the event of a fire:

- Raise an alarm.
- Turn off all machinery and power (gas and electricity).
- Close the doors and windows, but do not lock or bolt them. This will limit the oxygen fed to the fire and prevent its spreading.
- Try to deal with the fire if you can do so safely. Do not risk getting trapped.
- Anybody not involved in fighting the fire should leave calmly using the emergency exits and go to the designated assembly point. Failure to do this may mean that some person being unaccounted for and others may have to put themselves to the trouble of searching for him or her at risk to themselves.

Practice on fire extinguishers

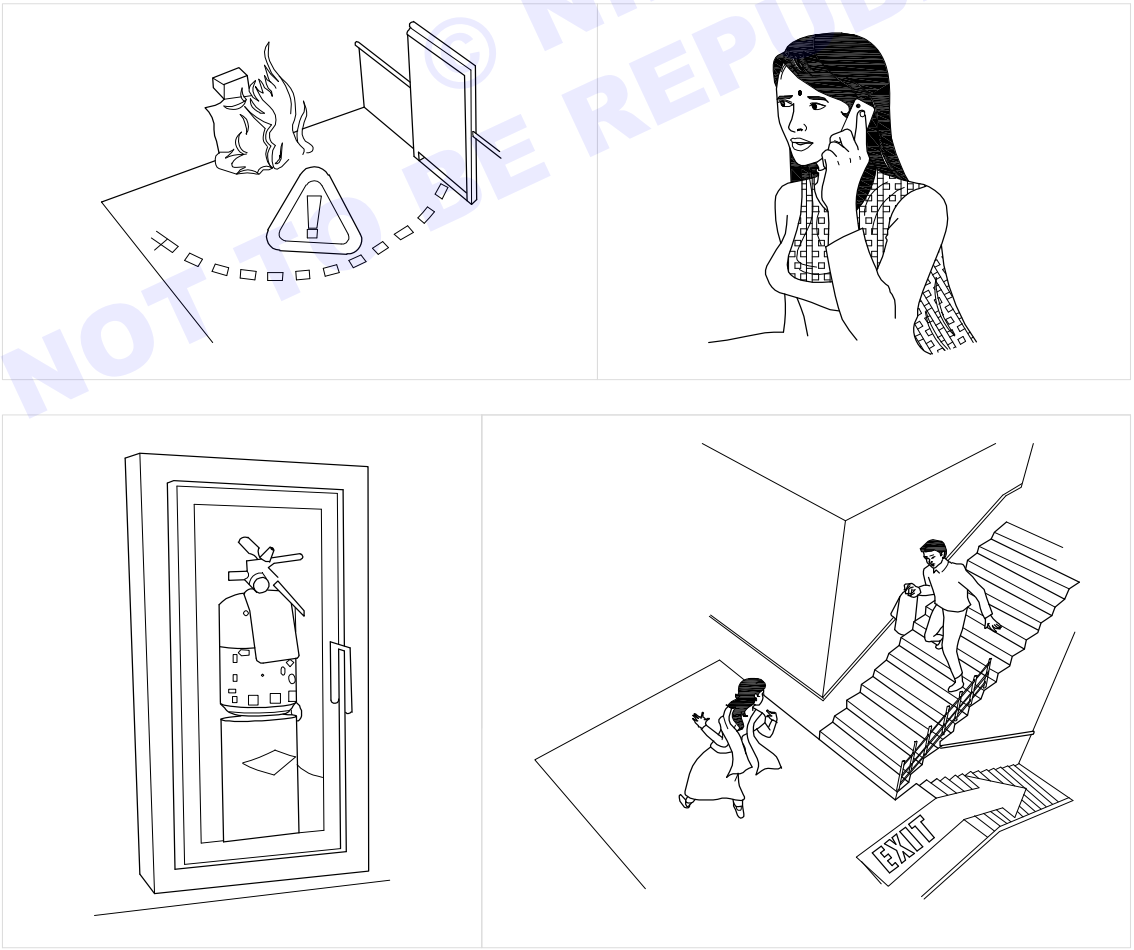
Objectives: At the end of this lesson you shall be able to
- **select the fire extinguishers according to the type of fire**
- **operate the fire extinguisher**
- **extinguish the fire.**

- Alert people surrounding by shouting fire, fire, fire when observe fire.
- Inform fire service or arrange to inform immediately.
- Open emergency exist and ask them to go away.
- Put “off” electrical power supply.

Don’t allow people to go nearer to the fire

- Analyze and identify the type of fire (Fig 1) Refer Table1.

Fig 1



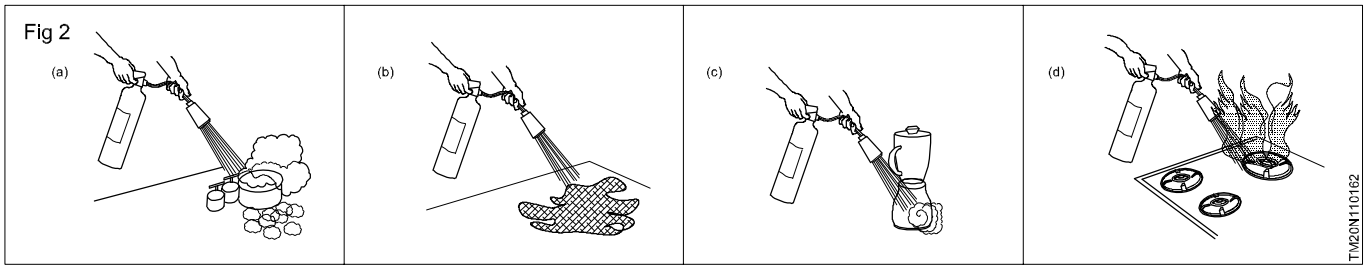
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Table-1

Class 'A'	Wood, paper, cloth, solid material
Class 'B'	Oil based fire (grease, gasoline, oil) liquefiablegases
Class 'C'	Gas and liquefiable gases
Class 'D'	Metals and electrical equipment

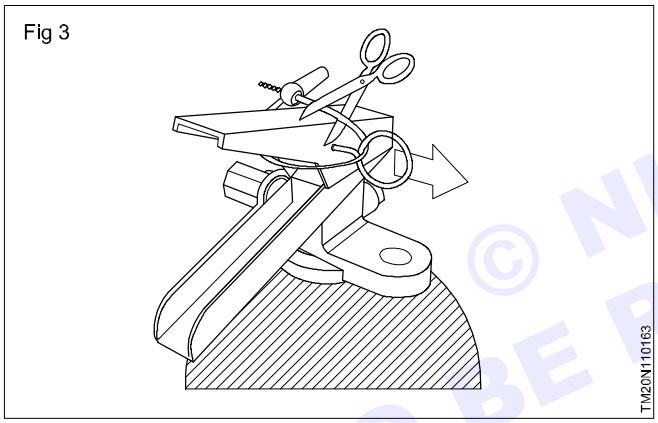
Fig 2



Assume the fire is 'B; type (flammable liquefiable solids)

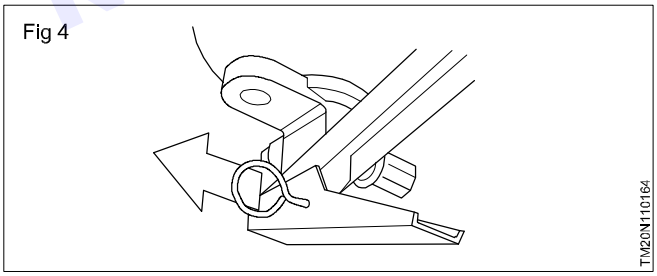
- Select CO_2 (Carbon di oxide) fire extinguisher.
- Locate and pickup, CO_2 fire extinguisher. Click for its expiry date.
- Break the seal (Fig 2)

Fig 3



- Pull the safety pin from the handle (Pin located at the top of the fire extinguisher) (Fig 3)
- Aim the extinguisher nozzle or hose at the base of the fire (this will remove the source of fuel fire) (Fig 3)

Fig 4



Keep yourself low

- Squeeze the handle lever slowly to discharge the agent (Fig 4)
- Sweep side to side approximately 15 cm over the fuel fire until the fire is put off (Fig 5)

Fire extinguishers are manufactured for use from the distance.

Fig 5

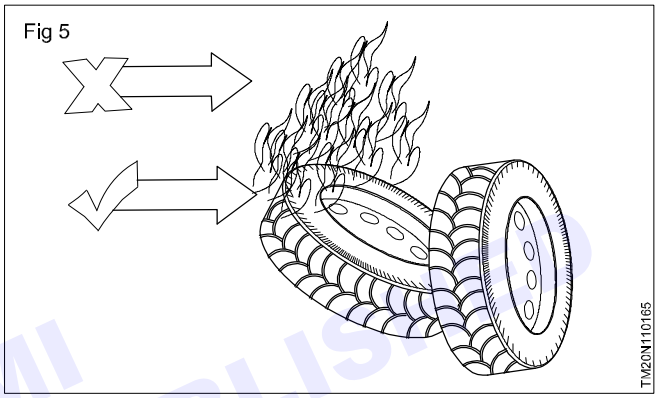
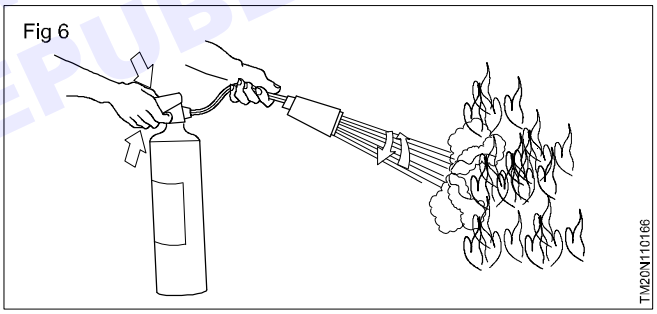


Fig 6



Caution

- **While putting off fire, the fire may flare up**
- **Do not be panic belong as it put off promptly.**
- **If the fire doesn't respond well after you have used up the fire extinguisher move away yourself away from the fire point.**
- **Do not attempt to put out a fire where it is emitting toxic smoke leave it for the professionals.**
- **Remember that your life is more important than property. So don't place yourself or others at risk.**

In order to remember the simple operation of the extinguisher. Remember P.A.S.S. This will help you to use the fire extinguisher.

P for Pull

A for Aim

S for Squeeze

S for Sweep

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Conductors - Insulators- Wires - Cables - Wire joints

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 materials used for conductors**
- **state the conductors by size**
- **state the properties of insulating materials**
- **state the different types of insulating tapes**
- **state the characteristic of semiconductors.**

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

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

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

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

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

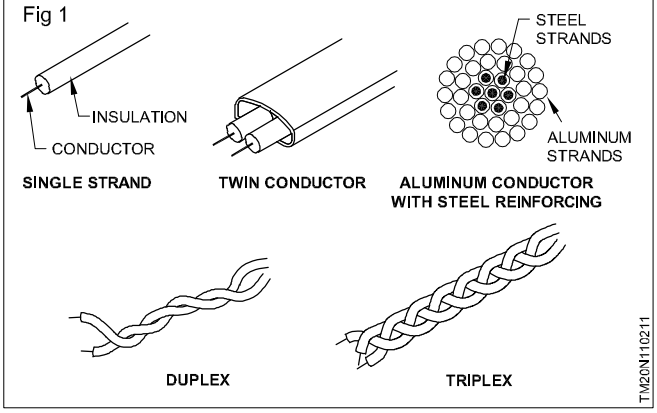
Conductors make up the main conducting path of electric current, and insulating materials prevent current flow through unwanted paths and minimises electrical hazards.

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

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

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

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

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

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

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

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

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

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

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

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

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

A common measure of wire diameter is the standard wire gauge (SWG), commonly used in our country. The resistance of a material increases as the length of the conductor increases, and the resistance decreases as

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the cross-sectional area of the conductor increases. We can compare one material with another by measuring the resistance of samples.

Classification of Conductors

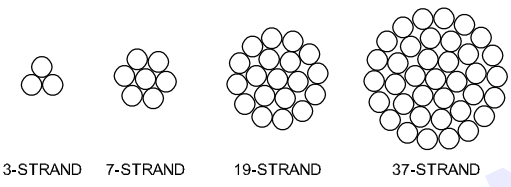
Wires and cables can be classified by the type of covering they have.

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

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

Stranded conductors: They consist of many strands of fine wires as shown in Fig 2. The wires in stranded conductors are usually twisted together. Stranded conductors are more flexible and have better mechanical strength.

Fig 2



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. Meg-ohmmeter (Megger) is the instrument used to measure insulation resistance. It measures high resistance values in mega ohms 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.

Insulating tapes

Various tapes are used for insulating electrical equipment, conductors and components. Some of these are adhesives. 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. The pressure causes layers to bend together. Application of this restores insulation but not other protective covering.

Friction tape: This is applied over the rubber tape. This is made up of cotton cloth impregnated with an adhesive. It does not stretch like the rubber tape. 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 types are made of cloth impregnated with varnish. They have usually no adhesive coating. They are available in sheets and rolls and are ideal for insulating motor connecting leads.

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.

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Joints in electrical conductors

Objectives: At the end of this lesson you shall be able to
- **state the necessity of joints, their types and uses.**

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

Definition of joint: A joint in an electrical conductor means connecting/tying or interlaying together of two or more conductors such that the union/junction becomes secured both electrically and mechanically.

Types of joints: In electrical work, different types of joints are used, based on the requirement. The service to be performed by a joint determines the type to be used.

Some joints may require to have good electrical conductivity. They need not necessarily be mechanically strong.

Example: The joints made in junction boxes and conduit accessories.

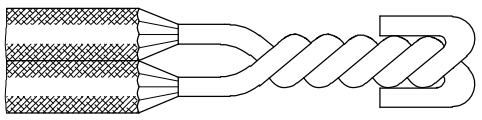
On the other hand, the joints made in overhead conductors, need to be not only electrically conductive but also mechanically strong to withstand the tensile stress due to the weight of the suspended conductor and wind pressure.

Some of the commonly used joints are listed below.

– Pig-tail or rat-tail or twisted joints
– Married joint
– Tee joint
– Britannia straight joint
– Britannia tee joint
– Western union joint
– Scarfed joint
– Tap joint in single stranded conductor

Pig-tail/Rat-tail/Twisted joint: (Fig 1) This joint is suitable for pieces where there is no mechanical stress on the conductors, as found in the junction box or conduit accessories box. However, the joint should maintain good electrical conductivity.

Fig 1



RAT TAIL JOINT

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Married joint: (Fig 2) A married joint is used in places where appreciable electrical conductivity is required, along with compactness.

Fig 2



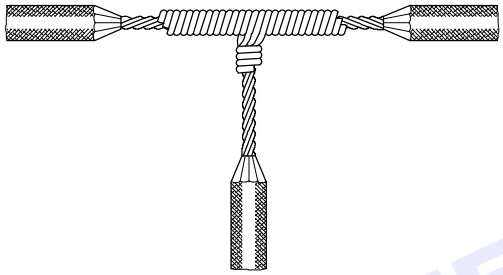
MARRIED JOINT

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As the mechanical strength is less, this joint could be used at places where the tensile stress is not too great.

Tee joint (Fig 3)**:** This joint could be used in overhead distribution lines where the electrical energy is to be tapped for service connections.

Fig 3



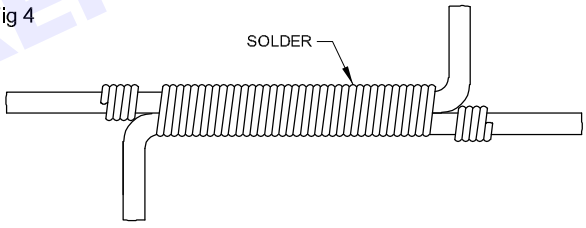
TEE JOINT

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Britannia joint: (Fig 4) This joint is used in overhead lines where considerable tensile strength is required.

It is also used both for inside and outside wiring where single conductors of diameter 4 mm or more are used.

Fig 4

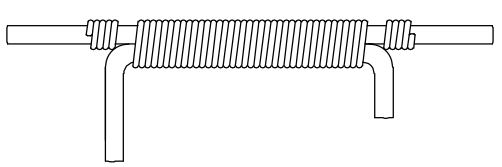


BRITANNIA JOINT

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Britannia tee joint: This joint (shown in Fig 5) is used for overhead lines for tapping the electrical energy perpendicular to the service lines.

Fig 5

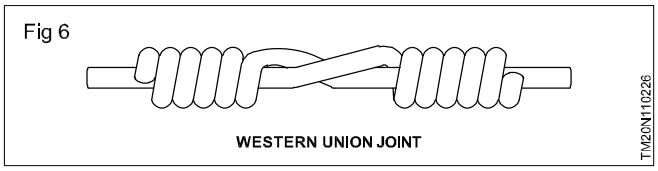


BRITANNIA TEE JOINT

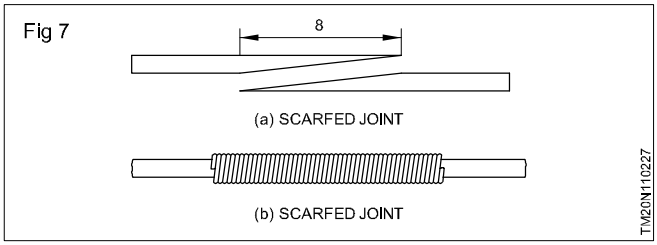
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Western union joint (Fig 6)**:** This joint is used in overhead lines for extending the length of wire where the joint is subjected to considerable tensile stress.



Scarfed joint (Fig 7)**:** This joint is used in large single conductors where good appearance and compactness are the main considerations, and where the joint is not subjected to appreciable tensile stress as in earth conductors used in indoor wiring.



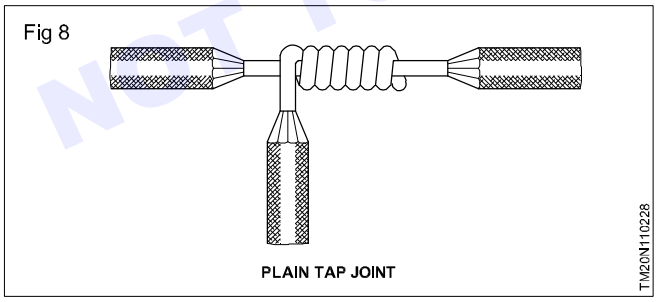
Tap joints in single stranded conductors of diameter 2 mm or less

By definition, a tap is the connection of the end of one wire to some point along the run of another wire.

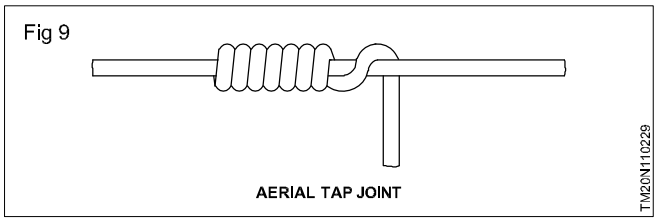
The following types of taps are commonly used.

– Plain
– Aerial
– Knotted
– Cross - Double - Duplex

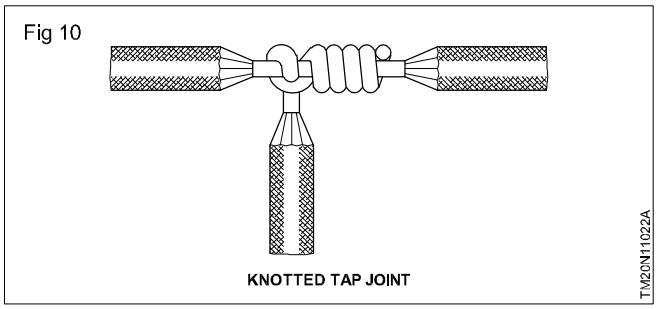
Plain tap joint: (Fig 8) This joint is the most frequently used, and is quickly made. Soldering makes the joint more reliable.



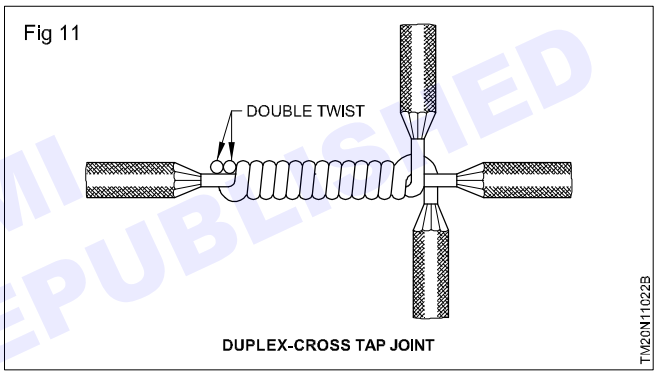
Aerial tap joint: This joint is intended for wires subjected to considerable movement, and it is left without soldering for this purpose. This joint is suitable for low current circuits only. It is similar to the plain tap joint except that it has a long or easy twist to permit the movement of the tap wire over the main wire.



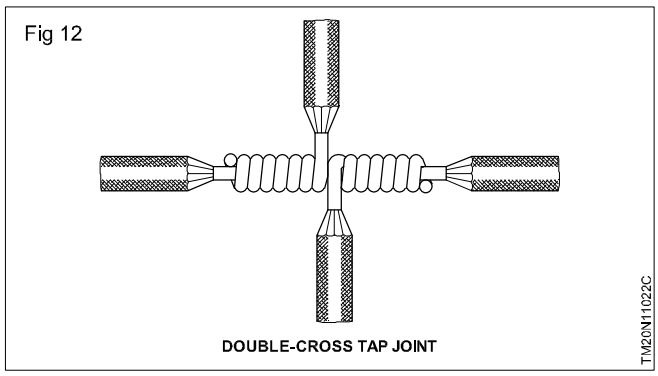
Knotted tap joint: A knotted tap joint is designed to take considerable tensile stress.



Duplex cross-tap joint: (Fig 11) This joint is used where two wires are to be tapped at the same time. This joint could be made quickly.



Double-cross tap joint: This joint is simply a combination of two plain taps. (Fig 12)



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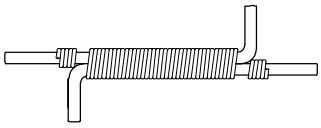
Britannia joint

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

- **assess the length of a Britannia joint and also the size of the binding wire.**

The Britannia joint shown in Fig 1 is done on bare copper conductors to extend the length, at places where they are not subjected to tensile stress like earth continuity conductors. However, it is also used in short span distribution lines (less than 80 metres) where the tensile stress is not appreciable. To improve the mechanical and electrical strength, the Britannia joint made in copper conductors needs to be soldered. Otherwise, the joint may get loosened due to vibrations caused by the air or elongation and contraction of the wires due to atmospheric temperature.

Fig 1

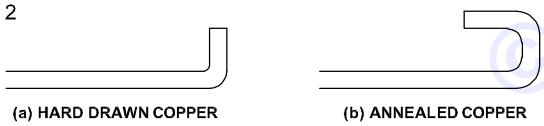


BRITANNIA JOINT

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The bend formed at the ends in the bare conductor should be about 90^0 as shown in Fig 2(a) for hard-drawn copper conductors, whereas, for annealed copper conductors, which are soft in nature, a complete bend (say 180^0) as shown in Fig 2(b) is recommended to avoid straightening of the bend when subjected to tensile stress.

Fig 2



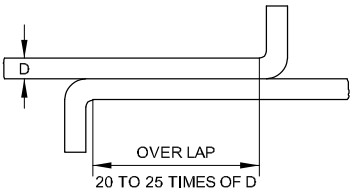
(a) HARD DRAWN COPPER (b) ANNEALED COPPER

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Any attempt to make the hard-drawn copper to bend more than 90^0 in cold state will result in cracks and breakage of the conductor. As HD copper has more tensile strength it is not necessary to bend it more than 90^0.

Overlap distance in Britannia joint: A Britannia joint should have a proper overlap distance to establish good electrical contact. This overlap distance depends upon the diameter of the conductors. For example, a 8 SWG conductor has an approximate diameter of 4 mm, and the overlapping distance will be about 20 to 25 times the diameter, and hence, will be about 80 mm to 100 mm as shown in Fig 3.

Fig 3



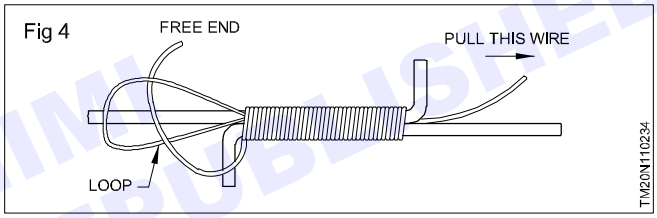
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Binding wire: The size of binding wire depends upon the size of the conductor. Table 1 gives the recommended sizes of binding wires.

Further the binding wire should be of the same material as that of the parent conductors but annealed to have easy bending characteristics. Preferably the binding wire should be tinned. The length of the binding wire depends upon the size of H.D.B. copper wire and the length of overlapping.

Interlaying of binding wire in between the HDB copper wire and threading after joint as shown in Fig 4 is necessary to obtain a mechanically strong Britannia joint.

Fig 4



TM20N110234

Britannia tee joint: This joint is used where tapping is to be taken to places perpendicular or at an angle to the main overhead lines. The method of making `Tee' and straight joints is about the same as both the joints require binding wire. Hence for selection of the binding wire and to assess the length of the joint, the same table may be used.

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Table 1

Sl.No.	Gauge number of copper conductors	Diameter of conductor in mm	Recommended copper binding wires	
			Gauge number	Diameter in mm
1	4 SWG	5.89	16 SWG	1.63
2	6 SWG	4.88	18 SWG	1.22
3	8 SWG	4.06	20 SWG	0.914
4	10 SWG	3.25	22 SWG	0.711

Fundamental of electricity - Electron theory - Ohm's Law

Objectives: At the end of this lesson you shall be able to
- **define an atom**
- **state the atomic structure**
- **energy shells in atoms.**

Introduction

Electricity is one of today's most useful sources of energy. Until the mid-1800s electricity was just a scientific curiosity. Electricity is a necessity in the modern world of sophisticated equipment and machinery.

Scientists discovered electromagnetism, that is the relationship between electric current and a magnetic field.

The terms used in electricity may confuse the layman, but electrical and electronics craftsman must know the specific meaning of each word and term.

Almost every electrical machine or appliance has a tag or nameplate stating the operating voltage and current of the unit. These terms also have special meanings. You must understand those meanings in order to make use of the information they provide.

Electrical voltage is often compared to pressure in a water system. The two ideas are not exactly the same. But they are enough alike to make the comparison useful. You may find electricity easier to understand at first if you think of voltage as a sort of 'electrical pressure' that pushes electric current through a wire or through a piece of equipment.

Another common name for voltage is electromotive force, abbreviated as emf. This term is used by many people, but it is misleading. Electromotive force is not the same as the force of gravity or the force that a tool exerts on a workpiece. It refers to the same 'electrical pressure' as voltage and it is measured in volts.

Electricity in motion is called electrical current. You can think of electric current as being similar to a current of water in a pipe or in a stream. But there are some important differences you must learn about in order to avoid confusion. Electric current is measured in amperes, often abbreviated as amps.

Electricity that does not move is called static electricity.

Structure of matter: To understand electricity, one must understand the structure of matter. Electricity is related to some of the most basic building blocks of matter - atoms, electrons and protons. All matter is made of these electrical building blocks and, therefore, all matter is said to be 'electrical'.

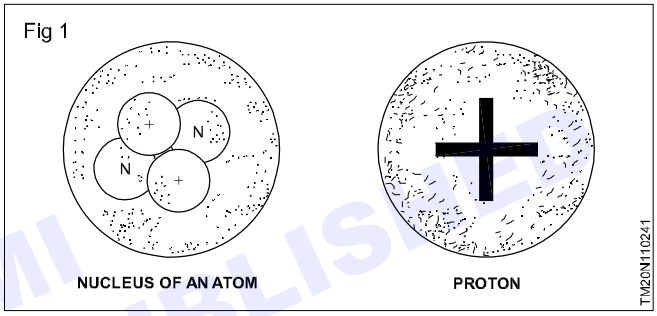
Matter is defined as anything that has mass and occupies space. All matter is made of tiny, invisible particles called molecules. A molecule is the smallest particle of a substance that has the properties of the substance. Each molecule can be divided into smaller parts by chemical means. The smaller parts of a molecule are called atoms.

Basically, an atom contains three types of sub-atomic particles that are of interest in electricity: electrons, protons and neutrons. The protons and neutrons are located in the centre, or nucleus of the atom, and the electrons travel around the nucleus in orbits.

Atomic structure

The nucleus: The nucleus is the central part of the atom. It contains the protons and neutrons of an atom as shown in Fig 1.

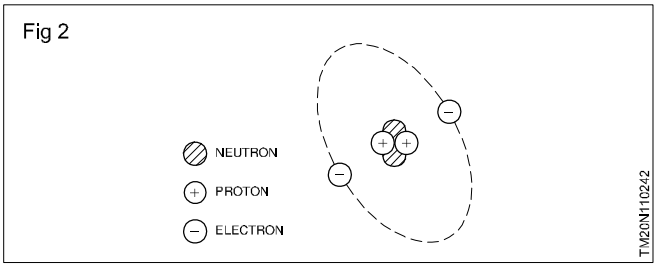
Fig 1



Protons: The proton has a positive electrical charge. It is almost 1840 times heavier than the electron and it is the permanent part of the nucleus; protons do not take an active part in the flow or transfer of electrical energy (Fig 1).

Electron: It is a small particle revolving round the nucleus in an atom as shown in Fig 2. It has a negative electric charge. The electron is three times larger in diameter than the proton. In an atom the No. of protons = No. of electrons.

Fig 2

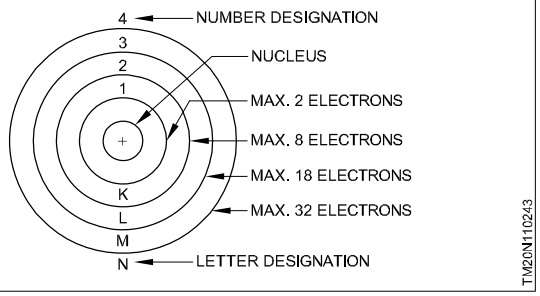


Neutron: A neutron is actually a particle by itself, it is generally thought of as an electron and proton combined, and is electrically neutral. Since neutrons are electrically neutral, they are not too much important to the electrical nature of atoms.

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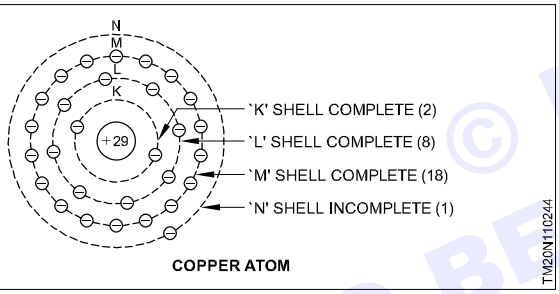
Energy shells: In an atom, electrons are arranged in shells around the nucleus. A shell is an orbiting layer or energy level of one or more electrons. The major shell layers are identified by numbers or by letters starting with 'K' nearest the nucleus and continuing alphabetically outwards. There is a maximum number of electrons that can be contained in each shell. Fig 3 illustrates the relationship between the energy shell level and the maximum number of electrons it can contain.

Fig 3



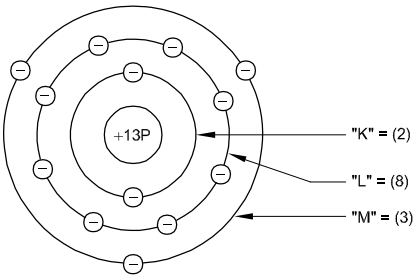
If the total number of electrons for a given atom is known, the placement of electrons in each shell can be easily determined. Each shell layer, beginning with the first, is filled with the maximum number of electrons in sequence. For example, a normal copper atom which has 29 electrons would have four shells with the number of electrons in each shell as shown in Fig 4.

Fig 4



Similarly an aluminium atom which has 13 protons and has 3 shells as shown in Fig 5

Fig 5



Electron distribution : The chemical and electrical behaviour of atoms depends on how completely the various shells and sub-shells are filled.

Atoms that are most chemically alive have one electron more or one less than a completely filled shell. Atoms that have the outer shell exactly filled are chemically inactive. They are called inert elements. All inert elements are gases and do not combine chemically with other elements.

Metals possess the following characteristics.

– They are good electric conductors.

– Electrons in the outer shell and sub-shells can move easily from one atom to another.

– They carry charge through the material.

The outer shell of the atom is called the valence shell and its electrons are called valence electrons. Because of their greater distance from the nucleus, and because of partial blocking of the electric field by electrons in the inner shells, the attracting force on the valence electrons is less. Therefore, valence electrons can be set free more easily. Whenever a valence electron is removed from its orbit it becomes known as a free electron. Electricity is commonly defined as the flow of these free electrons through a conductor.

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Ohm's Law

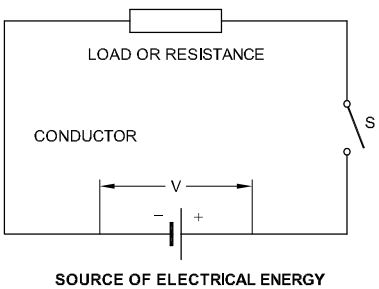
Objectives: At the end of this lesson you shall be able to
- **define emf and P.D. and their units**
- **state the method of connecting a voltmeter**
- **define current and its units**
- **state the method of connecting an ammeter**
- **describe a simple electric circuit.**

Introduction

In the modern world we use a number electric gadgets. All these devices should have complete electrical current path. Such a complete electric path is called as a circuit. A circuit should have a source of supply, load, insulated conductor to carry the current and a switch to control the circuit.

Simple electric circuit: A simple electric circuit (Fig 1) is the complete pathway of the current flow from the battery via the switch and the load, back to the battery.

Fig 1



An electric circuit consists of:

– voltage source

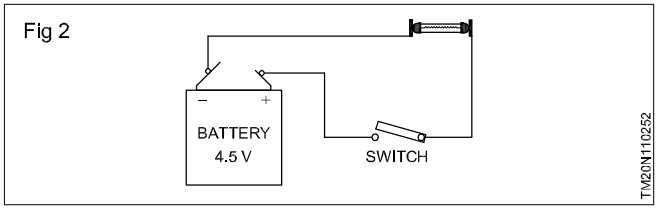
– connecting wires (conductors)

– load

– switch.

Question 1: In Fig 2, which is the source of electrical energy and which is the load?

Fig 2

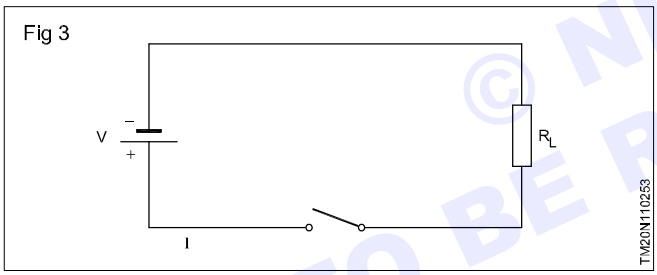


Open circuit: Two important extreme conditions can occur in a circuit: open circuit and short circuit.

In an open circuit, there is an infinitely high resistance in the circuit, provided most of the time by the open switch. Therefore, no current can flow.

For example, a battery is on an open circuit when it is not supplying current to the circuit, that is the switch is open, Fig 3. A wall socket, too, is an open circuit if no appliance is connected to it. Although there is no current flow, if there is no switch, there will be a voltage across the socket which will be live (a hazard!).

Fig 3



Question 2: In an open circuit what is the value of

(a) the circuit resistance and

(b) the current I.

Short circuit: The other important extreme condition is the short circuit

A short circuit will occur, for example, when the two terminals of a torch battery are joined, Fig 4a. A short circuit may also occur if the insulation between the two cores of a cable is defective. The resulting small load resistance will cause large currents which can become a hazard. A fuse could then blow and automatically switch off the current.

Question 3: Copy this table into your exercise book and complete it by putting very large; (or `theoretically infinite') and `very small' (or `theoretically zero') in the appropriate space.

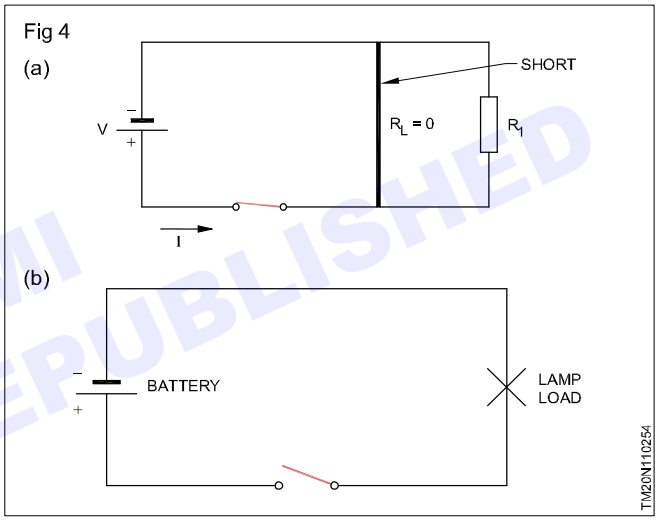
	on open circuit	on short circuit
Current		
Load resistance		

Electric current: Fig 4b shows a simple electric circuit. When the switch is closed, the lamp lights because the electrical current flows from the source of electrical energy (battery).

Electrons can move through a conductor at different rates, and electric current will, therefore, have different values.

This current (symbol I) is determined by the count of electrons that pass through a cross-section of a conductor in one second. Even very low currents the count of electrons is unimaginably large. For this reason, currents are not measured in electrons per second but in amperes (symbol A). A current of 1 ampere means that in one second about 6.24×10^{18} electrons move through a cross-section of the conductor.

Fig 4



There are special prefixes for the decimal multiples or decimal sub-multiples of the ampere.

1 kiloampere = 1 kA = 1000 A = 1×10^3A

1 milliampere = 1 mA = 1/1000 A = 1×10^{-3}A

1 microampere = 1 μA = 1/1000000 A = 1×10^{-6}A

Question 4: Express 2.5mA in ampere

SI Unit of electric charge: The charge is produced by the electrons which move during the charging process. The letter used to represent electric charge (or quantity of electricity) is Q. The quantity of electricity is not expressed in individual electrons but in the SI unit of the coulomb (abbreviated as capital C). One coulomb (1 C) corresponds to a quantity of electricity of about 6.24×10^{18} electrons.

The SI unit coulomb has the dimensions of ampere second (abbreviated As)

The following formula relates the above quantities:

Quantity of electricity = Current x Time

or in symbols, $Q = I \times t$

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Ammeters: In order to measure current, measuring instruments called current meters or ammeters are used. (Fig 5a)

An ammeter is used to measure current. For this the current must flow through the measuring instrument. Hence ammeter is connected in series with the load.

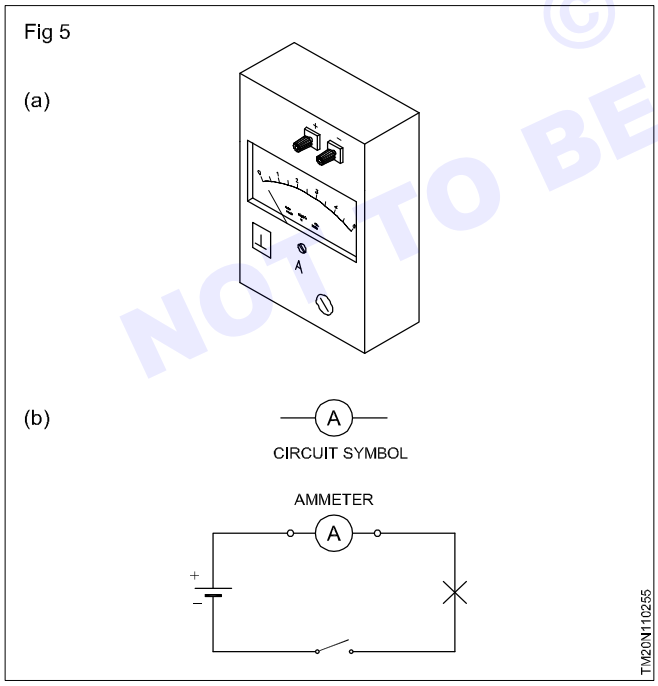
Question 5: Why is a current measuring instrument called an ammeter?

Electromotive force: It is now necessary to consider the reason for the motion of electrons in an electrical circuit.

In order to move the free electrons in one direction and to produce a current, a source of electrical energy is required. The torch battery is a source of electrical energy.

Within the battery the negative terminal contains an excess of electrons whereas the positive terminal has a deficit of electrons. The battery is said to have an electromotive force (emf) which is available to drive the free electrons in the closed path of the electrical circuit. The difference in the distribution of electrons between the two terminals of the battery produces this emf. Now the unit of emf is the volt and, through common usage, it is now accepted that the emf of an electrical source may be referred to as its 'voltage'. (The terminals of the battery are indicated on the circuit symbol by two lines, the longer line for the positive and the shorter for the negative terminal).

Potential difference: The voltage across the mains when the load is put on is known as potential difference and its unit is volt.



Question 6: What causes free electrons to move and produce a current in an electrical circuit?

The existence of a voltage between the terminals of an electrical source depends upon the different amounts of electrons on these terminals. A voltage can also exist when there is no current flowing. However, without a voltage there can be no flow of current.

An electrical voltage (symbol V) is measured in volts(V).

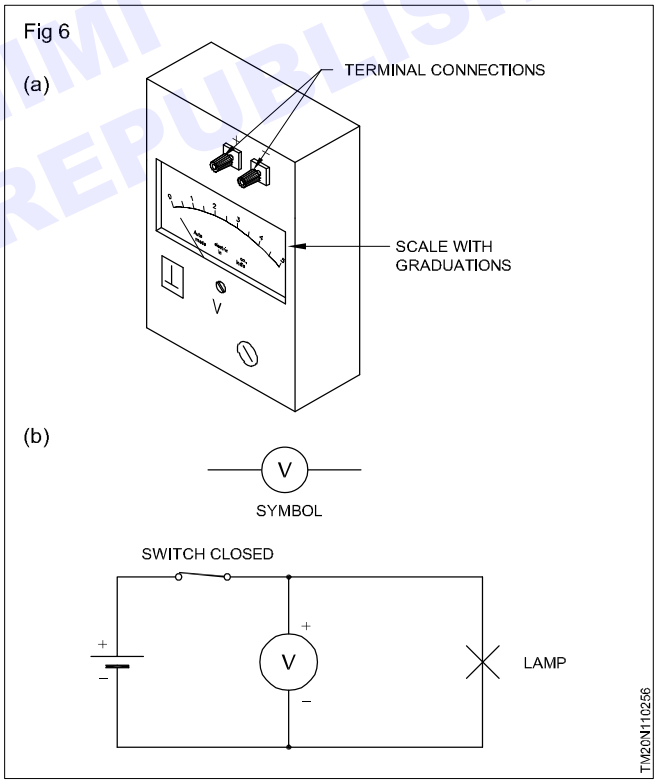
The unit of electrical voltage is the volt. The following expressions are used for the decimal multiples and sub-multiples of 1 volt.

1 kilovolt	= 1 kV	= 1000 V	= 1 x 10^3V
1 millivolt	= 1 mV	= 1/1000 V	= 1 x 10^{-3}V
1 microvolt	= 1 µV	= 1/1000000 V	= 1 x 10^{-6}V

Electrical voltage is measured with a voltmeter. In order to measure the voltage source the terminals of the source must be connected to the terminals of a voltmeter. Positive to the positive terminal and negative to the negative terminal, as shown in Fig 6b.

Resistance: In addition to current and voltage there is a third quantity that plays a role in a circuit: electrical resistance. Every material opposes the flow of electrical current to some extent.

Resistance is dependent upon the composition, length, cross-section and temperature of the relevant material. For the time being it is sufficient to know that the resistance of a metallic conductor increases if its length increases or if its cross-section is reduced.



Electrical resistance (symbol R) is measured in ohms (symbol W).

The unit of electrical resistance is the ohm. For the decimal multiples or decimal sub-multiples of the ohm we use the following expressions:

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1 kiloohm = 1 kW = 1000 W = 1 x 10^3W

1 milliohm = 1 mW = 1/1000 W = 1 x 10^{-3}W

1 microohm = 1 mW = 1/1000000 W = 1 x 10^{-6}W

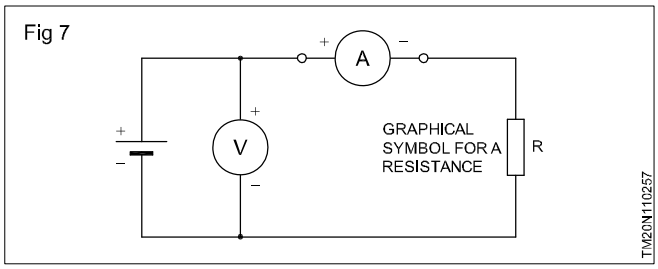
Question 7: What properties of a material is its electrical resistance dependent on?

Ohm's law: There is a fundamental relationship between the value of resistance R, measured in ohms (W), the current I, measured in amperes (A), and voltage V, measured in volts (V).

To appreciate this relationship a few measurements will have to be made. For this we use a circuit like the one given in the circuit diagram in Fig 7.

Notice the way that the ammeter and the voltmeter are connected in the circuit.

Fig 7



Question 8: Could the ammeter also be inserted in the lower conductor? Give a brief reason for your answer.

The following assumption will be taken as a basis for the first set of measurements.

A measured resistance R = 450 ohms does not change; it remains constant.

This is achieved by making the resistance out of, for instance, constantan wire whose resistance varies very little with change in temperature.

The voltage will be increased in steps, by connecting additional batteries together in series.

Now look at the results of the measurements.

In the following table the measured values of current are set out under the respective voltage values.

1. Table of measurements: R = 450 W constant

Voltage V in V	4.5	9	13.5	18
Current I in mA	10	20	30	40

From these measured results the following can be seen.

With a constant resistance R the current I increases directly as the voltage V; e.g. doubling the voltage doubles the current.

Or stated another way:

the current I is proportional to the voltage V as long as the resistance R does not change.

Question 9: In a circuit like the one above a voltage of V = 12V produces a current of 20 mA. What value of the current would result if, with the resistance remaining the same, the voltage was increased to 24V?

Now consider the results of a second series of measurements.

The circuit is still exactly the same as Fig 7 but now the voltage is unchanged (constant). The resistance is increased in steps from 450W to 1800W. This is achieved by inserting different values of resistance in the circuit.

2. Table of measurements: V = 18 V constant.

Resistance R in W	450	2.450 = 900	4.450 = 1800
Current in mA	40	20 = 1/2x40	10 = 1/4x40

From the results of the second measurements, it can be seen that with a constant voltage the current decreases relative to the increase in resistance; e.g. doubling the resistance results in halving of the current.

Or stated another way:

the current I is inversely proportional to the resistance R, as long as the voltage V does not change.

Question 10: In a circuit the current is to be increased from 1.2 A to 2.4 A. Which of the two alternative steps should be taken to bring about the required value?

Two different relationships for the values of the electrical current result from the two series of measurements.

These two relationships for the values of the electrical current result from the two series of measurements.

These two relationships can be more comprehensively set out in one formula. i.e.

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$I = \frac{V}{R}$$

$$1A = \frac{1V}{1\Omega} = 1\frac{V}{\Omega}.$$

This mutual dependency of the three basic quantities:

I, V, R

of an electric circuit is described as

Ohm's Law

It is among the most important laws of electro technology.

Ohm's Law says that the current I in a resistance is directly proportional to the voltage V across it and inversely proportional to the resistance R.

All metals increase in resistance with increase in temperature. This increase in resistance per ohm per degree rise in temperature is called temperature co-efficient of resistance.

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Key to questions

Question 1:

Electrical energy = Battery (4.5V)

Load = Lamp.

Question 2:

R_L (Circuit resistance)= **µ**

I = 0.

Question 3:

	On open circuit	On short circuit
Current	0 (very small)	µ (very high)
Load resistance	µ (very large)	0 (very small)

Question 4: 2.5 X 10^{-3}A or 0.0025 A

Question 5: Because with these instruments current can be had directly in amperes.

Question 6: EMF causes free electrons to move and produce a current in an electrical circuit.

Question 7: Electrical resistance of a material is dependent upon the composition, length, cross-section and temperature of the material.

Question 8: Yes. It does not matter where in the circuit the ammeter is inserted as the current is equal in all parts of the circuit.

Question 9: Current 40 mA (doubled).

Question 10: To double the current from 1.2 A to 2.4 A one can either keep voltage constant and change the resistance to half its value OR

keep the same resistance and double the voltage.

Mechanical work and power

Objectives: At the end of this lesson you shall be able to
- **define the terms related to work and power.**

Work: This may be defined as the overcoming of resistance or obstruction through a distance. The unit of measurement of work is joule which is equal to 0.102 kilogram-meter.

If a force of 'F' moves a body through a distance 'S' (Fig 1) in its direction of application, then,

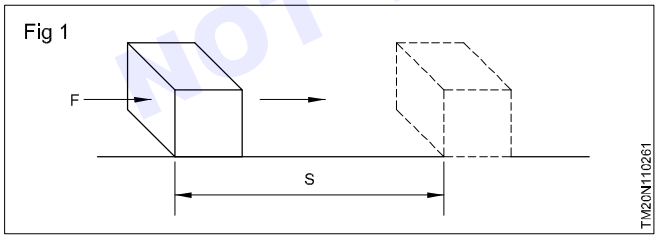
work done W = F x S

If F = 1N; S = 1m then

work done = 1 Nm or joule.

Hence one joule is the work done when a force of 1 N moves a body through a distance of 1m in the direction of its application.

Fig 1



Force: The absolute unit of force is `newton' (N). One newton is that force which accelerates a mass of one kilogram at 1m per s^2. This definition is obtained from Newton's Law of Motion.

That is F = ma.

Power: Machines were invented to assist in doing work. The amount of work a machine can do in a specific time determines its power.

Power is the measurement of the rate of doing work, and is the product of force and the distance moved in 1 second.

If a force of F newton moves a body with a velocity of v m/s then

power = F x v watt.

Horsepower: Horsepower (hp) is the common unit of measurement of mechanical power

1 hp = 75 mkg/s (Fig 2)

= 75 x 9.81

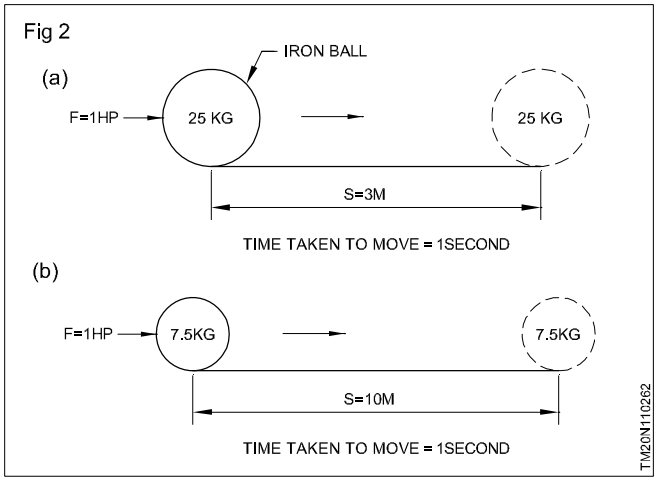
= 735.5 Nm/s or watt

(1 kg.weight = 9.81 N.)

As shown in Fig 2a, 2b and 3, the product of force x distance divided by time gives the horse power rating of the power required to do the job.

(Refer Fig 2a)

Fig 2



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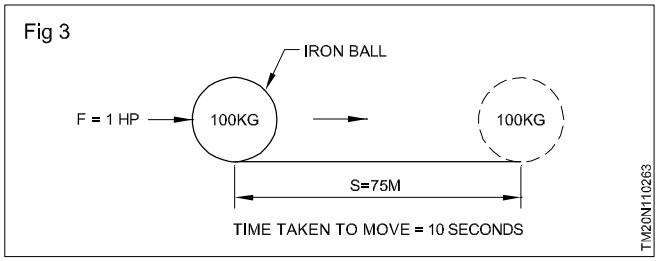
$$HP = \frac{\text{Work done}}{\text{Time required in sec.}} = \frac{25 \times 3}{1 \text{ sec.}} = 75 \text{ mkg / sec.}$$

Refer Fig 2b.

$$HP = \frac{\text{Work done}}{\text{Time required in sec.}} = \frac{7.5 \times 10}{1 \text{ sec.}} = 75 \text{ mkg / sec.}$$

Find the hp as shown in Fig 3.

Fig 3



Example 1 : A force of 60 N is applied to a body to move it at a uniform velocity through a distance of 20m in 8 seconds in the direction of the force. Calculate the value of the power.

Work done = 60 [N] x 20[m] = 1200 J

Therefore, power = work done per second

= 1200 [J] ¸ 8[s]

= 150 W.

Example 2: Calculate the power required to lift a mass of 300 kg at a constant speed through a vertical distance of 200m in 4 minutes.

Force required to lift load = 300 [kg] x 9.81 [N/kg]

= 2943 N

Work done in 4 min = 2943 [N] x 200 [m]

= 588 600J

Therefore, power = $\frac{588\ 600\text{J}}{(4 \times 60)(\text{s})}$

= 2.453 kW.

Electrical power

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

- **state the formula for calculating electrical power**
- **use the formula in conjunction with Ohm's law to describe the direct and indirect methods of measuring electrical power**
- **state the relation between mechanical and electrical power.**

Electrical power: The rate at which electrical energy is delivered to a load is called ELECTRICAL POWER. The unit of measurement of electric power is the WATT, and the symbol for power is P. In electrical circuits the power is equal to the current, multiplied by the voltage or P= I x E. Therefore, one watt of power is the result of one ampere of current driven by a one volt force through a circuit.

Example: A heater takes 4 amps at 250 volts. How much power does it consume?

P = E x I watts

= 250 x 4 = 1000 watts.

= 1 kilowatt

By simple algebra, we can write the 'Power Law' or 'Watts Law' in three ways as we did for Ohm's law.

$P = I \times E$

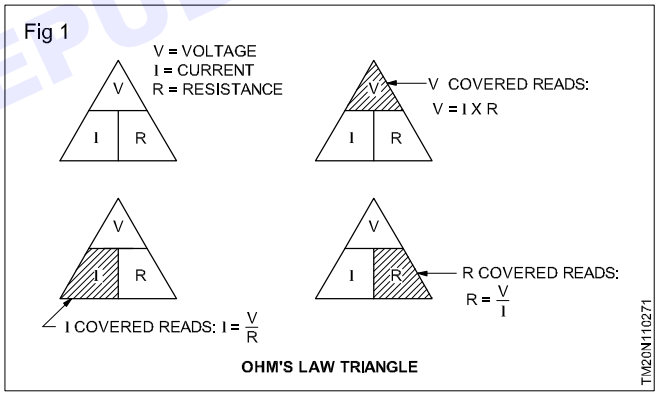
$I = \frac{P}{E}$

$E = \frac{P}{I}$

You know how to apply the memory device of Ohms law. To recapitulate, it is shown in Fig 1.

However, power in an electrical circuit could be measured directly with a wattmeter.

Fig 1



The three power law formulas can be easily recalled by arranging the three quantities within a triangle as shown in Fig 2.

The formulae (or equations) to solve for unknown voltage, current, resistance or power can be obtained by combining Ohm's law and Power law. This is shown in Fig 3.

Question: A certain appliance has a resistance of 100 ohms is connected to 200V supply. What is the power?

In your exercise book work out the answer to the problems using the pier wheel.

1 P = 500W, E = 250, I = ?

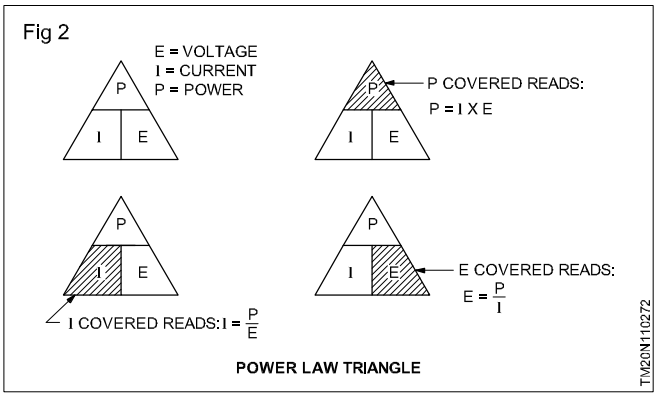
2 P = 10W, I = 1amp, R = ?

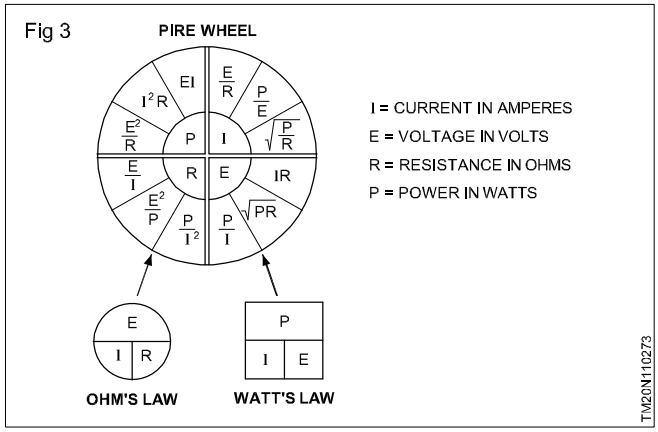
3 I = 0.001amp, R = 1Megohm, P = ?

4 I = 100mA, R = 100ohms, P = ?

5 P = 10W, I = 2amp, E = ?

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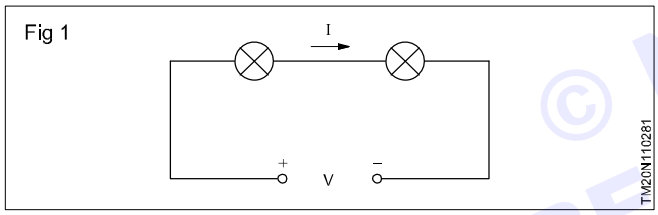


DC series circuit

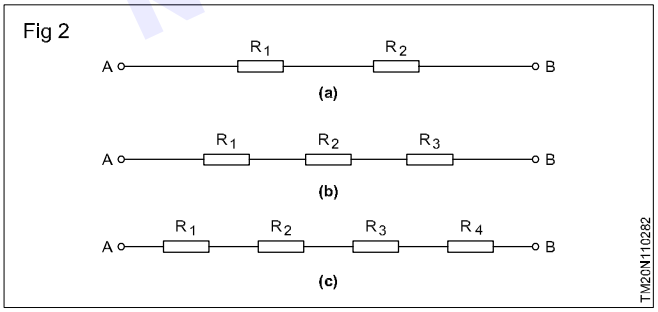
Objectives: At the end of this lesson you shall be able to

- **define a series connection**
- **calculate current in a series circuit**
- **calculate total resistance in a series circuit**
- **calculate voltage across elements in a series circuit**
- **state the uses of series connection.**

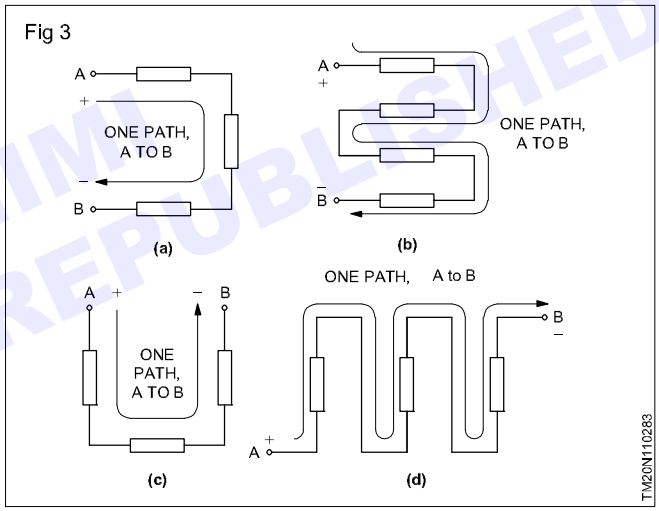
The series circuit: It is possible to connect two incandescent lamps in the way shown in Fig 1. This connection is called a series connection, in which the same current flows in the two lamps.



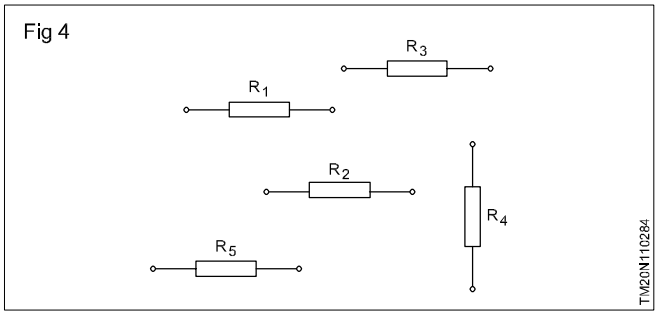
The lamps are replaced by resistors in the Fig 2. Fig 2a shows two resistors connected in series between point A and point B. Fig 2b shows three in series, and Fig 2c shows four in series. Of course, there can be any number of resistors in a series connection. Such connection provides only one path for the current to flow.



In an actual circuit diagram, a series connection may not always be as easy to identify as those in the figure. For example, Fig 3 shows series resistors drawn in other ways.



Question 1: An assembly of 5 resistors as shown in Fig 4. Draw the connection on the diagram to connect R_1,R_2,R_3,R_4 and R_5 in series with the same order. (Use your exercise notebook to copy the arrangement, and for drawing the connections and get it approved by your instructor).



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Current in series circuits: Current in a series circuit can be measured by inserting a meter in series. Will there be any difference in the reading of the meter in Figs 5a and 5b? No, the only difference between the two circuits is the position where the meter is inserted. Since there is only one path for the current, the same current flows through the circuit.

The current relationship in a series circuit is:

$I = I_{R1} = I_{R2} = I_{R3}$

Total resistance in series circuit: You know how to calculate the current in a circuit. By Ohms law, if resistance and voltage are known, R_1 offers some opposition to the current flow. As the same current should flow through R_2 in series it has to overcome the opposition offered by R_2.

The total resistance in a series circuit is equal to the sum of the individual resistances around the series circuit. This statement can be written as

$R = R_1 + R_2 + R_3 + ...$

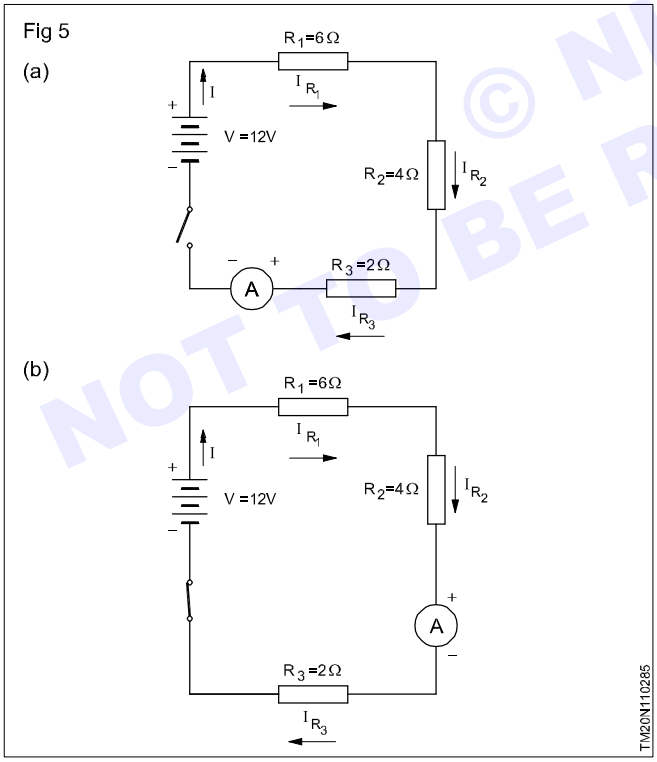
where R is the total resistance.

When a circuit has more than one resistor of the same value in series, the total resistance is

$R = r \times N$

where r is the value of each resistor and N is the number of resistors in the series.

Fig 5

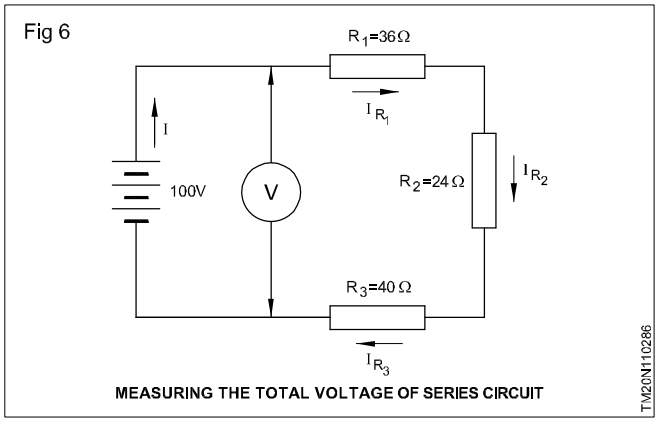


Voltage in series circuits: The source voltage divides up across the load resistors. It always divides up so that the sum of the individual load voltages equals the source voltage. That is,

$V = V_{R1} + V_{R2} + V_{R3} + ...$

The total voltage of a series circuit must be measured across the voltage source, as shown in Fig 6.

Fig 6

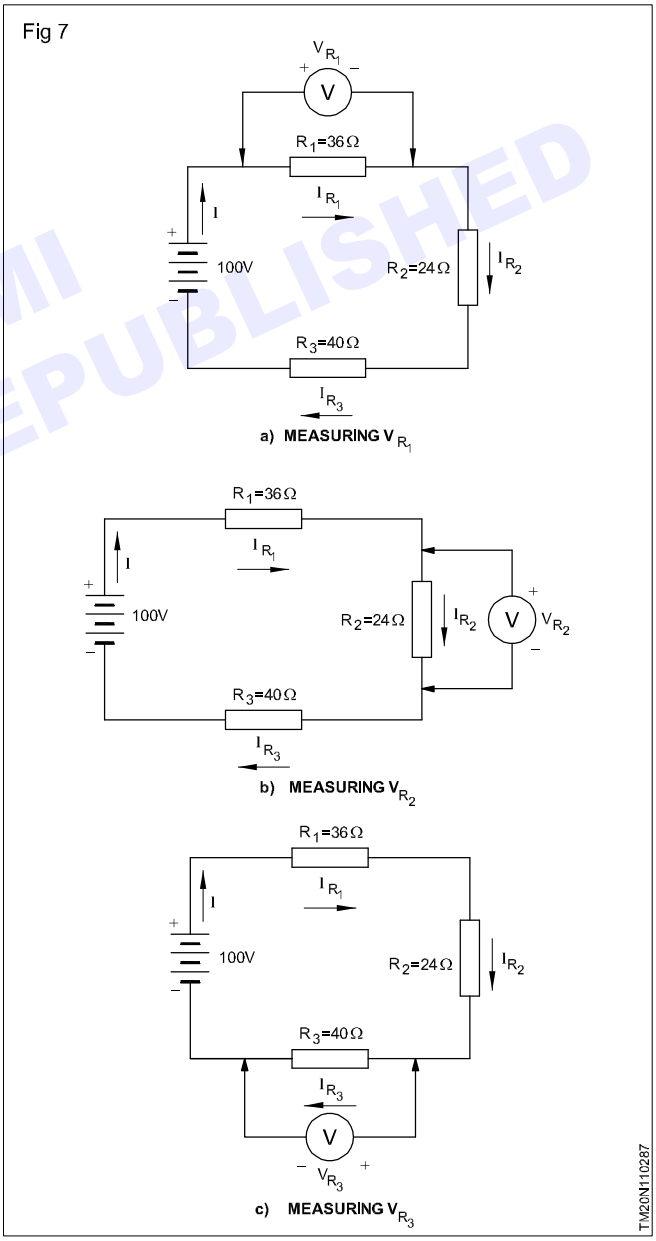


MEASURING THE TOTAL VOLTAGE OF SERIES CIRCUIT

Voltages across the series resistors are also easily measured. The correct connections for measuring series voltages are illustrated in Fig 7 a,b and c.

When Ohm's law is applied to the circuit as a whole, for an applied voltage V, the total resistance is R.

Fig 7



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$$I = \frac{V}{R}$$

Application of Ohm's Law: Applying Ohm's law to the series circuit the relation, between various currents could be stated as below:

$I = I_{R1} = I_{R2} = I_{R3}$

this could be stated as

$$\frac{V}{R} = \frac{V_{R1}}{R_1} = \frac{V_{R2}}{R_2} = \frac{V_{R3}}{R_3}$$

You can use any of the above formulae to calculate current in the series circuit. We know the total supply voltage.

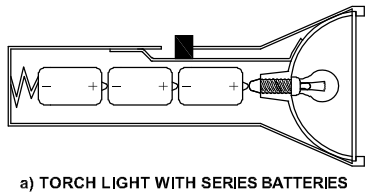
$V = (V_{R1} + V_{R2} + V_{R3})$

$IR = (IR_1 + IR_2 + IR_3)$

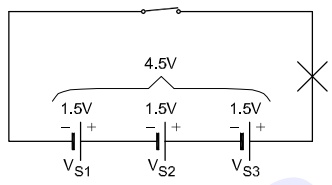
$R = (R_1 + R_2 + R_3)$

Voltage sources in series: When cells are placed in a torch light, they are connected in series to produce a larger voltage as shown in Figs 8a and 8b.

Fig 8



a) TORCH LIGHT WITH SERIES BATTERIES



b) SCHEMATIC OF TORCH LIGHT CIRCUIT

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Series voltage sources are added when their polarities are in the same direction, and subtracted when their polarities are in the opposite direction. For example, if one of the cells in a torch light is turned around as indicated in the schematic of Fig 9 its voltage reduces as follows.

$V_{Total} = VS_1 - VS_2 + VS_3$

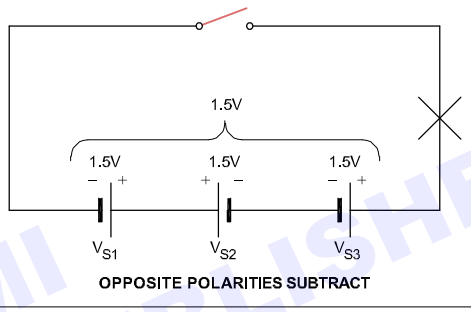
$= 1.5V - 1.5V + 1.5V$

$= 1.5V$

Use of a series connection

- Cells in torch light, car batteries, etc.
- Cluster of mini lamps used for decoration purposes
- Fuses
- Overload coil
- Multiplier of a voltmeter

Fig 9



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DC Parallel circuit

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

- **state the relation between resistance and conductance**
- **state the unit of conductance**
- **state the a parallel circuit for given conditions**
- **state the formulae that reflect the characteristics of a parallel circuit**
- **solve simple problems on parallel circuits**
- **list applications of a parallel circuit.**

Review of Ohm's Law: To begin with, let us look again at Ohm's Law. It represents the relationship between three important terms:

Term	Symbol	Unit	Abbrn.
PD(Voltage)	V	Volt	V
Resistance	R	Ohm	W
Current	I	Ampere	A

Ohm's Law expressed as a formula: V= R x I.

Expressed in words it is:

the potential difference (PD) across a resistor is equal to the product of the resistance of the resistor and the current through it.

Exercise 1: A torch battery with an emf of 4.5V and negligible resistance supplies a lamp with a current of 0.2A.

What is the resistance of the lamp?

Answer in your exercise book. Compare your answer with the solution given at the end of the information section

Electrical conductance: Conductance is opposite of resistance.

We can rearrange Ohm's Law,

$V = RI$ and obtain

$$I = \frac{V}{R}$$

$$\text{or current} = \frac{\text{Potential difference}}{\text{resistance}}$$

Such a formula would involve long division and as multiplication is often preferred, the formula can be written as $I = \frac{1}{R} \times V$

or, denoting G as the reciprocal of resistance I = GV.

The quantity G (= 1/R) is called the electrical conductance.

It is measured in units of Siemens so that a resistance of one ohm is equivalent to a conductance of one Siemens.

If R = 4W then

$$G = \frac{1}{4} S = 0.25 \text{ S.}$$

The higher the resistance of a circuit, the greater the opposition to the flow of electrical current. Hence a high resistance takes a low current.

A large conductance presents, on the other hand, low opposition to the flow of electrical current. Hence a high conductance takes a high current.

Good conductor - large conductance - small resistance

$$G = \frac{1}{R}.$$

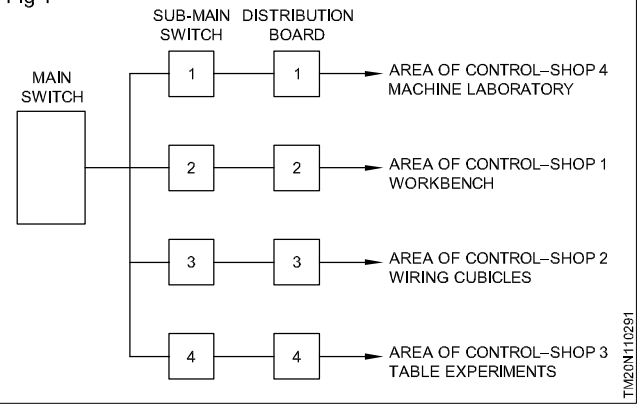
Exercise 2: What is the conductance of a lamp that has a resistance of R = 22.5W?

The node/ junction: An electrical current is in many ways analogous to the flow of water, in that it can divide into branches or paths.

In Fig 1, for example, a quantity of water W flows from the left every second. The water divides into the two quantities W_1 and W_2 and then recombines again to W. W_1 and W_2 added together are equal to the quantity W. Written as a formula

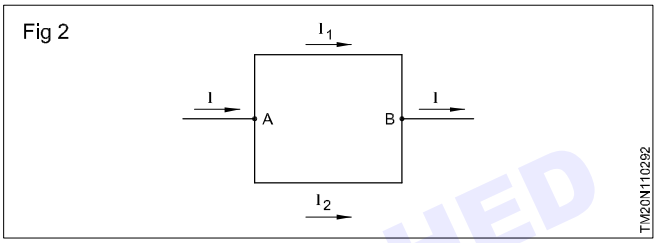
$W_1 + W_2 = W.$

Fig 1



Similarly, the electrical current I in Fig 2 divides at the node or junction point A, into two component currents I_1 and I_2 which, when added together, are exactly equal to I. Written as a formula:

Fig 2



$I_1 + I_2 = I.$

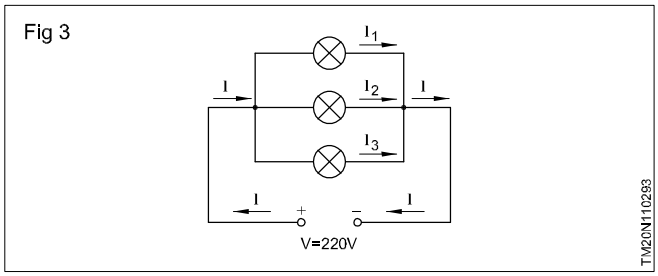
After recombining at node B the current I flows into the next part of the circuit.

In practice, a node is often a solder or screw terminal. It is represented in drawings as an enlarged dot. The current paths are drawn with a straight edge, normally either horizontally or vertically.

Exercise 3: Draw a circuit in which the current I divides at node A into three branch currents, I_1 = 1A, I_2 = 2A, I_3 = 3A, and which recombine at a node B. What is the current I?

The parallel circuit: The diagram (Fig 3) shows a circuit where the current flows in three parallel branches.

Fig 3



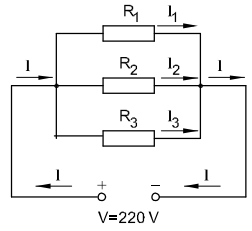
Three incandescent lamps are connected in parallel.

Now the total current is equal to the sum of the three parallel component currents, that is $I = I_1 + I_2 + I_3$.

For the purpose of this example, the three incandescent lamps will be represented by three resistors. Hence the diagram (Fig 4) is the equivalent circuit as shown in Fig 3 of the parallel circuit.

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Fig 4

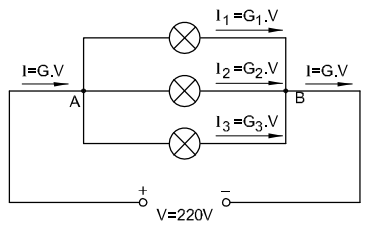


In this problem the three incandescent lamps are rated at 100W, 60W, and 40W. The ratings of the lamps, measured in watts, are not necessary for solving this problem, but you will gain an idea of the currents which flow in these lamps and in the cables connected to them.

Exercise 4: The total current from the supply is I = 0.91A. If I_1= 0.455A, and I_2= 0.273A, what is I_3?

The parallel circuit total conductance and individual conductance: In Fig 5, the current: at node A divides into three parallel paths. The potential difference between the two nodes A and B is V and this is the same for every current path between A and B.

Fig 5



The equation I =I_1+ I_2+ I_3 can, therefore, also be written (see diagram) as

$$GV = G_1V + G_2V + G_3V$$

$$= (G_1 + G_2 + G_3)V.$$

Dividing both sides of the equation by V, we find that

$$G = G_1 + G_2 + G_3$$

or expressed in other words:

the total conductance G of the parallel paths is equal to the sum of the conductance of individual paths.

Several wires in parallel give the same conductances as one thick wire with the same total cross-sectional area. Therefore, a thick wire has a higher conductance than a thin wire.

Exercise 5: If you compare electrical current to the flow of water through a pipe, with what can you compare the conductance?

– With the pipe cross-section

– With the length of the pipe

– With the gradient of the pipe

The parallel circuit: relationship between current and conductance: If, in a two-branch parallel circuit, G_2 is twice (or three times, or four times etc.) as large as G_1, then I_2 is twice (or three times, or four times, etc.) as large as I_1 (see Fig 6)

$I_1 : I_2 = G_1 : G_2$

In a parallel circuit the currents are proportional to the conductances of their individual paths.

Fig 6

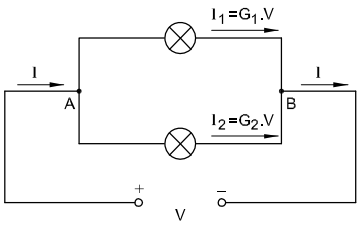
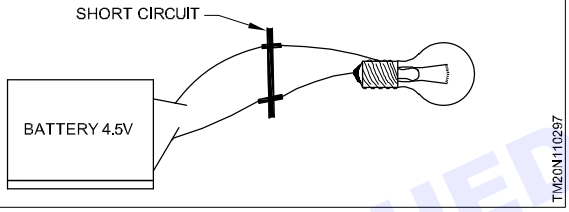


Fig 7



You may consider this as follows:

– the larger the conductance, the larger the current so that when several conductors are connected in parallel more current flows through the lower resistance path.

Exercise 6: If you place a thick wire (a short circuit) across the non-insulated leads to a lamp, a parallel path for the current is formed. The conductance of the parallel path is probably about 1000 times larger than that of the lamp. How do the currents in the conductors behave?

Intermediate test 1

The questions given below are on the subject covered in the preceding sections. Re-read the text in case any difficulty is experienced in answering.

1 What is the relationship between electrical conductance and electrical resistance?

2 In the following statements only two are correct. Which are they?

In parallel circuits

a individual conductances are added together to give the total conductance

b individual resistances are added together to give the total resistance

c individual currents are added together to give the total current.

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3 In an electrical circuit, what is a node?

Parallel circuit: relationship between current and resistance: If, in the constant potential difference across the parallel circuit, the resistance R_2 is twice (or three times, four times, etc.) as well as R_1, then the current I_2 will be one half (or one third, or one quarter, etc.) of that of I_1.

In a parallel circuit the currents are inversely proportional to the resistance of their individual paths.

$$I_1 : I_2 = R_2 : R_1$$

If in the above equation you make the product of the two outer elements equal to the product of the two inner elements, you obtain the equation

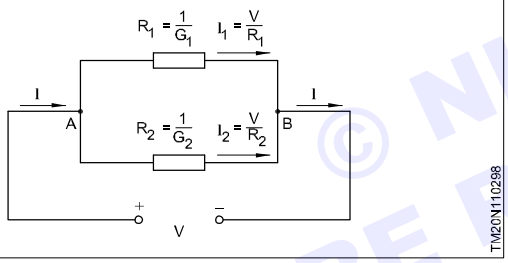
$$I_1 R_1 = I_2 R_2 = V.$$

$$\text{Therefore, } \frac{I_2}{I_1} = \frac{R_1}{R_2}$$

These quantities are shown in the Fig 8 .

Exercise 7: A 100W lamp and a 60W lamp are connected in parallel. The currents are 0.455A and 0.273A respectively. The resistance of the 100W lamp (with the larger current) is 484 ohms. What is the resistance of the 60W lamp?

Fig 8



Parallel circuit: Addition of reciprocal resistance: You learned that the conductance

$$G = \frac{1}{R}$$

This is called the reciprocal resistance. Each individual conductance is equal to its reciprocal resistance.

$$G_1 = \frac{1}{R_1}, \; G_2 = \frac{1}{R_2}, \; G_3 = \frac{1}{R_3}$$

We now write the rule of addition of conductances

$$\text{i.e., } G = G_1 + G_2 + G_3$$

in the form

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

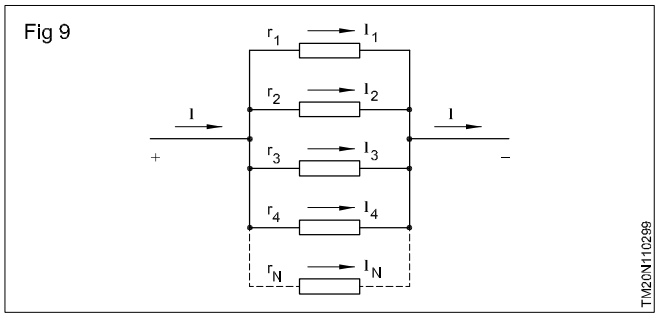
Expressed in words: in a parallel circuit by adding the reciprocal values of the individual resistances, the total reciprocal resistance value is obtained.

Exercise 8: Prove for the case when R_1 = 1ohm, R_2 = 2 ohms, R_3 = 3 ohms that when the resistances are connected in parallel their total resistance is smaller than the smallest single resistance, which in our example will be smaller than 1 ohm.

Special case: Equal Resistances in parallel

Total resistance, R of equal resistors in parallel (Fig 9) is equal to the resistance of one resistor, r divided by the number of resistors, N.

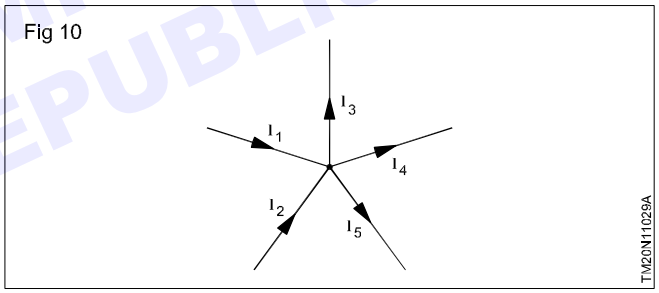
Fig 9



$$R = \frac{r}{N}$$

Exercise 9: Ten lamps are connected in parallel. The resistance of each lamp is 817 ohms. The current taken by the lamps when connected to 220V is 0.273A. What is the total resistance and current ?

Fig 10



Parallel circuit: the nodal rule: These laws governing the branching of electrical currents were laid down by the German physicist, Gustav Robert Kirchhoff in 1847.

The nodal low states that the sum of the currents flowing towards a node equals the sum of the currents flowing away from the node.

Expressed as a formula :

$$SI_{to} = SI_{away}$$

Therefore in the Fig 10

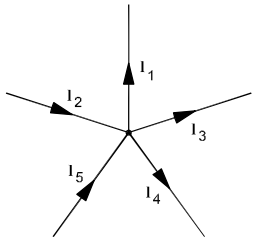
$I_1+I_2=I_3+I_4+I_5$.

(S is the Greek capital letter Sigma. It is the sign for 'sum of'.)

Exercise 10: Write the appropriate equation for the diagram illustrated in Fig 11.

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Fig 11



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Applications of parallel circuits: An electric system in which one section can fail and other sections continue to operate has parallel circuits. As previously mentioned, the electric system used in homes consists of many parallel circuits.

A domestic electric system uses parallel circuits for lights, heater, motor, radio, etc. Each of these devices operates independently of the others.

Individual television circuits are quite complex. However, the complex circuits are connected in parallel to the main power source. That is why the audio section of television receivers can still work when the video (picture) is inoperative.

Key to exercises

1 V = R x I is Ohm's Law and this gives

$$R = \frac{V}{I}$$

$$\text{Hence } R = \frac{4.5}{0.2}\Omega$$

$$= \frac{45}{2}\Omega$$

Therefore R = 22.5W.

2 $$G = \frac{1}{R} = \frac{1}{22.5}\ S = 0.044\ S.$$

The conductance G of the lamp is 0.044S.

3 (If you have drawn the nodes as enlarged dots then you have been particularly careful.)

4 $I = I_1 + I_2 + I_3$ can be transformed to

$I_3 = I - I_1 - I_2$

$I_3 = 0.91 - 0.455 - 0.273A = 0.182A$

5 (a) with the pipe cross section.

6 The current through the short-circuit is 1000 times as large as the current through the lamp.

7 $I_1 : I_2 = R_2 : R_1$

$$R_2 = \frac{I_1 R_1}{I_2}$$

$$= \frac{0.455}{0.273} \times 484\Omega = 806.66\Omega$$

8 From $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

it follows that $\frac{1}{R} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$

$$= \frac{6+3+2}{6} = \frac{11}{6}$$

so that $R = \frac{6}{11} = 0.545\ W$

9 Resistance of each lamp = r = 817W

Numbers of parallel branches = N = 10

Total resistance $R = \frac{r}{N} = \frac{817}{10} = 81.7W$

Total current $I = I_1 + I_2 + ...$

$I = 10 \times I_1$

$= 10 \times 0.273$

$= 2.73\ A.$

10 $I_1 - I_2 - I_3 - I_4 + I_5 = 0$

Answers to Intermediate Test 1

1 $G = \frac{1}{R}$ or $R = \frac{1}{G}$

Conductance is the reciprocal of resistance (or the inverse of resistance).

These answers are also correct.

When the conductance is large the resistance is small.

When the resistance is large the conductance is small.

2 (a) and (c) are correct.

The resistance of parallel connected resistors should not be added to obtain the total resistance (one adds the reciprocals of the resistance, i.e. the conductances, to obtain the total conductance).

3 A node is a junction point of electrical conductors or node is a point where two or more conductors are connected together.

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D.C Series parallel combination circuit

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

- **state the characteristics of series parallel circuit form circuit of series parallel combination**
- **give the examples of application of the combination circuit**
- **solve series parallel circuit problems.**

Summary of characteristics of DC circuits

Series circuit

1 The sum of the voltage drops equal the applied voltage. (Fig 1)

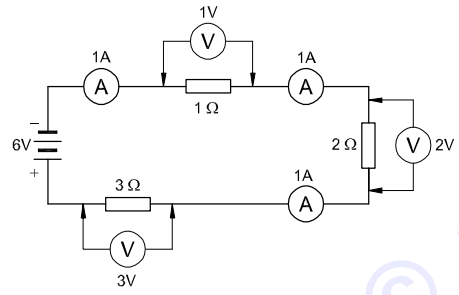
2 The total resistance is equal to the sum of the individual resistances that make up the circuit.

$R_t = R_1+R_2+R_3+...$ etc.

3 Current is the same in all parts of the circuit. (Fig 1)

4 Total power is equal to the sum of the power dissipated by the individual resistances.

Fig 1



CURRENT IS THE SAME THROUGHOUT THE CIRCUIT BUT THE VOLTAGE DROP VARIES ACROSS INDIVIDUAL RESISTANCES.

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Parallel circuit

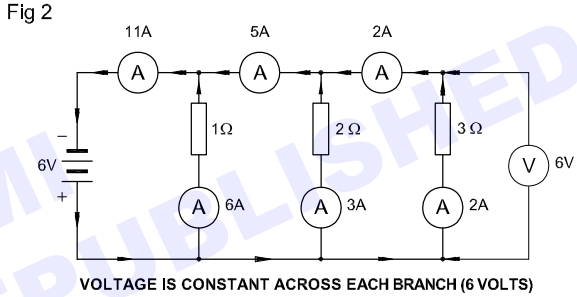
The applied voltage is the same across each branch. (Fig 2)

The total resistance equals the reciprocal of the sum of the reciprocal resistances. Resultant resistance is less than the smallest resistance of the parallel combination.

The current divides in each branch according to the resistance of each branch.

Total power is equal to the sum of the power dissipated by the individual resistances. (Same as series circuit.)

Fig 2



VOLTAGE IS CONSTANT ACROSS EACH BRANCH (6 VOLTS)

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Question 1

a In a series circuit the total resistance is always _____ than the individual resistance.

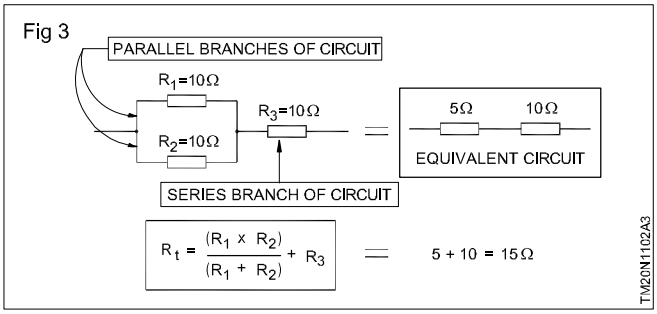
b In a series circuit the current has _____ path.

c In a series circuit more voltage will drop across _____ resistors when the current flows.

d In a parallel circuit the total resistance is _____ than the lowest resistor in the circuit.

Formation of series parallel circuit: The third type of circuit arrangement is the series-parallel circuit. In this circuit, there is at least one resistance connected in series, and two connected in parallel. The two basic arrangements of the series-parallel circuit are shown here. In one, resistors R_1 and R_2 are connected in parallel, and this parallel connection, in turn, is connected in series with resistance R_3. (Fig 3)

Fig 3

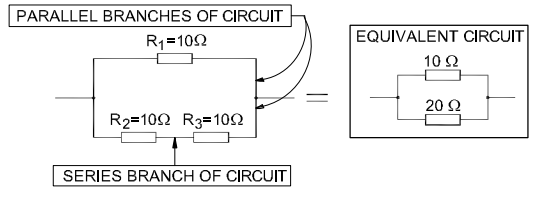


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Thus, R_1 and R_2 form the parallel component, and R_3 the series component of a series-parallel circuit. The total resistance of any series-parallel circuit can be found by merely reducing it into a simple series circuit. For example, the parallel portion of R_1 and R_2 can be reduced to an equivalent 5-ohm resistor (two 10-ohm resistors in parallel). Then it has an equivalent circuit of a 5-ohm resistor in series with the 10-ohm resistor(R_3), giving a total resistance of 15 ohms for the series-parallel combination.

A second basic series-parallel arrangement is shown in Fig 4 where basically it has two branches of a parallel circuit. However, in one of the branches it has two resistances in series (R_2 & R_3). To find the total resistance of this series -parallel circuit, first combine R_2 and R_3 into an equivalent 20-ohm resistance. The total resistance is then, 20 ohms in parallel with 10 ohms, or 6.67 ohms. From these circuits, it is seen the basic scheme in solving the series-parallel circuits is to combine all series resistances and add them to the resistance of all parallel branches in the circuit.

Fig 4



Combination circuits: Series-parallel combination appears to be very complex. However a simple solution is to break down the circuit into series or parallel groups. While solving problems each may be dealt with individually. Each group may be replaced by one resistance, having the value equal to the sum of all resistances.

Each parallel group may be replaced by one resistance value equivalent to the combined resistance of that group. Equivalent circuits are to be prepared for determining the current, voltage and resistance for each component.

Example: Determine the combined resistance of the circuit shown in Fig 5.

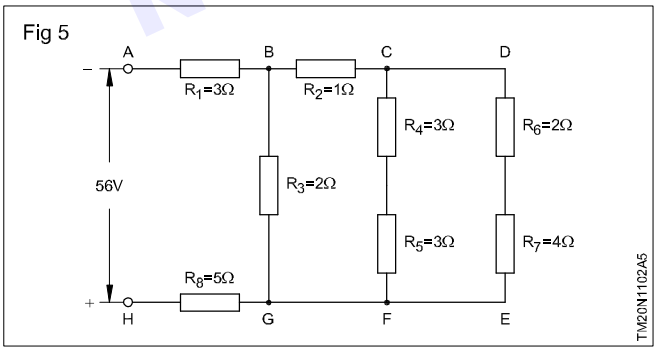
1 Combine R_6 and R_7.

$R_a = R_6 + R_7$

$R_a = 2 + 4$

$R_a = 6$ ohms.

Fig 5

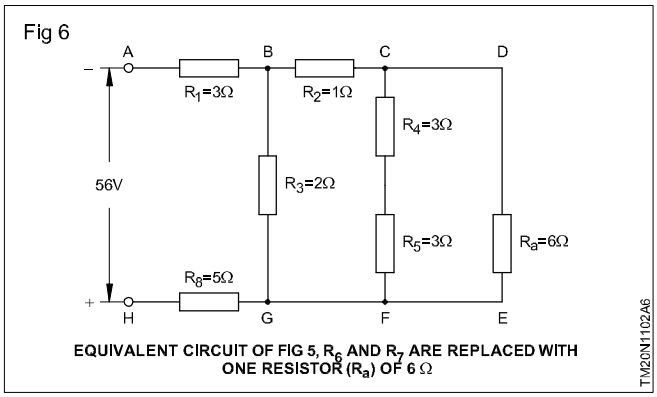


2 Draw an equivalent circuit. (Fig 6).

3 Combine R_4 and R_5. (Fig 6)

$R_b = R_4 + R_5$

Fig 6



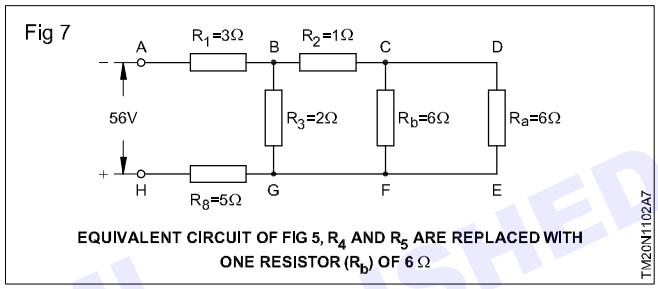
$R_b = 3 + 3$

$R_b = 6$ ohms.

4 Draw an equivalent circuit. (Fig 7).

5 Combine R_a and R_b. (Fig 7)

Fig 7



$$R_c = \frac{R_a \times R_b}{R_a + R_b} = \frac{6 \times 6}{6 + 6} = 3\Omega.$$

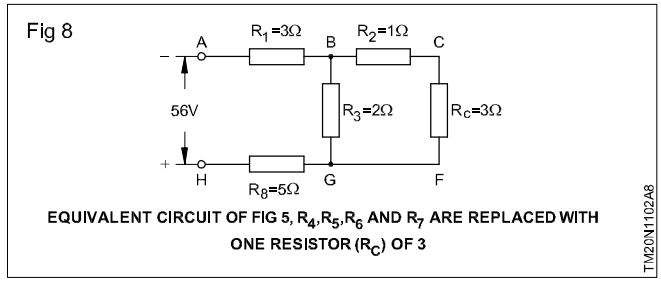
6 Draw the equivalent circuit. (Fig 8)

7 Combine R_2 and R_c.

$R_d = R_2 + R_c$

$R_d = 1 + 3 \quad R_d = 4$ ohms

Fig 8



8 Draw an equivalent circuit. (Fig 9)

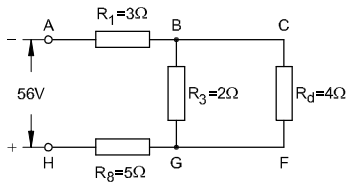
9 Combine R_3 and R_d.

$$R_e = \frac{1}{\frac{1}{R_3} + \frac{1}{R_d}} \qquad R_e = \frac{1}{\frac{1}{2} + \frac{1}{4}}$$

$$R_e = \frac{1}{\frac{2}{4} + \frac{1}{4}} \qquad R_e = \frac{1}{\frac{3}{4}} = \frac{4}{3} = 1\frac{1}{3}$$

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Fig 9



EQUIVALENT CIRCUIT OF FIG 5, R_2, R_4, R_5, R_6, AND R_7 ARE REPLACED WITH ONE RESISTANCE (R_d) OF 4 Ω

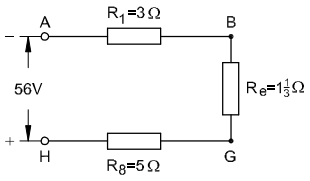
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Alternatively, we can use the formula.

$$R_e = \frac{R_3 \times R_d}{R_3 + R_d} = \frac{2 \times 4}{2+4} = \frac{8}{6} = 1\tfrac{1}{3}\Omega$$

10 Draw an equivalent circuit. (Fig 10)

Fig 10



EQUIVALENT CIRCUIT OF FIG 5, R_2, R_3, R_4, R_5, R_6, R_7 ARE REPLACED WITH ONE RESISTANCE (R_e) OF 1⅓. THE TOTAL CIRCUIT RESISTANCE EQUALS 9⅓ Ω

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11 Combine R_1, R_e, and R_8.

$R_t = R_1 + R_e + R_8$

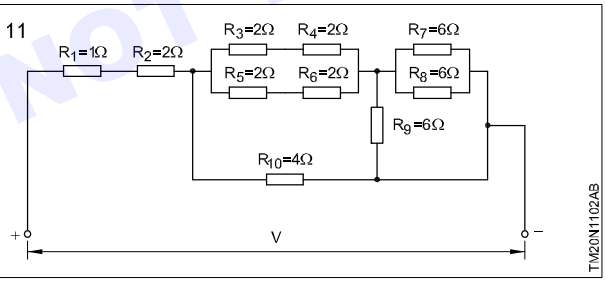
$R_t = 3 + 1\frac{1}{3} + 5$

$R_t = 9\frac{1}{3}$ ohms.

The combined resistance of the circuit is $9\frac{1}{3}$ ohms

Question 2: Simplify the given complex circuit. (Fig 11 of series parallel combinations)

Fig 11



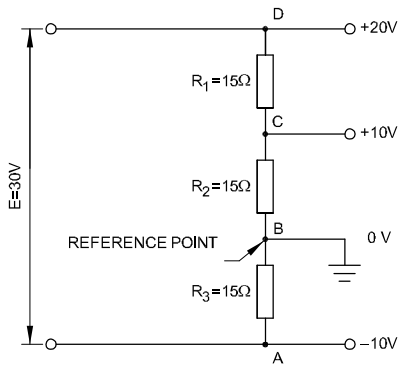
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Application of series parallel combination

Voltage divider: If one wants to have different voltages for different parts of a circuit, he can construct a voltage divider. In effect, a voltage divider is nothing more than a series-parallel circuit.

A good voltage divider cannot be designed without first looking at the load resistance. Note in Fig 12 that a voltage divider is made with three 15 ohm resistors to get 10 volts drop across each one.

Fig 12

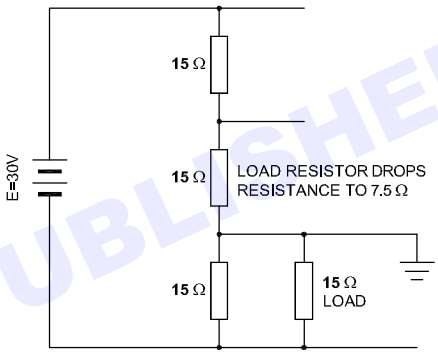


VOLTAGE VALUES ARE GIVEN FOR VOLTAGE DROP TESTS TAKEN ACROSS RESISTORS FROM A TO B (-10V), B TO C (+10V) AND B TO D (+20V). NOTE THAT THE CIRCUIT IS GROUNDED AT REFERENCE POINT B.

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However, as soon as another resistor (load) is added, (Fig 13) there is a further change. The load resistor serves to drop the total resistance of the lower part of the voltage divider. Use this formula for finding the equivalent resistance (R_{eq}) of resistors of equal value in a parallel circuit.

Fig 13



THREE 15 OHMS RESISTORS AND ONE 15 OHM LOAD RESISTOR SERVE AS A VOLTAGE DIVIDER THAT ROUTES DIFFERENT VOLTAGE TO DIFFERENT PARTS OF THE CIRCUIT.

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$$R_{eq} = \frac{R}{N} \text{ ohms}$$

$$R_{eq} = \frac{15}{2} = 7.5 \text{ ohms}$$

The equivalent resistance of these two 15 ohm resistors in the lower part of the voltage divider is 7.5 ohms. What will happen to the current in the circuit as a result of this resistance change?

Remember that as resistance goes down, the current goes up. Therefore, with the addition of the load resistor, the circuit will now carry higher amperage. It is important, then, when constructing a voltage divider circuit, to watch both resistance values and current values. Study Figure 13 to make sure you understand how a voltage divider works.

Question 3

Fill up the blanks with suitable words

1 In a parallel branch of combination circuit the total current is the sum of the branch _____.

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2 The voltage across each parallel section is equal to the product of current and _____.

3 In any series parallel circuit the largest current always flows in the smallest resistors. (State True or False.)

4 The total resistance of series parallel circuit is always less than the smallest parallel resistance. (State True or False.)

Answers to questions

Question 1

a greater

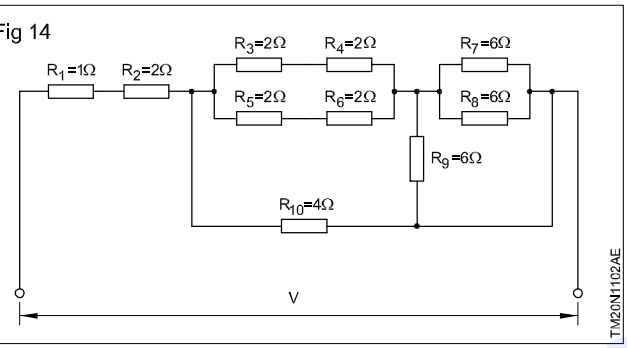
b only one

c high value

d less

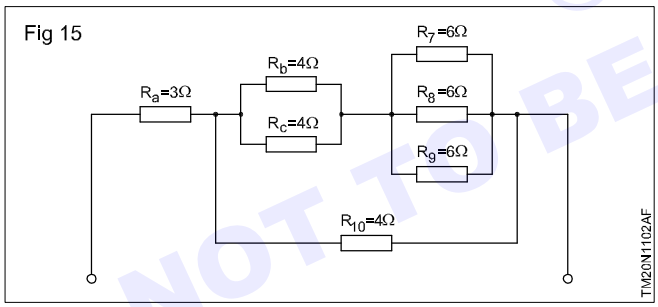
Question 2 (Fig 14)

Fig 14



Combining resistances in series i.e. R_1 & R_2, R_3 & R_4, R_5 & R_6 and redrawing the circuit. (Fig 15)

Fig 15



Combining parallel resistors R_b & $R_c = R_d$ and combining

$R_7 \parallel R_8 \parallel R_9 = R_e$ (Fig 16)

$$R_d = \frac{1}{\frac{1}{4}+\frac{1}{4}} = 2; \left(\frac{1}{R_e}\right) = \left(\frac{1}{6}\right) + \left(\frac{1}{6}\right) + \left(\frac{1}{6}\right)$$

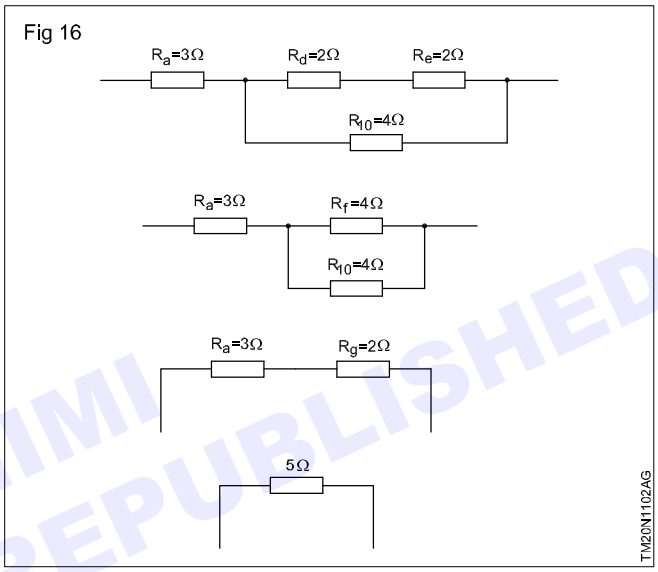
$R_e = 2.0\ \Omega$

Combining R_d & $R_e = R_f$

Combining $R_t \parallel R_{10} = R_g$

Total resistance = 3 + 2 = 5 ohms.

Fig 16



Question 3

1 currents

2 individual resistance

3 true

4 false

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Power & energy measurement

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

- **state the advantages of measuring power directly**
- **state the types of single phase wattmeters**
- **explain the construction and working of the induction type single phase wattmeter**
- **explain the method of connecting wattmeters through instrument transformers**
- **determine the main circuit power from the reading of wattmeter connected through the instrument transformers.**

Power in a single phase AC circuit can be calculated by using an ammeter, a voltmeter and a power factor meter with the help of the formula

Power in a single phase circuit = EI Cos ø watts.

In the same way power in a 3-phase balanced circuit can be measured by using one ammeter, one voltmeter and one power factor meter with the help of the formula

Power in a balanced 3 - phase circuit = $3E_P I_P \cos\phi$

or $\sqrt{3}\ E_L I_L \cos\phi$

where $E_P I_P$ are the phase values and

$E_1 I_1$ are the line values

This indirect method of measuring power in an AC circuit has the following disadvantages.

– Low accuracy due to a number of meters.

– Reading errors due to a number of meter readings.

– Cumbersome connections.

– Involves calculation every time the load changes and hence not suitable for changing loads.

To get an on the spot true power reading, a wattmeter is used. The power dissipated in the circuit can be read directly from the scale of the meter. The wattmeter takes the power factor of the circuit into account and always indicates the true power.

Types of wattmeters

There are three types of wattmeters in use as stated below.

– Dynamometer wattmeter

– Induction wattmeter

– Electrostatic wattmeter

Among the three, the electrostatic type is very rarely used. Information given here is for the other two types only.

Dynamometer type, single phase wattmeter: This type is commonly used as a wattmeter. Construction details and the working of this type of meter have already been discussed in Ex.302. Hence the trainees are advised to read the information before proceeding further.

Induction type single phase wattmeter: This type of wattmeters could be used only in AC circuits whereas a dynamometer type wattmeter could be used in both AC and DC circuits.

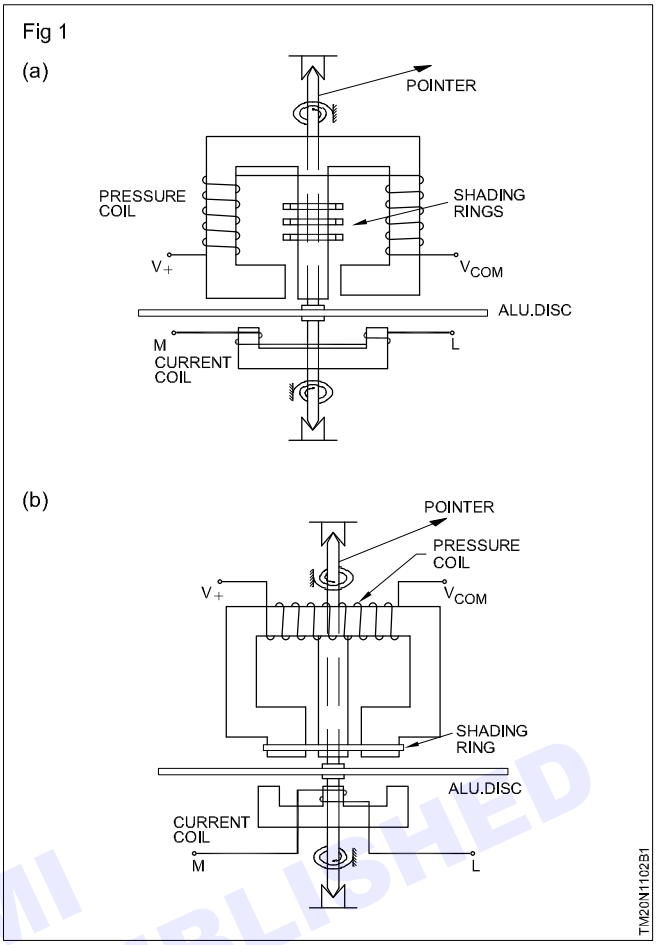
Induction type wattmeters are useful only when the supply voltage and frequency are almost constant.

Construction: Induction wattmeters having two different types of magnetic cores are shown in Figs 1a and 1b.

Both the types have one pressure coil magnet and one current coil magnet. The pressure coil carries a current proportional to the voltage whereas the current coil carries the load current.

A thin aluminium disc is mounted on a spindle in between the space of the magnets and its movement is controlled by springs. The spindle carries a weightless pointer at one end.

Fig 1



Working: The alternating magnetic fluxes produced by the pressure and current coils cut the aluminium disc and produce eddy currents in the disc. Due to the interaction between the fluxes and the eddy currents a deflecting torque is produced in the disc and the disc tries to move. Control springs attached to the two ends of the spindle control the deflection and the pointer shows the power in watts on a graduated scale.

Shaded rings provided in the pressure coil (shunt) magnet could be adjusted in order to cause the resultant flux in the magnet to lag in phase by exactly 90° behind the applied voltage.

Method of connecting wattmeter in single phase circuits - pressure coil connection to reduce erroneous measurement.

There are two ways of connecting the pressure coil of the wattmeter as shown in Fig 2.

Both the methods shown in Figs 2a & b need correction in power measurement due to the reasons stated below.

In the method of connection shown in Fig 2a, the pressure coil is connected on the 'supply' side of the current coil, and hence, the error in power measurement is due to the fact that the voltage applied to the voltage coil is higher than that of the load on account of the voltage drop in the current coil. As such the wattmeter measures the load power in addition to the power lost in the current coil.

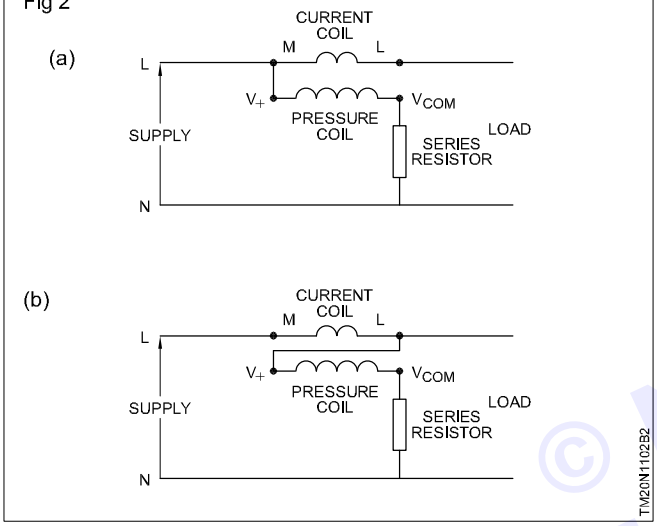
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On the other hand, in the method of connection shown in Fig 2b, the current coil carries the small current taken by the voltage coil, in addition to the load current, thereby introducing errors in power measurement. As such the wattmeter measures the load power in addition to the power lost in the pressure coil.

If the load current is small, the voltage drops in the current coil will be small, so that the method of connection, shown in Fig 2a, introduces a very small error and, hence, preferable.

On the other hand, if the load current is large the power lost in the pressure coil will be negligible when compared to the load power in the method of connection shown in Fig 2b, and, hence, a very small error is introduced resulting in the preference of this connection.

Fig 2

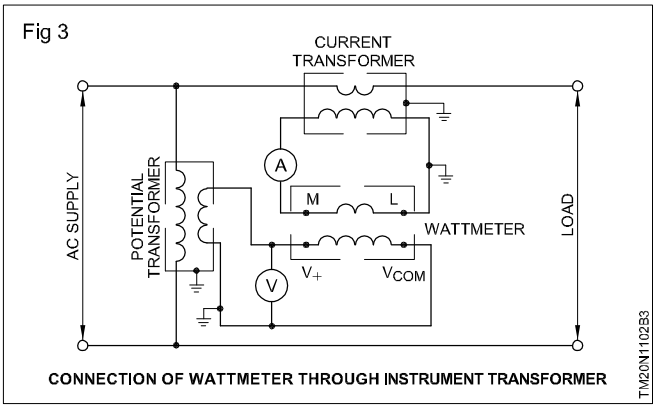


Connecting wattmeters through instrument transformer: Normally the rating of the current coil of the wattmeter is in the order of 1A, 5A, 10A, 20A, or 30 amps, whereas the pressure coil rating will be in the order of 110V, 220V, 300V, 500V. When the circuit in which the power to be measured has a current more than 30 amps and voltages more than 500V it is customary to use current and potential transformers along with the wattmeter to measure power in the circuit.

In practice, a wattmeter having a current coil rating of 5 amps and a pressure coil rating of 110V could be used along with the instrument transformers of different ratios to measure power in a variety of circuits having high current and high voltages. Connection of a wattmeter along with the instrument transformers is shown in Fig 3 in which an ammeter and a voltmeter are also connected in the circuit of the instrument transformers.

The primary winding of the current transformer is connected in series with the load and the secondary winding is connected in series with the current coil of the wattmeter and ammeter.

Fig 3



CONNECTION OF WATTMETER THROUGH INSTRUMENT TRANSFORMER

The primary winding of the potential transformer is connected across the supply, and the secondary winding is connected in parallel with a voltmeter and the potential coil of the wattmeter. For ensuring safety, one of the terminals of secondary winding and the casing of the instrument transformer are earthed.

Assuming there is negligible ratio and phase angle error in the instrument transformers, the power measured by the wattmeter needs to be multiplied by the C.T. and P.T. ratios to obtain the actual power consumed in the circuit.

Hence we have

Actual power consumed in the circuit = Ratio of CT x Ratio of PT x wattmeter reading.

Example: A wattmeter whose current coil rating of 5 amps and the voltage coil rating of 110V is connected through an instrument transformer and reads 400 watts. The CT ratio is 20:1 and the PT ratio is 100:1. Calculate the

a Voltage of the mains supply

b Current in the main circuit

c Actual power consumed by the circuit.

d Voltage of the wattmeter = Pressure coil rating of main supply x P.T. ratio

= 110 x 100/1 = 11000V = 11 KV.

e Current in the main circuit = Current coil rating of wattmeter x C.T. ratio

= 5 x 20/1 = 100 amps

f The actual power consumed in the main circuit = Ratio of C.T. x Ratio of P.T. x Wattmeter reading

= 20/1 x 100/1 x 400

= 800000 watts = 800KWatts

= 0.8 megawatts

Alternatively we have Actual power consumed in the circuit = Multiplying factor of the instrument transformer x wattmeter reading.

As such, Multiplying factor = Ratio of CT x Ratio of PT instrument transformer.

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Measurement of energy in single phase circuits

Objectives: At the end of this lesson you shall be able to
- **describe the construction and working principle of single phase energy meters**
- **state and explain creeping error in energy meter.**

Necessity of energy meter: The electrical energy supplied by the Electricity board should be billed, based on the actual amount of energy consumed. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt hours in practice. The meter used for this is an energy meter.

In AC, an induction type of energy meter is universally used for measurement of energy in domestic and industrial circuits.

Principle of a single phase induction type energy meter: The operation of this meter depends on the induction principle. Two alternating magnetic fields produced by two coils induce current in a disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries the load current. (Fig 1) Torque is proportional to the power as in wattmeter. The watt-hour meter must take both power and time into consideration. The instantaneous speed is proportional to the power passing through it. The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that period of time.

Fig 1

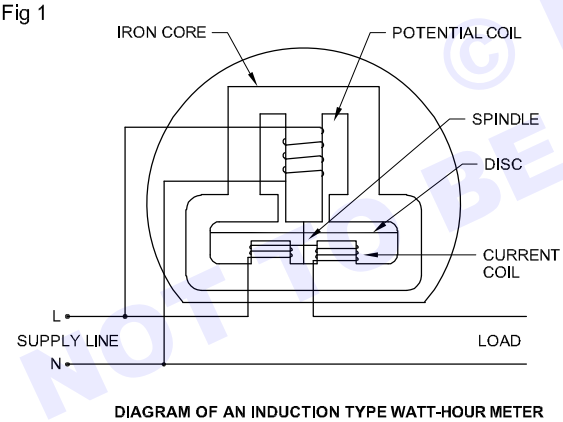


DIAGRAM OF AN INDUCTION TYPE WATT-HOUR METER

Parts and functions of an energy meter: The parts of the induction type single phase energy meter are as shown in Fig 1.

Iron core: It is specially shaped to direct the magnetic flux in the desired path. It directs the magnetic lines of force, reduces leakage flux and also reduces magnetic reluctance.

Potential coil (voltage coil): The potential coil is connected across the load and is wound with many turns of fine wire. It induces eddy current in the aluminium disc.

Current coil: The current coils, connected in series with load, are wound with a few turns of thick wire, since they must carry the full load current.

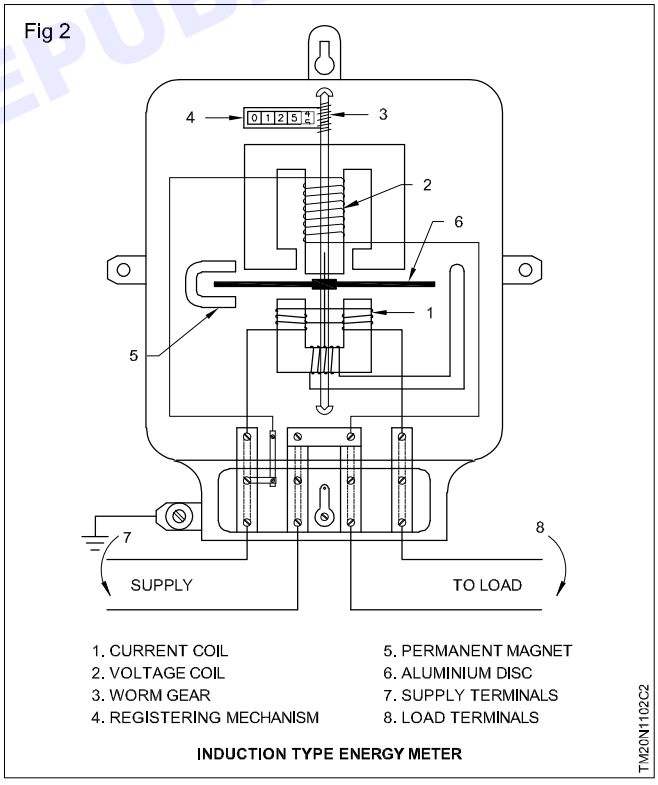
Disc: The disc is the rotating element in the meter, and is mounted on a vertical spindle which has a worm gear at one end. The disc is made of aluminium and is positioned in the air gap between the potential and current coil magnets.

Spindle: The spindle ends have hardened steel pivots. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. As the gear turns the dials, they indicate the amount of energy passing through the meter.

Permanent magnet/brake magnet: The permanent magnet restrains the aluminium disc from racing at a high speed. It produces an opposing torque that acts against the turning torque of the aluminium disc.

Functioning of energy meters: The rotation of the aluminium disc in Fig 2 is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

Fig 2



1. CURRENT COIL
2. VOLTAGE COIL
3. WORM GEAR
4. REGISTERING MECHANISM
5. PERMANENT MAGNET
6. ALUMINIUM DISC
7. SUPPLY TERMINALS
8. LOAD TERMINALS

INDUCTION TYPE ENERGY METER

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The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given period of time.

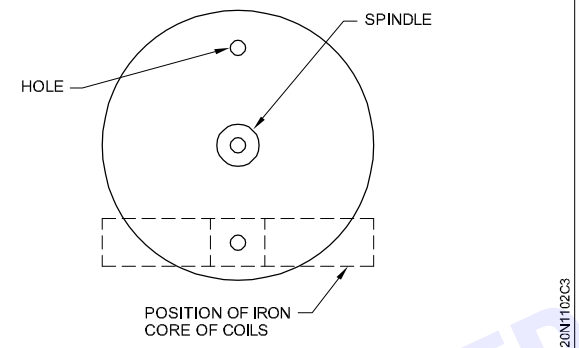
A small copper ring(shading ring) or coil (shading coil) is placed in the air gap under the potential coil, to produce a forward torque, large enough to counteract any friction produced by the rotating aluminium disc.

This counter torque is produced when the aluminium disc rotates in the magnetic field established by the permanent magnet. The eddy currents, in turn, produce a magnetic field that reacts with the field of the permanent magnet, causing a restraining action that is proportional to the speed of the disc. The faster the disc rotates, the greater the induced eddy currents, and greater the restraining action. This restraining action is necessary to make the speed of rotation proportional to the current taken by the load and also to stop the disc from further rotation due to inertia when the supply is disconnected.

Creeping error and adjustment: In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only the pressure coil is energised. This is called creeping. The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diametrically opposite holes are drilled in the disc (Fig 3). The disc will come to rest with one of the holes under the edge of a pole of the potential coil magnet, the rotation being thus limited to a maximum of half a revolution.

Fig 3



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Cells - Batteries - Charging methods

Objectives: At the end of this lesson you shall be able to
- **state and describe the principle and construction of a primary cell**
- **list the common primary cells in use**
- **explain the effect of the internal resistance of a cell.**

Cell: A cell is an electrochemical device consisting of two electrodes made of different materials and an electrolyte. The chemical reaction between the electrodes and the electrolyte produces a voltage.

Cells are classified as

– dry cells

– wet cells.

Cells and batteries are classified as either dry or wet. Historically, a dry cell is one that has a paste or gel electrolyte. It is semi-sealed and could be used in any position. With newer designs and manufacturing techniques, it is possible to completely (hermetically) seal a cell. With complete seals and chemical control of gas build-up, it is possible to use liquid electrolytes in dry cells. Today the term `dry cell' refers to a cell that can be operated in any position without electrolyte leakage.

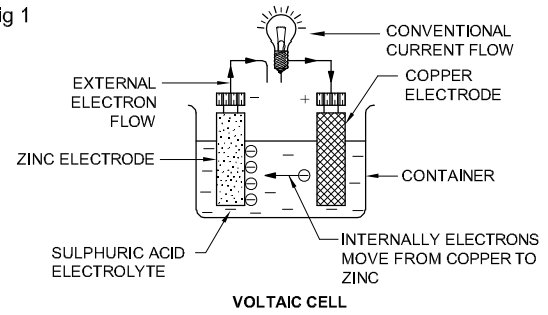
Wet cells are cells that must be operated in an upright position. These cells have vents to allow the gases generated during charge or discharge to escape. The most common wet cell is the lead-acid cell.

Primary cells: Primary cells are those cells that are not rechargeable. That is, the chemical reaction that occurs during discharge is not easily reversed. When the chemicals used in the reactions are all converted, the cell is fully discharged. It must then be replaced by a new cell. Included in the primary cell category are the following types.

– Voltaic cell
– Carbon-zinc (Leclanche cell) (Dry cell)
– Alkaline
– Mercury
– Silver oxide
– Lithium

Simple voltaic cell: A voltaic cell uses copper and zinc as the two electrodes and sulphuric acid as the electrolyte. When placed together a chemical reaction occurs between the electrodes and the sulphuric acid. This reaction produces a negative charge on the zinc (surplus of electrons) and a positive charge on the copper (deficiency of electrons). If an external circuit is connected across the two electrodes, electrons will flow from the negative zinc electrode to the positive copper electrode. (Fig 1) The electric current will flow as long as the chemical action continues. In this type of cell the zinc electrode is eventually consumed as part of the chemical reaction.

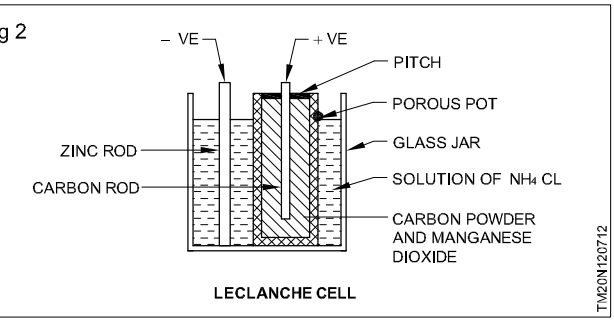
Fig 1



The voltaic cell is also known as a wet cell because it uses a liquid solution for the electrolyte.

Leclanche cell (Carbon-zinc cells) **:** The container of this cell is a glass jar. The jar contains a strong solution of ammonium chloride (NH_4Cl). This solution is an alkali and acts as the electrolyte. A porous pot is placed at the centre of the glass jar. This porous pot has in it a carbon rod surrounded by a mixture of manganese dioxide (MnO_2) and powdered carbon. The carbon rod forms the positive electrode of the cell and MnO_2 acts as the de-polarizer. A zinc rod is dipped in the solution in the jar and acts as the negative electrode. (Fig 2)

Fig 2



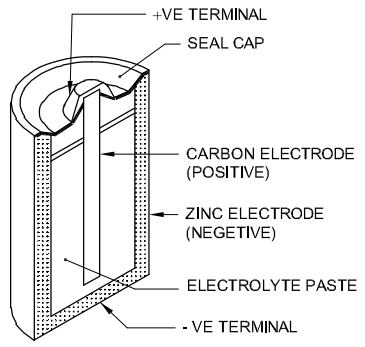
Dry cell (Carbon-Zinc cell): The danger of spilling the liquid electrolyte from a Leclanche type of cell led to the invention of another class of cells called dry cells.

he centre is a carbon rod which is the positive electrode. The electrolyte takes the form of a moist paste made up of a solution containing ammonium chloride. As with all primary cells, one of the electrodes becomes decomposed as part of the chemical reaction. In this cell the negative zinc container electrode is the one that is used up. As a result, cells left in equipment for long periods of time can rupture, spilling the electrolyte and causing damage to the neighbouring parts.

Carbon-zinc cells are produced in a range of common standard sizes. These include 1.5 V AA,C,D cells.

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Fig 3

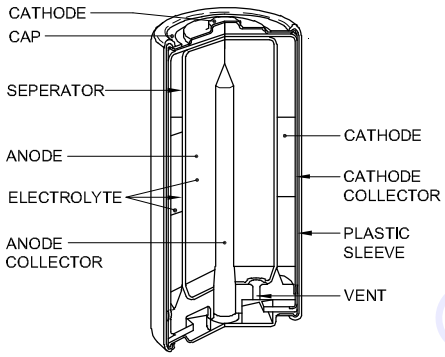


CARBON-ZINC DRY CELL

(AA Pen type cell, `C' medium size, 'D' large/economy size.)

Alkaline cells: Alkaline cells use a zinc container for the negative electrode and a cylinder of manganese di-oxide for the positive electrode. (Fig 4) The electrolyte is made up of a solution of potassium hydroxide or an alkaline solution.

Fig 4



ALKALINE CELL

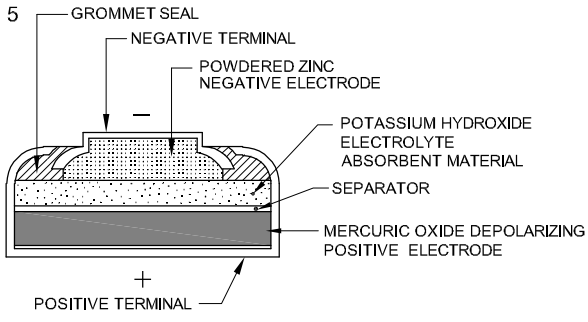
Alkaline cells are produced in the same standard sizes as carbon-zinc cells but are more expensive. They have the advantage of being able to supply large currents for a longer period of time. For example, a standard `D' type 1.5 V alkaline cell has a capacity of about 3.5 A.h compared with about 2 A.h for the carbon-zinc type. A second advantage is that the alkaline cell has a shelf life of about two and a half years as compared to about 6 to 12 months for the carbon-zinc type.

Mercury cells: Mercury cells are most often used in digital watches, calculators, hearing aids and other miniature electronic equipment. They are usually smaller and are shaped differently from the carbon-zinc type. (Fig 5)

The electrolyte used in this cell is alkaline and the electrodes are of mercuric oxide (cathode) and zinc (anode).

Silver oxide cells: Silver oxide cells are much like mercury cells. However, they provide a higher voltage (1.5 V) and they are made for light loads. The loads can be continuous, such as those encountered in hearing aids and electronic watches. Like the mercury cell, the silver oxide cell has good energy-to-weight and energy-to-volume ratios, poor low-temperature response, and flat output voltage characteristics. The structures of the mercuric and silver oxide cells are very similar. The main difference is that the positive electrode of the silver cell is silver oxide instead of mercuric oxide.

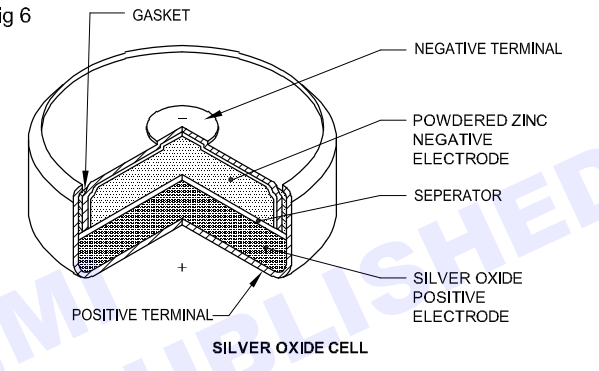
Fig 5



MERCURY CELL

Fig 6 shows the cross-section of a silver oxide cell.

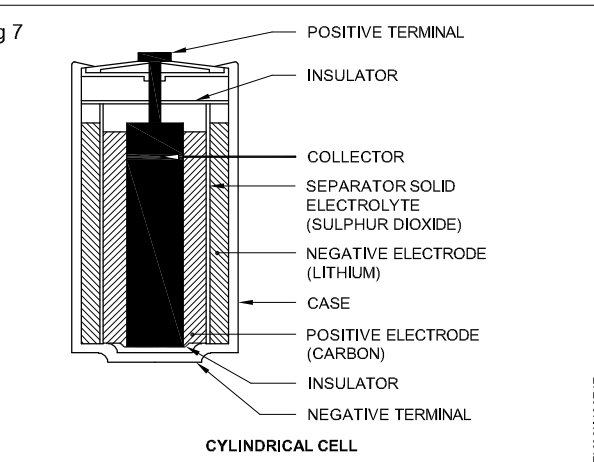
Fig 6



SILVER OXIDE CELL

Lithium cells: The lithium cell is another type of primary cell. (Fig 7) It is available in a variety of sizes and configurations. Depending on the chemicals used with lithium, the cell voltage is between 2.5 and 3.6 V. Note that this voltage is considerably higher than in other primary cells. Two of (Fig 7) the advantages of lithium cells over other primary cells are:

Fig 7



CYLINDRICAL CELL

– longer shelf life - up to 10 years

– higher energy-to-weight ratios up to 350 Wh/Kg.

Lithium cells operate at temperatures ranging from –50 to +75°C. They have a very constant output voltage during discharge.

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Uses: Primary cells are used in electronic products ranging from watches, smoke alarms, cardiac pacemakers, torches, hearing aids, transistor radios etc.

Internal resistance: The output voltage from a cell varies as the load on the cell changes. Load on a cell refers to the amount of current drawn from the cell. As the load increases, the voltage output drops, and vice versa. The change in output voltage is caused by the internal resistance of the cell. Since materials from which the cell is made are not perfect conductors, they have resistance. Current flowing through the external circuit also flows through the internal resistance of the cell.

According to Ohm's law, a current flowing through a resistance (either external or internal) results in a voltage drop (V = IR) . Any voltage developed across the internal resistance is not available at the terminals of the cell.

The voltage at the terminals is the voltage due to the chemical reactions minus the voltage dropped across the internal resistance. The terminal voltage of a cell, therefore, depends on both the internal resistance of the cell and the amount of load current.

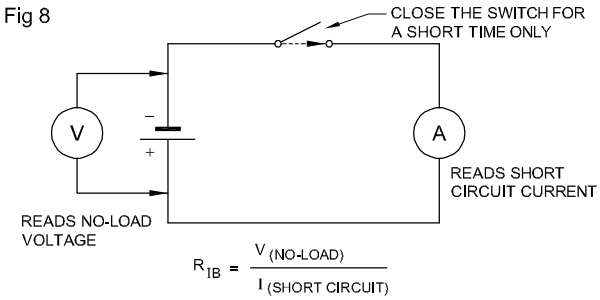
In some applications, the changes in cell terminal voltage are so small that they make no practical difference. In other applications, the changes are very noticeable. For example, when an automobile engine is started, the battery output voltage changes from about 12.6 to 8V.

The method of calculating the internal resistance of a cell is shown in Fig 8.

As a cell discharges, its internal resistance increases. Therefore its output voltage decreases for a given value of load current.

Defects of a simple cell: With a simple voltaic cell, the strength of current gradually diminishes after some time. This defect is mainly due to two causes.

Fig 8



CALCULATING CELL INTERNAL RESISTANCE

– Local action

– Polarisation

Local action: In a simple voltaic cell, bubbles of hydrogen are seen to evolve from the zinc plate even on open circuit. This effect is termed local action. This is due to the presence of impurities like carbon, iron, lead, etc. in the commercial zinc. This forms small local cells on the zinc plate and reduces the strength of current of the cell.

The local action is prevented by amalgamating the zinc plate with mercury. To do so, the zinc plate is immersed in dilute sulphuric acid for a short time, and afterwards, mercury is rubbed over its surface.

Polarisation: As current flows, bubbles of H_2 evolve at the copper plate on which they gradually form a thin layer. Due to this the current strength falls and finally stops altogether. This effect is called the polarization of the cell.

Polarisation can be prevented by using some chemicals which will oxidize the hydrogen to water before it can accumulate on the plate. The chemicals used to remove polarisation are called de-polarisers.

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Comparison of common primary cells

	Carbon - Zinc	Alkaline-Manganese	Mercury	Silver oxide
Negative, anode	Zinc	Zinc	Zinc	Zinc
Positive, cathode	Carbon	Manganese dioxide	Mercuric oxide	Silver oxide
Electrolyte	Ammonium Chloride	Potassium hydroxide	Potassium hydroxide	Potassium hydroxide
Nominal voltage, volts	1.5	1.5	1.35 or 1.4	1.5
Max. rated current amperes	2-30	0.05-20	0.003-3	0.1
Energy output				
Watt-hrs	22	35	46	50
Ampere-hours	2.0	3.5	6.0	8.0
Temperature range				
Storage ^{0}F	–40 to 120	–40 to 120	–40 to 140	–40 to 140
Operating ^{0}F	20 to 130	–5 to 160	–5 to 160	–5 to 160

Shelf life in months at 68°F to 80% initial capacity Shape of discharge curve	6 to 12 Sloping	30 to 36 Sloping	30 to 36 Flat	30 to 36 Flat

Grouping of cells

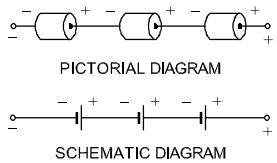
Objectives: At the end of this lesson you shall be able to

- **calculate the total voltage for the given cells connected in series**
- **calculate the cells required in series for a given voltage**
- **state the precautions to be observed while connecting cells in series**
- **calculate the cells in parallel required to get the rated ampere-hour output**
- **state the precaution to be observed while connecting cells in parallel**
- **calculate the cell groups required in series parallel groups to get required voltage and ampere-hour rating**
- **state the method of testing cells.**

Series and parallel cell connections: Often an electric circuit requires a voltage or current that a single cell is not capable of supplying alone. In this case it is necessary to connect groups of cells in various series and parallel arrangements.

Series cell connections: Cells are connected in series by connecting the positive terminal of one cell to the negative terminal of the next cell. (Fig 1)

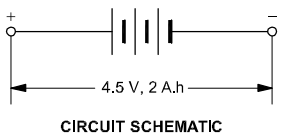
Fig 1



Identical cells are connected in series to obtain a higher voltage than is available from a single cell. With this connection of cells, the output voltage is equal to the sum of the voltages of all the cells. However, the ampere hour (A.h) rating remains equal to that of a single cell.

Example: Suppose three `D' flashlight cells are connected in series.(Fig 2) Each cell has a rating of 1.5 V and 2 A.h. The voltage and ampere hour rating of this battery would be:

Fig 2



V Battery = V per cell x No.of cells

= (1.5V) (3)

= 4.5 V

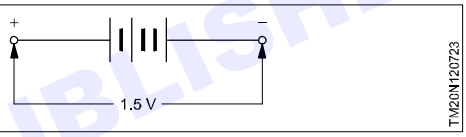
A.h Battery rating = A.h rating of 1 cell

= 2 A.h

If, by mistake, one cell connection is reversed in a series group, its voltage will oppose that of the other cells. This will produce a lower than expected battery output voltage.

Example: Suppose that one of the three `D' flashlight cells of the previous example is connected in reverse, (Fig 3) the output voltage then would be:

Fig 3



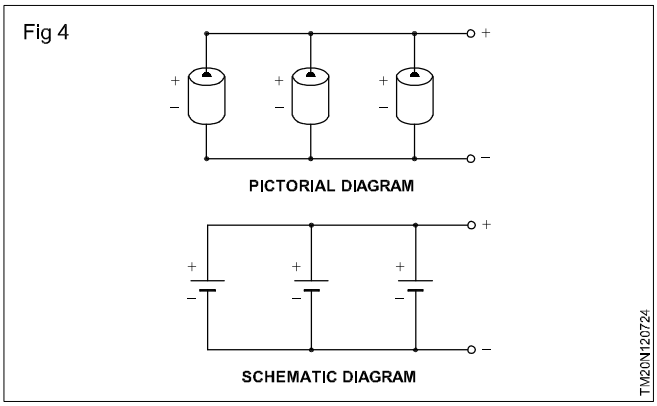
V Battery = (1.5V)+(1.5V) – (1.5V)

= (3.V) – (1.5V)

= 1.5V.

Parallel connection: Cells are connected in parallel by connecting all the positive terminals together and all the negative terminals together as in Fig 4.

Fig 4

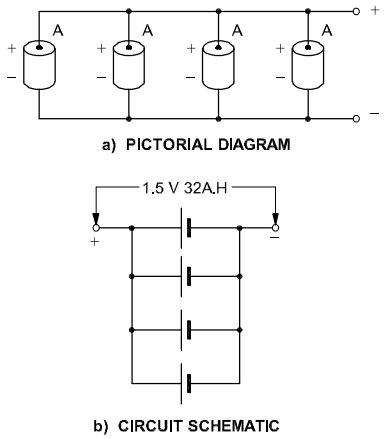


Identical cells are connected in parallel to obtain a higher output current or ampere-hour rating. With this connection of cells, the output ampere hour rating is equal to the sum of the ampere hour ratings of all the cells. However, the output voltage remains the same as the voltage of a single cell.

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Example: Suppose four cells are connected in parallel. (Fig 5) Each cell has a rating of 1.5 V and 8 A.h. The voltage and ampere-hour rating of this battery would be:

Fig 5 PARALLEL CONNECTION OF CELLS



a) PICTORIAL DIAGRAM

b) CIRCUIT SCHEMATIC

TM20N120725

V Battery = V rating of 1 cell

= 1.5 V

A h Battery rating = A h rating per cell x no. of cells

= (8 A h) (4)

= 32 A h.

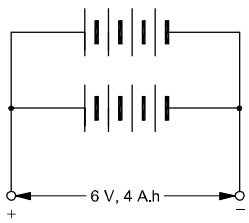
If, by mistake, a cell connection is reversed in a parallel group, it will act as a short circuit. All cells will discharge their energy through this short circuit path. Maximum current will flow through the short circuit and the cells may be permanently damaged.

Series parallel connection: Sometimes the requirements of a piece of equipment exceed both voltage and ampere hour rating of a single cell. In this case a series-parallel grouping of cells must be used.

The number of cells that must be connected in series to have voltage rating is calculated first and then the number of parallel rows of series connected cells is calculated for required ampere-hour rating.

Example: Suppose a battery operated circuit requires 6 V and a capacity of 4 A h.(Fig 6) Cells rated at 1.5 V and 2 A h are available to do the job. The required arrangement of cells would then be:

Fig 6



CIRCUIT SCHEMATIC

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$$\text{No. of cells in series} = \left(\frac{V_{required}}{V_{per\ cell}}\right)$$

$$= \frac{6\ V}{1.5\ V} = 4 \text{ cells}$$

$$\text{No. of parallel rows} = \left(\frac{A.h_{required}}{A.h_{per\ cell}}\right)$$

$$= \frac{(4\ A.h)}{2\ A.h} = 2 \text{ rows.}$$

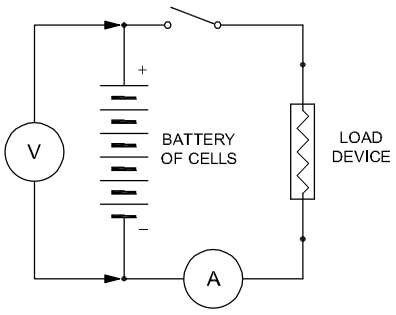
When connecting groups of cells or batteries in parallel, each group must be at the same voltage level. Paralleling two batteries of unequal voltage levels sets up a difference of potential energy between the two. As a result, the higher voltage battery will discharge its current into the other battery until both are at equal voltage value.

Testing primary cells or batteries: A visual inspection will tell you little about the useful life of a cell or battery unless it has deteriorated to the point where acid is spilling from the case.

A no-load voltage test of the cell of battery is another indication of cell or battery life. This test requires the cell or battery to deliver only a very small amount of current required to operate the voltmeter.

The best method that is used to check a cell or battery is an in-circuit test of the cell or battery voltage with the normal load connected to it.(Fig 7) A substantial drop in cell or battery voltage, when normal load is applied, indicates a bad cell or battery.

Fig 7 SWITCH OPEN (NO LOAD VOLTAGE INDICATED) SWITCH CLOSED (NORMAL LOAD VOLTAGE INDICATED)



TESTING A BATTERY UNDER LOAD

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Secondary cell (Lead acid)

Objectives: At the end this lesson you shall be able to
- **state the different terms used in electrolysis**
- **state Faraday's Laws of Electrolysis**
- **state and describe the working principle of a lead acid cell**
- **specify the storage battery**
- **explain the effect of temperature on specific gravity of electrolyte**
- **explain the terms - sulphation, buckling, partial short and efficiency.**

We learnt that most of the primary cell except rechargeable ones are usable once only. It does not supply current continuously. The secondary cells overcome this disadvantage.

Secondary cell: A cell that can be recharged by sending electric current in the reverse direction to that of a discharge mode is known as a secondary cell.

The secondary cell is also called a storage cell since after it is charged it stores the energy until it is used up or discharged.

In a secondary cell the charging and discharging processes are taking place according to Faradays Laws of Electrolysis.

Terms and definitions

Electrolyte: Electrolyte is a solution or paste capable of conducting an electric current because of its dissociation into positive and negative ions.

Electrodes: The conductor or terminal, usually metallic, through which an electric current enters or leaves is called an electrode.

Anode: One terminal of a device (such as battery or electron tube) that loses electrons in the external circuit during normal operation is called the anode. In a battery, the negative electrode is the anode and the positive electrode is the cathode.

Electrolysis: The process of decomposing liquids by the passage of electric current through the liquid is called electrolysis.

Electrochemical equivalent: The mass of a substance liberated from an electrolyte by one coulomb of electricity is termed as electrochemical equivalent (ece) of that substance.

The ece of silver is 1.1182 milligram/coulomb.

Coulomb: The unit of electric charge is a coulomb. The quantity of electricity is otherwise called charge (Q) and its unit is coulomb (C).

The coulomb is the product of current in ampere and time in seconds.

Faraday's Laws of Electrolysis

First Law: The mass of an ion liberated at an electrode is directly proportional to the quantity of electricity, that is, the charge which passes through the electrolyte.

Second Law: The masses of ions of different substances liberated by the same quantity of electricity are proportional to their chemical equivalents of the substance.

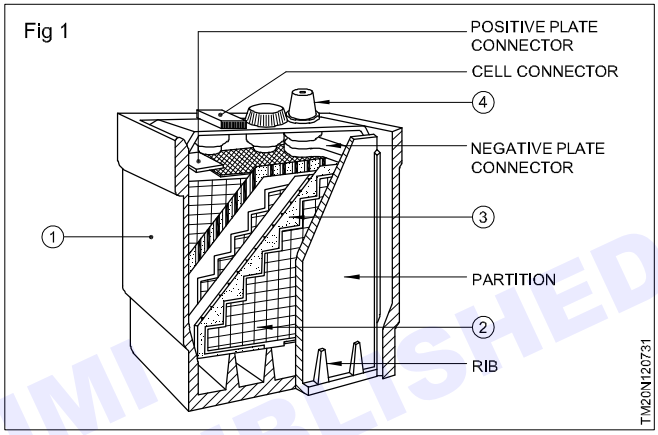
Types of secondary cells

– Lead acid cell

– Alkaline cell or nickel-iron cell

Lead acid cell (Fig 1)

Fig 1



Parts

1 Container

2 Plates

3 Separators

4 Post terminals

Container: The container is made of hard rubber, glass or celluloid to accommodate the active plates, separators and the electrolyte. The plates rest on ribs provided at the bottom of the container, and the space between ribs is known as sediment chamber.

Plates: Positive plates are of two types.

– Plante plate or formed plates

– Faure plate

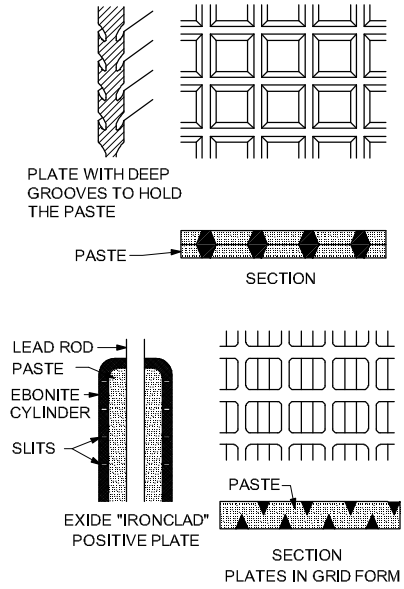
Plante plates: These are prepared by the process of repeated charging and discharging. They are made of pure lead at the beginning which changes to lead peroxide after charge.

Faure plate: Pasted or Faure plates are made of rectangular lead grid into which the active material i.e. lead peroxide ($Pb O_2$) is filled in the form of a paste. (Fig 2)

Negative plates are made of rectangular lead grid, and the active material is spongy lead (Pb) which is in the form of a paste. (Fig 3)

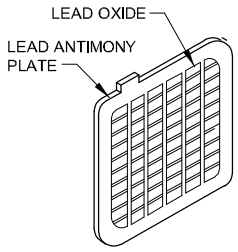
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Fig 2



CONSTRUCTION OF PASTED-TYPE ACCUMULATOR PLATES

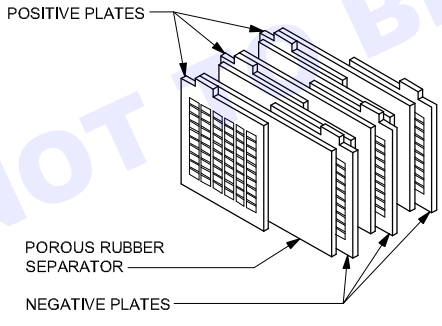
Fig 3



SINGLE LEAD PLATE

Separators: These are made of thin sheets of chemically treated porous wood or rubber. They are used to avoid short in between the positive and negative plates. (Fig 4)

Fig 4



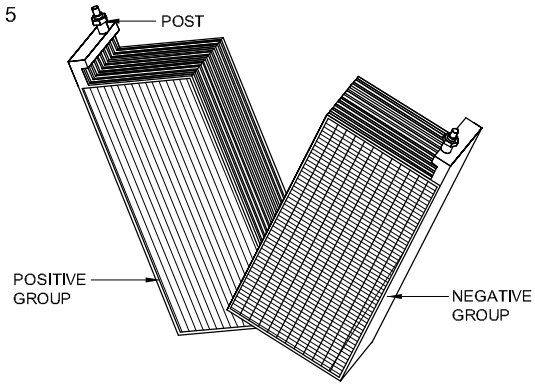
ARRANGEMENT OF PLATES AND SEPARATORS

Post terminal: A small pole extended upward from each group of welded plates from the plate connecter (see Fig 5) forms the post terminal.

Electrolyte: The electrolyte used in a lead acid cell is dilute sulphuric acid (H_2SO_4). The specific gravity of the electrolyte is 1.24 to 1.28. It varies according to the manufacturer's specification.

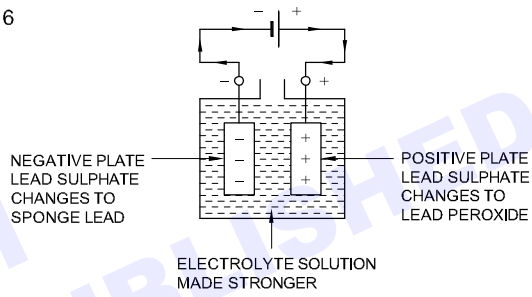
Working principle: The secondary cell has no significant electrochemical energy at the start. The energy must first be charged into the secondary cell. Then the cell retains the stored energy until it is used up. That is, both cell electrodes are basically lead sulphate ($Pb SO_4$). When the cell is charged, due to chemical reaction taking place in it, the lead sulphate electrode change to soft or spongy lead (Pb) (negative plate) and the other electrode changes to lead peroxide ($Pb O_2$) (positive plate).

Fig 5



At the same time the electrolyte solution is strengthened and becomes mostly sulphuric acid (H_2SO_4). (Fig 6)

Fig 6



DURING CHARGING PROCESS

The general recommended specification of a storage cell (battery) is given below.

- Voltage/Cell
- Ampere hour capacity
- No. of plates/cells
- Temperature
- Specific gravity of electrolyte
- No. of cells grouped

Voltage of a fully charged cell is 2.1 to 2.6V and the voltage falls to 1.8V after discharge.

Capacity: The unit of capacity of a storage cell is ampere-hour, that is the ability to discharge current in amperes continuously for one hour or vice versa.

The capacity of the cell depends on the following.

- Size of the plates
- No.of plates
- Active material used
- The strength of the electrolyte

Plates: There is always one more negative plate than the number of positive plates. That is, a negative plate at both ends of the cell gives not only more mechanical strength but also ensures that both sides of the positive plate are

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used. It also avoids buckling of positive plates. For example a nine plate cell is having four positive and five negative plates.

Temperature and specific gravity: The temperature of the electrolyte must be kept at 27°C and the specific gravity at 1.250 ± 0.010.

To correct the specific gravity reading to 27°C add 0.0007 to the observed hydrometer reading for each degree celsius above 27°C.

Excess temperature will cause more sulphation and buckling of the positive plate.

Defects

- Hard sulphation
- Buckling
- Partial short

Hard sulphation: Over discharging or the cell being left in a discharged condition for a long time cause sulphation on both electrodes and offers high internal resistance. The sulphation (hard) can be removed by recharging the cell for a longer period at a low rate called a trickle charge.

Buckling: The bending of electrodes due to overcharging and discharging, improper electrolyte and temperature is known as buckling.

Partial short: The sediments falling from the plates (electrodes) short- circuiting the positive and negative electrodes cause overheating of the particular cell during both charging and discharging periods. Such a cell may be replaced with a new one.

Efficiency: It is considered in two ways.

- Ampere-hour (Ah) efficiency
- Watt-hour (Wh) efficiency

$$\text{Ah efficiency} = \frac{\text{Output in Ah discharge}}{\text{Input in Ah charge}}$$

The watt-hour efficiency is always less than the ampere-hour efficiency because the potential difference during discharge is less than that during charge.

$$\text{Watt - hour efficiency} = \frac{\text{Ah efficiency} \times \text{Average volts on discharge}}{\text{Average volts on charge}}$$

The chemical action which takes place in the cell during charge and discharge cycles is given below for your reference.

During discharge

Positive plate

Lead peroxide + Hydrogen + Sulphuric Acid → Lead sulphate + water

$PbO_2 + H_2 + H_2SO_4 \rightarrow PbSO_4 + 2H_2O$

Negative plate

Pure lead + Sulphate = Lead sulphate

$Pb + SO4 = PbSO_4$

During charge

Positive plate

Lead sulphate + Sulphate + Water → Lead peroxide + Sulphuric acid

$PbSO_4 + SO_4 + 2H_2O \rightarrow PbO_2 + 2H_2SO_4$

Negative plate

Lead sulphate + Hydrogen → Lead + Sulphuric acid

$PbSO_4 + H_2 \rightarrow Pb + H_2SO_4$

The above reactions may be summarized thus:

	Positive plate	Electrolyte	Negative plate	
	Lead peroxide (PbO_2)	Sulphuric acid ($2H_2SO_4$)	Lead (Pb)	**Charge** ↓
↑ **Discharge**	Lead sulphate ($PbSO_4$)	Water ($2H_2O$)	Lead sulphate ($PbSO_4$)	

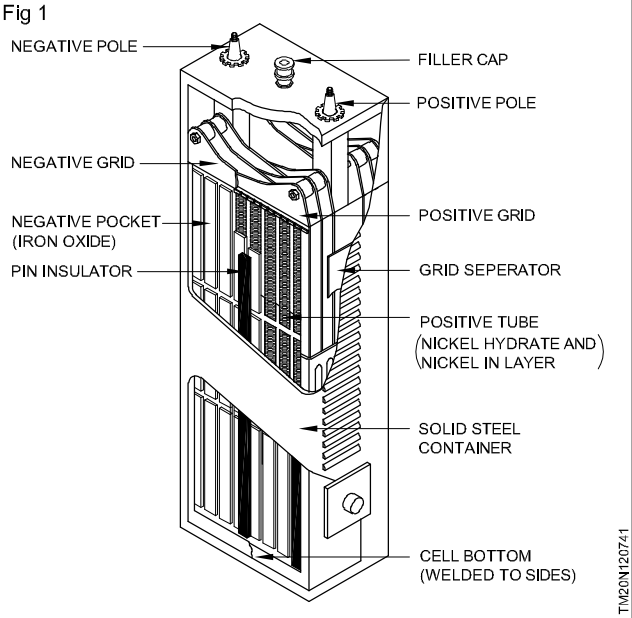
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Secondary cell (Nickel iron)

Objectives: At the end of this lesson you shall be able to
- **describe a nickel iron cell**
- **compare a nickel iron cell with a lead acid cell.**

The nickel iron cell or Edison cell (Fig 1)

Fig 1



Parts

- Positive plate
- Negative plate
- Electrolyte
- Container
- Separators

The positive plate is made of Nickel hydroxide($Ni(OH)_4$) tubes and perforated steel ribbon wound spirally and held together by steel ribs, and the whole lot is nickel-plated.

The negative plate is made of a nickel steel strip with fine perforation.

The electrolyte is 21% solution of potassium hydroxide (KOH) along with some quantity of lithium hydrate(LiOH).

The container is made of nickel-plated steel.

The separators are made of hard rubber strips and held in the nickel-plated container.

Chemical changes: On discharge, potassium hydroxide (KOH) splits up into K and (OH)ions. i.e. into potassium and hydroxide ions. OH ions travel towards the negative and oxidise the iron. K ions go to the anode and reduce Ni $(OH)_1$ to Ni $(OH)_2$. During charging, the opposite reactions take place. The chemical changes during charging and discharging can be represented by a reversible equation. (Equation 1)

It is seen from the equation that the electrolyte acts merely as a source for transfer of OH ions from one plate to another. It does not take part in any chemical change. As a result the density does not change to the same extent as in an ordinary lead acid cell. Thus, the density of the electrolyte remains almost the same during the action.

Characteristics: The emf of the cell when fully charged is 1.4V, and it reaches to 1.2 on discharge. If the voltage falls below 1.15, the cell is fully discharged.

The mechanical strength of plates is good since they are made of steel.

The cell is portable.

The cell can withstand heavy charge and discharge currents, and does not deteriorate even if left discharged.

Internal resistance is large, and so the efficiency is lower than that of a lead acid cell.

With increase in the temperature, the e.m.f. increases slightly but the capacity increases appreciably, and with a decrease in the temperature, the capacity decreases.

It is superior to a lead acid cell in mechanical strength, durability and robustness.

Moreover, as compared to lead-acid cells, the alkaline cells operate much better at low temperatures, do not emit obnoxious fumes, have very small self-discharge and their plates do not buckle or smell.

Shelf life: Batteries are also rated for shelf life in years. Even if a cell is not being used, an internal chemical reaction takes place within the cell. Technically called local action, this process is at work at all times and will eventually render the cell useless. Shelf life is defined as the time in years a stored battery will produce at least 75% of its initial capacity.

Temperature: Batteries are most often rated for a specific output capacity at room temperature or 20°c. Operating them above and below this temperature will reduce their rated output. For example, the automobile battery output drops on cold days making it more difficult to turn the engine over.

$$Ni(OH)_4 + KOH + Fe \rightleftharpoons Ni(OH)_2 + KOH + Fe(OH)_2$$

Hydrated nickel oxide — Potassium hydroxide — Ferrous — Nickel hydroxide — Ferrous hydroxide

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Comparison : Lead-acid cell and Edison cell

(The relative strong and weak points of the two cells have been summarised below.)

Sl.No.	Particulars	Lead-acid cell	Edison cell
1	Positive plate	PbO, lead peroxide	Nickel hydroxide $Ni(OH)_4$ or Nickel oxide (NiO_2)
2	Negative plate	Sponge lead	Iron
3	Electrolyte	Diluted H_2SO_4	KOH
4	Average emf	2.1 V/cell	1.2 V/cell
5	Internal resistance	Comparatively low	Comparatively higher resistance
6	Efficiency: amp-hour watt-hour	 90 - 95% 72 - 80%	Nearly 80% About 60%
7	Cost	Comparatively less than alkaline cell	Almost twice that of Pb-acid cell (Easy maintenance)
8	Life	Gives nearly 1250 charges and discharges	Five years atleast
9	Strength	Needs much care and maintenance. Sulphation occurs often due to incomplete charge or discharge.	Robust, mechanically strong, can withstand vibration, light, unlimited rates of charge and discharge. Can be left discharged, free from corrosive liquids and fumes.

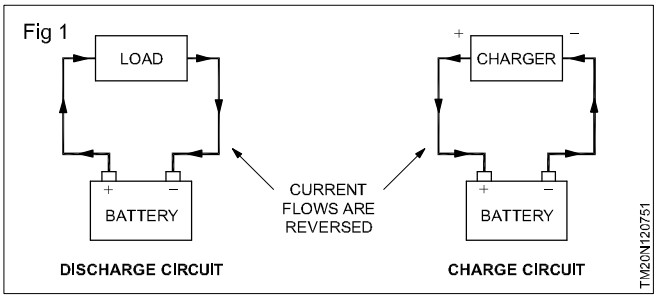
Charging secondary battery

Objectives: At the end of this lesson you shall be able to
- **describe the charging methods of secondary cells**
- **describe the use of a hydrometer**
- **describe the use of a high rate discharge tester**
- **differentiate between charged and discharged condition of a battery**
- **state the precautions to be followed while charging and discharging a battery.**

Necessity of charging: During discharge, due to chemical reaction, the active electrodes become smaller and the internal resistance becomes high causing a low output. To reverse the action, send a current (DC) through the battery or cell in the opposite direction to that of the discharge. This process is called charging. The charging can be done through a battery charger.

Battery chargers: When the chemical reaction in a rechargeable battery has ended, the battery is said to be discharged and can no longer produce the rated flow of electric current. This battery can be recharged, however, by passing direct current from an outside source to flow through it in a direction opposite to that in which it flowed out of the battery. When charging a battery, the negative lead of the charger must connect to the negative lead of the battery and the positive lead of the charger to the positive lead of the battery. (Fig 1) A reversal of these connections will produce a short circuit and may damage both the charger and the battery.

Fig 1



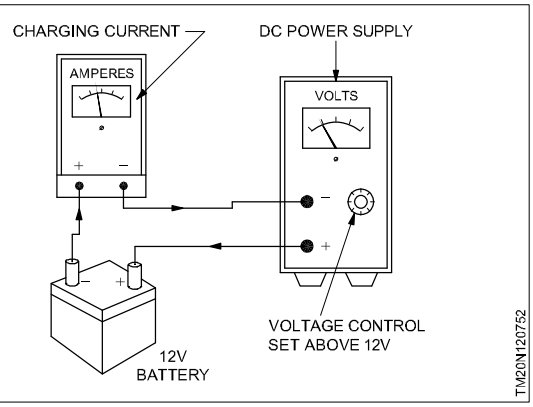
An automobile uses an automatic charging circuit as part of the car's electrical system, which is designed to recharge the battery as required. Out-of-car battery charging is done using large commercial type battery chargers. Smaller type chargers are also available for use on the smaller nickel-cadmium cells. A simple variable-voltage DC power supply works well as a battery charger.

Charging current: When charging any battery, it is important to set the charging current to a value recommended by the manufacturer. This current is set by

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adjustment of the output voltage on the charger and read by an ammeter connected in series with the charger and battery. (Fig 2) When the battery and charger are at the same voltage, no current flows. The charger voltage is set to a value higher than that of the battery to produce a current flow.

Fig 2



Before charging the battery or cell the following points are to be observed to ascertain the condition of the battery.

1 Specific gravity of the electrolyte

2 Voltage of each cell of the battery

3 Ampere hour capacity of each cell.

Hydrometer: The specific gravity of an electrolyte is measured with a hydrometer.

The main parts

– Rubber bulb

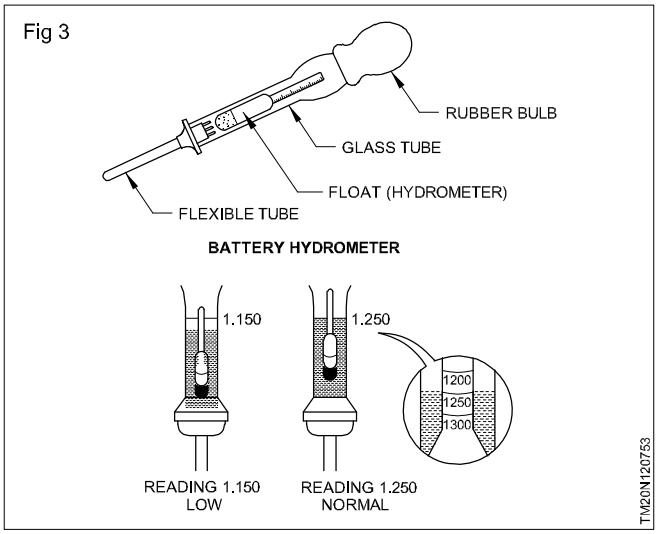
– Glass tube

– Float

– Flexible rubber tube

The charged condition of battery can be tested by means of a battery hydrometer. (Fig 3) This instrument measures the relative density of the battery electrolyte. Since the strength of the electrolyte varies directly with the state of charge of each cell, you need only to find what percentage of sulphuric acid remains in each cell electrolyte to determine how much energy is available.

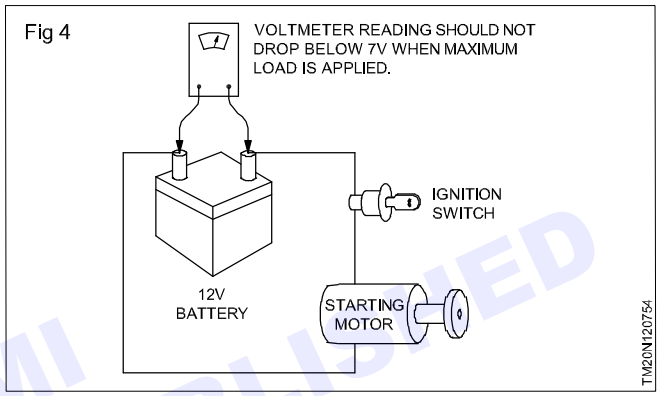
Fig 3



Cell condition	Hydrometer reading
Full charge	1.26
50% charge	1.20
Discharged	1.15

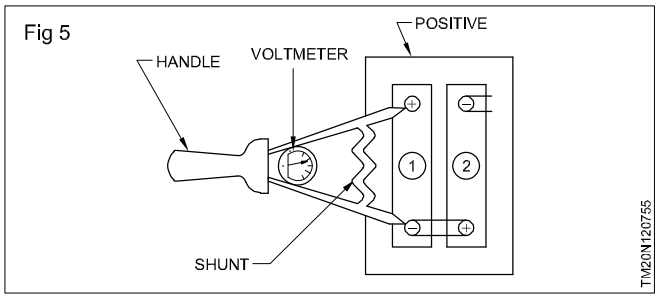
Voltage tests of lead-acid batteries, like primary cells, should be conducted under load. To make a simple light load voltage test of a car battery, check the value of the battery output voltage with and without the headlights on. A maximum load voltage test can be made by metering the battery voltage while operating the starting motor. (Fig 4) In the case of a 12V battery, a drop of battery output voltage below 7V indicates the battery is defective or not fully charged.

Fig 4



High rate discharge tester: The internal condition of the cell is determined by this test. A low range (0-3V) voltmeter is shunted by a low resistance as shown in Fig 5. The two terminal prods are pressed on to the terminals of a cell for testing. A fully charged cell which is in good condition reads in the range of full charge. A sulphated old battery will show the discharge reading. The meter is having three colours red, yellow and green - red for fully discharged, yellow for half charge, green for fully charged condition of the cell respectively.

Fig 5



Voltage of each cell: The voltage of the cell is measured with a M C voltmeter. The fully charged cell will indicate 2.5 to 2.6V and a fully discharged cell will indicate 1.8V to 1.6V.

After determining the condition of the battery or cell, the charging rate, and the method of charging are to be decided. The battery should always be charged at the rates recommended by the manufacturer.

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If you charge two or more batteries in series or in parallel, the potential difference between the terminals of the charging unit should not exceed the total voltage of all the batteries being charged in the case of series, and in the case of parallel the charging limit voltage should not exceed the voltage of a battery.

Before putting the battery under charge, the following precautions are to be followed.

Topping up: If the level of the electrolyte on the surface of the plate is less than 10 to 15mm then distilled water should be added to the indicated level of the cell after removing the vent plugs.

Do not add tap water or well water for topping up.

During charge the vent plugs are to be kept open for the escape of gas produced freely.

Ventilation: The room where batteries are to be charged should be well ventilated.

Naked flame should not be brought near the battery or cell when it is under charge.

The terminal posts should be free from corrosion and they must be covered with petroleum jelly before and after charging.

Improper electrolytes must not be used for compensating the electrolyte after it is fully charged.

The methods of charging secondary cells are:

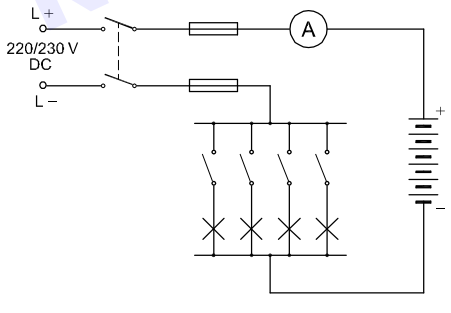
– constant current method

– constant potential method

– rectifier method.

Constant current method: This method is used where the supply is high voltage DC 220 V, 110 V, etc. but the battery is of low voltage 6 V, 12 V, etc. The emf of the battery is small in comparison to the supply voltage so a lamp-load or a variable resistor is connected in series with the battery. (Fig 6) This causes a loss of energy, so, the method is inefficient.

Fig 6

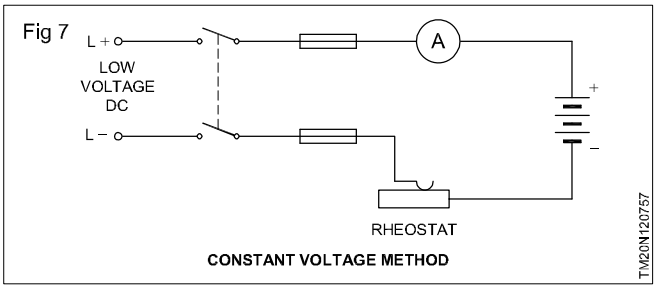


CONSTANT CURRENT METHOD

Use: For charging more number of cells at constant current rating.

Constant potential method: In this method, the voltage is maintained at a fixed value about 2.3 V per cell; the current decreases as the charging proceeds. A variable resistor is connected in series, so a voltage source of 2.5 to 2.6 V per cell is required. For a 12 V motor car battery, the charging dynamo is of about 15 V. In comparison to the constant current method less power is wasted for charging and less time is taken. Fig 7 shows the connections for a constant potential method of charging batteries.

Fig 7

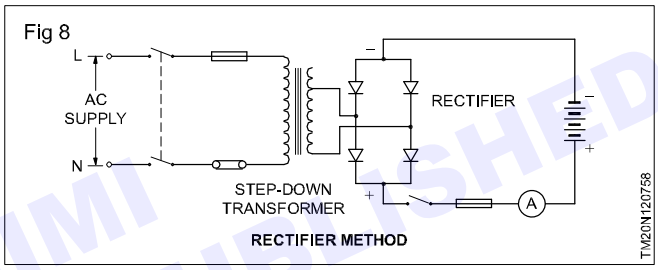


CONSTANT VOLTAGE METHOD

Use: For charging batteries of constant voltage rating.

Rectifier method: A rectifier for battery charging is generally made of diodes connected in the form of a bridge. (Fig 8) A transformer is used to step down the AC voltage to that suitable for diodes. Ammeter, voltmeter, switches and fuses are also used in the rectifier set.

Fig 8



RECTIFIER METHOD

Trickle charge: When the battery is charged at a very low rate, that is 2 to 3% of the normal rate for a long period, it is said to be a trickle charge.

Use : For central or sub-station batteries and for emergency lighting systems.

Initial charge: The first charge of a new, previously uncharged battery is called the initial charge. The process that occurs inside the battery is called forming the cells.

To conduct an initial charge, fill the cells with an electrolyte of a proper specific gravity, then replace the vent plugs. Make sure the holes in the plugs are clear. The battery should also be cool before you begin the initial charge.

Freshening charge: When a new battery is put into service for the first time, it may be given a brief charge to ensure that it starts in a fully charged condition. This kind of charge is called a freshening charge. Normally all that is required is charging at the finish rate until no change in specific gravity or voltage occurs over a three hour period.

Boost charge: If a battery is in danger of becoming over-discharged during a working shift, you can give it a supplementary charge during a rest period. This boost charge is not a conventional method of charging the storage battery. It is not recommended as a standard procedure. It is generally a high rate charge of short duration, used only to ensure that the battery will last until the end of the shift.

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Secondary cell/battery - Care & maintenance

Objectives: At the end of this lesson you shall be able to
- **state the care and maintenance of the battery**
- **state the precautions to be observed while charging and discharging a battery**
- **state the cleaning agents used for terminal cleaning**
- **state the effect of overcharging.**

The lead acid batteries must be operated under the right conditions if they are to function properly. Regular maintenance is necessary in order to maintain proper conditions and thus prolong the life of the battery.

Care and maintenance of batteries: The battery should not be discharged beyond the minimum value of voltage say, 1.75 V.

The battery should not be kept under a discharged condition for a long time.

The level of the electrolyte should always be kept to a minimum of 10 to 15 mm above the plates by adding distilled water only.

The battery should never be charged and discharged at a higher rate which weakens the plate structure. It should be done as per the manufacturer's instructions.

The battery should be recharged as early as possible after discharge.

A discharged battery should never be tested with a high rate discharge tester.

The high rate discharge tester should be used only on charged batteries and for less than ten seconds.

The specific gravity of the electrolyte should be checked before and after a battery is put on charge.

The battery charging room should always be well ventilated for the gases to escape freely.

The battery terminals must be free from corrosion. The terminals must always be kept clean and petroleum jelly should be applied on them.

The spilling of the electrolyte over the battery causes corrosion and it should be cleaned with soda water or ammonia water.

If the battery has not been used for a long period then the battery should be put on a trickle charge.

The vent plugs should be kept open while charging, for free liberation of gases.

Avoid overcharging and discharging at a high rate. This causes the plates to bend from their position and buckle.

Precautions

Make sure that, while charging, the positive terminal of the charger is connected to the positive terminal of the battery, and the negative terminal of the charger to the negative terminal of the battery. Otherwise, connecting it incorrectly causes very high current which can seriously damage both the battery and the charging unit.

Make sure the cell temperature during charge does not exceed the limit specified (43°C) as per the manufacturer's instruction.

A fully charged battery stored at 100°F(38°C) will loose almost all its charge in 90 days. The same battery stored at 60°F (15°C) will loose a little of its charge in the same period of 90 days. High temperature decreases the charging rate and shortens the life.

The rate of charging at the end of the period called finish rate is most important. It must not exceed the value recommended by the manufacturer.

During recharging, the lead acid battery produces flammable gases. An accidental spark can ignite these gases,causing an explosion inside the battery. Such an explosion can break the battery case and throw acid on the people and equipment in the area.

Do not top up the cell with improper water such as tap water, well water, mineral water or acids which will cause hard sulphation and increase the internal resistance.

Avoid improper cleaning agents for terminal posts and metal parts of the battery like emery or sandpaper. Use only the recommended cleaning agents such as baking soda water (warm), ammonia water, and wipe with cotton cloth or with an old brush.

Always wear safety glasses when working with lead acid cells and batteries. If acid does come in contact with clothing or with the skin, immediately flush with clean water. Then wash with soap and water except for eyes. Wash your hands in soap and water after handling batteries.

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Magnetism- types- materials - electromagnet - magnetic induction - types of induced e.m.f

Objectives: At the end of this lesson you shall be able to
- **state the different kinds of magnets**
- **state the molecular theory of magnetism**
- **describe the earth as a magnet**
- **state the classification of magnetic material.**

Magnetism and magnets: Magnetism is a force field that acts on some materials and not on other materials. Physical devices which possess this force are called magnets. Magnets attract iron and steel, and when free to rotate, they will move to a fixed position relative to the north pole.

Kinds of magnets

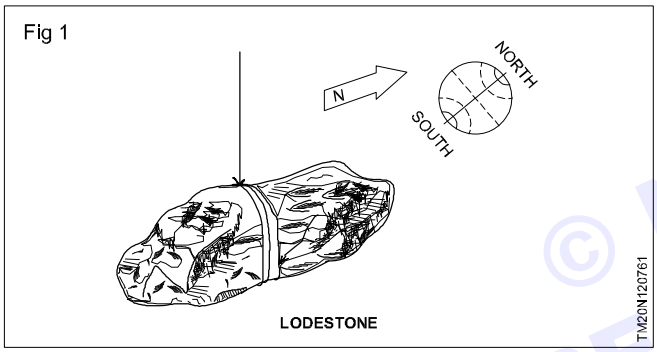
Magnets are classified into two groups.

– Natural magnets

– Artificial magnets

Lodestone (an iron compound) is a natural magnet which was discovered centuries ago. (Fig 1)

Fig 1



There are two types of artificial magnets. Temporary and permanent magnets.

Temporary magnets or electromagnets: If a piece of magnetic material, say, soft iron is placed in a strong magnetic field of a solenoid it becomes magnetised by induction. The soft iron itself becomes a temporary magnet as long as the current continues to flow in the solenoid. As soon as the source producing the magnetic field is removed, the soft iron piece will loose its magnetism.

Permanent magnets: If steel is substituted for soft iron in the same inducing field as in the previous case, due to the residual magnetism, the steel will become a permanent magnet even after the magnetising field is removed. This property of retention is termed retentiveness. Thus, permanent magnets are made from steel, nickel, ALNICO, TUNGSTEN all of which have higher retentiveness.

Molecular theory of magnetism: In magnetic materials such as iron, steel, nickel, cobalt and their alloys, which are ferromagnetic materials, the molecules themselves are tiny magnets, each of them having a north pole and south pole. This is basically due to their special crystalline structure and to the continuous movements of electrons in their atoms.

Under ordinary conditions, these molecules arrange themselves in a disorderly manner, the north and south pole of these tiny magnets pointing in all directions and neutralizing one another. Thus a non-magnetized ferromagnetic bar is one in which there is no definite arrangement of the magnetic poles as shown in Fig 2. When iron or steel is magnetized, the molecules are moved into a new arrangement as shown in Fig 3, which is caused by the force used to magnetize them.

Fig 2

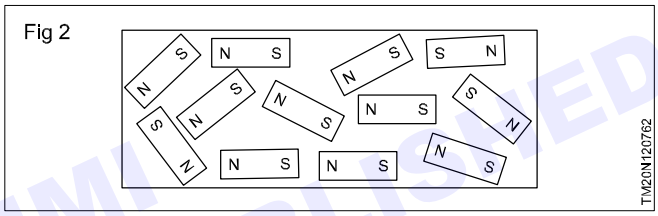
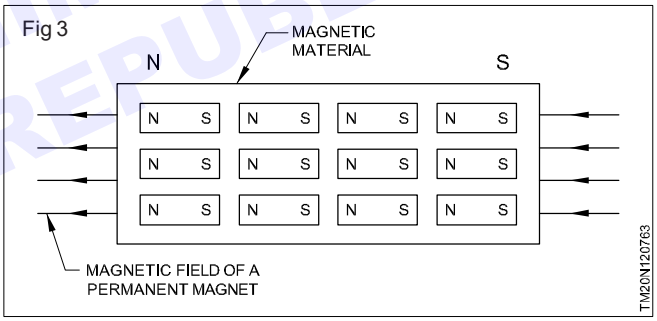


Fig 3



The earth's magnetic field: Since the earth itself is a large spinning mass, it too produces a magnetic field. The earth acts as though it has a bar magnet extending through its centre, with one end near the north geographic pole and the other end near the south geographic pole. (Fig 4)

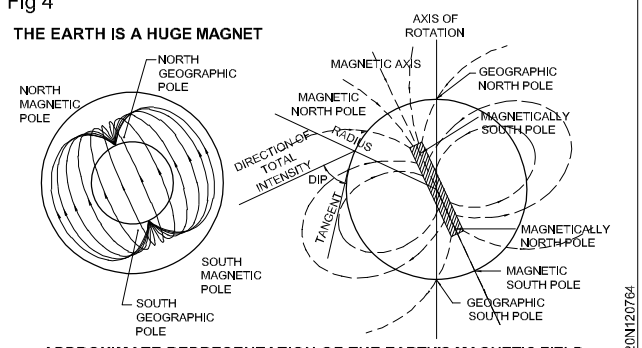
Classification of magnetic substances

Materials can be classified into three groups as follows.

Ferromagnetic substances: Those substances which are strongly attracted by a magnet are known as ferromagnetic substances. Ex. iron, nickel, cobalt, steel and their alloys.

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Fig 4



Paramagnetic substances: Those substances which are slightly attracted by a magnet of common strength are called paramagnetic substances. Their attraction can easily be observed with a powerful magnet. In short, paramagnetic substances are similar in behaviour to ferromagnetic materials. Examples: aluminium, manganese, platinum, copper etc.

Diamagnetic substances: Those substances which are slightly repelled by a magnet of powerful strength only are known as diamagnetic substances. Ex. bismuth, sulphur, graphite, glass, paper, wood, etc. Bismuth is the strongest of the diamagnetic substances.

There is no substance which can be properly called non-magnetic. It may also be noted that water is a diamagnetic material, and air is a paramagnetic substance.

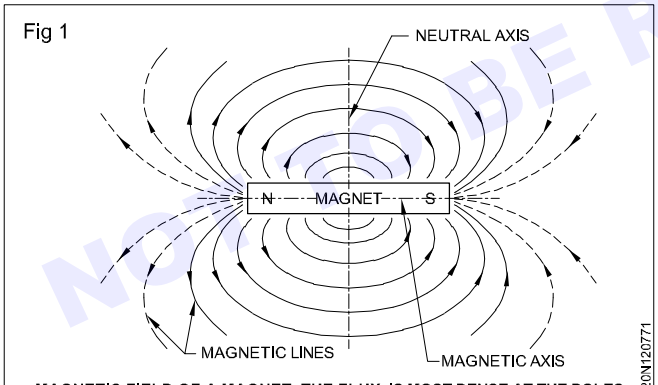
Magnetic terms and properties of magnet

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

- **define the terms magnetic field, magnetic line, magnetic axis, magnetic neutral axis and unit pole**
- **explain the properties of a magnet**
- **describe magnetic shielding**
- **describe the shape of magnets and the method of magnetizing**
- **state the application, care and maintenance of a permanent magnet.**

Magnetic fields: The force of magnetism is referred to as a magnetic field. This field extends out from the magnet in all directions, as illustrated in Fig 1. In this figure, the lines extending from the magnet represent the magnetic field.

Fig 1



The space around a magnet in which the influence of the magnet can be detected is called the magnetic field.

Magnetic lines: Magnetic lines of force (flux) are assumed to be continuous loops, the flux lines continuing on through the magnet. They do not stop at the poles.

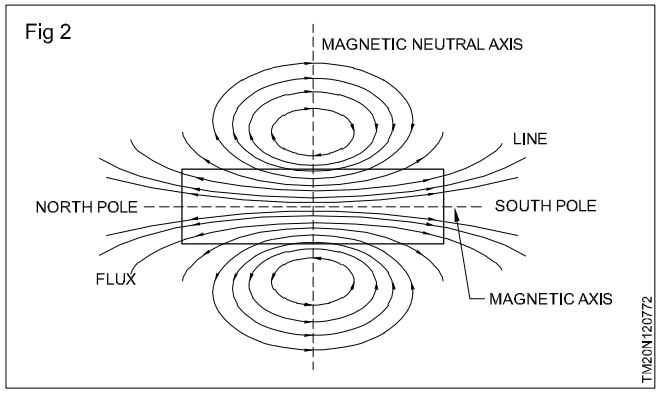
The magnetic lines around a bar magnet are shown in Fig 1.

Magnetic axis: The imaginary line joining the two poles of a magnet are called the magnetic axis. It is also known as the magnetic equator.

Magnetic neutral axis: The imaginary lines which are perpendicular to the magnetic axis and pass through the centre of the magnet are called the magnetic neutral axis.

Unit pole: A unit pole may be defined as that pole which, when placed one metre apart from an equal and similar pole, repels it with a force of 10 newtons.

Fig 2



Properties of a magnet

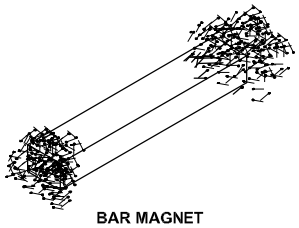
The following are the properties of magnets.

Attractive property: A magnet has the property of attracting magnetic substances (such as iron, nickel and cobalt) and its power of attraction is greatest at its poles. (Fig 3)

Directive property: If a magnet is freely suspended, its poles will always tend to set themselves in the direction of north and south. (Fig 4)

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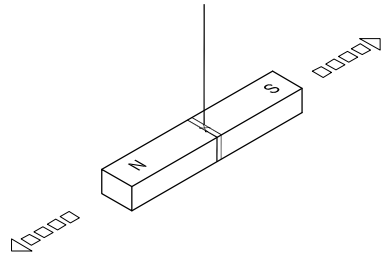
Fig 3



BAR MAGNET

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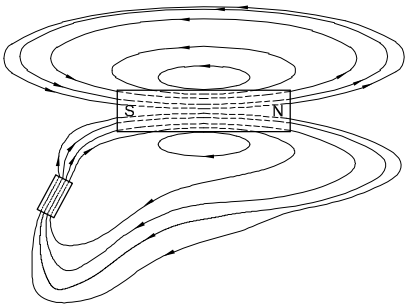
Fig 4



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Induction property: A magnet has the property of producing magnetism in a nearby magnetic substance by induction. (Fig 5)

Fig 5

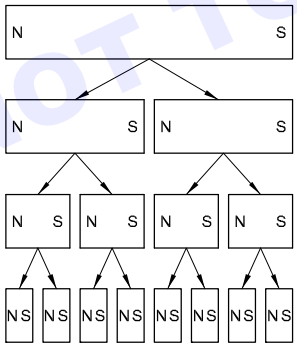


SOFT IRON PROVIDES A PATH FOR MAGNETIC LINES OF FORCE.

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Poles-existing property: A single pole can never exist in a magnet. If it is broken into its molecules, each molecule will have two poles. (Fig 6)

Fig 6



MAGNET WHEN DIVIDED

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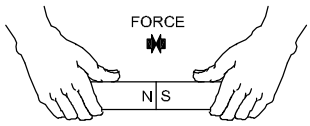
Demagnetising property: If a magnet is handled roughly by heating, hammering, etc. it will lose its magnetism.

Property of strength: Every magnet has two poles. The two poles of a magnet have equal pole strength.

Saturation property: If a magnet of higher strength is further subjected to magnetization, it will never acquire more magnetization due to its being already saturated.

Property of attraction and repulsion: Unlike poles (i.e. north and south) attract each other, (Fig 7) while like poles (north/north and south/south) repel each other. (Fig 8)

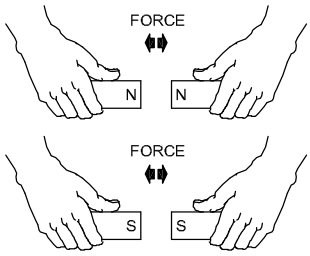
Fig 7



ATTRACTION

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Fig 8



REPULSION

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Assumed physical properties of magnetic lines of force: The lines of force always travel from the north to the south pole outside the magnet and from the south to the north pole inside the magnet.

All the magnetic lines of force complete their circuit (form a loop).

The magnetic lines do not cross each other. The lines of force travelling in one direction have a repulsive force between them, and, therefore, do not cross.

The magnetic lines prefer to pass and complete their circuit through a magnetic material.

They behave like a magnetic elastic band.

Magnetic shielding: Magnetic flux lines can pass through all materials. Magnetic materials have a very low reluctance to flux lines. The lines of flux will be attracted through a magnetic material even if they have to take a longer path. This characteristic allows us to shield things from magnetic lines of force by enclosing them with a magnetic material. This is the way anti-magnetic watches are made. Measuring instruments which are to be shielded are enclosed inside an iron case.

Shapes of magnets: Magnets are available in various shapes, with the magnetism concentrated at their ends known as poles. The common shapes are listed here.

– Bar magnet

– Horseshoe magnet

– Ring magnet

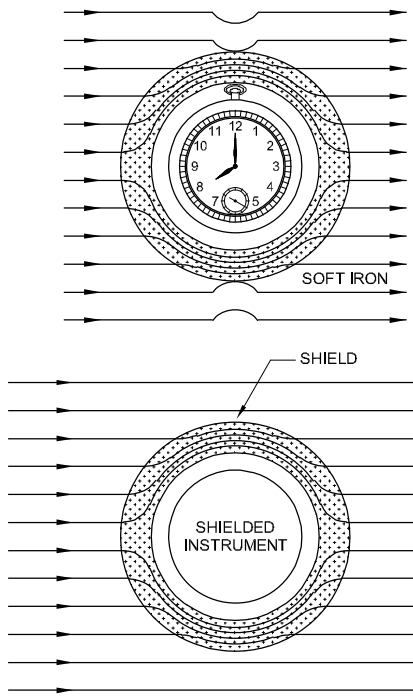
– Cylindrical type magnet

– Specially shaped magnets

Bar magnet: It is in the form of a rectangular block with the magnetism concentrated at the ends, north pole and south pole. (Fig 11a)

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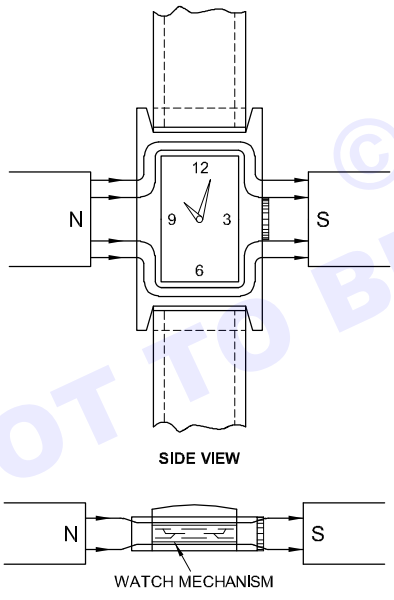
Fig 9



MAGNETIC SHIELD. THE SHIELD PROVIDES A LOW- RELUCTANCE PATH AROUND THE PROTECTED AREA.

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Fig 10



MAGNETIC MATERIALS SHIELD A WATCH FROM MAGNETIC FIELDS. THE SHIELD BECOMES ONLY TEMPORARILY MAGNETIZED. THE FLUX LINES CANNOT REACH THIS WATCH MECHANISM.

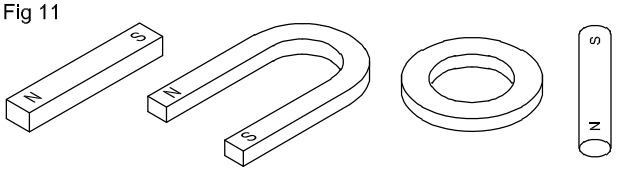
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Horseshoe magnet: A rectangular iron rod bent to the shape of a horseshoe with the magnetism concentrated at their ends forming the north pole and south pole. (Fig 11b)

Ring magnet: A ferrous metal formed into a ring as shown in Fig 11c is a ring magnet.

Cylindrical type magnet: It is formed by a cylindrical iron rod with concentration of magnetism at the north and south pole ends as shown in Fig 11d.

Fig 11

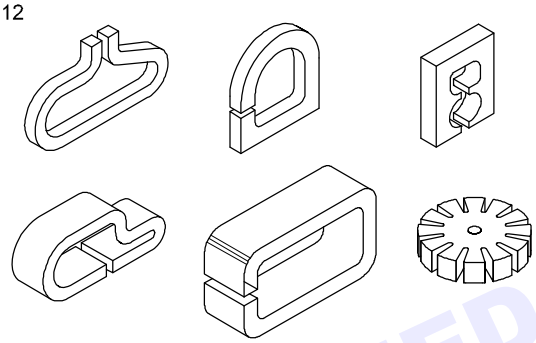


SHAPES OF PERMANENT MAGNETS

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Specially shaped magnets: Permanent magnets for special purposes like, for the use of magnet in automobiles, cycle dynamos, electrical instruments and energy meters, are made to special shapes depending upon the purpose for which they are needed. (Fig 12)

Fig 12



SPECIAL SHAPES OF MAGNET

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Methods of magnetization

There are three principal methods of magnetizing a material.

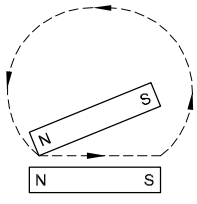
- Touch method
- By means of electric current
- Induction method.

Touch method: This method can be further divided into:

- single touch method
- double touch method, and
- divided touch method

Single touch method: In the single touch method, the steel bar to be magnetized is rubbed with either of the poles of a magnet, keeping the other pole away from it. Rubbing is done only in one direction as shown in Fig 13. The process should be repeated many times for inducing magnetization of the bar.

Fig 13



STEEL BAR

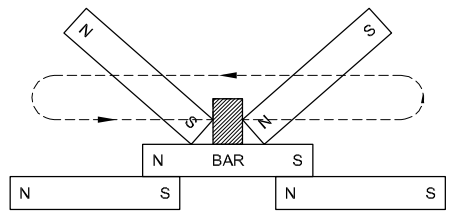
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Double touch method: In this method the steel bar to be magnetized is placed over the two opposite pole ends of a magnet, and the rubbing magnets are placed together over the centre of the bar with a small wooden piece in between, as shown in Fig 14. They are never lifted off the

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surface of the steel bar, but rubbed again and again from end to end, finally ending at the centre where the rubbing was started.

Fig 14

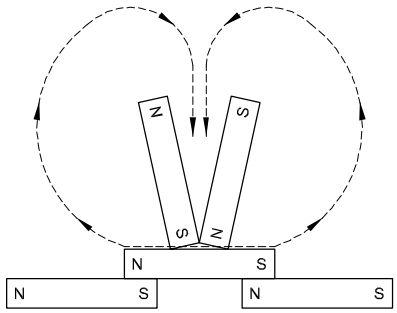


DOUBLE-TOUCH METHOD

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Divided touch method: Here the two different poles of the rubbing magnets are placed as in the previous case. They are then moved along the surface of the steel bar to the opposite ends. The rubbing magnets are then lifted off the surface of the steel bar and placed back in the centre of the bar. The whole process is repeated again and again as shown in Fig 15.

Fig 15



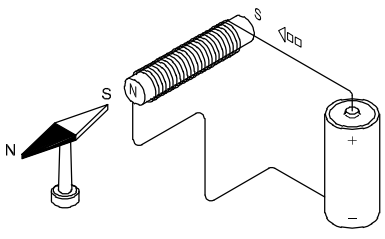
DIVIDED-TOUCH METHOD

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The steel bar thus magnetized becomes a permanent magnet but the degree of magnetization is very low.

By electric current: The bar to be magnetized is wound with an insulated copper wire, and then a strong electric current (DC) from a battery is passed through the wire for some time. The steel bar then becomes highly magnetized. If the bar is of soft iron, the magnetism remains as long as the current continues but almost completely disappears as soon as the current ceases. The magnet made by such an arrangement is called an electromagnet and is generally used in laboratories. (Fig 16)

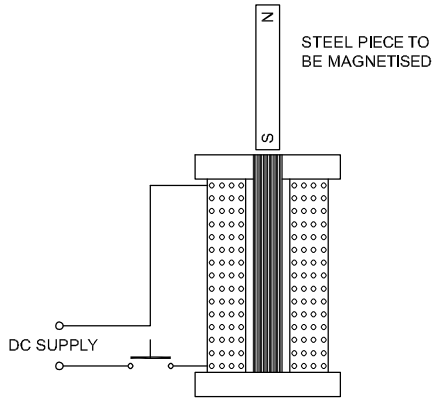
Fig 16



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Induction method: This is a commercial method of making permanent magnets. In this method a pole charger is used which has a coil of many turns and an iron core inside it as shown in Fig 17. The direct current supply is fed to the coil through a push-button switch.

Fig 17



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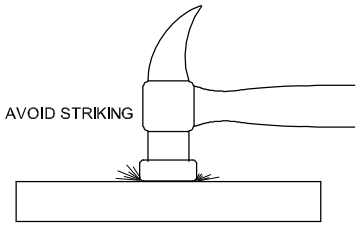
The steel piece to be magnetized is placed on the iron core kept inside the coil, and direct current is passed through the coil. The iron core now becomes a powerful magnet, and thus the steel piece is magnetised by induction. The magnetised piece is then removed after switching off the supply.

This is a commercial process for making permanent magnets for speakers, telephones, microphones, earphones, electrical instruments, magnets, compasses etc.

Care and maintenance of permanent magnets: Permanent magnets should not be thrown or dropped.

They should not be hammered. (Fig 18)

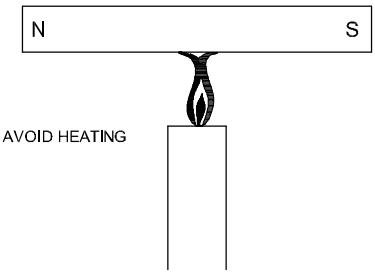
Fig 18



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They should not be heated. (Fig 19)

Fig 19



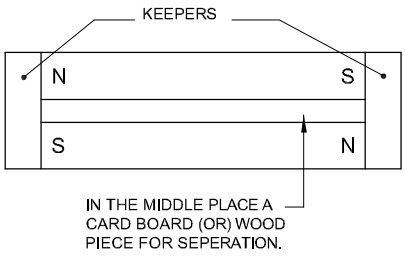
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Bar magnets should be placed side by side with their ends facing opposite polarity, with keepers at their ends.

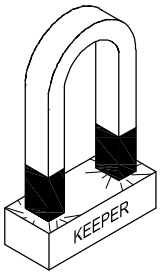
Keepers should be used while storing the magnets. (Fig 20)

Fig 20



Horseshoe magnet with keepers (Fig 21): As far as possible, the north and south poles of the magnet should be kept in the direction of the south and north directions of the earth respectively.

Fig 21



Electromagnetic induction, self-induced emf - inductors

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

- **state the principle and laws of electromagnetic induction**
- **state the difference between statically and dynamically induced emf**
- **state the difference between self and mutual induction**
- **state the factors which decide the inductance of the coil**
- **state the symbol and unit of inductance**
- **explain Lenz's law**
- **explain about the energy stored in a induction coil**
- **explain about the series and parallel connection of inductors**
- **describe the function of choke in a fluorescent light circuit**
- **state the factors that contribute to induced voltage**
- **list the example of coil used for high voltage generation.**

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Faraday's Laws of Electromagnetic Induction are also applicable for conductors carrying alternating current.

What are Faradays' Laws of Electromagnetic Induction?

Faraday's First Law states that whenever the magnetic flux is linked with a circuit changes, an emf is always induced in it.

The Second Law states that the magnitude of the induced emf is equal to the rate of change of flux linkage.

Accordingly induced emf can be produced either by moving the conductor in a stationery magnetic field or by changing magnetic flux over a stationery conductor. When conductor moves and produces emf, the emf is called as dynamically induced emf Ex. generators.

When changing flux produces emf the emf is called as statically induced emf as explained below. Ex: Transformer.

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 1)

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.

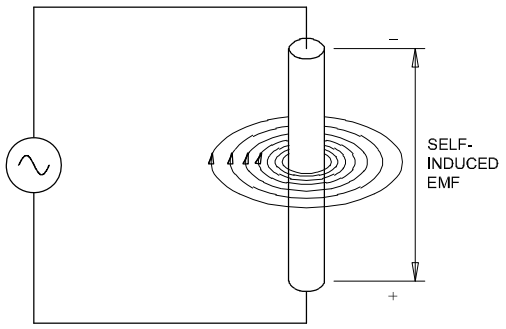
Devices which are used to provide inductance in a circuit are called inductors. Inductors are also known as chokes, coils, and reactors. Inductors are usually coils of wire.

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'

Fig 1



– 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 makeup of the coil. (Fig 2.)

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 2b): 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 2c): When the distance between the turns of wire in a coil is increased, the inductance of the coil decreases. Fig 3 illustrates why this is so. With widely spaced turns (Fig 3), many of the flux lines from adjacent turns does not link together. Those lines that do not link together produce no voltage in other turns. As the turns come closer together (Fig 3b) only a fewer lines of flux fail to link up.

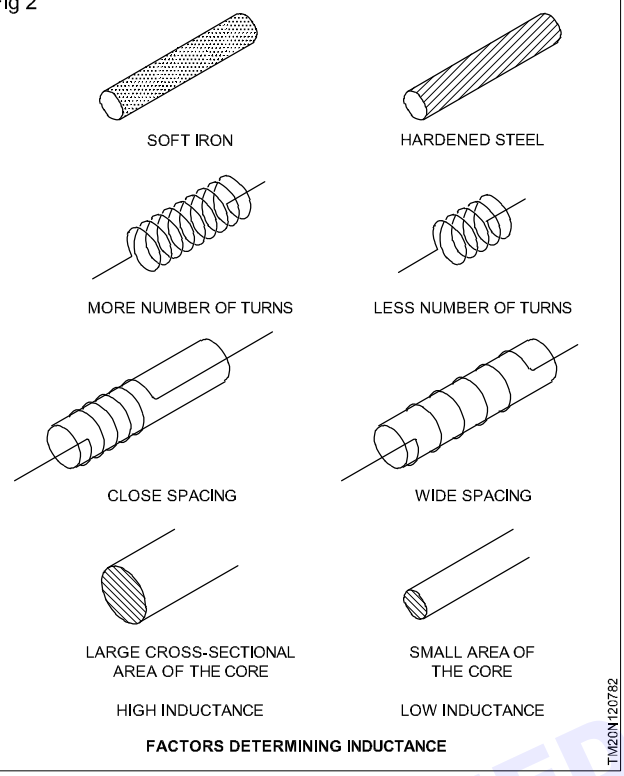
Cross sectional area (Fig 2d): For a given material having same number of turns, the inductance will be high with large cross-sectional area and will be low for smaller cross-sectional area.

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.

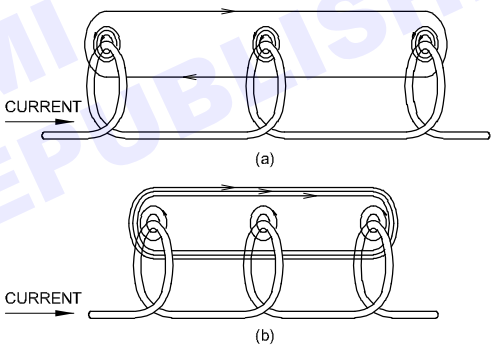
The inductance of straight conductors is usually very low, and for our proposes can be considered zero. The inductance of coiled conductors will be high, and it plays an important role in the analysis of AC circuits.

Fig 2



FACTORS DETERMINING INDUCTANCE

Fig 3

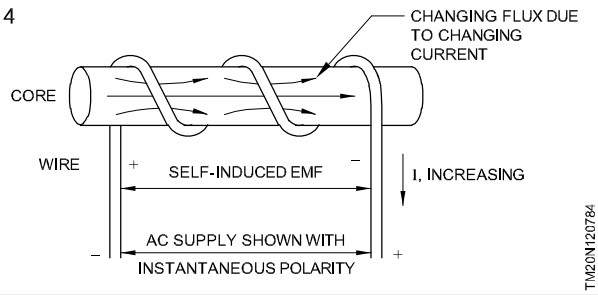


WIDELY SPACED TURNS PROVIDE LESS INDUCTANCE THAN CLOSELY SPACED TURNS

EFFECT OF TURN SPACING

What will be the direction of the induced emf? (Leng's Law): The direction of the self-induced emf is explained by Lenz's Law.

Fig 4



A change in current produces an emf whose direction is such that it opposes the change in current. In other words, when a current is decreasing, the induced emf is in the same direction as the current and tries to oppose the current from decreasing. And when a current is increasing,

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the polarity of the induced emf is opposite to the direction of the current and tries to prevent the current from increasing.

What will be the magnitude of induced emf?:The magnitude of self-induced emf depends on the rate at which the magnetic field changes. However magnetic field is proportional to current.

$$v = L \times \frac{di}{dt}$$

where

v is the emf induced in volts, V (some times called as counter emf (cemf)

L is the inductance in henrys, H

di is the change in current in amperes, A.

dt is the change in time in seconds s,

$\frac{di}{dt}$ is the rate of change of current in amperes/second, A/s.

Coefficient of self-inductance: It is defined as the flux linkage of weber turns per ampere in the coil.

By definition $L \times \frac{N\phi}{I}$ henry

where 'N' is the number of turns

'f' is the flux in webers

I is the current in amperes

But we know $f = \frac{NIa\mu_0\mu_r}{L}$ henry

where a is the cross-sectional area

m_r is the relative permeability of the core material

m_o is the absolute permeability and is equal to $4p10^{-7}$

L is the length of coil

$$\text{Therefore} = \frac{\phi}{I} = N \times \frac{N\mu_0\mu_r a}{L}$$

$$L = \frac{\mu_0\mu_r a N^2}{L} H \text{ or } L = \frac{N^2}{S} H$$

where 'S' is the reluctance.

This is only an informative equation.

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.

Series inductors: When inductors are connected in series, as in Fig 5a, the total inductance L_T is the sum of the individual inductances. The formula for L_T is expressed in the following equation for the general case of n inductors in series.

$L_T = L_1 + L_2 + L_3 + ...L_n$

Notice that inductance in series to resistance in series.

Parallel inductors: When inductors are connected in parallel, as in Figure 5(b), the total inductance is less than the smallest inductance. The formula for total inductance in parallel is similar to that for total parallel resistance.

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + ... \quad ..... \quad \frac{1}{L_n}$$

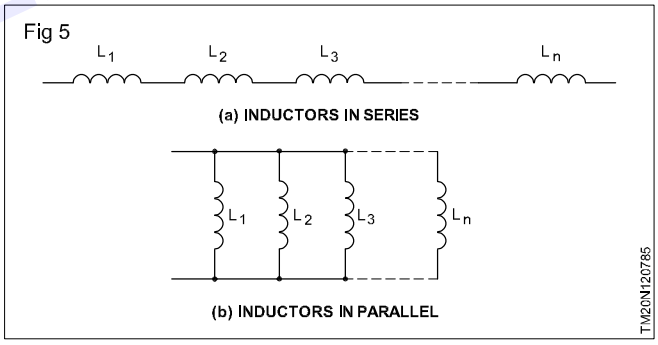
Example 1: The current in a 200mH coil increases from 2 to 5A in 0.1s. Calculate

a) the rate of change of current and

b) the self-induced emf.

Solution

Fig 5



a) $\frac{di}{dt} = \frac{5A - 2A}{0.1s} = 30A / s$

b) $V = L\frac{di}{dt} = \frac{200}{1000} \times 30\ A / s$

$= 6V.$

Example 2: What is the value of inductance of a coil that induces 20V when the current through the coil changes from 12 to 20 A in 2s?

We are given that

VL = 20 V, di = 20–12 = 8A, dt = 2s

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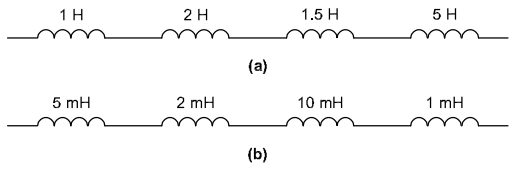
$$\frac{di}{dt} = \frac{8}{2} = 4 \text{ A/s.}$$

$$L = \frac{VL}{\frac{di}{dt}} = \frac{20}{4} = 5 \text{ H.}$$

Example 3: Determine the total inductance for each of the series connections in Fig 6.

Solution

Fig 6



a L_T = 1H + 2H + 1.5H + 5H = 9.5H

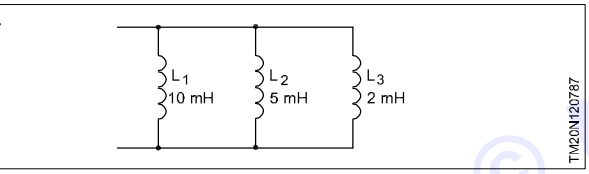
b L_T = 5mH + 2mH + 10mH + 1mH = 18mH

Note 1000mH = 1 mH

Example 4: Determine L_T in Fig 7.

Solution

Fig 7



$$L_T = \frac{1}{\left(\frac{1}{10}\text{mH}\right) + \left(\frac{1}{5}\text{mH}\right) + \left(\frac{1}{2}\text{mH}\right)}$$

$$= \frac{1}{0.1 + 0.2 + 0.5}$$

$$L_T = \frac{1}{0.8} = 1.2 \text{ mH.}$$

Types of Inductor: Basically, all inductors are made by winding a length of conductor around a core (Fig 8). The conductor is usually a solid copper or aluminum wire coated with enamel insulation, and the core is made either of magnetic material, such as powered iron, or of insulating material. When an inductor is wound around an insulating core, the core is used only for a support, since it has no magnetic properties. If heavy wire is used in making the inductor, a core is actually not needed; the rigid loops of wire support themselves. When a magnetic core is not used, the inductor is usually referred to as an air-core inductor. (Fig 9)

Fig 8

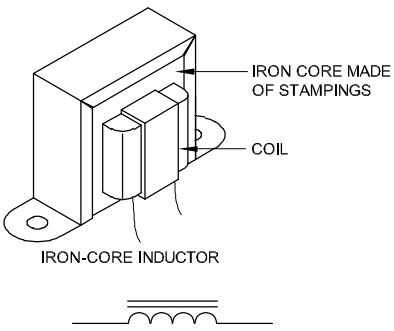
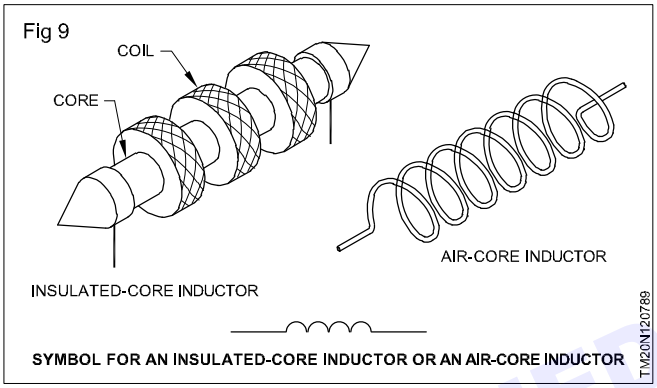
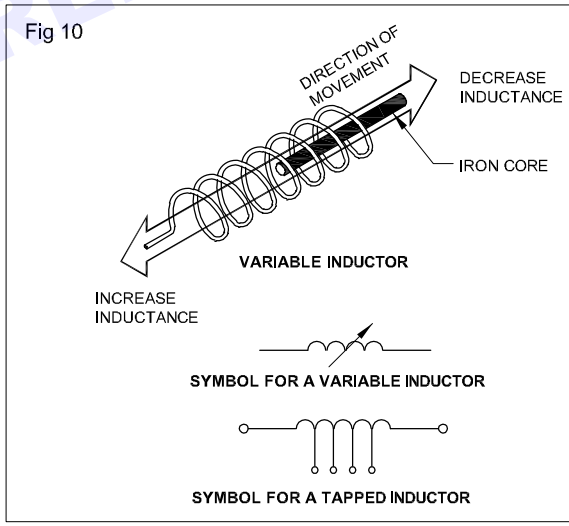


Fig 9



Inductor with set values of inductance that cannot be changed are called fixed inductors. Inductors whose inductance can be varied over some range are called variable inductors. Usually, variable inductors are made so that the core can be moved into and out of the winding. The position of the core will determine the inductance value. (Fig 10)

Fig 10



Conductors are also frequently called chokes or coils. All these three terms mean the same thing.

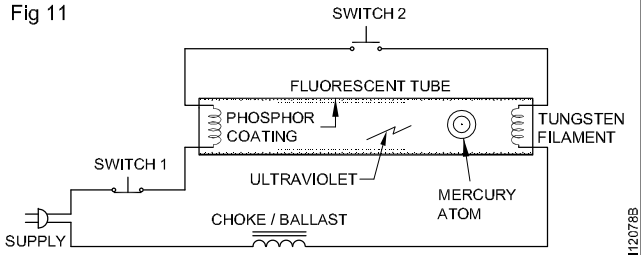
Fixed inductors are used as ballast in gas discharge lamps. They are also used in electronics as power supply filters. Variable inductors and tapped inductors are used for obtaining variation of current in welding transformers to suit the electrode size and weld material.

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Application of inductance in a fluorescent lamp circuit: Fig 11 shows a fluorescent lamp circuit. The inductor (ballast) is used to induce a momentary high voltage to fire the lamp. The ballast then limits the current through the lamp, after the lamp is lit, because of the coil's inductive reactance. The operation of the lamp circuit is as follows.

The fluorescent lamp is a glass tube with a tungsten filament sealed at each end. The inner surface of the tube is coated with a phosphor material this determines the colour of the light produced. Most of the air is removed during manufacture and a small amount of argon gas and mercury are admitted to the sealed tube. (Fig 11)

Fig 11



LIGHT SCHEMATIC DIAGRAM OF FLUORESCENT

When the momentary contact of the switch 2 is pushed (CLOSED), and held closed for several seconds, a complete series path exists for current to flow through the two filaments to become heated, emitting electrons. A dull glow is observed at each end of the tube. When the switch 2 is released (OPEN), the current through the ballast is interrupted, causing a high voltage to be momentarily induced. This voltage, along with the 240V input, is sufficient to cause the lamp to 'fire'. This means that the current is conducted through the ionized gas in the tube from one filament to the other.

It should be noted that the ballast gets its name from the second function it provides. After the lamp is lit, a typical 40W lamp requires only 110V to maintain proper current through the lamp. The opposition to alternating current caused by the inductance, its inductive reactance, help in the applied 240V dropping to the required value across the lamp.

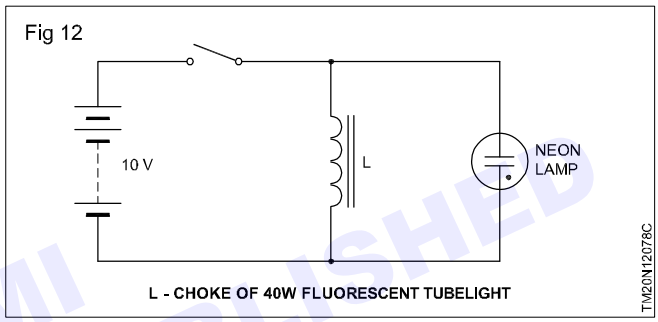
Fluorescent lamps that use a single on/off switch1 in the supply line for control purposes employ a starter inplace of the switch 2.

When a fluorescent lamp circuit is connected to DC supply, the choke serves the first purpose only. An additional resistor is to be connected in series to limit the current through the lamp.

Is there any disadvantage with inductance? Inductance increases arcing in switch contact which is a major disadvantage. A large voltage across the contacts, while opening the switch of the inductive circuit, sets an arc, and the stored energy in the magnetic field increases the arcing. Additional measures are required to suppress the arc in such circuits.

Application of inductance for high voltage generation: The ability of a coil to induce high voltage can be observed by connecting a neon lamp across a coil as in Fig 12.

Fig 12



L - CHOKE OF 40W FLUORESCENT TUBELIGHT

A neon lamp used as an indicator requires a minimum of about 70V to 'fire' or light. It is observed that a battery does not light the lamp as the voltage is only 10V at the time of switching ON. But when the switch is opened the lamp flashes indicating the presence of high voltage, more than 70 V.

A major application of the high voltage induced in a coil by interrupting the current through the coil is in fluorescent lamp circuits and ignitors of petrol engines.

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Counter EMF - inductive reactance - time constant

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

- **explain the term CEMF**
- **explain about the inductive reactance**
- **state the reasons for the difference between ohmic resistance and impedance of a coil**
- **explain time constant of an inductive circuit.**

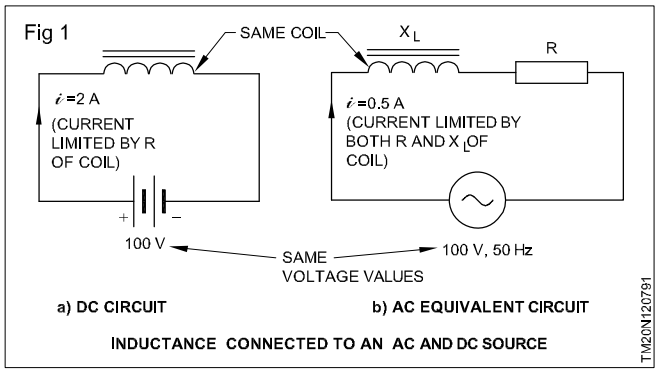
CEMF and LENS's law: The voltage induced in a conductor or coil by its own magnetic field is called a counter electromotive force (cemf). Since the induced emf (voltage) is always opposing, or countering, the action of the source voltage, it is known as cemf. Counter electromotive force is sometimes referred to as back electromotive force (bemf).

In any type of inductive circuit there is an important relationship between the direction of the current change and the induced voltage. Lenz's law states that a cemf always has a polarity which opposes the force that created it.

The inductance rating of an inductor refers to its ability to generate a counter voltage to a change in current flow. One henry (1H - the SI unit) represents the inductance of a coil in which a current change of one ampere per second (1 A/s) will produce a cemf of one volt (1V)

Inductive reactance: The opposition offered to an AC current flow by the inductive effect is called inductive reactance. Inductive reactance is the result of the cemf of the inductor. The inductor cemf is just equal to (and opposite) the source voltage.

Current flow through a coil connected to a DC source is limited by the wire resistance of the coil only (Fig 1a) Current flow through the same coil connected to an AC source is limited by the wire resistance and the inductive reactance (Fig 1b)



The reactance of an inductor can be calculated with the following formula

$X_L = 2p\ fL = 6.28\ fL$

The inductive reactance is in ohms while the frequency is in hertz and the inductance is in henrys.

From the above formula it can be seen that inductive reactance is directly proportional to both frequency and inductance.

This direct proportional relationship makes sense when one recalls two things.

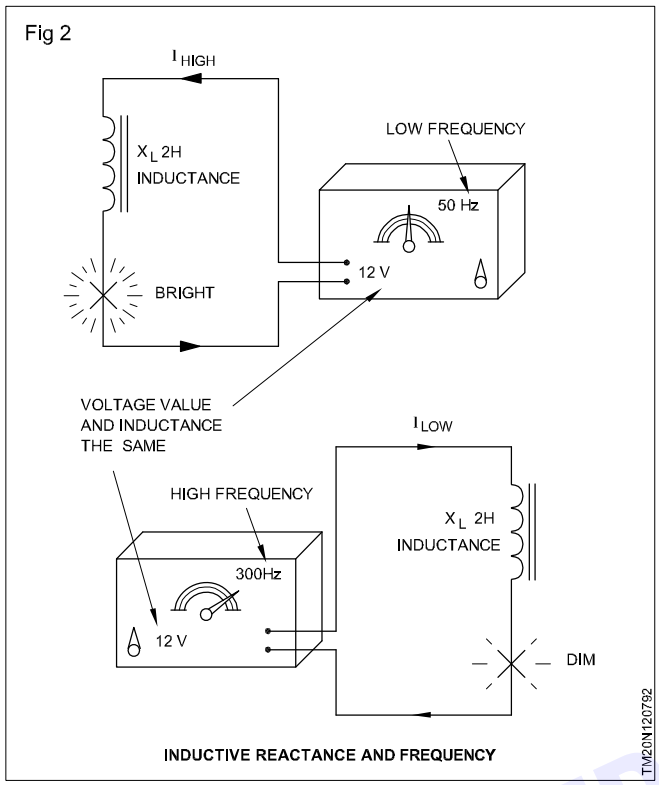
– The higher the frequency, the more rapidly the current is changing. Thus more cemf and more reactance are produced. (Fig 2)

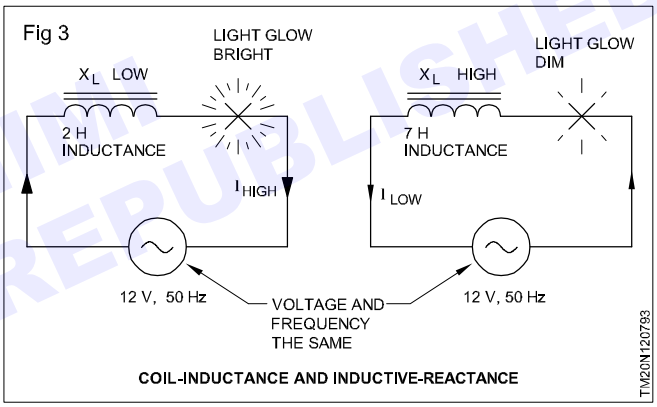
– The higher the inductance, the more the flux change per unit of current change. Again more cemf and reactance are produced. (Fig 3)

OHMIC resistance: The DC resistance is the resistance measured with a very accurate ohmmeter. It is the total resistive effect to pure DC.

Effective resistance: In general, a pure resistive circuit reacts in much the same way for both AC or DC. There are, however, some differences that must be considered. These differences vary with the frequency of AC and are generally negligible at low frequencies.

The following five factors affect the amount of current flow in a pure resistive circuit.





– DC resistance

– skin effect

– Eddy currents

– Hysteresis

– Dielectric stress

The DC resistance is the resistance offered by the conductor (element) to pure DC. The fact that the alternating current changes in value and direction tends to make it flow along the outer surface of the conductor. This phenomenon, known as skin effect, reduces the inner conductive effect of the conducting material and increases the circuit resistance.

Alternating current produces a magnetic flux which changes its polarity with each reversal of current flow. The change in polarity causes the molecules in the metal parts near the circuit to be in motion, thus producing heat. The heat either radiates back into the circuit conductors or retards the dissipation of heat produced by the current flowing in

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the conductors. The hysteresis effect increases the effective resistance of the circuit.

Eddy currents are caused by voltages induced into the conductors and other surrounding metal parts. They are directly proportional to the frequency of the supply. The heat produced by these currents tends to increase the effective resistance of the circuit.

As the alternating voltage varies in strength, the stress on the conductor insulation increases and decreases. This variation in electric stress also produces heat which increases the circuit resistance.

Effect of inductance present in a AC circuit: Coils have varied uses in electrical engineering such as

–excitation coils in electric machines or magnets

–relay coils in switching devices

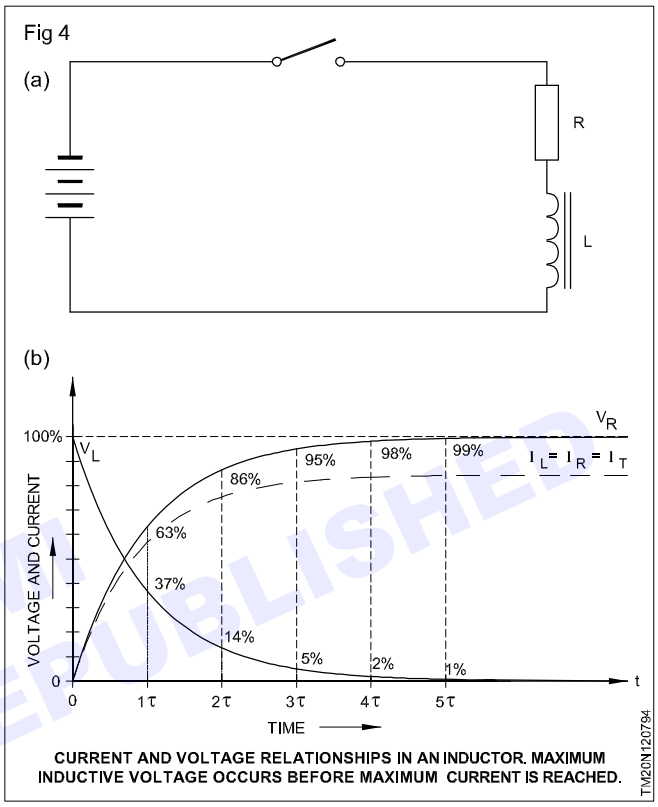
–choke coils for limiting current etc.

If a coil with the current passing through it is compared to a vehicle being moved, then the momentary value of the coil's current **i** can be compared to the velocity **V** of the vehicle. An increase in the current corresponds to accelerating the vehicle and a decrease in the current corresponds to braking (retarding) the vehicle. Due to the inertia of the vehicle's mass the velocity cannot suddenly change. The same applies to the coil's current, where a sudden change is prevented by the self-induced emf (voltage).

Time constant for inductors: When a coil with inductance L and resistance R_L is fed by a direct voltage (Fig 4a) the flux increasing with the current induces cemf, so that the current only increases to its final value $I = \frac{V}{R_L}$ with a time delay Fig 4b. The time constant for an RL circuit is defined as the time required for the current through the resistor-inductor to rise to 63.2% of its final value.

The time constant of an RL circuit can be calculated using the formula $t = \frac{L}{R}$.

The time constant is in seconds when L is in henry and R is in ohms. The current after the time t = t has reached 63.2% of its final value. The table shows after five time constants have elapsed (t=5t), the current has reached 99.3% of its final value, i.e. it has practically reached its final value.



CURRENT AND VOLTAGE RELATIONSHIPS IN AN INDUCTOR. MAXIMUM INDUCTIVE VOLTAGE OCCURS BEFORE MAXIMUM CURRENT IS REACHED.

Time t =	τ	2τ	3τ	4τ	5τ	6τ	7τ	8τ
Current value I =	63.2%	86.46	95.02	98.10	99.33	99.75	99.9	99.966

Dynamically induced EMF

Objectives: At the end of this lesson you shall be able to
- **state the principle of the DC generator**
- **explain Faraday's Laws of Electromagnetic Induction**
- **explain the method of producing dynamically induced EMF, its magnitude and direction.**

Generator: An electrical generator is a machine which converts mechanical energy into electrical energy.

Principle of the Generator: To facilitate this energy conversion, the generator works on the principle of Faraday's Laws of Electromagnetic Induction.

Faraday's Laws of Electromagnetic Induction: There are two laws.

The first law states

– Whenever the flux linking to a conductor or circuit changes, an emf will be induced.

The second law states

– The magnitude of such induced emf(e) depends upon the rate of change of the flux linkage.

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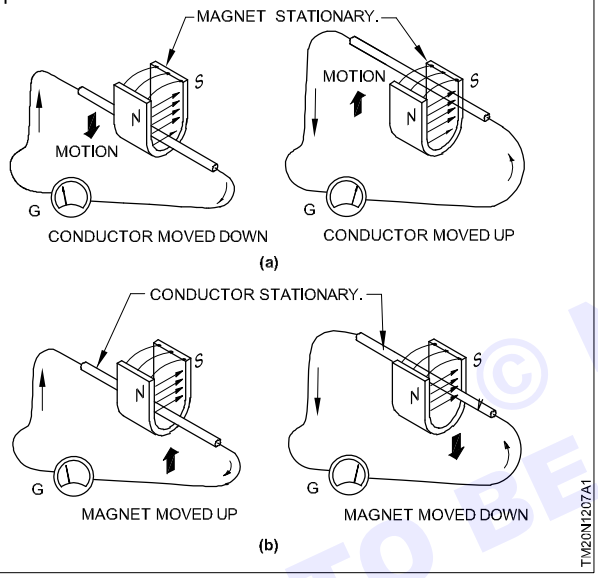
$$e \propto \frac{\text{Change of flux}}{\text{Time taken for change}}$$

Types of emf: According to Faraday's Laws, an emf can be induced, either by the relative movement of the conductor and the magnetic field or by the change of flux linking on a stationary conductor.

Dynamically induced emf: In case, the induced emf is due to the movement of the conductor in a stationary magnetic field as shown in Fig 1a or by the movement of the magnetic field on a stationary conductor as shown in Fig 1b, the induced emf is called dynamically induced emf.

As shown in Figs 1a & 1b, the conductor cuts the lines of force in both cases to induce an emf, and the presence of the emf could be found by the deflection of the needle of the galvanometer `G'. This principle is used in DC and AC generators to produce electricity.

Fig 1

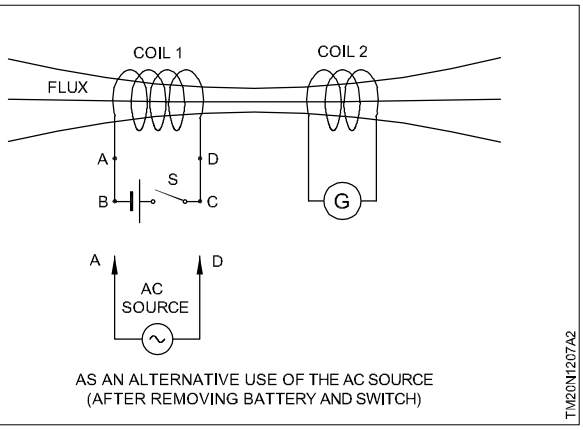


Statically induced emf: In case, the induced emf is due to change of flux linkage over a stationary conductor as shown in Fig 2, the emf thus induced is termed as statically induced emf. The coils 1 and 2 shown in Fig 2 are not touching each other, and there is no electrical connection between them.

According to Fig 2, when the battery (DC) supply is used in coil 1, an emf will be induced in coil 2 only at the time of closing or opening of the switch S. If the switch is permanently closed or opened, the flux produced by coil 1 becomes static or zero respectively and no emf will be induced in coil 2. EMF will be induced only when there is a change in flux which happens during the closing or opening of the circuit of coil 1 by the switch in a DC circuit.

Alternatively the battery and switch could be removed and coil 1 can be connected to an AC supply as shown in Fig 2. Then an emf will be induced in coil 2 continuously as long as coil 1 is connected to an AC source which produces alternating magnetic flux in coil 1 and links with coil 2. This principle is used in transformers.

Fig 2



Production of dynamically induced emf: Whenever a conductor cuts the magnetic flux, a dynamically induced emf is produced in it. This emf causes a current to flow if the circuit of the conductor is closed.

For producing dynamically induced emf, the requirements are:

– magnetic field

– conductor

– relative motion between the conductor and the magnetic field.

If the conductor moves with a relative velocity 'v' with respect to the field, then the induced emf `e' will be

$$= BLV \text{ Sinq Volts}$$

where

B = magnetic flux density, measured in tesla

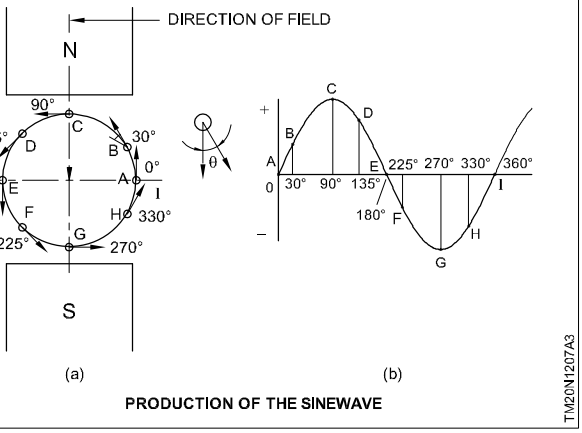
L = effective length of the conductor in the field in metres

V = relative velocity between field and conductor in metre/second

q = the angle at which the conductor cuts the magnetic field.

Let us consider Fig 3a in which conductors A to I are placed on the periphery of the armature under magnetic poles. Assume for this particular generator shown in Fig 3a, the value of BLV = 100V.

Fig 3



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Accordingly the conductor A induces an emf

= BLV Sin q where q = zero and Sin zero is equal to zero

= 100 x 0 = zero.

emf induced in

Conductor B = BLV Sin 30°

= 100 x 0.50

= 50 volts.

emf induced in

Conductor C = BLV Sin 90°

= 100 x 1

= 100 V.

emf induced in

Conductor D = BLV Sin 135°

= BLV Sin 45°

= 100 x 0.707

= 70.7 volts.

emf induced in

Conductor E = BLV Sin 180°

= Sin 180°= 0

= 100 x 0

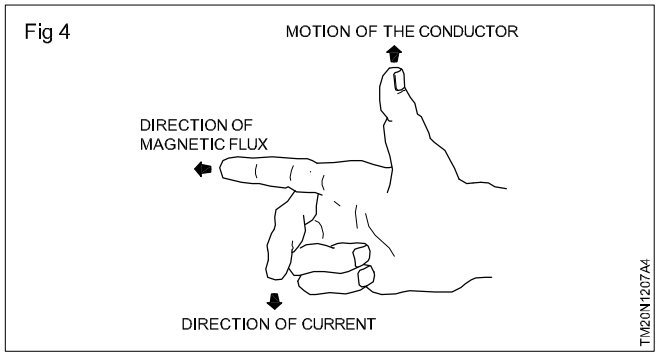
= zero.

Likewise for every position of the remaining conductors in the periphery, the emf induced could be calculated. If these values are plotted on a graph, it will represent the sine wave pattern of induced emf in a conductor when it rotates under N and S poles of uniform magnetic field.

The emf induced by this process is basically alternating in nature, and this alternating current is converted into direct current in a DC generator by the commutator.

Fleming's right hand rule: The direction of dynamically induced emf can be identified by this rule. Hold the thumb, forefinger and middle finger of the right hand at right angles to each other as shown in Fig 4 such that the forefinger is in the direction of flux and the thumb is in the direction of the motion of the conductor, then the middle finger indicates the direction of emf induced, i.e. towards the observer or away from the observer.

Fig 4

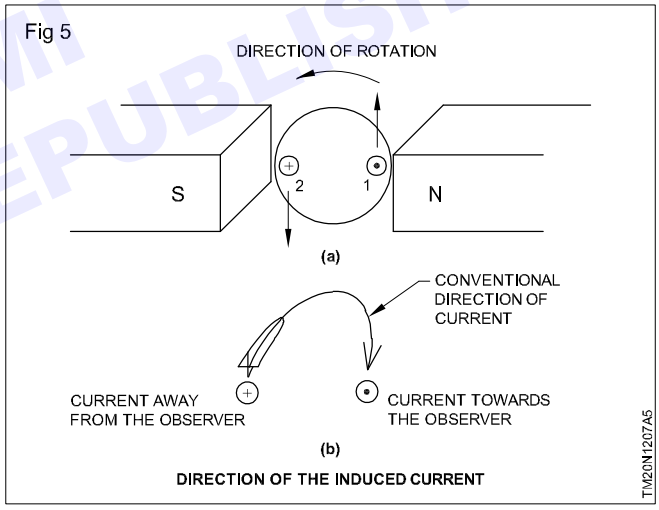


Imagine a conductor moving in between north and south poles in an anticlockwise direction as shown in Fig 5a.

Applying Fleming's right hand rule, we find that the conductor 1 which is moving upwards under the north pole will induce an emf in the direction towards the observer indicated by the dot sign and the conductor 2 which is moving down under the south pole will induce an emf in the direction away from the observer indicated by the plus sign.

Fig 5b indicates the current direction in the form of an arrow. The dot sign indicates the pointed head of the arrow showing the current direction towards the observer and the plus sign indicates the cross-feather of the arrow showing the current direction away from the observer.

Fig 5



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D.C generator - Principle - Parts - Types - Characteristics and applications

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

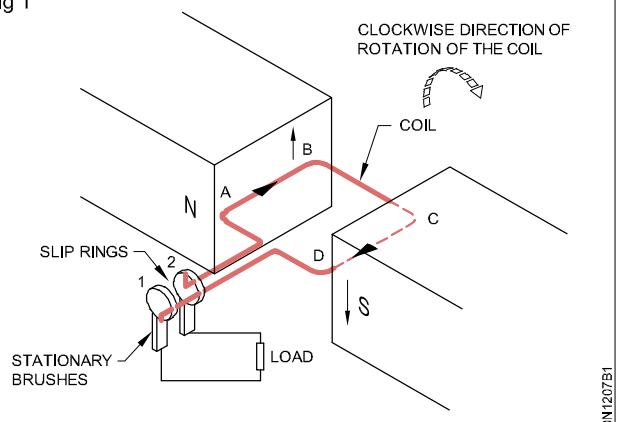
- **explain the function of the split rings (commutator) and slip-rings.**

Introduction

A generator produces electrical power with the help of the rotation of a group of conductors in a magnetic field. It uses the principle of electromagnetic induction to convert the input mechanical power into electrical power.

Slip rings: Let us consider a simple AC generator having a single loop of wire and rotated within a fixed magnetic field, as shown in Fig 1.

Fig 1



SIMPLE AC GENERATOR

Let each end of the single loop coil be connected to copper or brass rings called slip rings. These slip-rings are insulated from each other, insulated and mounted on the shaft. In a broader sense this rotating assembly (coil, shaft & slip-ring) is called armature. The wire loop (armature coil) is connected to an external circuit by means of two brushes which are positioned to rub against the slip-rings. As the armature is rotated at a uniform angular velocity, the generated voltage in the loop conductor will actually be of alternating voltage.

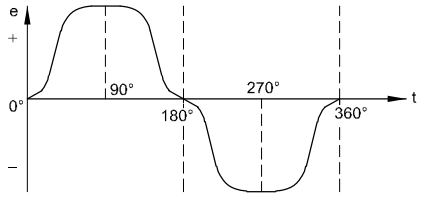
For the clockwise rotation indicated, the direction of generated voltage and the resulting current in the coil side under the north pole will be directed from A to B making the slip-ring 2 negative. This is readily confirmed by using Fleming's right hand rule. Similarly the direction of the induced voltage and the resulting current under the south pole is to be directed from C to D making the slip- ring 1 as positive. When the conductor AB moves from the north pole to the south pole, the direction of induced emf in it will reverse, so that the current will now flow from B to A making the slip-ring 2 positive. At the same time coil side CD has moved into the north pole region and its induced emf is reversed and current will flow from D to C making the slip-ring 1 negative.

Thus for one half of a revolution (for a two-pole generator) the emf is directed around the coils A to B & C to D. For the other half of the revolution the emf is directed around the coil D to C and B to A. The current in the externally connected load resistor via the stationary brushes in contact with the pair of slip rings `1'and `2' will be alternating (AC) in nature.

Wave-shape of the induced voltage: When the output voltage is plotted against electrical degrees we get the output wave-form.

The output wave-form obtained across the load, according to the pole shape shown in Fig 1, will not be of sinusoidal shape due to un-uniform magnetic field but of rectangular shape as shown in Fig 2.

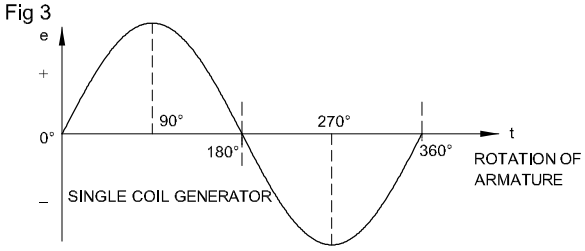
Fig 2



WAVE-FORM SHOWS COIL ROTATES UNDER UN-UNIFORM MAGNETIC FIELD

However, if the magnetic field is uniform, the output wave-form will be of sinusoidal shape as shown in Fig 3.

Fig 3



WAVE-FORM SHOWS COIL ROTATES UNDER UNIFORM MAGNETIC FIELD (SINE WAVE)

Simple generator with split-rings: A direct current generator is simply an AC generator provided with split rings instead of slip-rings.

The split ring is a ring made up of hard drawn copper cut into two segments, insulated from each other and the shaft in which it is mounted. A commercial generator uses a number of split rings called commutators. The split ring is a device for reversing the brush contact with the armature coil terminals, every time the induced current in the coil reverses, so that the output current taken by the brushes remains always in the same direction.

As shown in Fig 4a, if the armature rotates clockwise the split ring rotates with it, and the brushes and the poles are stationary in their position. As shown in Fig 4a, when the moving coil is in the horizontal position, the induced current will flow through the coil from ABCD to the segment `B' via the positive brush and load to the negative brush and segment A. The direction of current flow in the external circuit is shown in Figures 4a and c.

When the armature rotates so that the coil just assumes a vertical position as in Fig 4b, the brushes will short-circuit both the segments. The induced emf is zero and no current flows through the load circuit for a short moment.

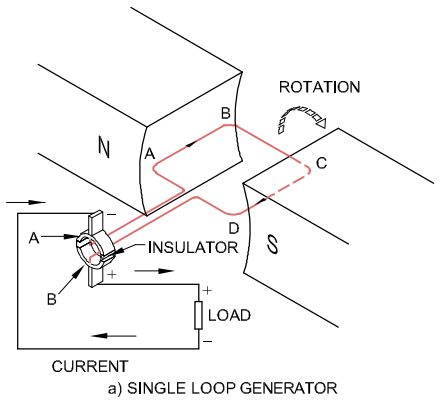
When the armature rotates and the coil assumes the position as indicated in Fig 4c, the coil side AB will enter the south pole region and its induced emf will reverse, compared to the direction it had while moving under the north pole region as shown in Fig 4a.

But when this happens the split ring segments `A' and `B' will also have exchanged their positions since they rotate along with the coil.

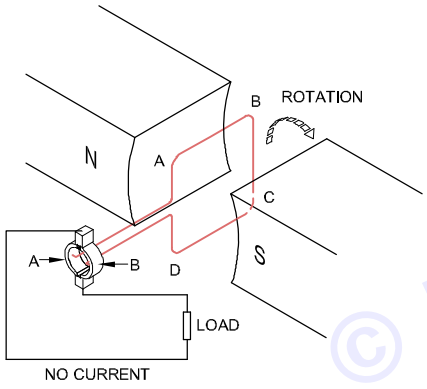
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As the emf in the coil sides AB and CD reverse their polarity, the split ring segments to which they are connected simultaneously change their positions under the stationary brushes. As a result, the polarity of the brushes remains fixed and the current direction through the load remains as shown in Fig 4c which is the same as shown in Fig 4a.

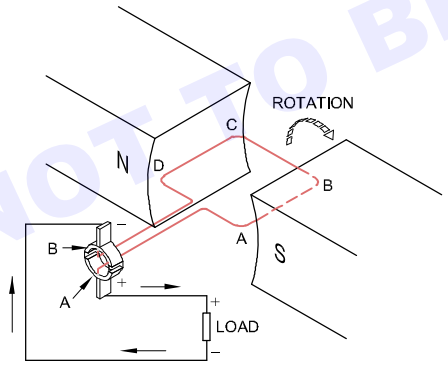
Fig 4



a) SINGLE LOOP GENERATOR



b) SINGLE LOOP GENERATOR



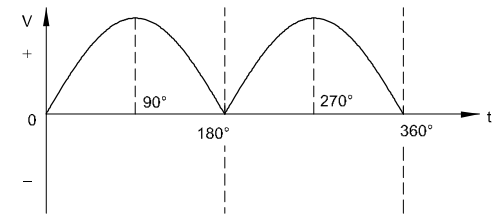
c) SINGLE LOOP GENERATOR

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Fig 5 represents the generated voltage of a simple DC generator. The voltage is uni-directional due to the split ring action.

The induced emf by a single loop (one turn) coil is very small in magnitude and pulsating in nature as shown in Fig 5. Coils, having a number of turns in series, multiply the generated emf by the same number. However to get a steady (DC) current it is necessary to increase the pulses produced in the armature; thereby their average value is constant.

Fig 5



VOLTAGE PRODUCED IN A LOOP UNDER UNIFORM MAGNETIC FIELD

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There are two ways to increase the number of pulses during each rotation of the armature.

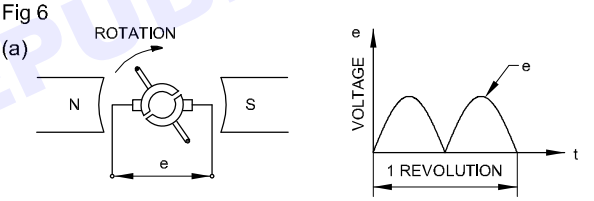
– Increase the number of field poles.

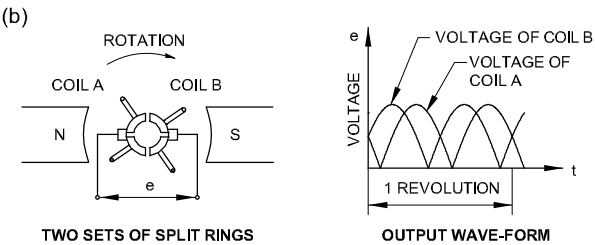
– Increase the number of separate coils (multi-coil) in the armature.

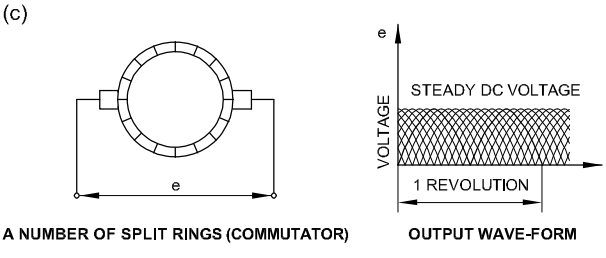
The multi-coils necessitate a multiple segment split-rings which is called a commutator.

Fig 6 represents the generated voltages and their wave shapes when the armature has different number of split rings, i.e. commutator segments. The practical generator will have more number of commutator segments as shown in Fig 6c, and the induced emf will be as shown in the adjoining graph.

Fig 6







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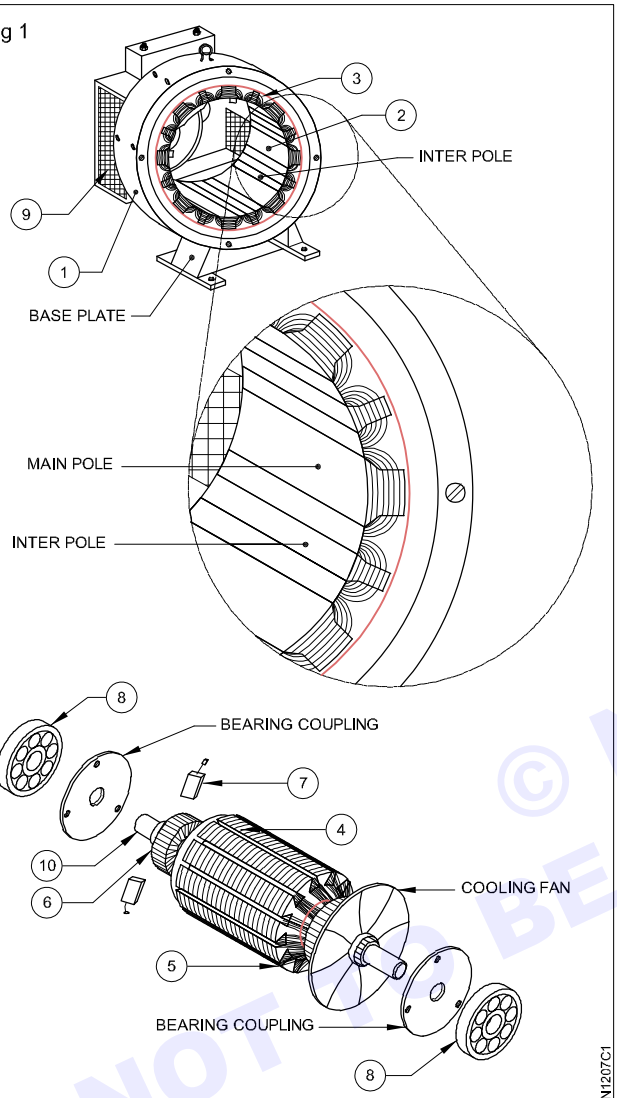
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Parts of a DC generator and their functions

Objectives: At the end of this lesson you shall be able to
- **describe the parts of a DC generator and their functions.**

A DC generator consists of the following essential parts as shown in Fig 1.

Fig 1



PARTS OF A DC MACHINE

1 Frame or yoke

2 Field poles and pole-shoes (Figs 3,4 & 5)

3 Field coils or field winding (Fig 6)

4 Armature core

5 Armature windings or armature conductors

6 Commutator

7 Brushes

8 Bearings and end plates (Figs 14 & 15)

9 Air filter for fan

10 Shaft

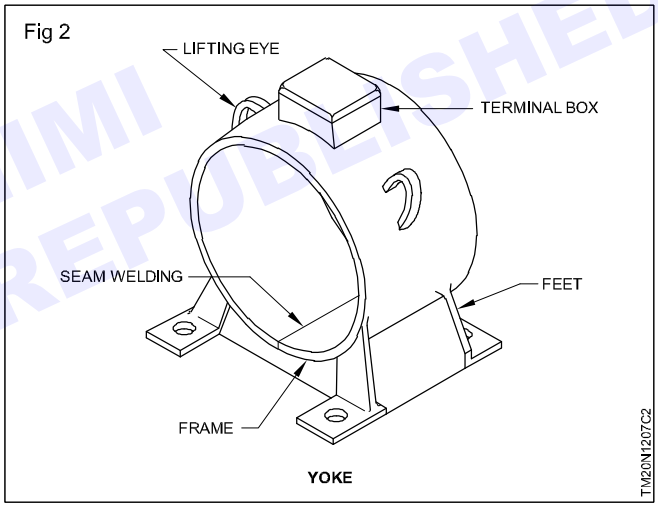
The yoke, the pole cores, the armature core and the air gaps between the poles and the armature core form the magnetic circuit, whereas the armature conductors, field coils, commutators, and brushes form the electrical circuit.

Yoke: The outer frame or yoke serves a dual purpose.

Firstly, it provides mechanical support for the poles and acts as a protecting cover for the whole machine as shown in Fig 1. Secondly, it allows the magnetic circuit to complete through it.

In small generators where cheapness rather than weight is the main consideration, yokes are made of cast iron. But for large machines usually cast steel or rolled steel is used. The modern process of forming the yoke consists of rolling a steel slab round a cylindrical mandrel, and then welding it at the seams. The feet, the terminal box etc. are welded to the frame afterwards as shown in Fig 2. Such yokes possess sufficient mechanical strength and have high permeability.

Fig 2



YOKE

Poles cores and pole shoes (Fig 3): The field magnets consist of pole cores and pole shoes. The pole shoes serve two purposes; (i) they spread out the flux in the air gap uniformly and also, being of a larger cross-section, reduce the reluctance of the magnetic path, and (ii) they also support the field coils.

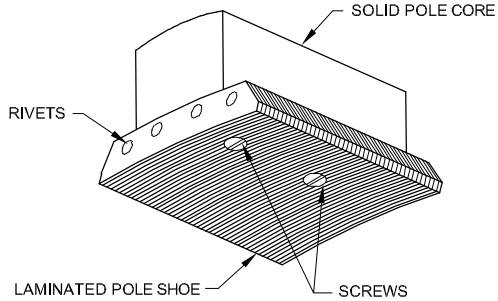
There are two main types of pole construction.

The pole core itself may be a solid piece made out of either cast iron or cast steel but the pole shoe is laminated and is fastened to the pole face by means of countersunk screws as shown in Fig 3.

In modern designs, the complete pole cores and pole shoes are built of thin laminations of annealed steel which are riveted together under hydraulic pressure. The thickness of laminations varies from 1mm to 0.25mm. The laminated poles may be secured to the yoke in any of the following two ways.

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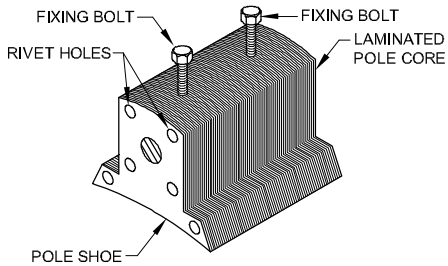
Fig 3



SEPERATE POLE SHOE BOLTED TO POLE CORE

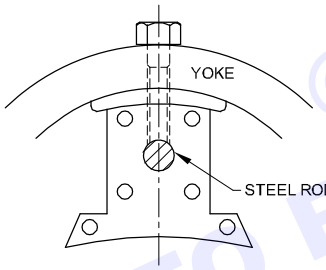
Either the pole is secured to the yoke by means of screws bolted through the yoke and into the pole body as in Fig 4 or holding screws are bolted into a steel bar which passes through the pole across the plane of laminations as in Fig 5.

Fig 4



LAMINATED POLE CORE

Fig 5



HOLDING SCREW BOLTED IN TO STEEL BAR POLE CORE ASSEMBLY

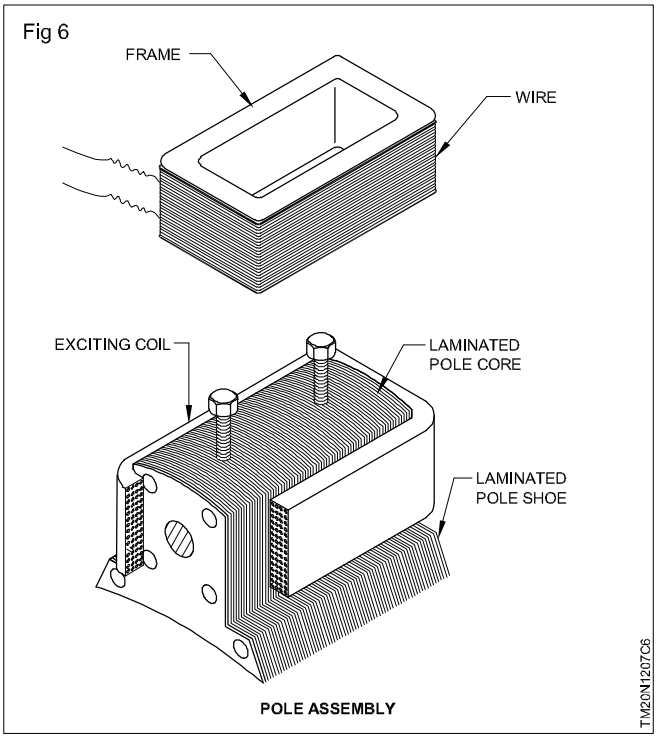
Pole coils (Field coils): The field coils or pole coils, which consist of copper wire or strip are former-wound for the correct dimension. Then the former is removed and the wound coils are put into place over the core as shown in Fig 6.

When a current is passed through the coils, they magnetise the poles which produce the necessary flux that is cut by revolving armature conductors.

Both thick gauge wire winding (series) and thin gauge winding (shunt) are wound, one over the other with separate insulations, and the terminals are brought out separately.

Armature core: The armature core houses the armature conductors and rotate in the magnetic field so as to make the conductors to cut the magnetic flux. In addition to this, its most important function is to provide a path of very low reluctance to the field flux, thereby allowing the magnetic circuit to complete through the yoke and the poles.

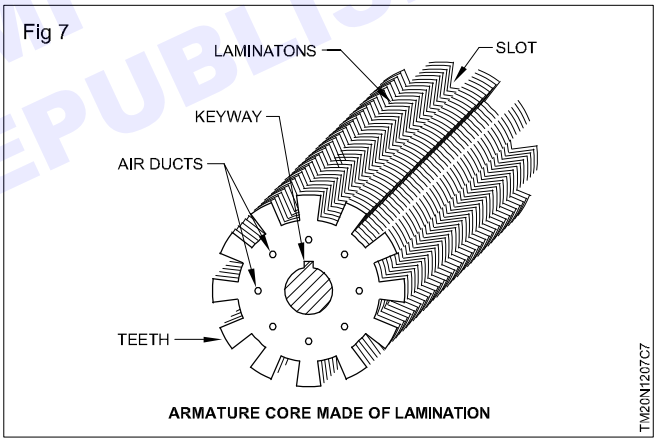
Fig 6



POLE ASSEMBLY

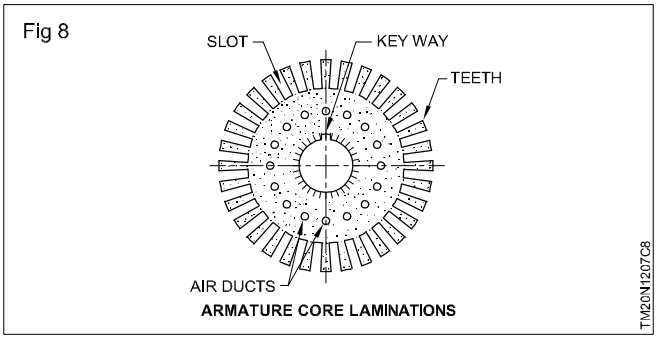
The armature core is cylindrical or drum-shaped as shown in Fig 7, and is built up of circular sheet steel discs or laminations approximately 0.5mm thick as shown in Fig 8.

Fig 7



ARMATURE CORE MADE OF LAMINATION

Fig 8



ARMATURE CORE LAMINATIONS

The slots are either die-cut or punched on the outer periphery of the disc and the keyway is located on the inner diameter as shown. In small machines, the armature stampings are keyed directly to the shift. Usually these laminations are perforated for air ducts which permit axial flow of air through the armature for cooling purposes.

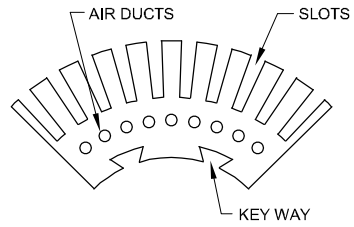
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Such ventilating holes are clearly visible in the laminations shown in Figs 7,8 and 9.

Up to armature diameters of about one metre, the circular stampings are cut out in one piece as shown in Fig 8. But above this size, these circles, especially of very thin sections, are difficult to handle because they tend to distort and become wavy when assembled together. Hence, the circular laminations, instead of being cut out in one piece, are cut in a number of suitable sections of segments which form part of a complete ring.

A complete circular lamination is made up of four or six or even eight segmental laminations. Usually, two keyways are notched in each segment and are dovetailed or wedge-shaped to make the laminations self-locking in position as shown in Fig 9.

Fig 9



SEGMENTAL LAMINATION

The purpose of using lamination is to reduce the loss due to eddy currents. Thinner the laminations are, greater the resistance offered against eddy current loss.

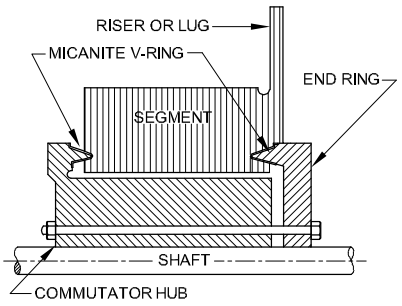
Armature windings: The armature windings are usually former-wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape with a coil puller. Various conductors of the coils are insulated from each other. The conductors are placed in the armature slots which are lined with tough insulating material. After placing the conductors in the slot, this slot insulation is folded over the armature conductors, and is secured in place by special, hard, wooden or fibre wedges.

Commutator: The function of the commutator is to facilitate collection of current from the armature conductors. It rectifies i.e. converts the alternating current induced in the armature conductors into uni-directional current for the external load circuit. It is of cylindrical structure and is built up of wedge-shaped segments of high conductivity, hard-drawn or drop-forged copper. These segments are insulated from each other by thin layers of mica. The number of segments is equal to the number of armature coils.

Each commutator segment is connected to the armature conductor by means of a copper lug or riser. To prevent them from flying out under the action of centrifugal forces, the segments have V-grooves, these grooves being insulated by conical micanite rings. A sectional view of a commutator is shown in Fig 10, whose general appearance when assembled is shown in Fig 11.

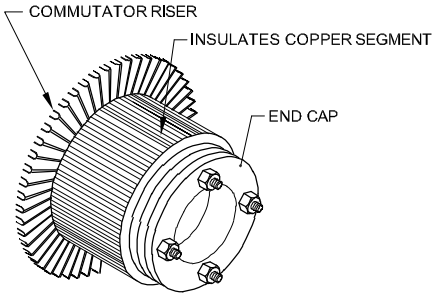
Brushes: The brushes whose function is to collect current from the commutator are usually made of carbon and graphite and are in the shape of a rectangular block.

Fig 10



SECTIONAL VIEW OF COMMUTATOR

Fig 11

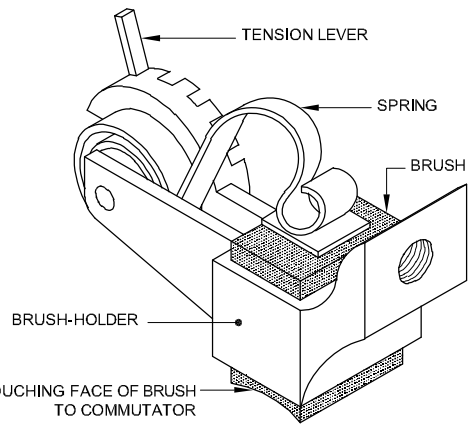


COMPLETE ASSEMBLY OF COMMUTATOR

These brushes are housed in brush-holders, shown in Fig 12, which have a box-holder for the brush, a spring to maintain the brush tension and a hole to fix the holder to the rocker arm. The brushes can slide in the rectangular box, open at both ends. The brushes are made to bear down on the commutator by a spring whose tension can be adjusted by changing the position of the tension lever in the notches. A flexible, copper pigtail mounted at the top of the brush conveys the current from the brushes to the holder. The number of brushes per spindle depends on the magnitude of the current to be collected from the commutator.

Brush-rocker: The spindle is used to have a number of brushes connected in a large machine. There may be only two brushes for a small machine. All the spindles are insulated and attached to the brush rocker.

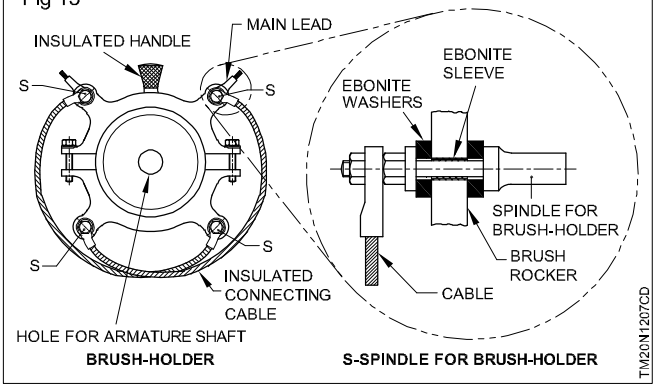
Fig 12



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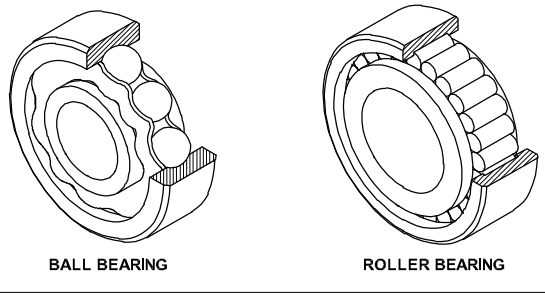
The brush-rocker may either be supported by a bearing cover in a small machine or by brackets attached to the yoke as shown in Fig 13. The brush position to the neutral axis can be set by changing the position of the brush-rocker.

Fig 13



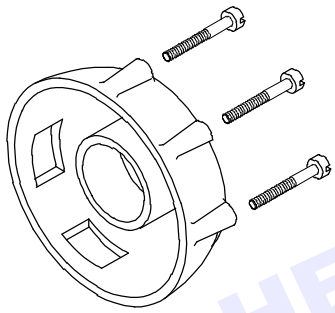
Bearings (Fig 14): Because of their reliability, half-bearings are frequently employed, though for heavy duties roller bearings are preferable. The ball and rollers are generally filled with hard oil for quieter operation and for reduced bearing wear. When sleeve bearings are used, these are lubricated by ring oilers fed from an oil reservoir in the bearing bracket.

Fig 14



End plates (Fig 15): The bearings are housed in these end plates, and they are fixed to the yoke. They help the armature for frictionless rotation and to position the armature in the air gap of the field poles.

Fig 15



Types of DC generators

Objectives: At the end of this lesson you shall be able to
• classify and identify the different types of DC generators and their terminal markings.

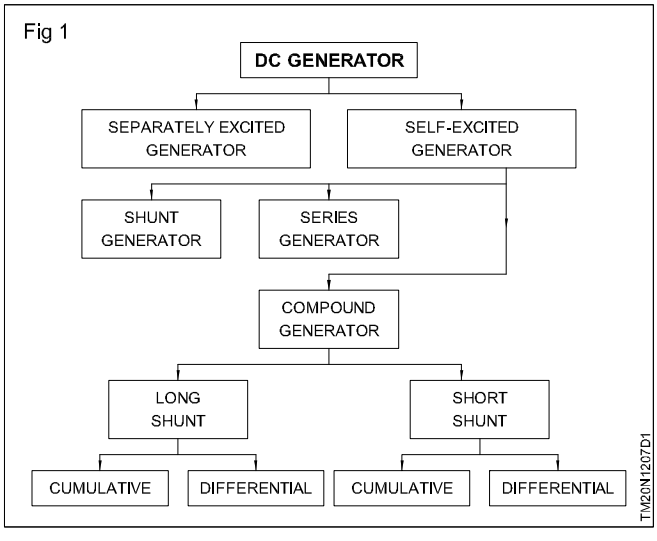
Types of DC generators: The type of a DC generator is determined by the manner in which the field excitation is provided. In general, the methods employed to connect the field and armature windings, fall into the following groups. (Fig 1)

Separately excited generator: The field excitation for a separately excited generator, shown in Fig 2, is supplied from an independent source, such as storage battery, separate DC generator or rectified DC supply from an AC source.

The field excitation voltage may be the same as that of generated (armature) voltage or may differ. Generally, the excitation voltage will be of low voltage, say 24, 36 or 48V DC.

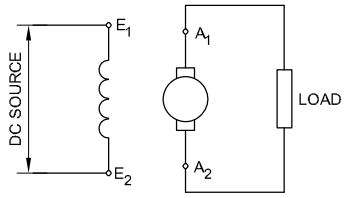
Self-excited generator: The field excitation is provided by its own armature. In this type of generators, initially the voltage is built up by residual magnetism retained in the field poles. Self-excited generators may be further classified as shunt, series and compound generators.

Fig 1



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Fig 2

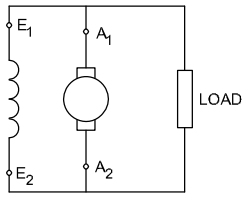


CONNECTION DIAGRAM OF SEPARATELY EXCITED DC GENERATOR

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Shunt generator: The field winding is connected to the armature terminals as shown in Fig 3. (i.e. shunt field winding is connected in parallel with armature winding). The shunt field contains many turns of relatively fine wire and carries a comparatively small current only which is a small percentage of the rated current of the generator.

Fig 3

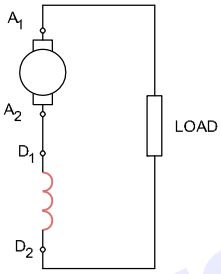


SHUNT GENERATOR

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Series generator: The field winding is connected in series with the armature winding as shown in Fig 4. The series field winding has a few turns of heavy wire. Since it is in series with the armature it carries the load current.

Fig 4



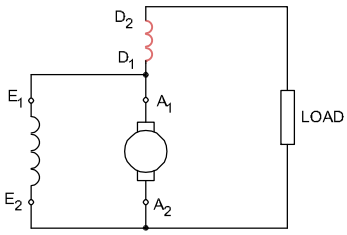
SERIES GENERATOR

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Compound generator: The field excitation is provided by a combination of shunt and series field windings.

Short-shunt compound generator: This is a generator in which the shunt field is directly across the armature as shown in Fig 5.

Fig 5

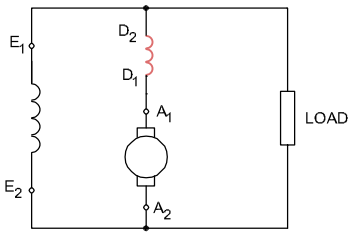


SHORT SHUNT COMPOUND GENERATOR

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Long-shunt compound generator: This is a generator in which the shunt field is connected after the series field as shown in Fig 6.

Fig 6

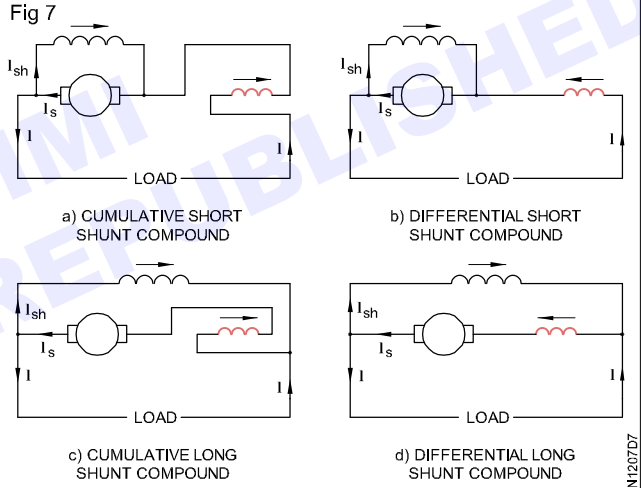


LONG SHUNT COMPOUND GENERATOR

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Differential and cumulative compound generator: The compound generators can also be further classified as cumulative and differential. In cumulative compound generators the magnetising forces of the shunt and the series field ampere-turns are cumulative, i.e. they both tend to set up flux in the air gap in the same direction. However, in case the ampere turns of the shunt winding oppose those of the series winding, the machine is said to be differentially compound would generator. Both the types are shown in Fig 7.

Fig 7



TYPES OF DC COMPOUND GENERATORS

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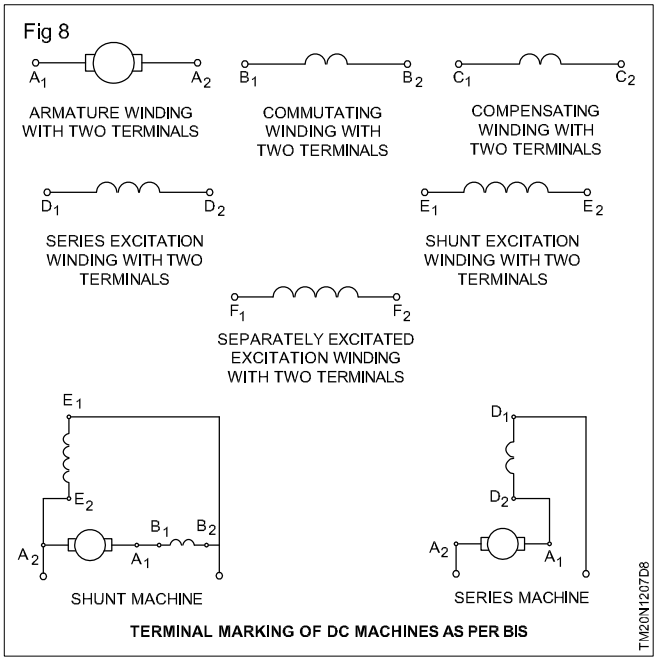
Terminal markings: As per BIS 4718-1975 the terminal markings for DC commentator machines shall be according to the marking principles stated below.

– Windings are distinguished by capital letters.

– End points and intermediate points of windings are distinguished by a numerical suffix.

– Winding letters for DC windings are chosen from the earlier part of the alphabet. (Fig 8)

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Methods of measuring the speed of a rotating shaft

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

- **describe the method of measuring speed by the**
  - **revolution counter and stopwatch**
  - **tachometer**
  - **stroboscopic method.**

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Measurement of speed: Speed is defined as a scalar quantity. Electricians must know how to measure the speed of rotating electrical machines. The speed of rotating machines is measured in two ways.

– Direct method (contact method)

– Indirect (non-contact) method

In practice both the methods are being used by electricians.

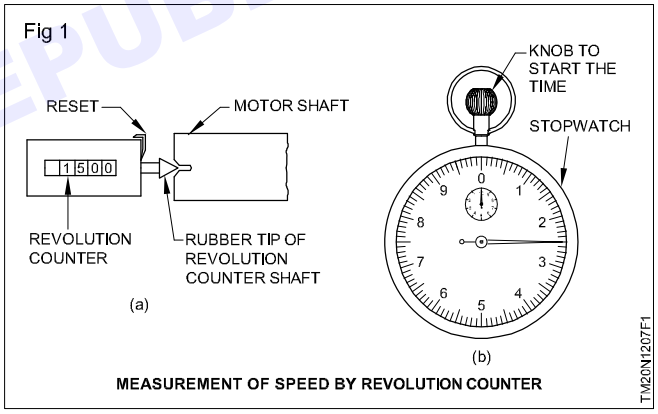
In the direct method two types of instruments as stated below are used for measuring speeds.

– Revolution counter and stopwatch

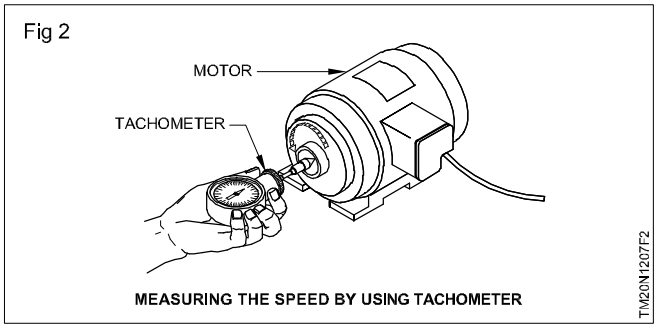
– Tachometer

Revolution counters: Revolution counters are of two types; one is a dial type counter, which is an earlier version and has become obsolete. The other type is a digital counter which is shown in Fig 1a. The spindle of the counter which is provided with a conical rubber bush is placed in the countersunk portion of the machine shaft for measuring speed. The revolution counter counts the number of revolutions as long as its rubber brush is in contact with the shaft. To get the revolution per minute, it is necessary to have a timing device.

Hence to measure the speed of the rotating shaft with the revolution counter, a stopwatch is also necessary. Just when the rotation of the shaft speed is transferred through friction to the counter, the stopwatch begins to tick. Both the revolution counter and the stopwatch are stopped at the same time and the number of revolutions indicated in the counter per minute gives the speed of the shaft in r.p.m. The accuracy of this method is not very great, as human reflexes are involved.



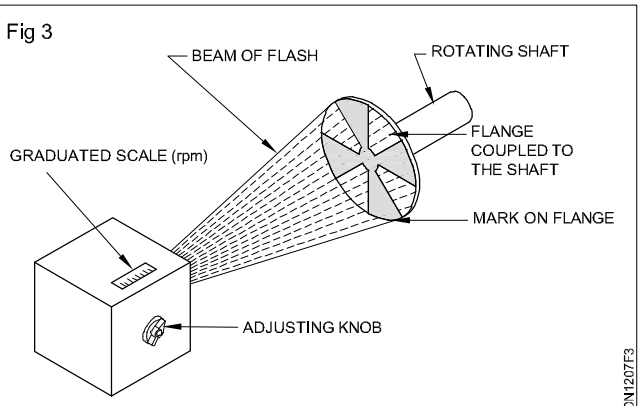
The second instrument used for direct measurement of speed is a tachometer as shown in Fig 2. The speed is directly shown by a needle over a calibrated dial.



The tachometer is used in the same way as that of the revolution counter except that a stopwatch is not required.

Stroboscope: A device for observing moving bodies by making them visible intermittently, and, thereby, giving them the optical illusion of being stationary, is called a stroboscope. To make this principle clear, let us say a mark is made at one point on a rotating shaft and a light is made to flash over the mark. If the time of moving the mark once around, and the gap between two consecutive flashes are the same, then the mark appears to be stationary, and, thereby the shaft appears to be stationary. Fig 3 shows the stroboscope and its light rays falling on a sectionized disc fitted on the rotating shaft.

Fig 3



STROBOSCOPE

The flashing light rays can be varied up to 50,000 flashes per second. The rate of flashing is controlled by a variable frequency electronic oscillator, calibrated for speeds in r.p.m.

While measuring speeds with this instrument, the rate at which the lamp flashes is varied until the sectionized disc, fitted on the shaft, appears to be stationary. The speed in r.p.m. can be read on the oscillator for that particular setting of the flash rate. This instrument is used for speed measurement in small torque motors like precision tool motors, tape recorder motors etc. where direct contact type, speed measurement will load the motors and change their speed.

As the stroboscope makes the rotating part to appear stationary, the operator should always be careful not to touch the shaft.

Separately excited DC generator

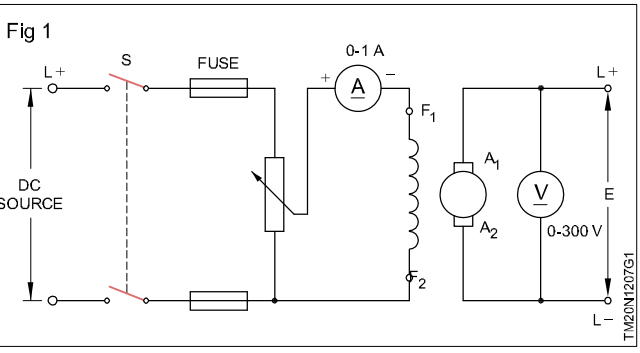
Objectives: At the end of this lesson you shall be able to

- **analyse the magnetisation characteristic of a separately excited generator**
- **explain the reasons for not building up voltage in a separately excited DC generator**
- **analyse load characteristics of a separately excited DC generator**
- **state the advantages of the separately excited generator over the self-excited DC generator.**

Introduction

A DC generator is the most commonly used separately excited generator, used for electroplating and battery charging. A separately excited generator is one in which the magnetic field is excited from an external DC source. The DC source may be a DC generator or a battery or a metal rectifier connected to an AC supply. Generally a potential divider is connected across the DC source, and the required DC voltage is supplied to the field as shown in Fig 1.

Fig 1



An ammeter is connected in the field circuit to measure the field current. The shaft of the generator is coupled to a prime mover. (Not shown in Fig 1)

Magnetisation characteristic: This characteristic gives the relation between the field flux and the induced voltage in a generator. However, it is difficult to measure the field flux, and, hence, the field current is taken instead of the field flux. The characteristic curve is drawn by keeping the field current in the `X' axis and the induced emf in the `Y' axis. To draw the characteristic curve, the connections are made as shown in Fig 1, and then, the prime mover is started and made to run at its rated speed, keeping the field switch `s' open. The terminal voltage which appears at the armature terminals is measured and recorded. This small voltage E_r is known as residual voltage which is due to the residual magnetism available in the field cores.

Throughout the experiment, the speed of the generator is held constant. Next, the field switch `S' is closed keeping the potential divider at its minimum position, and gradually the field current is increased in steps. For each step, the field current and the corresponding voltage at the armature terminals are noted. The readings are tabulated in Table 1.

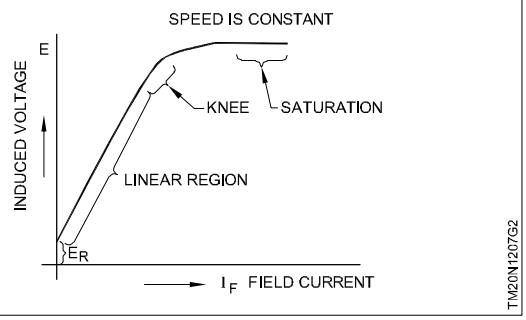
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Table 1

Sl.No.	Field current	Terminal voltage

If a graph is plotted between the field current and the terminal voltage, the curve will be as shown in Fig 2. The field current is taken on the X-axis and the emf E on the Y-axis. The curve drawn is known as the magnetisation characteristic of a separately excited generator.

Fig 2



A study of the curve indicates that it starts just above the origin, travels straight in the linear region indicating that the emf induced is directly proportional to the field current I_f.

As the poles are in the process of saturation, the relation between the terminal voltage and the field current no longer stands in direct proportion as indicated by the knee portion of the curve.

Finally when the poles get fully saturated the induced emf ceases to increase even at the increased field current which is indicated by the last portion of the curve and named as saturation region.

Reasons for not building up of voltage in a separately excited generator and their remedies

Sometimes a separately excited generator may not build up voltage. The probable reasons and remedies thereof are given in Table 2.

Load characteristic of a separately excited generator: The load characteristic shows the relation between the load current and the terminal voltage. Through this characteristic curve, we can determine the behaviour of the generator on load.

Table 2

Reasons	Remedies
A break or opening in the armature or field circuit.	Test the field and armature circuits for open circuit. Locate the fault and rectify.
A short circuit in the armature or field.	Test the field and armature for short circuit. Locate the fault and rectify.
Loose brush connections or loose brush contact.	Tighten the brush connections. Check up the brush tension. Adjust, if necessary. If the brushes are worn out, replace them.
A dirty or severely pitted commutator.	Clean the commutator for dirt, dust and greasy material. Use trichloroethylene. If the segments are pitted, dress them up.
The speed is too low.	Increase the speed of the generator to its rated speed.
The DC supply for excitation is absent.	Check the DC supply across the field winding terminals. If the supply is not there, check the supply source and rectify the fault Where AC main supply is converted as DC supply through rectifiers, the fault may be located in the rectifier circuit.

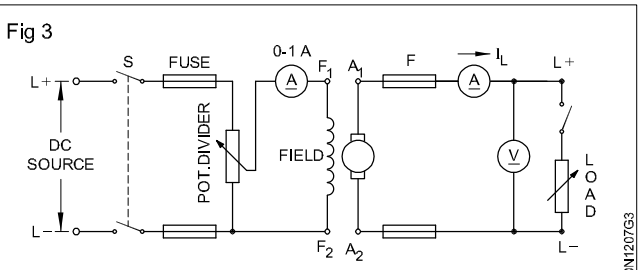
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Fig 3 shows the method of connecting the separately excited DC generator to obtain the load characteristic. The generator speed should be brought to the rated value with the help of the prime mover and the voltage is built up to its normal rated voltage. Then the load switch is closed. Gradually the load is increased in steps. Each time, the load current I_L in amps and the corresponding terminal voltage `V' in volts are noted. The readings are tabulated in Table 3.

Table 3

Sl.No.	Loadcurrent I_L in amps	Terminal voltage in volts

Fig 3

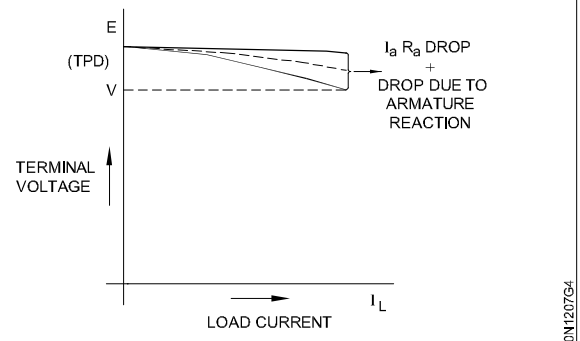


SEPARATELY EXCITED DC GENERATOR

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The graph shown in Fig 4 is the load characteristic or external characteristic of a separately excited generator having load current in the X axis and terminal voltage in the Y axis.

Fig 4



EXTERNAL CHARACTERISTIC OF A SEPARATELY EXCITED DC GENERATOR

TM20N1207G4

It is observed from the graph that a slight voltage drop occurs when the generator is loaded. This is due to the armature voltage drop (I_aR_a) and armature reaction.

If the voltage drop from no load to full load is very small, the separately excited DC generator can be regarded as a constant voltage generator.

Advantages of a separately excited generator

The terminal voltage remains almost stable when compared to the self-excited generators because the field circuit is independent of the induced voltage.

As the field is independent, the I_aR_a drop in the armature will not affect the field flux.

This generator can be used where a wide range of terminal voltage is required.

Disadvantage

The disadvantage of a separately excited generator is the inconvenience of providing a separate DC source for excitation.

Besides it is expensive.

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Testing of D.C machine for continuity and insulation resistance

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

- **state the necessity of measuring the insulation resistance of an electrical machine**
- **state the frequency of tests**
- **state the required conditions for the tests**
- **state the reasons for the low value of insulation resistance in the machines**
- **state the method of improving the insulation resistance of DC machines.**

Necessity of measuring insulation resistance: The most important aspect in the maintenance of DC machines is taking care of the insulation. Electrical insulation of DC machine windings is designed for the satisfactory operation at the specified voltage, temperature and to retain the electrical and mechanical strength and the dimensional stability over many years of operation. The insulation resistance of DC machines in service should be checked periodically, preferably every month. The possibility of reduction in the value of insulation resistance is due to the continuous working of the machine under full load condition, the heat generated in the winding and local atmospheric moisture, dust and dirt. If they are not checked in time, the insulation becomes weak and the winding will loose its dielectric property, and will ultimately lead to failure of the machine. Periodical checks and measurement of insulation resistance and improvement thereof to the required level will ensure prevention of failure of insulation, and thereby, the breakdown of the machine.

A common device for measuring insulation resistance is a direct indicating insulation tester or Megger. The measurements are made at voltages 500/1000 volt DC depending upon the voltage rating of the machine.

Measurement of insulation resistance: Insulation resistance shall be measured between the winding and frame (earth), and between windings.

For low and medium voltage rated machines, the insulation resistance, when the high voltage test is applied, shall not be less than one megohm as per B.I.S. 9320 - 1979. The insulation resistance shall be measured with a DC voltage of about 500 V applied for a sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.

When it is required to dry out windings at site to obtain the minimum value of insulation resistance, it is recommended that the procedure for drying out as specified in IS:900-1965 may be followed.

Frequency of test: Periodical checks or tests are predetermined in preventive maintenance programmes with a forethought. The planning of the preventive maintenance (PM) schedule should be based on the past experience of maintenance personnel, and the recommendations made by the machine manufacturer. Usually the measurement of insulation resistance is a

must during the period of overhauls. The duration of overhaul will be once in 6 months, ideal for DC machines where they are working continuously. Overhauling is done once a year, for such of those machines as are not working continuously. The overhauling is done during plant shut-down periods.

However in DC machines where the overhaul interval is too long, or delayed, it is advisable to have constant vigil and check the insulation resistance at least once a month regularly, and maintain a record of the values of the insulation resistance tests as shown in Table 1.

Required conditions for test: The high potential dielectric test and the insulation resistance test are the principal methods of evaluating insulation capability and condition of the machine. The insulation resistance test is often used as a measure of the condition of the winding. Insulation resistance is the ratio of the applied voltage to the leakage current which passes in the circuit at some specified time after the voltage is applied. Direct, rather, than alternating voltages are used for measuring insulation resistance.

Table 1

Insulation resistance test

Date	Time	Weather condition	Duty cycle	Test between terminals	Insulation resistance	Remarks

The principal currents affecting insulation resistance on application of the test potential for sufficient time are (1) leakage current over the winding surface (2) conduction in current through the insulation material and (3) absorption current in the insulation. The first two currents are steady with time, but the last current delays approximately exponentially from an initial high value. Such insulation resistance measurements are affected by surface conditions (dirt or moisture on the windings), moisture within the insulation wall and the insulation temperature. The magnitude of the test potential may also affect the insulation value, especially if the insulation is not in good condition. Therefore, it is desirable to use insulation resistance as a measure to determine the condition of the machine over a period of years, and to make readings under similar conditions each time and record the values in the test card of the machine in a table similar to Table 1. However, before testing the winding for insulation resistance, it is recommended that the continuity test should be conducted in the armature and field windings to ensure soundness of the respective circuits. As sometimes continuity tests will not reveal internal short circuits, resistance measurement test is recommended, and a record should be maintained for comparison at intervals.

Reasons for low value insulation resistance: The low value of insulation resistance in DC machines is due to excess heat developed in the winding due to their routine working with full load condition or overloading at times or frequent starting with loads. In addition to this, high ambient temperatures are also the reason for low insulation resistance. The other possibility is accumulation of unnecessary local dust and dirt, carbonisation due to brush, local atmospheric moisture, acids and alkalies present in the surroundings of the machine etc. All these are collectively or individually responsible for the weakening of insulation resistance of the winding. Because of these conditions the dielectric property of the insulating material gets reduced, which, in turn, results in low or poor insulation resistance, responsible for the breakdown of the winding due to insulation failure.

Method of improving insulation resistance: On identifying the weak insulation resistance, during the course of preventive maintenance observation in a DC machine, it is necessary to improve the insulation resistance to restore it to a safe value.

Improvement of insulation resistance could be done by any one of the following methods after cleaning the dust and dirt from the machinery.

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– By blowing hot air through the machines.

– By heating the machine with carbon filament or incandescent lamps.

– By dismantling and varnishing the winding of the machine.

The following steps are to be adopted for dismantling and varnishing.

– Measure the insulation resistance value between the windings and the frame of the machine and record the value.

– Mark and dismantle the machine.

– Remove dirt and dust in the field winding by blowing dry air with the help of an electric blower.

– Clean and remove dirt, dust and carbon on the armature with special attention to the commutators.

– Clean the brushes, brush-holders and rocker arms.

– Measure the insulation resistance of the winding with an insulation tester; note the values.

– Heat and dry the field coils and armature by external measures.

– Apply insulating varnish of air-drying type to field coils and armature conductors.

– Dry the varnish coating on field coils and armature by external means.

– Measure the insulation resistance and note the improved value of insulation resistance.

– Assemble the machine.

– Measure the insulation value between the windings and the frame of the machine; record the values. Compare these results with those of the first step and make sure the present value shows improvement.

– Connect the machine to the system and run it to check its normal working condition.

Reference: BIS 9320-1979.

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D.C Motors - principle - types - starters maintenance - characteristics - applications trouble shooting

Objectives: At the end of this lesson you shall be able to
- **explain the working principle of a DC motor - action of the current - carrying conductor in the magnetic field and Fleming's left hand rule**
- **state the different types of DC motors.**

Introduction: A DC motor is a machine which converts DC electrical energy into mechanical energy. It is similar to a DC generator in construction. Therefore, a DC machine can be used as a generator or as a motor. Even today, because of the excellent torque, speed and load characteristics of DC motors, 90% of the motors used in precision machines, wire drawing industry and traction are of this type. The DC motor needs frequent care and maintenance by qualified electricians. Hence more job opportunities exist in this area for an electrician.

Principles of a DC motor: It works on the principle that whenever a current-carrying conductor is kept in a uniform magnetic field, a force will be set up on the conductor so as to move it at right angles to the magnetic field. It can be explained as follows. Fig 1a shows the uniform magnetic field produced by a magnet, whereas Fig 1b shows the magnetic field produced around the current-carrying conductor. Combining the effects of Fig 1a and Fig 1b in one figure, Fig 1c shows the resultant field produced by the flux of the magnet and the flux of the current-carrying conductor. Due to the interactions of these two fields, the flux above the conductor will be increased and the flux below the conductor is decreased as represented in Fig 1c. The increased flux above the conductor takes a curved path thus producing a force on the conductor to move it downwards.

Fig 1

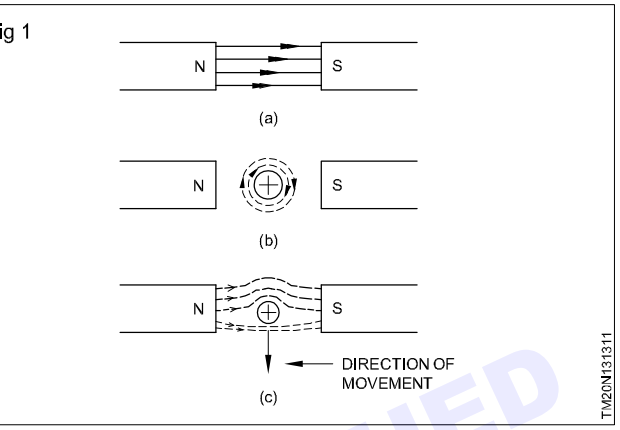
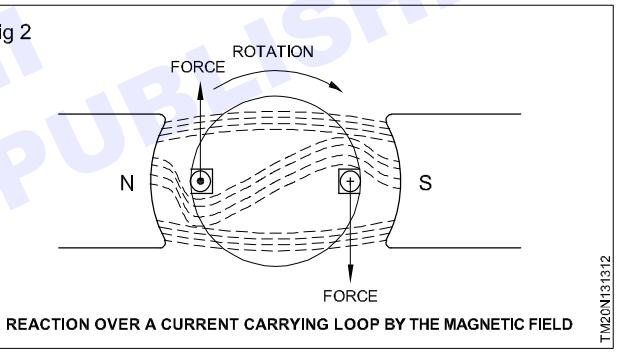


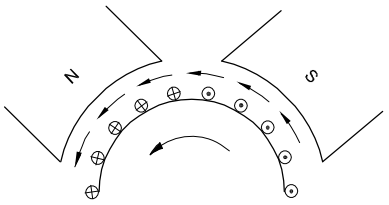
Fig 2



REACTION OVER A CURRENT CARRYING LOOP BY THE MAGNETIC FIELD

If the conductor in Fig 1 is replaced by a loop of wire as shown in Fig 2, the resultant field makes one side of the conductor move upwards and the other side move downwards. It forms a twisting torque over the conductors, and they tend to rotate, if they are free to rotate. But in a practical motor, there are a number of such conductors/ coils. Fig 3 shows the part of a motor. When its armature and field are supplied with current, the armature experiences a force tending to rotate in an anticlockwise direction as shown in Fig 3.

Fig 3



REACTION OVER THE ARMATURE CURRENT CARRYING CONDUCTORS BY THE MAGNETIC FIELD

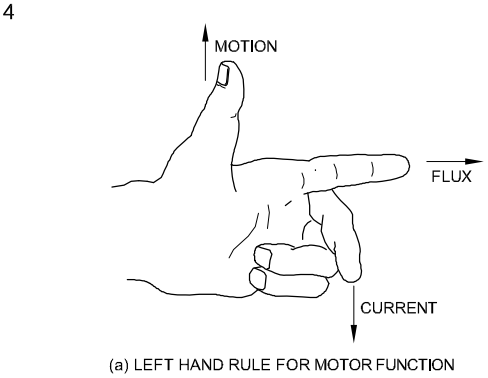
The direction of rotation or movement can be determined by Fleming's left hand rule. Accordingly, the direction of rotation of the armature could be changed either by changing the direction of armature current or the polarity of the field.

Fleming's Left Hand Rule: The direction of force produced on a current-carrying conductor placed in a magnetic field can be determined by this rule. As shown in Fig 4a, hold the thumb, forefinger and middle finger of the left hand mutually at right angles to each other, such that the forefinger is in the direction of flux, and the middle finger is in the direction of current flow in the conductor; then the thumb indicates the direction of motion of the conductor. For example, a loop of coil carrying current, when placed under north and south poles as shown in Fig 4b, rotates in an anticlockwise direction.

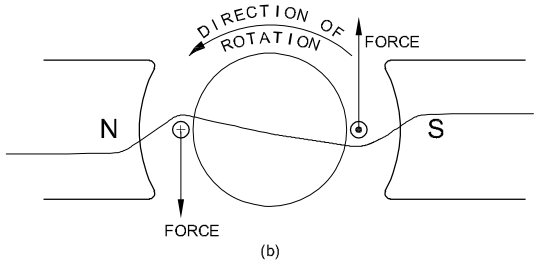
Types of DC motors: As the DC motors are identical in construction to that of DC generators, they are also classified as series, shunt and compound motors, depending upon their connection of field winding with the armature and supply.

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Fig 4



(a) LEFT HAND RULE FOR MOTOR FUNCTION



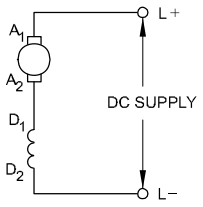
(b)

FLEMING'S LEFT HAND RULE

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When the armature and field are connected in series, as shown in Fig 5, it is called a series motor.

Fig 5

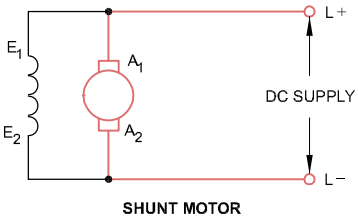


SERIES MOTOR

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When the armature and field are connected in parallel across supply, as shown in Fig 6, it is called a shunt motor.

Fig 6

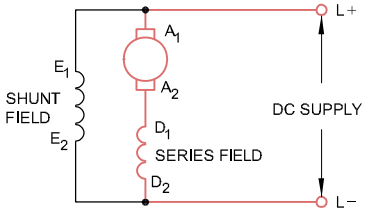


SHUNT MOTOR

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When the motor has two field coils, one in series with the armature and the other in parallel with the armature, as shown in Fig 7, it is called a compound motor.

Fig 7



COMPOUND MOTOR

TM20N131317

The relation between applied voltage, back emf, armature voltage drop, speed and flux of DC motor. method of changing direction of rotation.

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The relation between applied voltage, back emf, armature voltage drop, speed and flux of DC motor. Method of changing direction of rotation

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

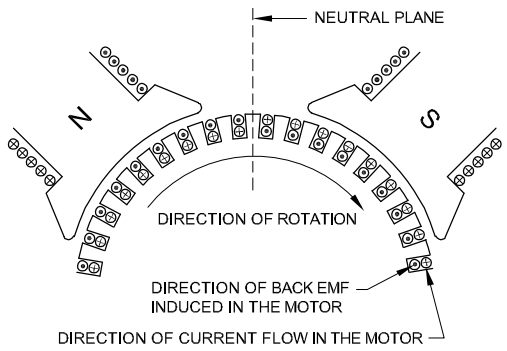
- **explain the relation between applied voltage, back emf, armature voltage drop - speed - flux**
- **describe the method of changing the direction of rotation of a DC motor.**

Back emf: As the armature of a DC motor starts rotating, the armature conductors cut the magnetic flux produced by the field poles. Due to this action, an emf will be produced in these conductors. The induced emf is in such a direction as to oppose the flow of current in the armature conductor as shown in Fig 1. As it opposes the supply voltage it is called `BACK EMF' and is denoted by E_b. Its value is the same as that found in the generator. It could be written as

$$E_b = \frac{\varnothing ZNP}{60A} \text{ volts}$$

The direction of the induced (back) emf could be determined by Fleming's right hand rule.

Fig 1



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Applied voltage: The voltage applied across the motor terminals is denoted by `V'.

Armature voltage drop: Since armature conductors have some resistance, whenever they carry current a voltage drop occurs. It is called I_aR_a drop because it is proportional to the product of the armature current I_a and armature resistance R_a. It has a definite relation with the applied voltage and back emf as shown by the formula

$V = E_b + I_aR_a$.

Alternatively, $I_aR_a = V - E_b$.

Further the back or counter emf E_b depends upon flux per pole 'Ø' and speed `N'. Therefore, the applied voltage, back emf, armature drop, flux and speed are related to one another as follows.

$$E_b = V - I_aR_a$$

$$\frac{\varnothing ZNP}{60A} = V - I_aR_a$$

$$\therefore N = \frac{(V - I_aR_a) \times 60A}{\varnothing ZP} \text{ rpm}$$

For a given motor ZPA and 60 are constants and can be denoted by a single letter K

$$\text{where } K = \frac{60A}{\varnothing ZP}$$

Therefore $N = K E_b/Ø$.

It shows that the speed of a DC motor is directly proportional to E_b and inversely proportional to the flux Ø.

Reversing the direction of rotation of DC motors: The direction of rotation of a DC motor can be changed either by changing the direction of the armature current or by changing the direction of the field current. The direction of rotation of a DC motor cannot be changed by interchanging the supply connections because this changes the direction of the field as well as the armature current. Its effect is as shown in Figs 2 and 3.

Fig 2

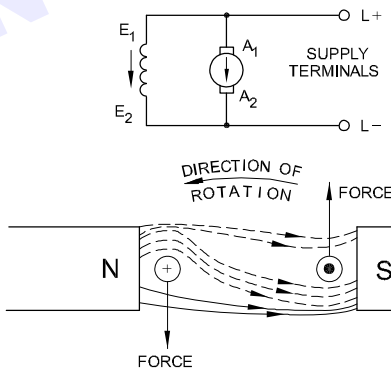
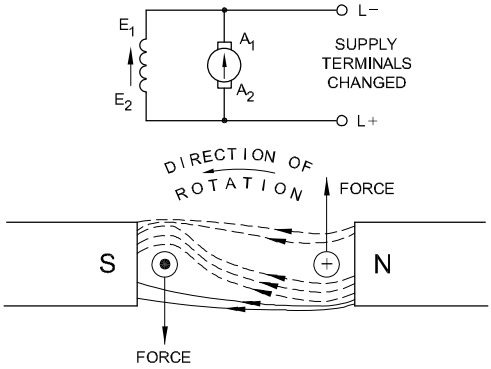


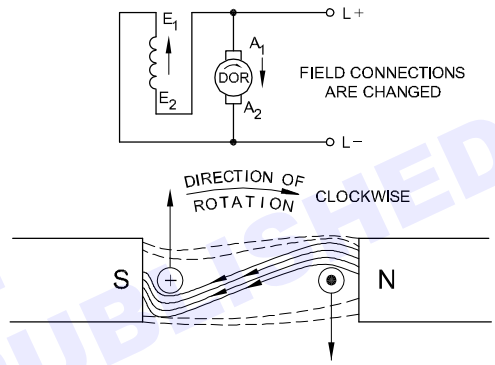
Fig 3



EFFECT OF CHANGING SUPPLY TERMINALS

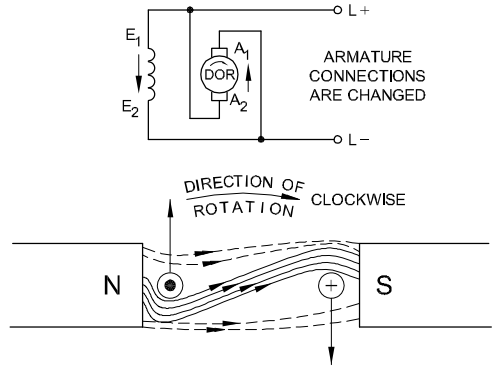
But when the field current direction alone is changed, the direction of rotation changes as shown in Fig 4. When the armature current direction alone is changed, the direction of rotation changes as shown in Fig 5.

Fig 4



EFFECT OF CHANGING THE FIELD CURRENT DIRECTION

Fig 5



EFFECT OF CHANGING THE ARMATURE CURRENT DIRECTION

To reverse the direction of rotation of a compound motor without changing its characteristics, the best method is to change only the armature current direction. In case, changing the direction of rotation needs to be done by changing the field terminals, it is essential to change the current direction in both the shunt and series windings. Otherwise, the machine, which was running as cumulatively compounded, will change its characteristic as differentially compounded or vice versa.

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DC Motor starters

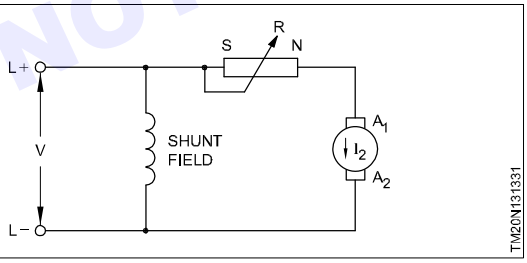
Objectives: At the end of this lesson you shall be able to
- **state the necessity of starter for a DC motor**
- **state the different types of starters - construction and working principle of 2-point, 3-point and 4-point starters.**

Necessity of starters: Since the armature is stationary before starting, the back emf which is proportional to speed is zero. As the armature resistance is very small, if the rated voltage is applied to the armature, it will draw many times the full load current, and thereby, there is every possibility of damaging the armature due to heavy starting current. Therefore, the starting current should be limited to a safe value. This is done by inserting a resistance in series with the armature at the time of starting for a period of 5 to 10 seconds. As the motor gains in speed, back emf is built up, and then the starting resistance could be gradually cut off. Fig 1 shows such an arrangement. Resistance R is fully included in the armature circuit by keeping the moving arm in position `S' at the time of starting, and then it is moved towards position `N' to exclude the resistance `R' when the motor has picked up its speed. But such an arrangement will be purely manual and needs constant monitoring. For example, if the motor is running, the resistance `R' will be excluded, and the moving arm position will be at position `N'. In case the supply fails, the motor will stop but the moving arm will still be in position `N'. When the supply returns, as there is no resistance included in the armature circuit through `R', the armature may draw heavy current and may get damaged. To prevent such a happening a device called starter is used in motor circuits.

In addition to the automatic inclusion of resistance at the time of starting, the starters may protect the motor from overload and will switch `off' the motor, when supply fails. These starters are named according to the number of connecting terminals as explained subsequently.

Types of starters: Starters used to start the DC motors are generally of three types.

Fig 1



– Two-point starter

– Three-point starter

– Four-point starter

Two-point starter: This contains the following components.

– The series resistor required for starting a motor.

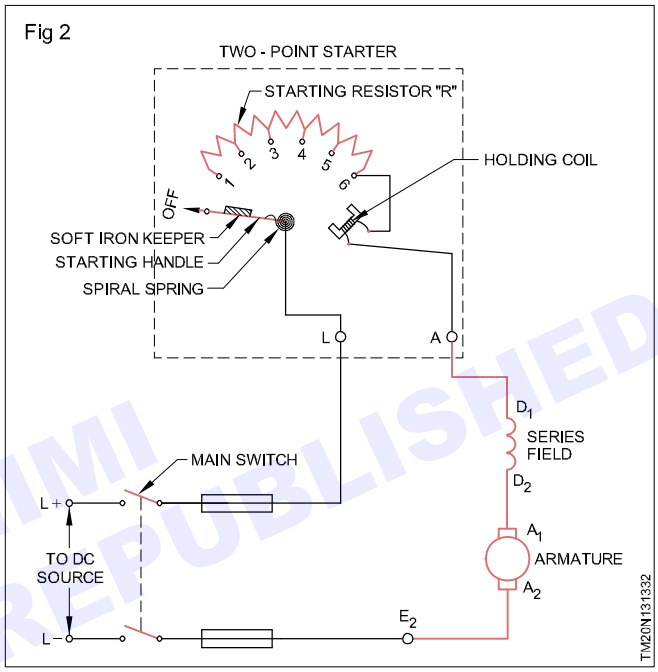
– The contacts (brass studs) and switching arm required to include or exclude the resistor in the armature circuit.

– A spring on the handle to bring the handle to the `OFF' position when supply fails.

– An electromagnet to hold the handle in the `ON' position.

The two-point starter is frequently used with a DC series motor. The starting resistance, electromagnet armature and the series field are all connected in series as shown in Fig 2.

Fig 2



When the arm is moved to the first contact point, the circuit is completed, and the armature begins to rotate. As the armature speed increases, the arm is slowly moved towards the right side electromagnet, thereby the starter resistance is reduced. When the arm is against the electromagnet, complete starter resistance is cut off from the circuit.

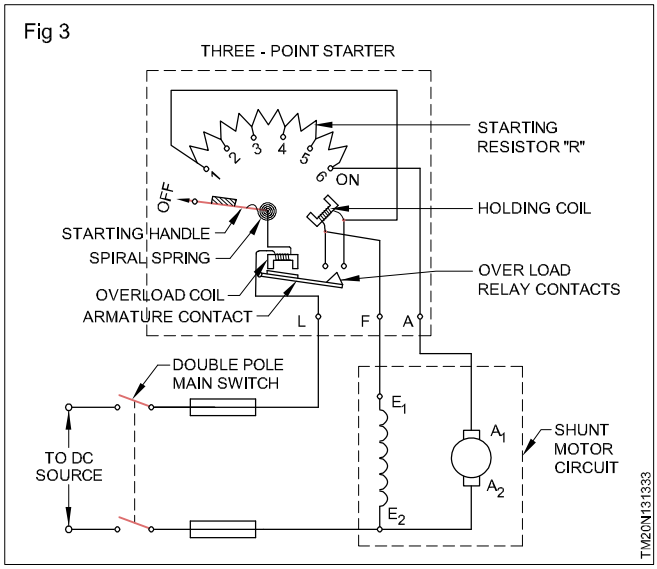
The electromagnet is wound with a thick gauge wire to carry the rated armature current of the motor. This holds the handle in the `ON' position when the motor is working. The handle comes back to the `OFF' position, due to spring action when the electromagnet demagnetises due to failure of supply. This starter in general will not have protection against overloads.

Three-point starter: Fig 3 shows the internal diagram of a three(terminal) point starter connected to a DC shunt motor. The direct current supply is connected to the starter, the motor circuit through a double pole switch and suitable fuses. The starter has an insulated handle or knob for the operator's use. By moving the starter handle from the `off' position to the first brass contact (1) of the starter, the armature is connected across the line through the starting resistance. Note that the armature is in series with the total starting resistance. The shunt field, in series with

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the holding coil, is also connected across the line. In this mode of operation, the rush of the initial current to the armature is limited by the resistance. At the same time, the field current is at the maximum value to provide a good starting torque.

Fig 3



As the handle arm is moved to the right, the starting resistance is reduced and the motor gradually accelerates. When the last contact is reached, the armature is connected directly across the supply; thus, the motor is at full speed.

The holding coil is connected in series with the shunt field to provide a `no-field release'. If the field circuit opens by accident, the motor speed will become excessive should the armature remain connected across the line. To prevent this increase in speed, the holding coil is connected in series with the field. In case of an open circuit in the field, there will be no current through the holding coil, and hence, it will be demagnetized, and the spring action returns the arm to the `off' position.

An overload coil is provided to prevent damage to the motor from overload. Under normal load condition, the flux produced by the O/L coil will not be in a position to attract the armature contact. When the load current increases beyond a certain specified value, the flux of the O/L coil will attract the armature. The contact points of the armature then short-circuit the holding coil and demagnetize it. This enables the handle to come to the `OFF' position due to the tension of the spiral spring.

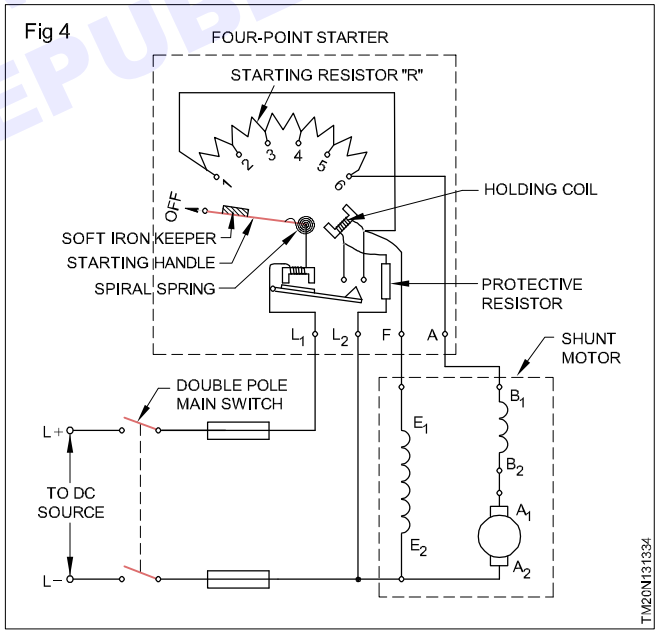
This type of starter can be used to start both shunt and compound motors.

However, a 3-point starter will be found to be tripping when the motor speed is controlled through the field regulator. The reason could be explained as stated below.

When the speed of a shunt or compound motor is to be increased beyond its rated speed, the resistance is increased in the field regulator to reduce the field current, and thereby, the field flux. While doing so, the holding coil which is in series with the field gets very low current and produces less holding force on the handle armature against the tension of the spiral spring. When the current reduces below a certain value, the handle is pulled out from the `ON' position to the `OFF' position. This is an undesirable effect. To avoid this, the 3-point starter circuit is modified, and the holding coil circuit is made independent of the field circuit. Such a starter is called a 4-point starter.

Four-point starter: In applications where many motor speeds are to be increased beyond their rated value, a four-terminal, face plate starter is used with the motor. The four(terminal) point starter, shown in Fig 4, differs from the three-point starter in that the holding coil is not connected in series with the shunt field. Instead, it is connected across the supply in series with a resistor. This resistor limits the current in the holding coil to the desired value. The holding coil serves as a no-voltage release rather than as a no-field release. If the line voltage drops below the desired value, the magnetic attraction of the holding coil is decreased, and then the spring pulls the starter handle back to the `off' position.

Fig 4



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Relation between torque, flux and armature current in a DC motor

Objectives: At the end of this lesson you shall be able to
- **explain the relation between torque, flux and armature current**
- **solve problems pertaining to metric HP; load current, rated voltage, torque and speed of DC motors.**

Relation between armature current, flux and torque

Torque: The turning or twisting moment of a force about an axis is called torque. It is equal to the product of force and the radius of the pulley.

Consider a pulley of radius `r' metres acts upon by a circumferential force `F' newton, and rotates at a speed of `n' r.p.s. as shown in Fig 1.

Then torque T = F x r newton-metres(N-m)

Work done by this force

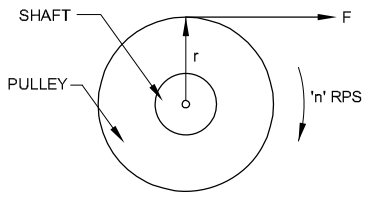
in one revolution = Force x distance

= F x 2pr joules.

Power developed in one second = F x 2pr x n joule/second or watts

= (Fxr)2pn watts

Fig 1



TORQUE PRODUCTION IN A MOTOR

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As 2pN is angular velocity w in radian/second and

(F x r) = Torque T

Power developed = T x w watts

P = Tw watts.

Torque of a motor: Let T_a be the torque developed by the armature of a motor in newton-metre and `n' the speed of armature in r.p.s.

Then the power developed in the armature = T_a 2pn watts.

As we know the electrical power is converted into mechanical power

Electrical power supplied to the armature = $E_b I_a$ where

E_b is the back emf

I_a is the armature current.

Electrical power supplied to the armature = Mechanical power developed in the armature

We get $E_b I_a = T_a 2pn$

Since $E_b = \frac{\varnothing ZnP}{A}$ volts (By taking `n' in r.p.s.)

$T_a \times 2pn = \frac{\varnothing ZnP}{A} \times I_a$

By cross multiplication we get

$$T_a = \frac{\varnothing ZP \times I_a}{2\pi A} \text{ Newton - metre}$$

$$\text{or } T_a = \frac{0.159\ \varnothing ZP}{A} \times I_a \text{ Newton - metre}$$

For a given motor. ZP and A are constants as they depend upon the design.

$\frac{0.159\ ZP}{A}$ can be regarded as constant 'K'

Then $T_a = K\varnothing I_a$

where Ø is the flux pole in weber

I_a is the armature current

$$K = \frac{0.159\ ZP}{A}$$

T_a is the armature torque in newton metres.

Therefore, we can say the torque of a DC motor is directly proportional to the field flux and the armature current.

The other formula which gives torque

$$T_a \text{ is } = \frac{9.55 \times E_b I_a}{N} \text{ Newton - metre}$$

where `N' is speed in r.p.m.

Shaft torque: The complete armature torque calculated above is not available for doing useful work because of the losses in the motor.

> **The torque which is available for doing work is known as shaft or output torque, and it is denoted as T_{sh}.**

The difference ($T_a - T_{sh}$) is known as loss of torque due to iron, friction and windage losses of motor.

$$\text{One H.P. metric} = \frac{2\pi n T_{sh}}{735.5} = \frac{2\pi N T_{sh}}{60 \times 735.5} \text{ HP}$$

where 'n' is the speed is in r.p.s., N is the speed in r.p.m.

and T_{sh} is the shaft torque in newton metre.

If the torque is given in kg. metre, it can be converted into newton metre as given below.

Newton metre = Kg. metre x 9.81

Example 1: A 250V, 4 pole, wave-wound DC series motor has 782 conductors in its armature. It has a combined armature and series field resistance of 0.75 ohms.

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The motor takes a current of 40 A. Estimate its speed, armature torque and H.P. if the flux per pole is 25 milli-weber.

$E_b = V - I_a R_a$

$= 250 - (40 \times 0.75)$

$= 250 - 30 = 220$ volts

Therefore, $E_b = \frac{\varnothing ZnP}{A}$ volts

$$N = \frac{E_b \times 60 \times A}{\varnothing ZP} = \frac{220 \times 60 \times 2}{25 \times 10^{-3} \times 782 \times 4}$$

$$= \frac{220 \times 60 \times 2 \times 10^3}{25 \times 782 \times 4} = 338 \text{ rpm.}$$

$$T_a = \frac{9.55 \times E_b I_a}{N} = \text{Nm}$$

$$T_a = \frac{9.55 \times 220 \times 40}{338} = 248.64 \text{ Nm.}$$

Assuming armature Torque T_a = Shaft torque T_{sh}

$$\text{Metric H.P.} = \frac{2\pi NT_{sh}}{60 \times 735.5} = \frac{2 \times 22 \times 338 \times 248.64}{7 \times 60 \times 735.5}$$

$= 11.97$ HP metric.

The torque is proportional to I_a and Ø. But Ø is constant for shunt motor T a I_a.

Therefore, T_{a1} a I_{a1} and T_{a2} a I_{a2}.

Therefore, $\frac{T_{a2}}{T_{a1}} = \frac{I_{a2}}{I_{a1}}$

As T_{a2} is double of T_{a1} we have $\frac{T_{a2}}{T_{a1}} = 2$

$$2 = \frac{I_{a2}}{I_{a1}} = \frac{I_{a2}}{50}$$

Therefore $I_{a2} = 50 \times 2 = 100$ amps.

$E_{b1} = V - I_a R_a$

$= 220 - (50 \times .2)$

$= 220 - 10 = 210$ volts

$E_{b2} = V - I_a R_a$

$E_{b2} = 220 - (100 \times .2)$

$= 220 - 20 = 200$ volts.

Now $= \frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}$

$= \frac{N_2}{500} = \frac{200}{210}$

Therefore, $N_2 \frac{200 \times 500}{210} = 476$ rpm.

Example 2: A 220V DC shunt motor runs at 500 r.p.m. when the armature current is 50A. It has an armature resistance of 0.2 ohm. Calculate the speed if the torque is doubled.

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Characteristics and applications of a DC series motor

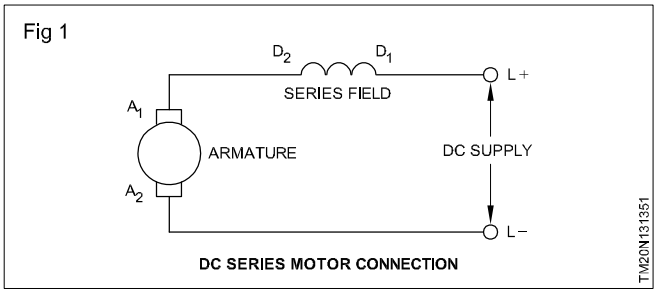
Objectives: At the end of this lesson you shall be able to

- **explain the characteristics of a series motor**
  - **torque versus load**
  - **speed versus load**
  - **speed versus torque**
- **state the uses of a DC series motor**
- **explain the method of changing the direction of rotation of a DC series motor**
- **state the method of loading the motor and explain the brake test.**

DC series motors: The DC series motor, like the DC series generator, has its field connected in series with the armature as shown in Fig 1. Due to this mode of connection, all the current that flows through the armature must also flow through the field, and hence, the field strength varies with the change in the load.

A DC series motor has a very high starting torque. In some motors, it may be as high as five times the full load torque. Further, the speed of the DC series motor also varies with the load.

Fig 1

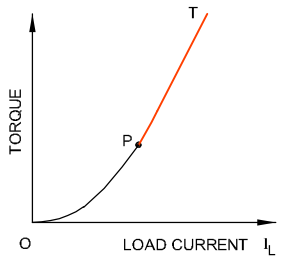


DC SERIES MOTOR CONNECTION

Characteristics of DC series motors: The torque `T' in a DC motor is proportional to the flux `Ø' and the armature current `I_a'. The speed is inversely proportional to the flux. The relation between these factors i.e. torque vs load, speed V_s load and torque V_s speed are plotted on a graph, and are known as characteristic curves of motors. The study of these characteristics enables us to understand the behaviour of the motors under different conditions.

Torque load characteristics of the DC series motor: Fig 2 shows the torque load characteristic curve of a DC series motor. At low or light load, the torque is low due to the low armature current and low field flux. But as the load increases, the torque also increases proportionate to the square of the armature current up to the point `P' of the curve. This could be illustrated by the formula T proportional to armature current and field flux. T α I_a Øse as $Ø_{se}$ is proportional to I_{se} and, further, I_{se} is proportional to the armature current. We have

Fig 2



TORQUE-LOAD CHARACTERISTIC

$T \alpha I_a I_{se}$

$T \alpha I_a I_a$

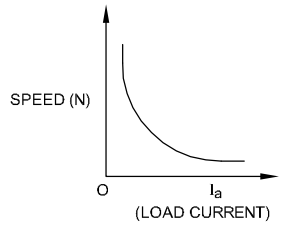
$T \alpha I_a^2$.

Beyond this point 'P' the curve becomes a straight line, and indicates the torque is proportional to the armature current only as the field cores are saturated. This curve shows that the torque is low at light loads and increases at heavy loads. Further the starting current of a DC series motor is about 1.5 times the full load current and the torque is about 2.25 times (1.5^2) the full load torque assuming the poles are not saturated.

Speed Vs load characteristics: Fig 3 shows the speed load characteristic curve of a DC series motor. From the curve it is clear that when the load is small the speed is high, and as the load increases the speed decreases. As the curve shown is parallel to the `Y' axis at low load currents, it can be inferred that the speed attains a dangerous value. Therefore, the DC series motors are seldom used without load. Care should be taken while using belt drives where the load can be `OFF' if the belt breaks or slips out. To avoid this, usually the load is connected directly or through gears to a DC series motor.

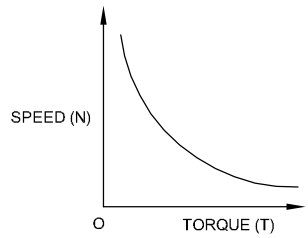
Speed-torque characteristics: Fig 4 shows the speed-torque characteristic of a DC motor. It shows that when the torque is low, the speed is high. This is due to the low field flux (N α 1/Ø). As the torque increases the motor draws more current and causes the speed to reduce. This is due to the increased field flux by increased load current in the DC series field.

Fig 3



SPEED-LOAD CHARACTERISTIC

Fig 4



SPEED-TORQUE CHARACTERISTIC

Uses of a DC series motor: The DC series motor is used in applications where torque and speed requirements vary substantially, and in jobs that require a heavy starting torque and a high rate of acceleration as in traction, hoists, cranes, and heavy construction trucks.

Method of changing the direction of rotation of a DC series motor: We know that by applying Fleming's left hand rule, the direction of rotation of the armature in a DC motor could be determined. According to Fleming's left hand rule, either by changing the polarity of the field or by changing the direction of current in the armature, the direction of rotation could be changed. However, if the polarity of the supply is changed, as both the polarity of field and the direction of current in the armature change, the direction of rotation will remain unchanged. Therefore, the direction of rotation of a DC series motor can be changed by changing either the field or the armature connection.

Method of loading a DC series motor: A DC series motor should never be operated without load. To keep the speed of the DC series motor within safe limits, we have to maintain a certain load on the shaft. This could be done by connecting the DC series motor to a direct-coupled load or by mounting a gear-coupled load.

The method of loading a DC series motor of small capacity for testing in a laboratory is by the brake test which is explained below.

Brake test (Method I): It is a direct method and consists of applying a brake through a special (camel hair) belt to a water-cooled drum mounted on the motor shaft as shown in Fig 5. One end of the belt is fixed to the ground via a spring balance S, and the other end is connected to a suspended weight W1. The motor is run and the load on the motor is adjusted till it carries its full load current.

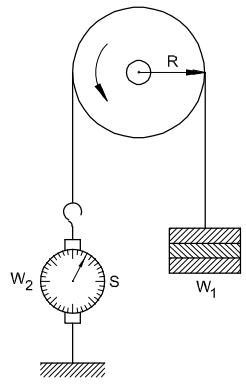
Let W_1 – suspended weight in kg.

W_2 – reading on spring balance in kg.wt.

The net pull on the belt due to friction at the pulley is

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Fig 5



BRAKE TEST

TM20N131355

$(W_1 - W_2)$ kg. wt. or 9.81 $(W_1 - W_2)$ newton. If R-radius of the pulley is in metre then, the shaft torque T_{sh} developed by the motor

$= (W_1 - W_2)R$ kg.m

$= 9.81(W_1 - W_2)R$ N–m

If n – motor or drum speed in r.p.s.

Motor output power $= T_{sh} \times 2\pi n$ watt

$= 2\pi \times 9.81\ n\ (W_1 - W_2)R$ watt

$= 61.68\ n\ (W_1 - W_2)R$ watt.

Let, V = supply voltage;

I = load current taken by the motor.

Then, input power = VI watt.

Therefore, efficiency $= \dfrac{\text{output}}{\text{input}} = \dfrac{61.68n(W_1 - W_2)R}{VI}$

Further the metric horsepower developed by the motor can be calculated by the formula

$$\text{HP metric} = \frac{2\pi n T_{sh}}{735.6}$$

where 'n' is the speed in r.p.s.

T_{sh} is the shaft torque in newton metres.

The power rating given in the name-plate of the motor indicates the horsepower which is developed at the shaft.

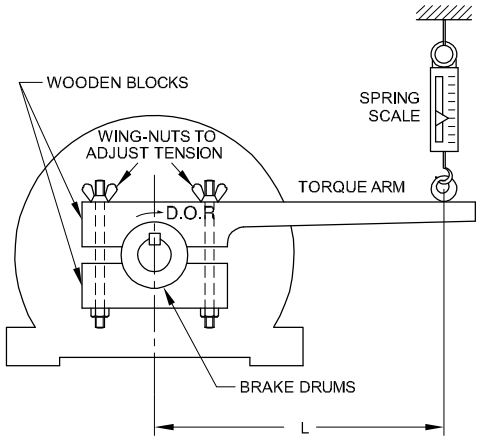
The simple brake test described above can be used for small motors only, because in the case of larger motors, it is difficult to dissipate the large amount of heat generated at the brake.

It is most important to remember that a series motor should never be operated without a load.

The field is very weak at no load. Operating the motor without a load will allow the motor to reach such high speeds that the centrifugal force will cause the windings to tear free.

Brake test (Method II): The torque developed by a motor may be measured alternatively by a device called a prony brake as shown in Fig 6.

Fig 6



PRONY BRAKE USED FOR MEASURING TORQUE DEVELOPED BY A MOTOR

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There are various prony brake designs available. In Fig 6, the brake drum is encased in split wooden blocks. By tightening the wing-nuts, the pressure of the wooden blocks on the brake drum can be varied, and thereby, the load can be adjusted to the desired value. The brake drum has an extension torque arm that is fastened to a spring scale which measures the force developed on the brake drum in newtons. The torque developed is the product of the net force on the scale (in newtons) X the effective length (L) of the torque arm in metres.

Torque = force x distance

= spring balance reading in Kg.wt x 'L' in metres.

The efficiency and the output of the motor in metric horsepower could be calculated as explained in the above paragraphs.

Example 1: A prony brake arm is 0.4 m in length. The wing-nuts on the brake are tightened on the motor pulley, creating a force of 50 Kg.wt. What is the torque that is being developed by the motor?

1 Kg.wt = 9.8 newtons

Torque = force x length(distance)

= 50 x 9.81 x 0.4

= 196.2 newton metres.

Example 2: In the above case calculate the metric horsepower developed by the motor when the shaft speed is 1500 r.p.m.

$$\text{HP metric} = \frac{2\pi n T_{sh}}{735.6}$$

$$n = \text{r.p.s.} = \frac{N}{60} = \frac{1500}{60} = 25 \text{ r.p.s.}$$

$T_{sh} = 196.2$ N.m

$$\text{HP metric} = \frac{2\pi \times 25 \times 196.2}{735.6} = 41.9 \text{ HP metric.}$$

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Electrical wiring accessories - wirings - diagrams - battern - PVC conduit wiring - test board

Objectives: At the end of this lesson you shall be able to
- **classify, specify, identify and state the uses of the accessories employed in domestic wiring.**

Electrical accessories: An electrical domestic 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.

Rating of accessories: The standard current ratings of the accessories are 6, 16 and 32 amps. The voltage rating is 240V AC as per B.I.S. 1293-1988.

Construction of accessories: These accessories should be provided with complete enclosures, which shall afford adequate protection against accidental contact with all live parts. The parts and the materials normally used are as shown in Table 1.

Table 1

Part	Materials
1 Base	Vitrified, ceramic material or Non-ignitable, moulded, insulating material.Eg. Bakelite
2 Covers, cover-plate and actuating member (knob)	Tough non-ignitable insulating materials. Eg. Bakelite (Knob may be of metal but should be insulated from the live parts.)
3 Springs	Corrosion -resistance metal
4 Terminals	Plated brass terminal posts and screws.
5 Attachment fitting screws and other non-current carrying parts	Mild steel, aluminium alloy or insulating material.

Mounting of accessories: The accessories are designed to mount either on the surface or concealed (flush type).

Surface mounting type: Accessories are provided with a seating so that when mounted they project wholly above the surface on which they are mounted.

Flush-mounting type: These accessories are designed to mount behind or incorporated with a switch plate, the back of the plate being flush with the surface of the wall or switch box.

The electrical accessories used in wiring installation, are classified according to their uses.

– Controlling accessories
– Holding accessories
– Safety accessories
– Outlet accessories
– General accessories

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 250 volts.

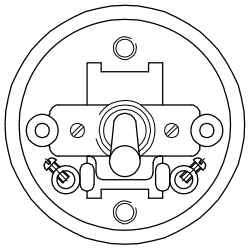
Types of switches according to their function and place of use

1 Single pole, one-way switch
2 Single pole, two-way switch
3 Intermediate switch
4 Bell-push or push-button switch
5 Pull or ceiling switch
6 Double pole switch (D.P. switches)
7 Double pole, iron clad (D.P.I.C.) switch.
8 Three-pole, iron clad (T.P.I.C.) switch.

Of the above 1,2,3,4 and 6 may be either surface mounting type or flush-mounting type.

Single pole, one-way 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 1.

Fig 1



6 AMP SINGLE-WAY SURFACE MOUNTING SWITCH (COVER REMOVED)

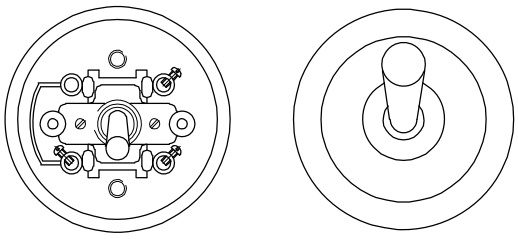
TM20N131361

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 2. 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.

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Fig 2



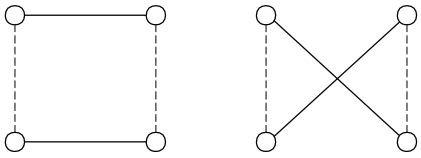
(a) 6 AMP 2-WAY SURFACE MOUNTING SWITCH (COVER REMOVED)

(b) A 2-WAY SWITCH WITH A METAL CAP

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Intermediate switch: This is a four-terminal device capable of making or breaking two connections from two positions as shown in Fig 3. This switch is used along with 2 way switches to control a lamp from three or more positions.

Fig 3



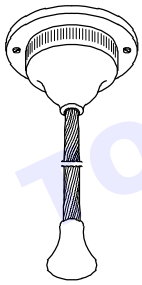
INTERMEDIATE SWITCH CONNECTIONS

TM20N131363

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 4 is normally a two-terminal device functioning as a one-way switch to make or break a circuit.

Fig 4



PULL SWITCH

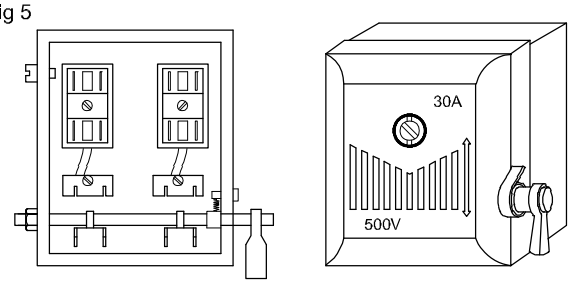
TM20N131364

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 5 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 5



DPIC MAIN SWITCH

TM20N131365

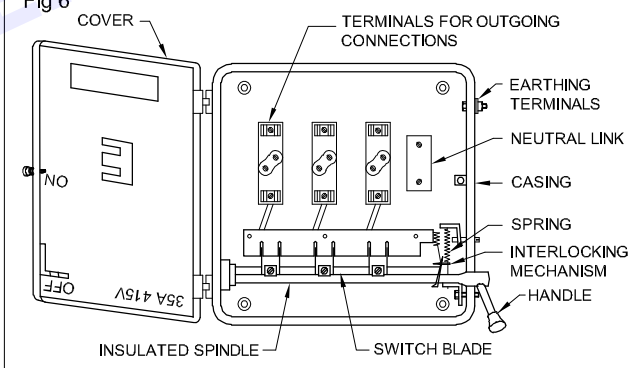
Specification of these switches should have:

– current rating
– voltage rating
– type of enclosure

(sheet steel or cast iron).

Triple (three) pole iron-clad main switch: This is shown in Fig 6 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 6



FUSED ICTP `N' SWITCH

TM20N131366

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.

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Holding accessories

Lamp-holders : A lamp-holder is used to hold a lamp. Earlier, brass holders were most commonly used but nowadays these have been replaced by bakelite holders. These may contain solid or hollow spring contact terminals. Four types of lamp-holders are mainly available.

– Bayonet cap lamp-holders

– Screw type holders

– Edison screw type lamp-holders

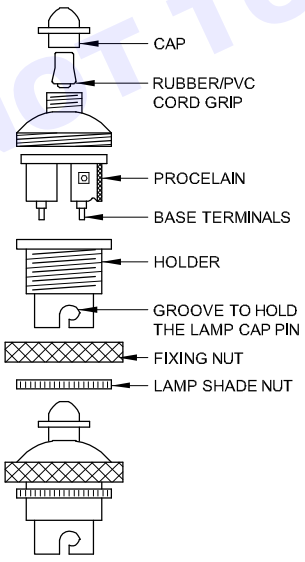
– Goliath Edison screw type lamp-holders

According to the Bureau of Indian Standard, 732, clause 5.8, all incandescent lamps, unless hung at a height of 2.5m (8ft), shall be provided with standard bayonet holders for lamps up to and including 200 watts. For lamp powers above 200 W and up to 300 watts Edison screw holders are to be used and for above 300 watts Goliath screw holders are to be used.

Bayonet cap lamp-holders: In this type, the bulb is fitted into the slot, and is held in position by means of two pins in the lamp cap. It has solid or hollow spring contact terminals, and the supply mains through the switch are connected to these contacts. In B.C. types there are two grooves on the circular construction of all types of holders. The groove and the contact terminals are at right angle to each other. In this type of holders, the lamp is inserted, forced in, turned slightly and then left in position. These holders can be classified further as explained below.

Pendent lamp-holders: This holder shown in Fig 7 is used in places where the lamps are required in a hanging position. These holders are made of either brass or bakelite. An exploded view of this holder shows the parts of the holder. These holders are used along with ceiling roses for suspending the lamps from the ceiling.

Fig 7



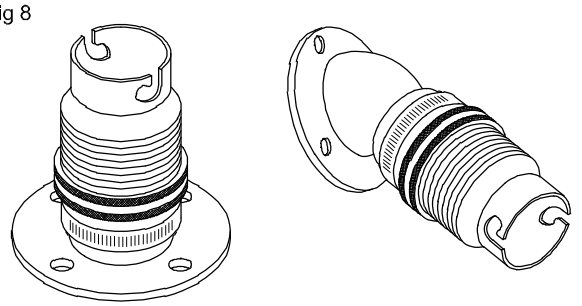
EXPLODED VIEW OF PENDENT HOLDER

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Batten lamp-holders: The straight batten holder, shown in Fig 8a, is used on a flat surface on the round block, wooden board etc. These holders are made of either brass or bakelite.

Angle holders: The angle bottom holder, shown in Fig 8b, is to hold the lamp in a particular angle. These are made of either brass or bakelite. These are used for advertising boards, window display, kitchens etc.

Fig 8



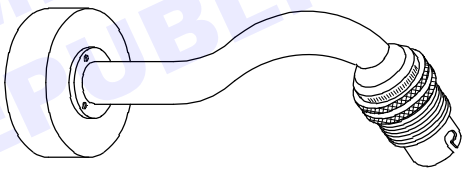
(a) BRASS BATTEN HOLDER (b) ANGLE HOLDER

TM20N131368

Bracket holders: This holder, shown in Fig 9, is used with a bracket. These are made of brass and are used to give direct light to a particular place. Brass bracket holders need to be earthed as per BIS recommendations.

These are fixed on the bracket by the internal threading of the cap.

Fig 9

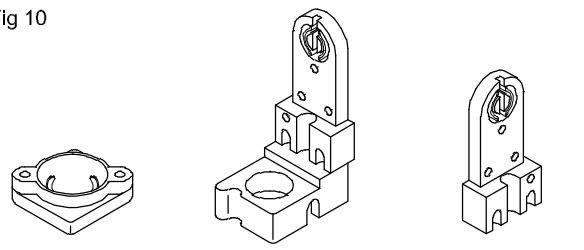


BRACKET HOLDERS

TM20N131369

Tube light or fluorescent lamp-holders and starter-holders: Generally the fluorescent lamp-holders are of a bi-pin type. Fig 10 shows a holder for the fluorescent lamp, a holder for the starter and a combined holder for the tube and starter.

Fig 10



HOLDER FOR THE STARTER | COMBINED TUBE AND STARTER HOLDER | FLUORESCENT PIN TUBE HOLDER

TM20N13136A

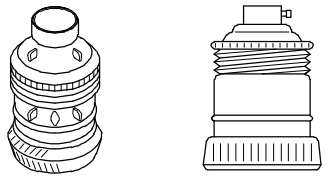
Edison screw-type lamp-holders: In this type, the holder is provided with inner screw threads and the lamp is fitted in it by screwing. It has a centre contact which is connected to the live wire and the screwed cap is connected to the neutral wire.

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For lamps with wattage above 200W and not exceeding 300W, Edison screw-type holders are used.

Edison screw lamp holders have spring-loaded central contact to ensure good contact. An Edison screw-type holder as shown in Fig 11.

Fig 11

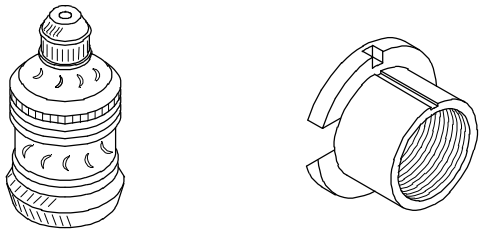


EDISON SCREW TYPE HOLDER

TM20N13136B

Goliath Edison screw-type holders (Fig 12): The cover of this type of holder is made of porcelain. Such holders are used in studios, headlights, floodlights, focusing lights etc.

Fig 12



GOLIATH EDISON SCREW LAMP HOLDER

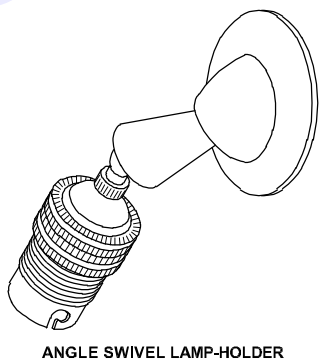
TM20N13136C

These holders are used for more than 300W lamps.

Swivel lamp-holders: The swivel lamp-holder is designed for wide angle directional lighting which is used for the lighting of shop windows, showcases, etc. It consists of a ball and socket joint fitted between a back plate and the lamp-holders. It is available in bayonet cap type, small bayonet cap type and Edison screw type. All these type of holders are also available for wall fixing patterns or ceiling pattern.

One type of swivel lamp-holders is shown in Fig 13.

Fig 13



ANGLE SWIVEL LAMP-HOLDER

TM20N13136D

Specification of a lamp-holder: While specifying the lamp-holders, the type of material used for construction, type of gripping, type of mounting, working current and voltages should also be specified.

Safety accessories: A fuse is a safety accessory. It is connected in series with the circuit and protects the electrical apparatus and equipment from damage, when excess current flows.

There are several types of fuses used in the electrical field. But the kit-kat type fuse is commonly used in domestic installation. While specifying fuses in general, their type, current capacity and working voltage also should be specified.

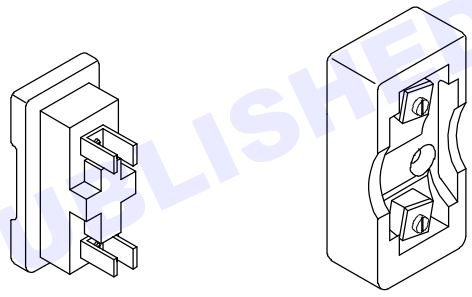
Types of fuses

– Kit-kat type (Rewirable fuse)

– Iron-clad fuse cut out

Kit -Kat type fuse: These are the ones mostly used in domestic installations. This fuse consists of a porcelain base having two fixed contacts, for connecting the incoming and outgoing cables. The bottom part of the fuse is called the base and the top is called the fuse-carrier. The line and load wires are connected in the base terminals and the carrier is provided with a fuse, as shown in Fig 14. The base is fixed but the carrier is removable.

Fig 14



FUSE CARRIER

FUSE BASE

KIT-KAT FUSE

TM20N13136E

Advantages

– Easy to rewire the fuse.

– Very cheap to replace the fuse wire.

These kit-kat fuses are meant for low rupturing capacity, and not suitable for power circuits. They are capable of delivering enormous amount of power in case of short circuit.

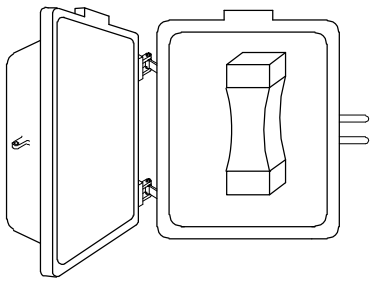
Iron-clad fuse cut outs (Fig 15): These are kit-kat fuses in an iron cover. The iron cover has facility to be closed and sealed with a lead seal. This is used at the incoming side of the power supply and sealed by the supply authorities to ensure the line is not loaded beyond a certain prescribed current capacity.

Outlet accessories: These accessories are used to take the supply for the portable appliances like table fans, TV, electric irons etc.

Socket outlet current rating: The standard ratings shall be 6,16 and 32 amperes and 240 volts. The following types are normally used for domestic purposes. They have to be specified according to the mounting type, number of pins, current capacity and voltage.

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Fig 15



IRON CLAD CUT - OUT

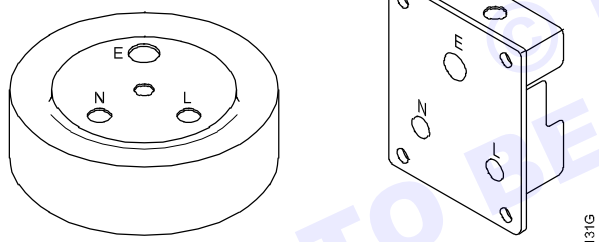
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Two-pin socket: This socket is rated as 6A, 250V, having only two pins without earth connection. These are suitable only for double insulated appliances (having PVC or insulated body).

Two-pin plug: It is used for taking the supply from the socket. It has got two pins of the same size.

Three-pin socket: This type of socket is suitable for light and power circuits. These sockets are rated as 6A, 250V or 16A, 250V, and are available as surface-mounting type and flush type. They are shown in Fig 16. There are three terminals marked as Line (L) Neutral (N) and Earth (E). The line terminal is always on the right hand side, the neutral terminal on the left hand side, and the top is the earth terminal which is larger in diameter. In all the cases, the earth wire must be connected to the earth terminal of the socket.

Fig 16



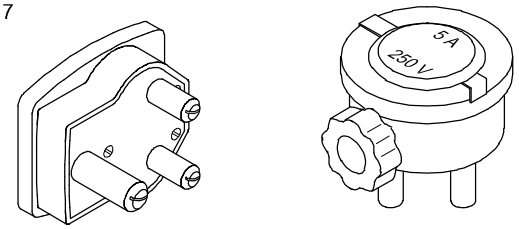
3-PIN 16 AMP SOCKET WITH TOP COVER

FLUSH TYPE SOCKET

EL15131G

Three-pin plug: It is used for taking the supply from the socket. It has three pins. Two are similar in size and the third one is bigger and longer which is for earth as shown in Fig 17. These are also rated as 6A,250V or 16A, 250V. These are made of bakelite, PVC materials.

Fig 17



THREE-PIN PLUG

TM20N13136H

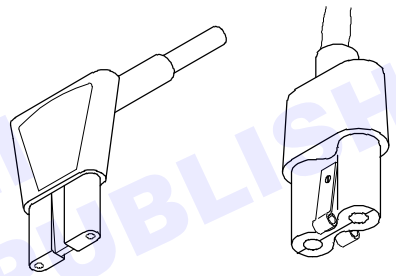
A socket which is controlled by a switch, is also available. Multi-pin sockets are also available which are suitable for 2 pins and 3 pins having 5 holes in one unit. Further multi-pin sockets for 3 pin of 6 amps and 16 amps are also available having 6 holes in one unit.

General accessories: Some accessories are used for general and special purposes such as:

– appliance connectors (or) iron connectors
– adapters
– ceiling roses
  a two-plate
  b three-plate
– connectors
– distribution board
– neutral links.

Appliance connectors or iron connectors : These are used as female connectors to supply current to electric kettles, electric iron, hotplate, heaters etc. It is made of bakelite or porcelain. The wires are connected with two brass terminals and the earth connection is provided with a twin nickel spring. The cable entry has a rubber protection type. These are rated as 16A, 250V. Some different types of iron connectors are shown in Fig 18.

Fig 18



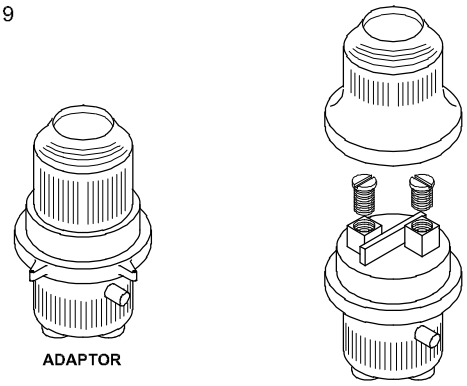
FLAT CONNECTOR WITH SIDE ENTRY

IRON CONNECTOR DIRECT ENTRY

TM20N13136I

Adaptor: An adaptor is shown in Fig 19. They are used for taking supply from a lamp holder for small appliances. They are made out of bakelite. They are available in ratings up to 6 A 250 V.

Fig 19



ADAPTOR

ADAPTOR WITH CAP OPENED

TM20N13136J

Adaptors with multiple plugs are also available for taking supply to a number of appliances from a single point.

These adaptors should not be used in bathrooms or other damp places.

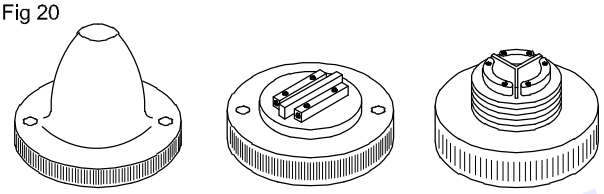
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Ceiling roses: Ceiling roses are used to provide tapping points from the wiring for supplying power to fans, pendent-holders, tube lights etc. Normally flexible wires are used for tapping from the ceiling roses.

Ceiling roses have two parts, base and cover, both made of bakelite. The cover has a hole in the centre for the connecting wires to be taken out. There are threadings on the internal sides so that the cover may be fixed or tightened with the base. The base has terminals and holes for fixing on the block etc. and for wires to connect with the supply. Two types of ceiling roses are in use.

Two-plate ceiling rose (Fig 20 a & b): This is made of bakelite and it has 2 terminals (phase & neutral) which are separated from each other by a bakelite bridge. Each of the terminal plates is provided with a metallic sleeve and a binding screw on one side through which the circuit wire from the back via the mounting block enters them. The other side of the terminal plate is provided with a washer and screw for tap wire connection. The two-plate ceiling rose is used for 6A, 250V current capacity. It is not used in circuits whose voltage exceeds 250V.

Fig 20



TOP COVER LOOKS THE SAME FOR (a) & (b) | (a) BASE OF TWO PLATE CEILING ROSE | (b) BASE OF THREE PLATE CEILING ROSE

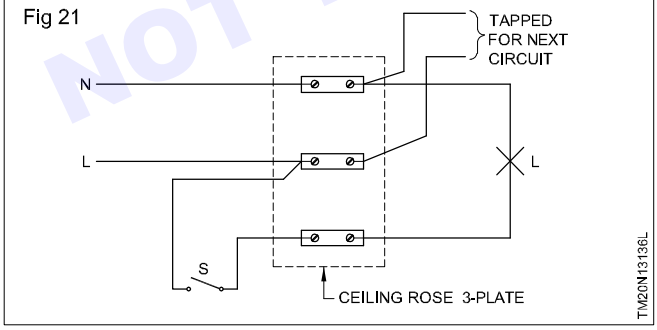
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Three-plate ceiling rose: This type of ceiling rose has 3 terminals which are separated from each other by a bakelite bridge. It can be used for two purposes. (Fig 20 a & c)

– Bunch light control

– To provide tapping for phase wire as shown in Fig 21.

Fig 21

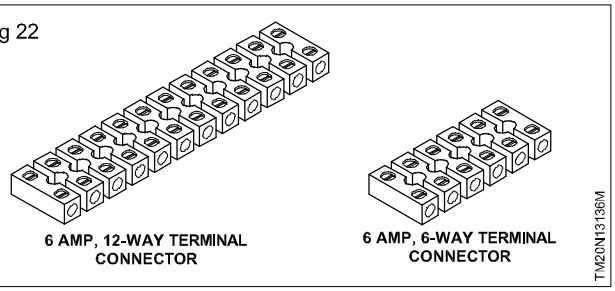


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These ceiling roses are available in the rating of 6A, 250V. The covered 2 plate and 3 plate ceiling roses will look alike but could be identified by seeing the rear side.

Connectors (Fig 22): Connectors are used to extend the length of the wire without jointing. They are made of porcelain, bakelite or PVC based material. There is a brass sleeve with threading for small screws to tighten the wire in the sleeves as shown in the figure. These are available in single way, two-way, three-way, six-way, 12-way types. These are rated according to the current and voltage capacity - 6A 250V, 16A 250V, 32A 250V, 16A 500V, 32A 500V etc.

Fig 22

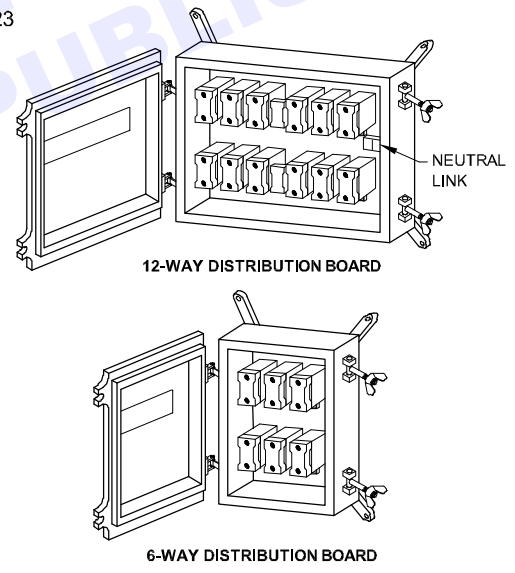


6 AMP, 12-WAY TERMINAL CONNECTOR | 6 AMP, 6-WAY TERMINAL CONNECTOR

TM20N13136M

Distribution board (Fig 23): These are used where the total load is high and is to be divided into a number of circuits. These are used where the load is more than 800W. The number of fuses in the board is according to the number of circuits, and a neutral link is also provided so that the neutral wire can be taken for different circuits. All these branch fuses are enclosed in a metal box. These boards are available as two-way, three-way, 4,6,12-way types as shown in Fig 23.

Fig 23

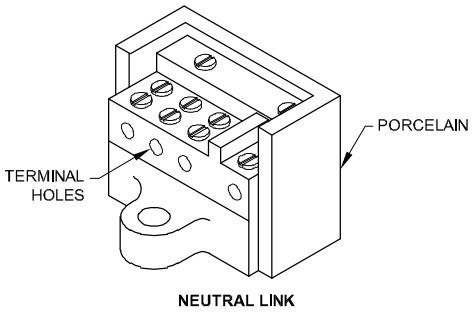


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Neutral link: In a three-phase system of wiring installations, the phases are controlled through switches, and the neutral is tapped through a link called neutral link. The neutral link consists of a terminal for incoming current and a multi-way outgoing circuit. The metal terminals are mounted on high grade vitreous porcelain base. (Fig 24) The ratings are 16A, 32A, 64A, 100A neutral link.

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Fig 24



The accessories' rating shall be 240V and 6 or 16 amps from the year 1991, instead of 250V and 5 or 15 amps as per BIS 1293-1988.

B.I.S. Symbols used for electrical accessories

Objectives: At the end of this lesson you shall be able to
- **interpret various symbols used in electrical wiring diagrams as per B.I.S. specification**

In electro technical engineering symbols are used in layouts and wiring circuits to represent the electrical parts or the function of the circuit.

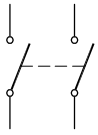
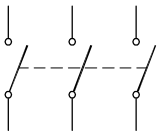
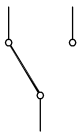
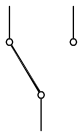
Since the drawing of the actual device is very laborious and would be drawn by each person differently, standardised symbols are used. With the help of the symbols, an electric circuit can be represented easily and can be described precisely as well.

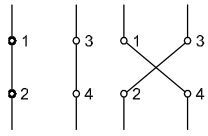
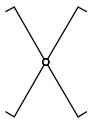
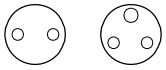
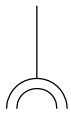
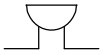
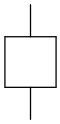
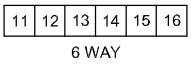
The symbol represents only the function of a part irrespective of the structure and form.

Depending on the purpose of an application, different wiring schemes are used. For example, current flow diagram representation, plans of installation etc. The symbols of various plans of installation (layout) and the current flow diagrams (circuit diagram) differ from one another. A few examples of standard symbols recommended by B.I.S. 2032 (different parts) used for wiring are given here.

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Some symbols from B.I.S. for two wiring schemes

Sl.No.	Description	Symbols used in the circuit diagram	Symbols used in layout
1	One-way switch, single pole		
2	One-way switch, two poles		
3	One-way switch, three poles		
4	Multi-position switch single pole		
5	Two-way switch		

6	Intermediate switch		
7	Push-button or bell-push		
8	Socket outlets, 6A		
9	Socket outlets, 16A		
10	Lamp or outlet for lamp		
11	Fuse		
12	Bell		
13	Buzzer		
14	Earth point		
15	Circuit breaker		
16	Terminal strip		N.A
17	Link (closed)		N.A

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18	Plug and socket (male and female)		N.A
19	Ceiling rose N.A: Not applicable		N.A

Diagrams and systems used in domestic wiring installation

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

- **identify a layout, installation plan, circuit -diagram and wiring diagram, and state their uses**
- **identify the B.I.S. symbols used in electrical layout drawings.**

In electrical wiring work, the electrician is supplied with a layout of wiring installation and an installation plan initially.

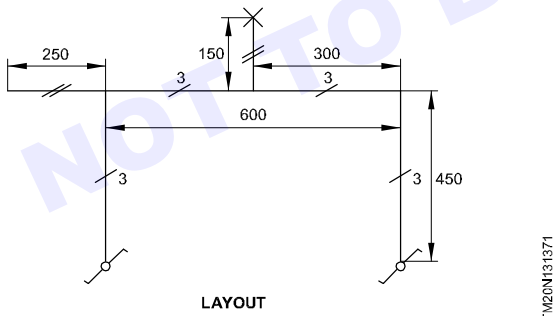
On the basis of the layout and installation plan, the electrician should draw the circuit and wiring diagrams before the commencement of work for systematic execution of the work.

The terms used in wiring installation drawings are explained here.

Layout diagram: Some customers give their requirements in writing. But a few can give them in the form of a layout diagram to the electrician. In the case of a written requirement, the electrician will prepare a layout diagram and then get the approval of the consumer.

The layout diagram shown in Fig 1 is a simplified version of the wiring diagram. Its purpose is to inform the reader quickly and exactly, what the circuit is designed for without giving any information on the circuit itself.

Fig 1



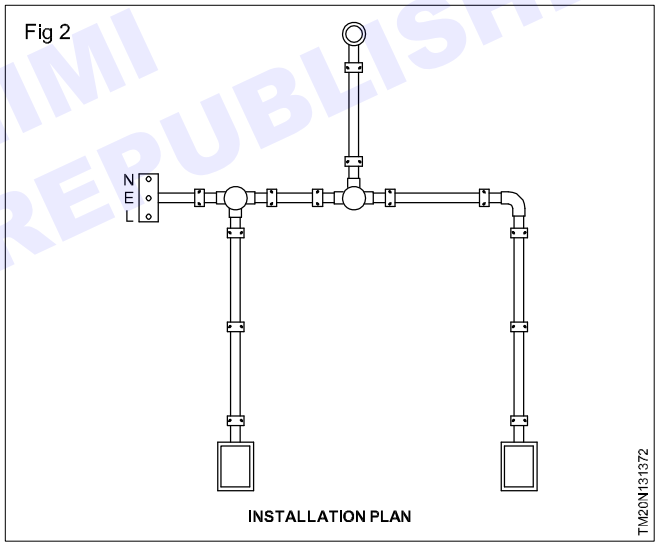
This type of layout diagram is used for preparing architectural diagrams, plans, etc. of a building.

In a layout diagram, it is necessary to indicate with symbols details like whether the wiring is on the surface or concealed, and the run `up' or `down', the number of wires in run, dimensions, and accessories with appropriate I.S. symbols.

Normally the layout plan is drawn and then the wiring diagram. After completion of the wiring diagram, the number of cables to be run in each cable run and the size of conduit or batten are estimated. With the help of the distance marking in the layout plan, the estimation of cables, could be made.

Installation plan: (Fig 2) This plan shows the physical position of accessories in an installation, and also gives the final appearance of the installation. It may not be possible to draw the installation plan for the entire layout diagram. But it can be restricted to a small part of the installation to highlight the type of conduit, accessories, spacing of gutties, clamps etc.

Fig 2



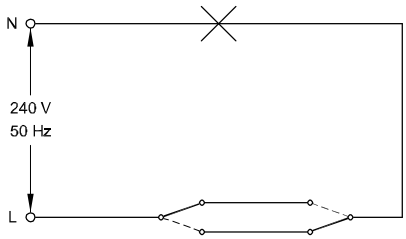
Circuit diagram (Fig 3): This shows the schematic connections of the circuit for a specific task in the simplest form, incorporating the graphical symbols.

The purpose of a circuit diagram is to explain the function of the various accessories in the circuit. Fig 3 is an example of a circuit diagram for controlling a lamp from two different places.

Wiring diagram: (Fig 4) This is the diagram in which the position of the components in the diagram bears a resemblance to their actual physical position.

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Fig 3



SCHEMATIC (CIRCUIT) DIAGRAM

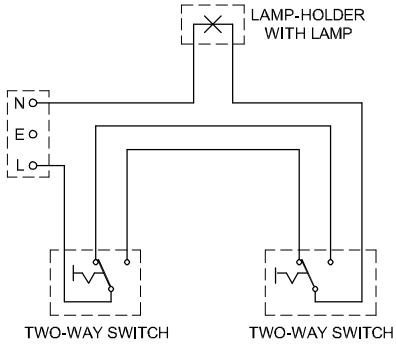
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The wiring diagram may not have distance marking. Use of the wiring diagram along with the layout diagram enables the technician in the initial stages of the planning to specify/estimate the required type, size and length of the cables, and also to decide on the vertical, horizontal and ceiling runs of the cable. The wiring diagram is of great use to test and rectify faults in the installation during maintenance work. Fig 4 also shows the wiring plan for controlling a lamp from two different places with their actual locations.

The B.I.S. symbols used in the wiring are given here.

Items	Symbols
I Wiring	
1 General wiring	
2 Wiring on the surface	
3 Wiring under the surface	
4 Wiring in conduit	
a Conduit on the surface	
b Conduit concealed	
The type of conduit may be indicated, if necessary.	
5 Wiring going upwards	
6 Wiring going downwards	
7 Wiring passing vertically through a room	
II Fuse-boards	
1 Lighting circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	

Fig 4



WIRING DIAGRAM

TM20N131374

For his own good and to facilitate quick location of faults at a later stage, the customer should insist on the electrician giving him a copy of the wiring diagram soon after the completion of wiring. The electrician should make it a point to do so.

Graphical symbols used for electrical installation in a building: It is common practice to indicate the electrical fittings in architectural diagrams, building plans etc. by graphical symbols.

Items	Symbols
2 Power circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	
III Switches and switch outlets	
a Single pole	
b Two-pole	
c Three-pole	
2 Single pole pull-switch	
3 Multi-position switch	
4 Two-way switch	
5 Intermediate switch	
6 Pendent switch	
7 Push-button or bell-push	
IV Socket outlets	
1 Socket outlet, 6A	

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	Items	Symbols
2	Socket outlet,16A	
3	Combined switch and socket outlet, 6A	
4	Combined switch and socket outlet, 16A	
5	Interlocking switch and socket outlet, 6A	
6	Interlocking switch and socket outlet 16A	
V	**Lamps**	
1	Lamp or outlet for lamp	
	Group of three 40 W lamps	3x40 W
2	Lamp, mounted on a wall or light bracket	
3	Lamp, mounted on ceiling	
4	Counterweight lamp fixture	
5	Chain lamp fixture	
6	Red lamp fixture	
7	Lamp fixture with built-in switch	
8	Lamp fed from variable voltage supply	
9	Emergency lamp	
10	Panic lamp	
11	Bulk-head lamp	
12	Watertight light fitting	WT
13	Battern lamp-holder (Mounted on the wall)	BH
14	Projector	
15	Spotlight	
16	Floodlight	
17	Fluorescent lamp	
	Group of three 40W fluorescent lamps)	3x40 W

	Items	Symbols
VI	**Electrical appliances**	
1	General If necessary, use designation to specify.	
2	Heater	
VII	**Bells, buzzers and sirens**	
1	Bell	
2	Buzzer	
3	Siren	
4	Horn or hooter	
5	Indicator (at `N' insert number of ways)	N
VIII	**Fans**	
1	Ceiling fan	
2	Bracket fan	
3	Exhaust fan	
4	Fan regulator	
XI	**Telecommunication apparatus**	
1	Aerial	
2	Loudspeaker	
3	Radio receiving set	
4	Television receiving set	
X	**Earthing**	
	Earth point	

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B.I.S. Regulations, recommendations and the N.E. code pertaining to wiring installations

Objectives: At the end of this lesson you shall able to
- **state the B.I.S. recommendations and the National Electrical Code pertaining to electrical installations**
- **state the B.I.S. regulations and recommendations of the National Electrical Code of Practice with regard to the mounting levels of switches, sockets, distribution boards, cable runs etc.**

The wiring installation shall generally be carried out in conformity with the requirements of the Indian Electricity Act 1910, as updated from time to time and the Indian Electricity Rules 1956, framed thereunder, and also the relevant regulations of the electric supply authority of the concerned area. (State Government)

To govern the installation of electrical wirings in buildings, with particular reference to safety and good engineering practice, the Indian Standard is published.

The following are some of the extracts of B.I.S. (Bureau of Indian Standards) regulations pertaining to wiring installations. All the B.I.S. regulations are recommended by the National Electrical Code (NEC).

Batten wiring - NE code and B.I.S. recommendations

Objectives: At the end of this lesson you shall be able to
- **state the NE code/BIS recommendations with respect to selection of cables, cable runs and accessories in batten wiring installation**
- **describe the types of clips (size, material, shape)**
- **state the B.I.S. regulation regarding spacing of clips.**

Batten wiring: Tough rubber-sheathed (T.R.S.) or PVC-sheathed cables are suitable to run on teak wood battens.

Varnishing of teak wood batten: Prior to erection, these shall be painted with one coat of varnish or an approved paint for the colour to match with the surroundings.

Method of securing the battens: These battens shall be secured to the walls and ceilings by flat-head wood screws to wood plugs at an interval not exceeding 75cm. The flat-head wood screws shall be countersunk within the wood batten and smoothed down with a file.

Suitability of tough rubber-sheathed cable: Wiring with tough rubber-sheathed cables is suitable for low voltage installation, and shall not be used in places exposed to sun and rain, nor in damp places. It may, however, be installed in the above places, provided the wires are sheathed in special protective covering to withstand dampness and other atmospheric factors.

Suitability of PVC-sheathed cable: Wiring with PVC-sheathed cables is suitable for medium voltage installation, and may be installed directly under exposed conditions of sun and rain or damp places. This system of wiring is also suitable in situations where acids and alkalies are likely to be present.

Protection of tough rubber-sheathed or PVC-sheathed wiring from mechanical damage: In cases where there are chances of any damage to the wiring, such wiring shall be covered with sheet metal protective covering, the base of which is made flush with the plaster or brickwork as required or the wiring shall be drawn through a conduit pipe.

Such protective covering shall in all cases be fitted on all down-drops within 1.5m from the floor.

Painting: If so required, the tough rubber-sheathed wiring shall, after erection, be painted with one coat of an oil-free paint or distemper of suitable colour over a coat of oil-free primer, and the PVC-sheathed wiring shall be painted with a synthetic enamel paint of a quick drying type.

Bends in wiring: The wiring shall not in any circumstances be bent so as to form a right angle but shall be rounded off at the corners to a radius not less than six times the overall diameter of the cable.

Passing through walls: Where conductors pass through walls, one of the following methods shall be employed. Care shall be taken to see to it that wires pass freely through the protective pipe or box, and that the wires pass through in a straight line without any twist or cross on either end of such holes.

Where a wall tube passes outside a building and is exposed to the weather as a result, the outer end shall be well mounted and turned downwards, and properly bushed on the open end.

Passing through floors: All cables taken through the floors shall be enclosed in an insulated, heavy gauge steel conduit extending 1.5m above the floor and flush with the ceiling below. The ends of all conduits or pipes shall be neatly bushed with porcelain or PVC or wood brushings.

Buried cables: The tough rubber-sheathed cables shall not be buried directly in plaster. Where it is specified, they may be taken in teak wood channeling or a cement chase or conduit pipe buried in the wall.

Stripping of outer covering: While cutting and stripping the outer covering of the cables, care shall be taken so that the sharp edge of the cutting instrument does not touch the rubber or PVC-sheathed insulation of the

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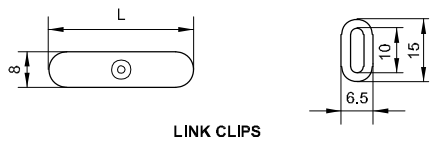
conductors. The protective outer covering of the cables shall be stripped off near the connecting terminals, and the protective covering shall be maintained as close to the end of the connecting terminals as possible and practicable. Care shall be taken to avoid hammering on the link clips with any metal instruments, after the cables are laid. Where junction-boxes are provided, they shall be made moisture-proof with a plastic compound.

Link clips: Link clips are used for firmly clipping the cables in position.

Link clips are of two types:

– Link clip which has separate linking eye. (Fig 1)

Fig 1

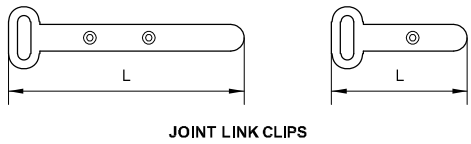


LINK CLIPS

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– Joint link clip which has combined linking eye.(Fig 2)

Fig 2



JOINT LINK CLIPS

TM20N131382

They are available in the following sizes.

25mm, 32mm, 40mm, 50mm, 63mm, 80mm, out of which up to 40mm clips have one hole, while above that they have two holes for fixing.

Typical lighting circuits

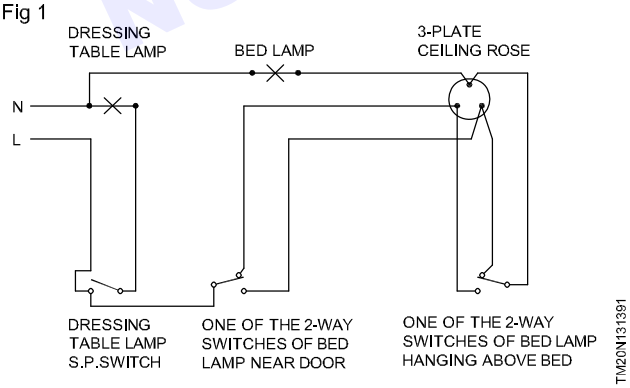
Objectives: At the end of this lesson you shall be able to

• draw schematic diagrams for typical wiring circuits using special accessories.

House wiring requirements may be as simple as one lamp controlled by one switch or may be a special requirement of controlling one lamp from two or more number of places. For example, such circuits are used for staircases, bedrooms and the corridor lighting system. The basic principle involved in such circuits, and the requirement of additional special accessories are discussed below.

Circuit No.1 - Bedroom lighting: A bedroom may require one lamp at the dressing table controlled by a switch, and one lamp just above the bed which may require dual control by two 2-way switches, one provided near the entrance (door) and the other provided above the bed in the form of a pendant switch hanging from a 3-plate ceiling rose. Fig 1 shows such an arrangement.

Fig 1

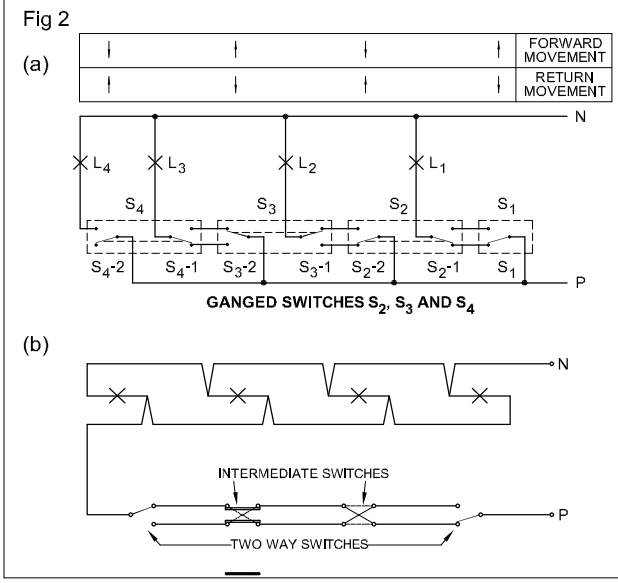


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Circuit No.2 - Corridor lighting circuit: Let us consider a long corridor having 4 lamps, L1, L2, L3and L4 which are to be controlled such that as a person moves in the corridor, in either direction, he switches ON one light after the other while the lamp lighted earlier is switched off. Such an arrangement is shown in Fig 2a. Switches S2,S3 and S4 are ganged two-way switches operated by cross-bars.

According to another requirement for corridor lighting circuits, the entire set of lamps in the corridor is controlled from 4 different places in such a way that all lamps together can be switched `ON' or switched `OFF' by any one of the control switches from four different places as shown in Fig 2b.

Fig 2



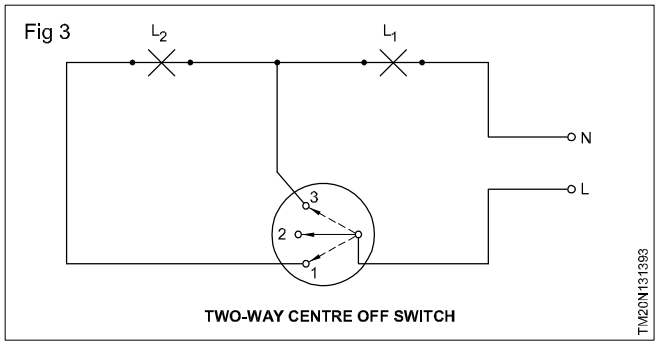
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Circuit No.3 - Series/parallel circuits: Connection of single and two way switches or special switches called two-way centre OFF switches may be used to provide bright or dim lights in the same circuit through a series or parallel connections. Such lamps are commonly found in corridors and bedrooms of hostels, hospitals, railway compartments etc.

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With two-way centre off switch to control one lamp bright and two lamps dim

Fig 3 shows two lamps controlled by a two-way centre off (ON/OFF and ON) switch. When the switch position is on the terminal No.3, the lamp L1 burns bright and when the switch is in position No.1, the lamps L1 and L2 are connected in series so as to give dim light. Switch position 2 indicates `OFF' position.



With one 2-way centre off switch and one 1-way switch to control two lamps independently bright or dim

According to the circuit shown in Fig 4, when the two-way switch is on, terminal 3, L2 is short circuited and the lamp L1 burns bright. Alternatively when the two-way switch is on terminal 1, the lamp L1 is short-circuited while the lamp L2 burns bright and when the two-way switch is on terminal 2 , both the lamps give dim light because they are in series.

With one 2-way switch and one 1-way switch to control two lamps in such a way that one lamp is bright or two lamps are dim.

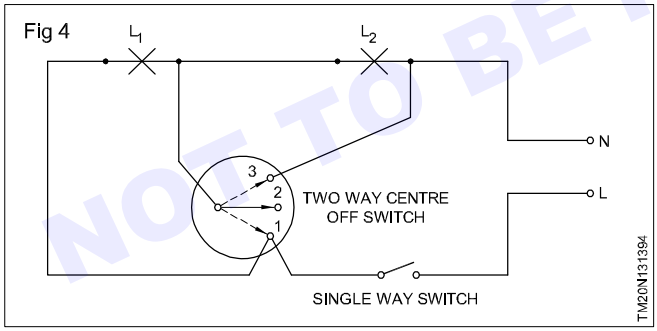
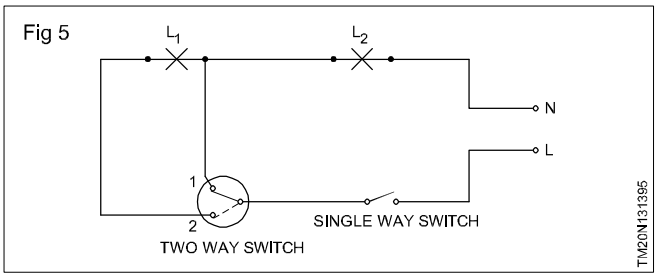


Fig 5 shows such a circuit. When the single way switch is in `ON' position and the two-way switch is in position 1, then the lamp L2 burns bright and lamp L1 is off. When the two-way switch is in position 2 both the lamps are in series and burn dim.

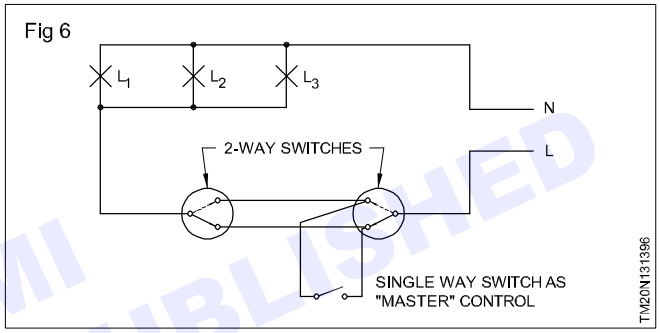


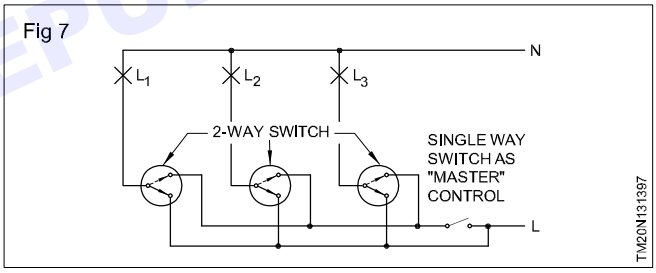
Circuit No.4 - Master switch controls: A master switch derives its name from its function and any switch, such as a one-way or two-way switch, depending on the circuit requirement, can be used for this function. A master switch can be used as `master off', `master on' or a `variable master' control.

A master `OFF' switch is incorporated in a circuit to keep the lamps in the `OFF' position irrespective of the position of the individual switches. Further this switch prevents one from switching `ON' the lamps. Single way switches incorporated as shown in Figs 4 and 5 are examples of such controls.

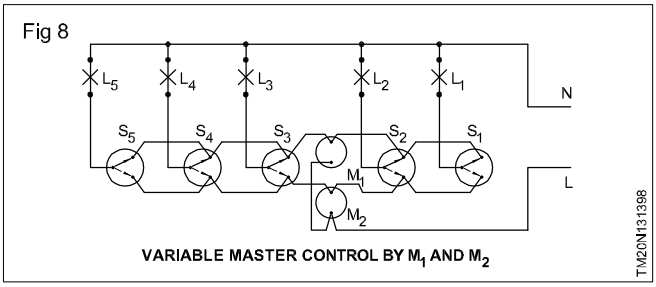
A master `ON' switch is incorporated in a circuit to keep the lamps in an `ON' position irrespective of the position of the individual switches. Further this switch prevents one from switching `OFF' the lamps.

Figs 6 and 7 show the application of a master `ON' switch, with variations in connection.





Variable master control: When master `ON' and `OFF' controls are incorporated together, the control is called variable master control. As shown in Fig 8, the lamps L1 to L5 are controlled independently by switches S1 to S5 respectively whereas two single-way switches M1 and M2 act as variable master controls. A careful study of the circuit will reveal the following conditions.



M_1OFF M_2OFF - All lamps off irrespective of their position.

M_1or M_2ON - All lamps can be individually controlled for `ON' or `OFF'.

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M1and M2ON - All lamps will be ON irrespective of their position.

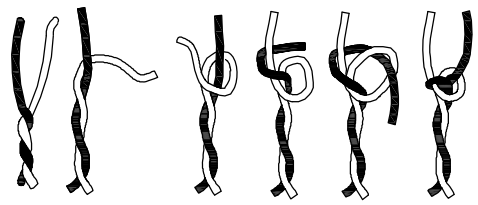
Apart from the above there are a number of special switches available in the market to have various combinations of connections. One such switch is the manual switch. You are advised to investigate the number of terminals in such switches and the mode of connection in those switches with the help of a multimeter or Megger.

Cord grip and underwriter's knot: When a lamp or a lamp with its shade is hung from the ceiling, the flexible cable connected to the lamp-holder is subjected to mechanical stress due to the weight of the lampshade and the lamp.

If the stress is not removed, the cable connection may come out of the terminals and result in shock hazards. To relieve the strain from the terminals of the pendent, lamp holders and ceiling roses, a cord grip or underwriter's knot is used. A cord grip or underwriter's knot is also used in pull-switches and other portable appliance connectors.

Underwriter's knot: A knot is made on twin-twisted or twin-core flexible cable inside the accessories cap cover. The standard procedure of making this type of knot (underwriter's knot) is as shown in Fig 9.

Fig 9

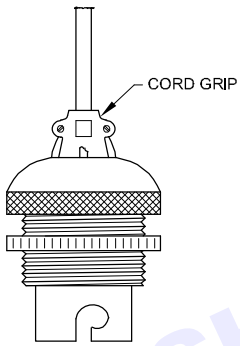


UNDERWRITER'S KNOT

TM20N131399

Cord grip: In some of the electrical accessories like lamp-holders, appliance connectors, plug pin tops etc. a cord grip arrangement is provided. It is an effective means of relieving the terminals from strain due to pulling or twisting of the cord. A cord grip used in a lamp-holder as shown in Fig 10.

Fig 10



LAMP-HOLDER WITH CORD GRIP

TM20N13139A

Conduit wiring - types of conduits - non-metallic conduit

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

- **distinguish between the different types of conduits used in wiring**
- **state the gauge, diameter and length of the metallic and non-metallic conduits available in the market**
- **state the variations in the conduit wiring system**
- **compare metal and PVC conduit wiring**
- **state the different types of accessories used in non-metallic conduits wiring**
- **state the selection of a suitable size of conduit for a specific number and size of cables.**

In general, a conduit is defined as a tube or channel. Tubular conduit is the most commonly used material in electrical installations. When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.

Types of conduits

There are four types of conduits used for wiring.

– Rigid steel conduit
– Rigid non-metallic conduit
– Flexible steel conduit
– Flexible non-metallic conduit

Rigid steel conduit:

This can be further divided into:

– heavy gauge screwed conduit and
– light gauge conduit.

Heavy gauge screwed conduit: This can be either solid-drawn or seam-welded. A solid-drawn conduit is expensive, and hence, its use is restricted to gas-tight, explosive-proof installations. Seam - welded conduit is the one commonly used in modern domestic, commercial and industrial wiring.

Light gauge conduit: This is constructed from a length of flat, thin sheet steel which is manufactured to form a tube. The seam, which is often left open, does not provide a weatherproof installation. Hence, the use of a light gauge conduit is restricted to indoor-conduit wiring to have protection for inlaid cables. This conduit itself should not be used as earth continuity conductor; separate earthing conductors are, therefore, necessary.

Size of metal conduits: Commercially metal conduits are available in lengths of 3.00 metres and in diameters from 16 mm to 65 mm.

> **Normally the conduit pipe size refers to the outer diameter, whereas for G.I. pipes, the sizes are referred to in terms of the internal diameter.**

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All metallic conduits get corroded in damp and chemical environment. Hence conduits are to be protected against corrosion by galvanising them, when used for outdoor work or where dampness is present. For dry environments black enamelling on the conduit would be sufficient.

Non-metallic conduits: These are made of fibres, asbestos, polyvinyl chloride (PVC), high density polyethylene (HDP) or polyvinyl (PV). Of the above, PVC conduits are popular owing to their high resistance to moisture and chemical atmosphere, high dielectric strength, low weight and low cost. These conduits may be buried in lime, concrete or plaster without harmful effects.

However, light gauge (lower than 1.5 mm wall thickness) PVC pipes are not as strong as metal conduits against mechanical impact. Special PVC pipes called heavy gauge, high impact types are available in the market which can withstand heavy mechanical impact as the wall thickness of the pipes is more than 2 mm.(Refer Table 1)

Table 1

Nominal size of conduit in mm	Wall thickness of heavy gauge conduit in mm	Wall thickness of light gauge conduit in mm
Metal 16	1.6	1
19	1.8	1.0
25	1.8	1.2
32	1.8	1.2
38	2.0	—
50	2.24	—
64	2.5	—
Non- metal 16 to 64	2 or more than 2	Less than 1.5

There are some PVC conduits called heavy gauge, high temperature type which are of special base material made to withstand temperatures up to 85°C. These PVC conduits are available in 4 m length.

Flexible conduits: Apart from rigid conduits, flexible conduits are also used for protecting cable-ends connected to a vibrating machine. In the case of metal flexible conduits, steel strips are spirally wound to form a tube. However, these flexible conduits cannot be relied on as the sole means of earthing due to the manufacturing method as well as material. Hence earthing conductors should run either externally or internally to the flexible conduit to form the earth connection.

Variation in conduit-wiring system: There are two types of conduit-wiring systems as stated below, for either metal of non-metallic types.

– Surface conduit-wiring system done on wall surfaces.

– Concealed (recessed) conduit-wiring system done inside the concrete, plaster or wall.

Selection of the type of conduit: Metallic or PVC conduits are equally popular in electrical installations.

Selection of the type of conduit depends upon the following criteria.

– Location-outdoor or indoor

– Atmosphere-dry or damp or explosive or corrosive

– Working temperature

– Physical damage due to mechanical impact

– Weight of conduit-runs

– Cost

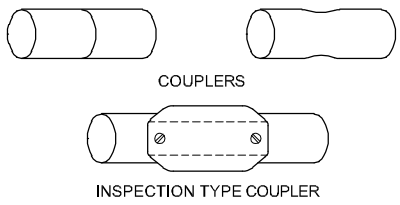
A comparison between metal and PVC conduit wirings given in Table 2 will help in choosing the right type of conduit for a specific installation.

Non-metallic conduit accessories: Non-metallic conduit fittings and accessories shall be fabricated or moulded to the required shape. They shall be so designed and constructed that they can be fitted with the corresponding conduit sizes without any adjustment, and ensure ready limited mechanical protection to the cables. These fittings and accessories are used for conduit extension and tappings or to assist the pulling conductors.

Inspection type, non-metallic fittings and accessories are permitted to be used only with surface-mounting type wiring. Inspection fittings shall be so constructed that the screws used for fixing the cover do not deform the conduits or damage the insulation of the cables enclosed.

PVC fittings and accessories couplers (Fig 1): Normally push-type couplers are used and the conduit shall be pushed right through to the interior of the fittings. Inspection type couplers are used in straight conduit-runs to assist in the inspection of the straight cables.

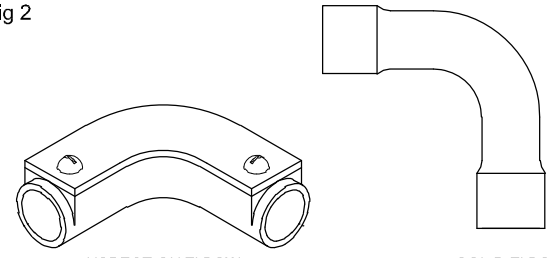
Fig 1



TYPES OF COUPLERS

Elbow (Fig 2): The axis of any elbow shall be a quadrant of a circle plus a straight portion of each end. Elbows are used at sharp ends of nearby walls or roofs and walls.

Fig 2

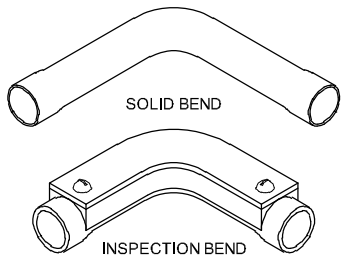


TYPES OF ELBOWS

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Bends (Fig 3): A bend gives a diversion of 90°C in the turn of a conduit, and a normal bend shall be a large sweep. Inspection-type bends are used to assist in the inspection at the corners and for drawing cables.

Fig 3



TYPES OF BENDS

Tees (Fig 4): Tees are used to take diversion from the main line either to drop to switch points or to the light points. It may be either an ordinary type or an inspection type. Inspection-type tees are used to assist in the inspection in case there is a need.

Fig 4

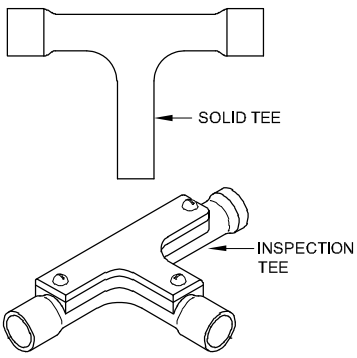


Table 2

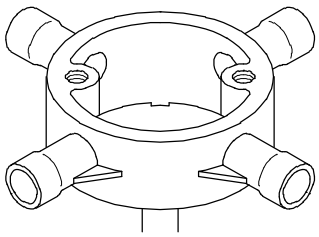
Metal conduit	PVC conduit
1 Provides good physical protection to cables.	Comparatively poor.
2 Weighs more for a given length.	Lighter.
3 Needs skill and time for installation.	Needs less skill and time.
4 Risk of electric shock due to leakage.	No risk as PVC is an insulator.
5 Good earth continuity available through the pipe itself.	Not possible. Separate earth wire is required.
6 Can be used in gas-tight and explosive-proof installation.	Not suitable.
7 Not resistant to corrosion, needs protective coating.	Resistant to corrosion.
8 Large ambient temperature range.	Suitable for limited temperature range. At temperatures above 60°C, the conduit starts melting. At very low temperatures the conduit cracks.
9 Fire-resistant.	Not fire-resistant.
10 More costly.	Less costly.

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Boxes

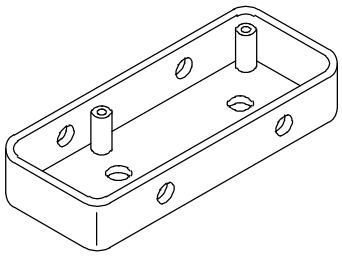
Circular boxes (Fig 5): Small, circular boxes shall be provided with two machine screws of a diameter not less than 2.8 mm for fixing the covers. Large, circular boxes have four machine screws of a diameter not less than 4 mm for fixing a cover. They are available in single-way, two-way, three-way and four-way as well as back outlet types which can be used as per necessity in the wiring.

Fig 5



Rectangular boxes (Fig 6): These boxes shall be provided with two machine screws of a diameter not less than 2.8 mm for fixing the cover. They can be used as a junction box or a switchboard, for fixing flush-type switches.

Fig 6



RECTANGULAR BOX

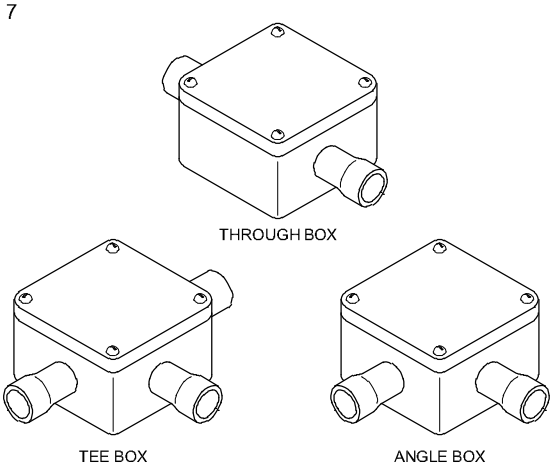
Apart from the above types, various other types are used as junction boxes. (Fig 7)

Selection of conduit size: Non-metallic conduit pipes, used in wiring, should have a minimum size of 16 mm in diameter. Where a large number of conductors are to be drawn, the size of the diameter depends on the size of the conductor and the number of conductors.

Table 3 gives details of numbers and the size of conductors that can be drawn in each size of a non-metallic conduit.

Example: For selection of a PVC conduit :

Fig 7



TYPES OF BOXES (JUNCTION BOXES)

When 2.5 sq mm 250V grade, single core cables of six numbers are to be drawn in a single run we can use 25 mm non-metallic conduit. (Table 3) When 6 sq mm. 250V single core 6 cables are to be drawn in a single pipe, we can use 32 mm PVC pipe. (Table 3)

Table 3
Size of conduit and permissible number of cables of 250 V grade

Size of cable		Size of conduit(mm)					
Nominal cross-sectional area mm^2	Number and diameter in mm of wires	16	19	25	32	38	51
		(Number of cables, max. in straight run)					
1.0	1/1.12 Cu	5	7	13	20	-	-
1.5	1/1.40 Al/Cu	4	6	10	14	-	-
2.5	1/1.80 Al/Cu	3	5	10	14	-	-
4	1/2.24 Al/Cu 7/0.85 Cu	2	3	6	10	14	-
6	1/2.80 Al/Cu 7/1.06 Cu	-	2	5	8	11	-
10	1/3.55 Al 7/1.40 Cu	-	-	4	7	9	-
16	7/1.70 Al/Cu	-	-	2	4	5	12
25	/2.24 Al/Cu	-	-	-	2	2	6
35	7/2.50 Al/Cu	-	-	-	-	2	5
50	7/3.00 Al 19/1.80 Al/Cu	-	-	-	-	2	3

Cu - For copper conductors only. Al - For aluminium conductors only.

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Test board and colour code of cables

Objectives: At the end of this lesson you shall be able to
- **explain the method of using a test board**
- **state the general colour codes used in cables.**

Test board: A test board is used for conducting the following tests.

– **Continuity test** (Load connected in series with a lamp)

Ex: Testing fan winding, condition of choke and tube light starter etc.

– **Direct test**

Ex Testing electrical appliances of 1000 watts or lower rating for proper functioning.

The schematic diagram of connection of a testing board is shown in Fig 1 with all the outlets and controls. Sockets P_1 and P_2 provide direct, single-phase supply whereas socket P_3 and terminal block T provide a single-phase supply in series with the lamp L_3.

Continuity test: While performing a continuity test, the appliance to be tested is connected to the socket P_3 or to the terminal T which are in series with the lamp L_3 and are controlled by switch S_3. Normally this test is conducted by the electrician to ascertain whether the appliance is open-

circuited or short-circuited. A low wattage, appliance when connected, will make the lamp L_3 to burn dim, and a high wattage appliance will make the lamp to burn bright. According to the brightness of the lamp, the behaviour of the appliance, as well as the wattage of the appliance and the lamp and the condition of the appliance could be judged. `No light' indicates either open circuit or high resistance in the appliance. In the same way, a choke coil and a starter of a tube light can be checked. (The flickering of the lamp L_3 with the starter indicates that the starter is good.)

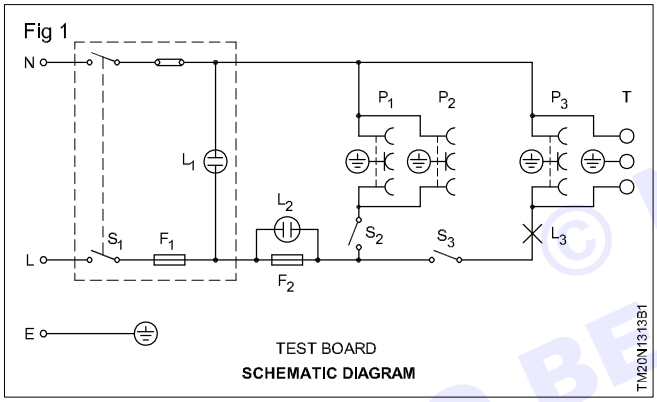
Thus the testing board also works as a continuity tester.

Direct testing: By connecting the appliance direct to the socket P_1 or P_2, the performance of the appliance can be verified after repair.

Fuses: If the indicator lamp L_1 does not burn, it indicates no supply. On the other hand, in normal conditions, the indicator lamp L_2 will not burn, and it burns only when the fuse F_2 is open.

Thus the test board is a cheap and handy test set which is easy to use by an electrician to carry out his routine checks in the course of his work.

Fig 1



Colour identification of cables: The colour of the cables indicates their function. Every electrician should be able to identify the colour code used in electrical work and follow it meticulously to avoid hazards. Table 1 gives the colour code and the alpha-numeric notation as recommended by N.E.Code.

For purposes of the N.E. code, the provisions of Table 1 shall apply for the general application of marking conductors in installation. The rules also apply for marking conductors in equipment/apparatus.

Table 1

Alpha-numeric notation and colours

Designation of conductors		Identification by	
		Alpha-numeric notation	Colour
Supply AC system	Phase 1	L1	Red
	Phase 2	L2	Yellow
	Phase 3	L3	Blue
	Neutral	N	Black
Apparatus AC system	Phase 1	U	Red
	Phase 2	V	Yellow
	Phase 3	W	Blue
	Neutral	N	Black
Supply DC system	Positive	L+	Red
	Negative	L-	Blue
	Mid-wire	M	Black
Supply AC system (Single phase)	Phase	L	Red
	Neutral	N	Black
Protective Earth conductor		PE	Green and yellow
Earth		E	No colour other than the colour of the bare conductor.

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Fuses

Objectives: At the end of this lesson you shall be able to
- **explain the purpose of the fuse in a circuit**
- **classify the different types of fuses and their uses.**

Purpose of fuses: A fuse is a safety device used for the purpose of protecting a circuit against excess current. In the event of excessive current, the fuse element melts and opens up the circuit thereby protecting it from damage.

Symbols: These are the graphical symbols used to illustrate an electrical fuse in electro-technical diagrams.

– General symbols of a fuse (Fig 1a)

– Fuse with terminals and protective housing (Fig 1b)

Placement of fuses: In electrical installations, the fuses are always connected into the live wires (L_1, L_2, and L_3 as shown in Fig 2) and never into the neutral N or the protective earth line PE.

Fig 1

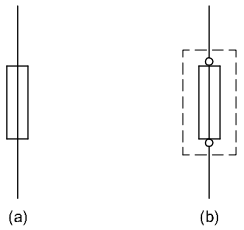
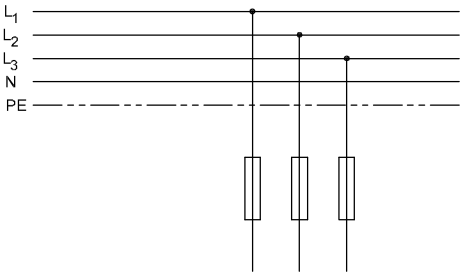


Fig 2



Terminology

Fuse element: The part of the fuse which is designed to melt and open up a circuit.

Fuse-carrier: The removable portion for carrying the fuse element.

Fuse base: The fixed part of the fuse provided with terminals for connection to the circuit which is suitable for the reception of the fuse- carrier.

Current rating: Safe maximum current that can pass continuously without overheating.

Fusing current: The current at which the fuse element melts.

Cut-off factor: Time (period) taken by a fuse to interrupt the circuit in the event of a fault.

Fusing factor: Ratio between minimum fusing current and current rating.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Rated current}}$$

The fusing factor for a re-wirable fuse varies between 1.4 to 1.7 and may go up to 2.0, but for a HRC fuse it is 1.1

However, a fuse selected for over-current protection should not have a fusing factor of more than 1.4.

Types of fuses used in domestic wiring:

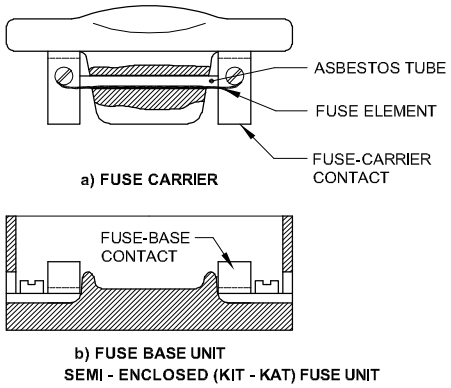
– Re-wirable type (up to 200A)

– Cartridge type (up to 1250A)

Rewirable type fuse (Fig 3): The fuse element in this type of fuse consists of a wire which may be replaced when necessary. These fuses are simple in construction and the initial cost as well as the renewal cost is very low.

The fuse elements used in this type are tinned copper wire, lead and tin alloy. Approximate sizes of fuse elements of tinned copper wire or aluminium wire for use in semi-enclosed fuses are shown in Table 1.

Fig 3



The fuse element will melt after approximately 2 minutes when carrying a current equal to twice the current rating. However, the cut-off time factor varies in rewirable fuses due to:

– the construction of the carrier (design of fuse-carrier/ base)

– the manner in which the fuse wire has been fitted

– the length of time the fuse was in service

– ambient temperature

– the amount of current etc.

Small fuse wires in parallel in a carrier to carry a large current should be avoided, as far as possible. The actual rating becomes less than the sum of the ratings of the individual strands. A paralleling factor of 0.7 to 0.8 is used to multiply the sum of the rating of individual strands to get the actual current rating.

Table 1

Current rating for	Approximate fusing current Amp.	Tinned copper wire		Aluminium wire dia. in mm
		S.W.G.	Diameter in mm	
1.5	3	40	.12192	--
2.5	4	39	.13208	–
3.0	5	38	.1524	.195
4.0	6	37	.17272	–
5.0	8	35	.21336	–
5.5	9	34	.23368	–
6.0	10	33	.254	.307
7.0	11	32	.27432	–
8.0	12	31	.29464	–
8.5	13	30	.31496	–
9.5	15	–	----	.400
10.0	16	29	.34544	–
12.0	18	28	.37592	–
13.0	20	–	----	.475
13.5	25	–	----	.560

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14.0	28	26	.4572	–
15.0	30	25	.508	.630
17.0	33	24	.5588	–
18.0	35	–	----	.710
20.0	38	23	.6096	–
21.0	40	–	----	–
22.0	45	–	----	.750
24.0	48	22	.7112	.850
25.0	50	–	----	.90
29.0	58	21	.8128	–
30.0	60	–	----	1.00
34.0	70	20	.9144	1.22
37.5	80	–	----	1.25
38.0	81	19	1.016	--
40.0	90	–	----	1.32

43.0	98	–	1.1176	–
43.5	100	–	----	1.40
45.0	106	18	1.2192	–
55.0	120	–	----	1.60
62.0	130	–	----	1.70
65.0	135	17	1.4224	–
66.0	140	–	----	1.80
69.0	150	–	----	1.85
73.0	166	16	1.6256	–
75.0	175	–	---	2.06
78.0	197	15	1.8288	–
80.0	200	–	----	2.24
102.0	230	14	2.032	–
130.0	295	13	2.3368	–

Alternating current - fundamentals - A.C simple circuits - R.L.C series circuit - R.L.C parallel circuit

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

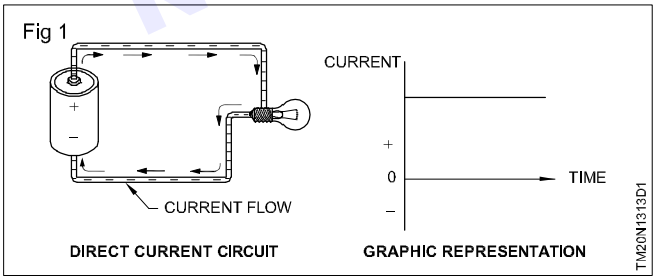
- **define alternating current and direct current**
- **explain the difference between alternating current and direct current**
- **list the advantages and disadvantages of alternating current**
- **sketch common AC and DC wave-forms**
- **define the various terms and values associated with a current or voltage sine wave**
- **calculate the effective, rms, peak, and peak-to-peak values of sine wave.**

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Direct current (DC): Electric current can be defined as the flow of electrons in a circuit. Based on the electron theory, electrons flow from the negative (−) polarity to the positive (+) polarity of a voltage source.

Direct current (DC) is the current that flows only in one direction in a circuit. (Fig 1) The current in this type of circuit is supplied from a DC voltage source. Since the polarity of a DC source remains fixed, the current produced by it flows in one direction only.

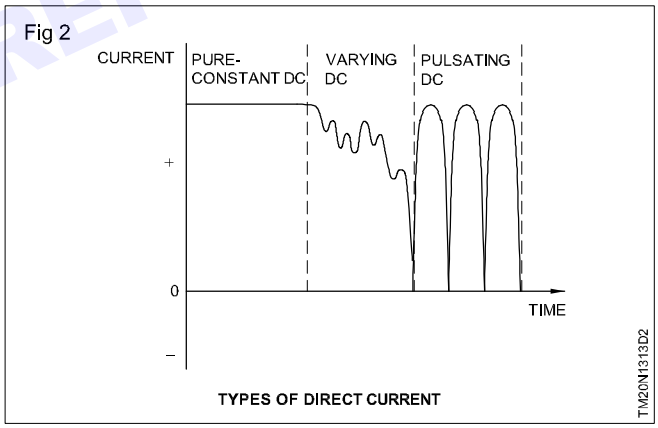
Fig 1



Dry cells are commonly used as a DC voltage source. Both the voltage and polarity of the dry cell are fixed. When connected to a load, the current produced flows in one direction at some steady or constant value.

A direct current flow need not necessarily be constant, but it must travel in the same direction at all times. There are several types of direct current, and all of them depend upon the value of the current in relation to time. (Fig 2)

Fig 2

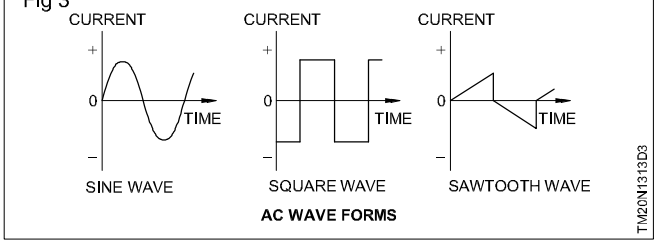


A constant DC current shows no variation in value over a period of time. Both varying and pulsating DC currents have a changing value when plotted against time. The pulsating DC current variations are uniform, and repeat at regular intervals.

Alternating current (AC): An alternating current (AC) circuit is one in which the direction and amplitude of the current flow change at regular intervals. The current in this type of circuit is supplied from an AC voltage source. The polarity of an AC source changes at regular intervals resulting in a reversal of the circuit current flow.

Alternating current usually changes in both value and direction. The current increases from zero to some maximum value, and then drops back to zero as it flows in one direction. This same pattern is then repeated as it flows in the opposite direction. The wave-form or the exact manner in which the current increases and decreases is determined by the type of AC voltage source used. (Fig 3)

Fig 3



Alternating current generator: Alternating current is used wherever a large amount of electrical power is required. Almost all of the electrical energy supplied for domestic and commercial purposes is alternating current. AC voltage is used because it is much easier and cheaper to generate, and when transmitted over long distances, the power loss is low.

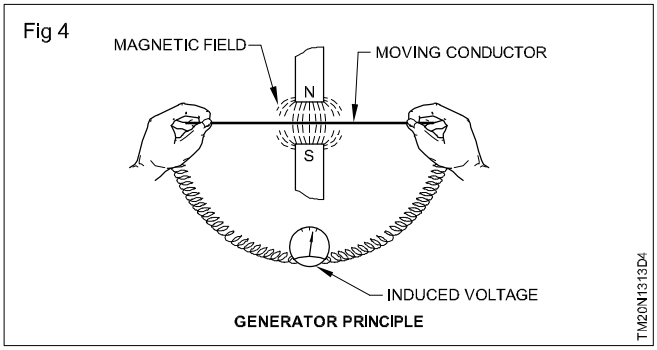
AC equipment is generally more economical to maintain and requires less space per unit of power than the DC equipment.

Alternating current can be generated at higher voltages than DC, with fewer problems of heating and arcing. Some standard values of voltages are 6.6kV (6600V), 11kV(11000V) and 33kV(33000V) The values are increased to 66 000, 110 000, 220 000, 400 000 volts for transmission over long distances. At the load area, the voltage is decreased to working values of 240V and 415V.

The basic method of obtaining AC is by the use of an AC generator. A generator is a machine that uses magnetism to convert mechanical energy into electrical energy. The generator principle, simply stated, is that a voltage is induced in a conductor whenever the conductor is moved through a magnetic field so as to cut the lines of magnetic force.

Figure 4 shows the basic generator principle. A change in a magnetic field around a conductor tends to set electrons in motion. The mere existence of a magnetic field is not enough; there must be some form of change in the field.

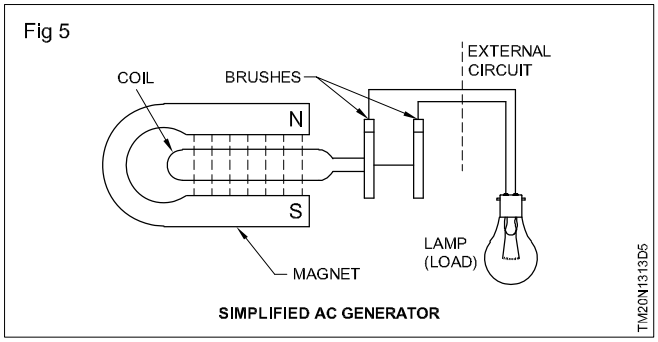
Fig 4



If we move the conductor through the magnetic field, a force is exerted by the magnetic field on each of the free electrons within the conductor. These forces add together and the effect is that voltage is generated or induced into the conductor.

An AC generator produces an AC voltage by causing a loop of wire to turn within a magnetic field. This relative motion between the wire and the magnetic field causes a voltage to be induced between the ends of the wire. This voltage changes in magnitude and polarity as the loop is rotated within the magnetic field. (Fig 5) The force required to turn the loop can be obtained from various sources. For example, very large AC generators are turned by steam turbines or by the movement of water.

Fig 5



The voltage produced by a single loop generator is too weak to be of much practical value. A practical AC generator has many more turns of wire wound on an armature. The armature is made up of a number of coils wound on an iron core. The AC voltage induced in the armature coils is connected to a set of slip rings from which the external circuit receives the voltage through a set of brushes. An electromagnet is used to produce a stronger magnetic field.

The sine wave: The shape of the voltage wave-form generated by a coil rotating in a magnetic field is called a sine wave. The generated sine wave voltage varies in both voltage value and polarity.

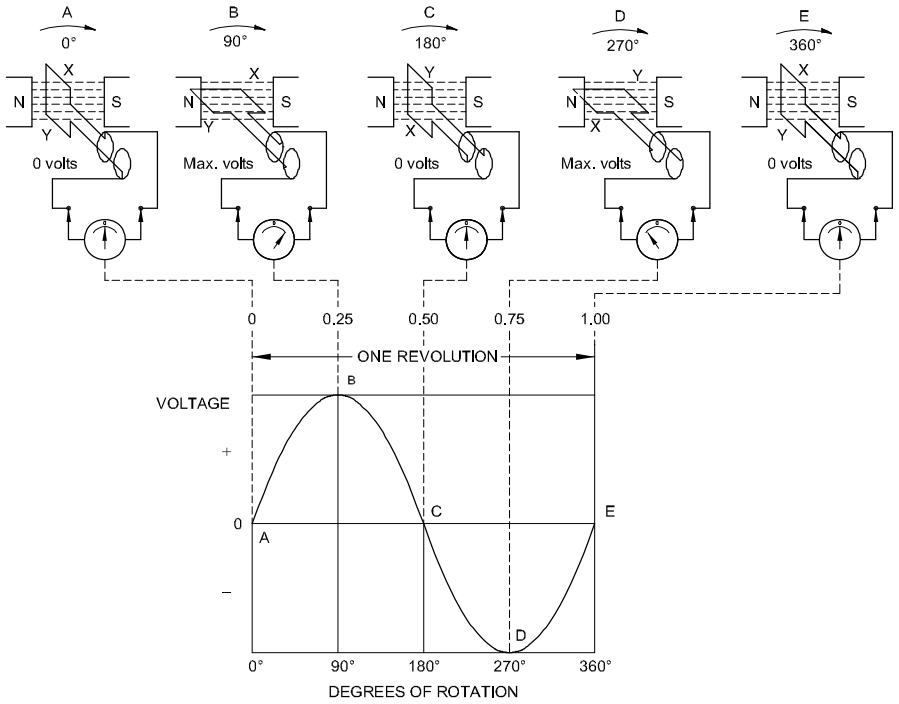
If the coil is rotated at a constant speed, the number of magnetic lines of force cut per second varies with the position of the coil. When the coil is moving parallel to the magnetic field, it cuts no lines of force. Therefore, no voltage is generated at this instant. When the coil is moving at right angles to the magnetic field, it cuts the maximum number of lines of force. Therefore, maximum or peak voltage is generated at this instant. Between these two points the voltage varies in accordance with the sine of the angle at which the coil cuts the lines of force.

The coil is shown in five specific positions in Fig 6. These are intermediate positions which occur during one complete revolution of the coil position. The graph shows how the voltage increases and decreases in amount during one rotation of the loop. Note that the direction of the voltage reverses each half-cycle. This is because, for each revolution of the coil, each side must first move down and then up through the field.

The sine wave is the most basic and widely used AC wave-form. The standard AC generator (alternator) produces a voltage of sine wave-form. Some of the important electrical characteristics and terms used when referring to AC sine wave voltage or current are as follows.

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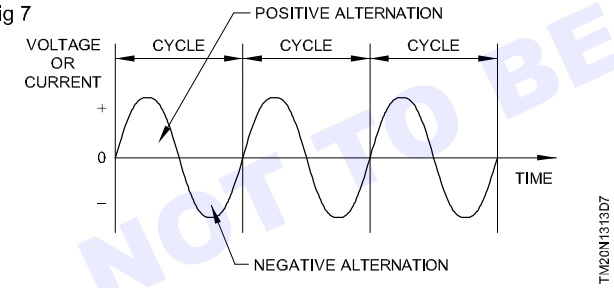
Fig 6



GENERATION OF AN ALTERNATING VOLTAGE: AS THE LOOP ROTATES THROUGH THE MAGNETIC FIELD. THE AMOUNT AND POLARITY OFTHE VOLTAGE CHANGES WITH ANGLE AND DIRECTION OF MOTION.

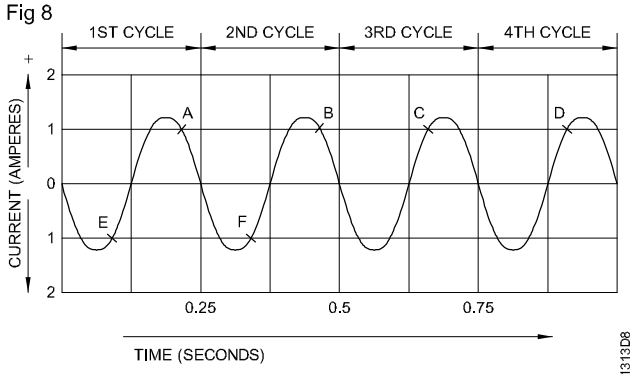
Cycle: One cycle is one complete wave of alternating voltage or current. During the generation of one cycle of output voltage, there are two changes or alternations in the polarity of the voltage. These equal but opposite halves of a complete cycle are referred to as alternations. The terms positive and negative are used to distinguish one alternation from the other. (Fig 7)

Fig 7



Period: The time required to produce one complete cycle is called the period of the wave-form. In Fig 8, it takes 0.25 seconds to complete one cycle. Therefore, the period (T) of that wave-form is 0.25 seconds.

Fig 8



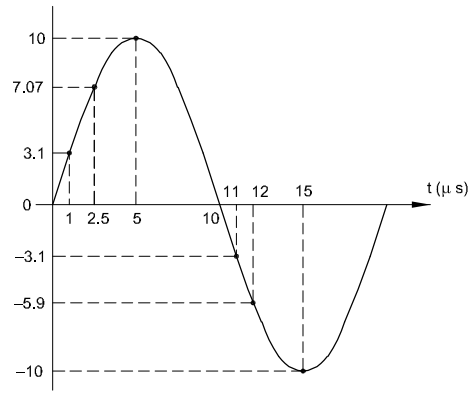
CYCLE, PERIOD, AND FREQUENCY. THE WAVEFORM HAS A PERIOD OF 0.25 SECONDS AND FOUR CYCLES PER SECOND.

The period of a sine wave (any symmetrical wave-form) need not necessarily be measured between the zero crossings at the beginning and the end of a cycle. It can be measured from any point in a given cycle to the corresponding point in the next cycle. (See Fig 8-AB, CD or EF)

Frequency: The frequency of an AC sine wave is the number of cycles produced per second. (Fig 8) The SI unit of frequency is the hertz (Hz). For example, the 240V AC at your home has a frequency of 50 Hz.

Instantaneous value: The value of an alternating quantity at any particular instant is called instantaneous value. The instantaneous values of a sine wave voltage is shown in Fig 9. It is 3.1 volts at 1µs, 7.07 V at 2.5µs, 10V at 5µs, 0V at 10µs, 3.1 volt at 11 µs and so on.

Fig 9



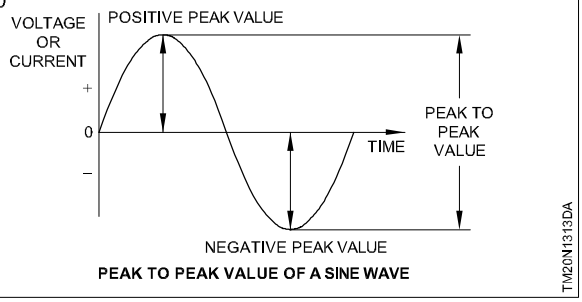
EXAMPLE OF INSANTANEOUS VALUES OF A SINE WAVE VOLTAGE

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AC voltage and current values: Since the value of a sine wave of voltage or current continuously changes, one must be specific, while referring to and describing the values of the wave-form. There are several ways of expressing the value of a sine wave.

Peak value or maximum value: Each alternation of the sine wave is made up of a number of instantaneous values. These values are plotted at various heights above and below the horizontal line to form a continuous wave-form. (Fig 10)

Fig 10



PEAK TO PEAK VALUE OF A SINE WAVE

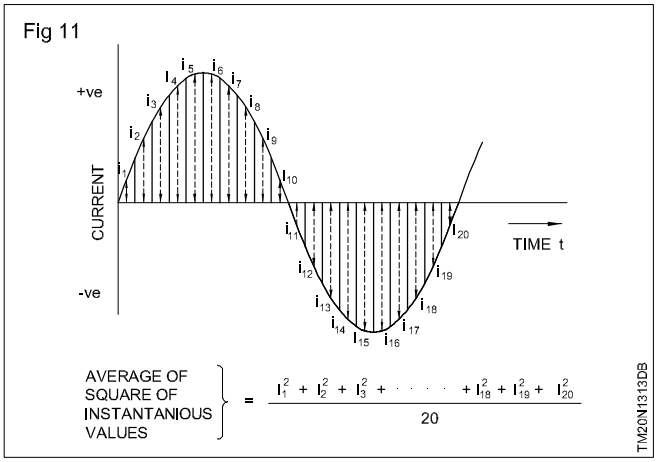
The peak value of a sine wave refers to the maximum voltage or current value. Note that two equal peak values occur during one cycle.

Peak-to-peak value: The peak-to-peak value of a sine wave refers to its total overall value from one peak to the other. (Fig 10) It is equal to two times the peak value.

Effective value: The effective value of an alternating current is that value which will produce the same heating effect as a specific value of a steady direct current. In other words, an alternating current has an effective value of 1 ampere, if it produces heat at the same rate as the heat produced by 1 ampere of direct current, both flowing in the same value of resistance.

Another name for the effective value of an alternating current or voltage is the root mean square (rms) value. This term was derived from a method used to compute the value. The rms is calculated as follows. The instantaneous values for one cycle are selected for equal periods of time. Each value is squared, and the average of the squares is calculated (values are squared because the heating effect varies as square of the current or voltage). The square root of this is the rms value. (Fig 11)

Fig 11



By using this method it can be proved that the effective value of a sine wave of current is always equal to 0.707 times its peak value. A simple equation for calculating the effective value of sine wave is:

for voltage, $V = 0.707\ V_m$

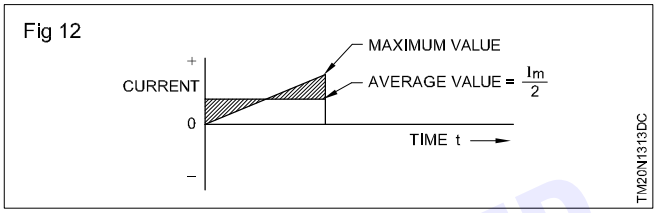
for current, $I = 0.707\ I_m$

where subscript m refers to the maximum value.

When an alternating current or voltage is specified, it is always the effective value that is meant, unless otherwise stated. Standard AC meters indicate effective values only.

Average value: It is sometimes useful to know the average value for one half cycle. If the current is changed at the same rate over the entire half cycle as in Fig 12, the average value would be one half of the maximum value.

Fig 12



However, because the current does not charge at the same rate, another method is used. Find the area covered by the curve over the horizontal axis, then divide that area by the base horizontal length. It has been determined that the average value is equal to 0.637 times the maximum value for sine wave-form i.e.

for voltage, $V_{av} = 0.637\ V_m$

for current, $I_{av} = 0.637\ I_m$

where subscript av refers to the average value and subscript m refers to the maximum value.

Form factor (k_f): Form factor is defined as the ratio of effective value to average value of half cycle.

For sinusoidal AC

$$k_f = \frac{0.707\ I_m}{0.6637\ I_m} = 1.11$$

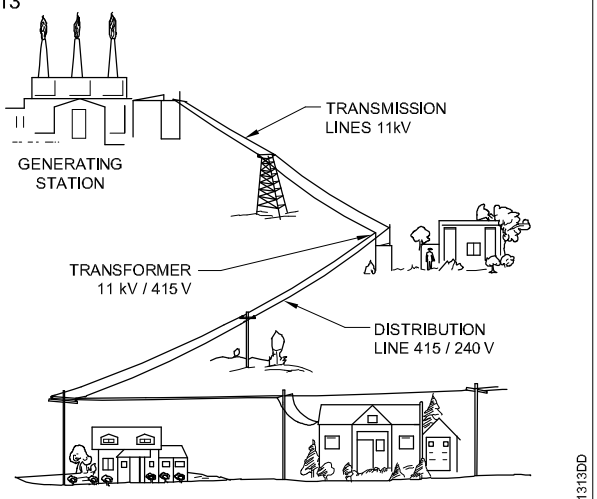
where the subscript m refers to the maximum value.

Advantages of AC: AC voltages can be raised or lowered with ease. This makes it ideal for transmission purposes. Large amounts of power can be transmitted at high voltage and low currents with minimum loss. Because the current is low, smaller transmission wires can be used to reduce installation and maintenance costs. (Fig 13)

DC generators limit their output voltage to 6000V or less. The voltage cannot be raised or lowered through the transformers. Long distance transmission requires heavy cables. AC generators are built with a capacity up to 500000 kilowatts. The DC generators capacity is limited to 10000 kw.

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Fig 13



TRANSMISSION AND DISTRIBUTION LINES FROM GENERATING STATION TO RESIDENCES

AC motors are less expensive to build, install and maintain than the DC motors. DC motors have one distinct advantage over AC motors: they have better speed control.

Neutral and earth conductors

Objectives: At the end of this lesson you shall be able to
- **describe the purpose of earthing**
- **describe the two types of earthing**
- **differentiate between `neutral' and `earth wire'.**

Earthing: The importance of earthing lies in the fact that it deals with safety. One of the most important, but least understood, considerations in the design of electrical systems is that of earthing (grounding). The word `earthing' comes from the fact that the technique itself involves making a low-resistance connection to the earth or to the ground. The earth can be considered to be a large conductor which is at zero potential.

Purpose of earthing: The purpose of earthing is to provide protection to personnel, equipment and circuits by eliminating the possibility of dangerous or excessive voltage.

There are two distinct considerations in the earthing of an electrical system: earthing of one of the conductors of the wiring system, and earthing of all metal enclosures which contain electrical wires or equipment. The two types of earthing are:

– System earthing

– Equipment earthing.

System earthing: This consists of earthing one of the wires of the electrical system, such as the neutral, to limit the maximum voltage to earth under normal operating conditions.

Equipment earthing: This is a permanent and continuous bonding together (i.e. connecting together) of all non-current carrying metal parts of the electrical equipment to the system earthing electrode.

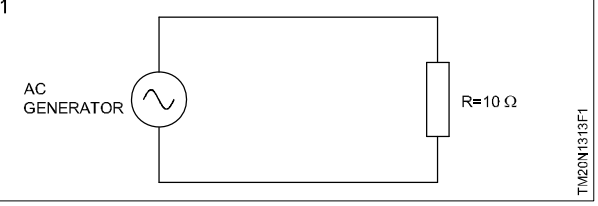
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AC simple circuit - with resistance only

Objectives: At the end of this lesson you shall be able to
- **state phase relationship between voltage current and power in an AC circuit with pure resistance**
- **solve problems of AC series circuit and AC parallel circuit with pure resistance only.**

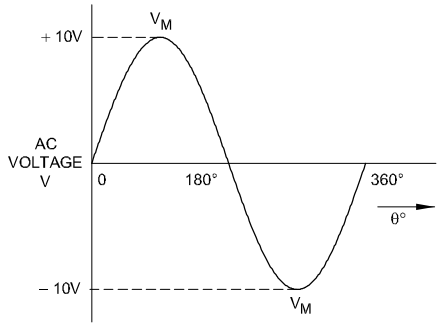
When an AC voltage is applied across a resistance, an AC current flows through the resistance. (Fig 1)

Fig 1



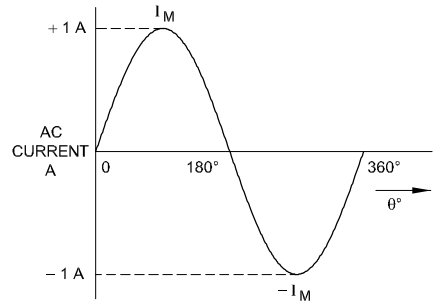
The magnitude of the current at any instant is directly proportional to the magnitude of the voltage at that instant, and is inversely proportional to the value of the resistance. This is the same relationship that exists between the current, voltage, and resistance in a DC circuit, and so Ohm's Law also applies to the instantaneous values of current and voltage in an AC circuit. This means that at any instant when the voltage is zero, the current is also zero. And when the voltage is maximum, the current must also be maximum, since the resistance is constant. (Figs 2 & 3)

Fig 2



SINE WAVE

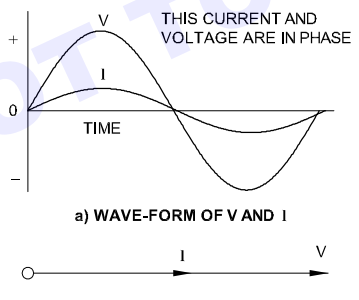
Fig 3



When the voltage reverses and becomes negative, the current also reverses, in as much as it always flows from positive to negative. Thus, at every instant of time the current is exactly in step with the applied voltage. This is illustrated in Figs 2 & 3. As the two graphs have the same reference horizontal axis, they can be plotted one over the other as in Fig 4a.

From the figure 4a it is clear that voltage and current start from zero and reach the maximum values, either in positive or negative direction at the same time. This also could be illustrated through a vector diagram shown in Fig 4b.

Fig 4



The two wave-forms are thus `in step' with each other, and are said to be in phase.

The term `phase' is used to indicate the time relationship between alternating voltages and currents. In an AC resistive circuit, therefore, the current and voltage are `in phase'. The term `in phase' can also be used for two voltages or two currents.

When two currents or voltages are in phase, it does not mean that their magnitudes are the same. The peak magnitudes are reached at the same time, but they can have different values.

Since the average, effective and peak values of AC current and voltage are derived from the instantaneous values, Ohm's Law applies to them also.

$$Irms = \frac{Vrms}{R} = \frac{.707\ Vmax}{R}$$

In Figs 1,2 and 3

$$Irms = = \frac{.707 \times 10V}{10\ ohms}$$

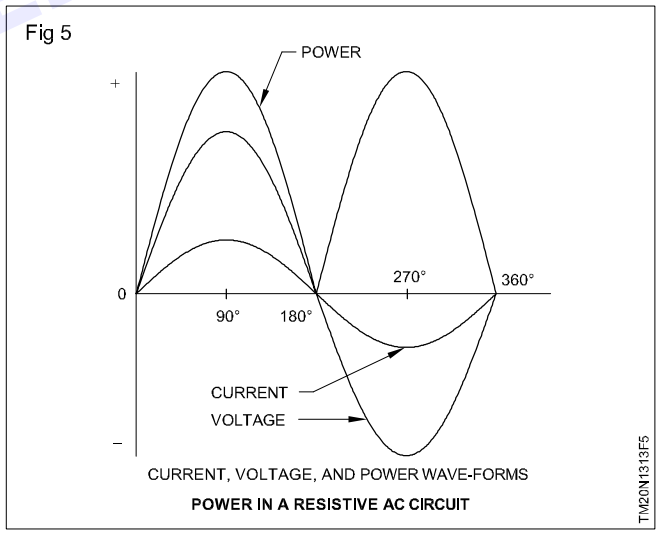
.707A is the rms value of Imax (1A).

Power in resistive AC circuits: As with DC, power is the product of current and voltage. With AC, the values of current and voltage vary with time. At any instant, the power is equal to the current at that instant multiplied by the voltage at that instant. As shown in Fig 5 the product of the instantaneous current and voltage is the instantaneous power. Plotting all the instantaneous powers produces a power wave-form. However, notice that the power wave-form is always positive for in-phase currents and voltages. A negative current multiplied by a negative voltage yields a positive power. This means that the resistive load is converting electric energy into heat energy during the complete cycle. For in-phase circuits, that is, resistive circuits, we can state:

$$P = IV = I^2R = \frac{V^2}{R}$$

where I and V are the rms current and voltage.(Fig 5) respectively.

Fig 5



CURRENT, VOLTAGE, AND POWER WAVE-FORMS

POWER IN A RESISTIVE AC CIRCUIT

Example 1: How much power is used by the resistive load in Fig 6?

Given: V = 3.5V

I = 1.4A

Find: P

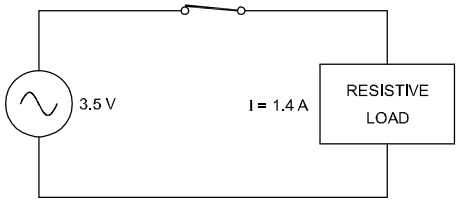
Known: P = IV

Solution: P = 1.4A x 3.5V = 4.9W

Answer : The power used is 4.9W.

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Fig 6



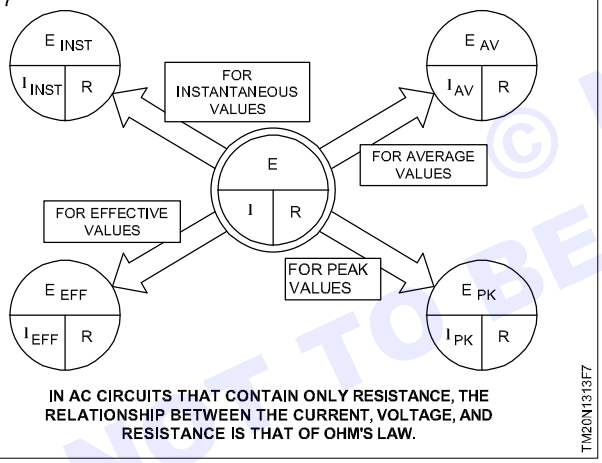
RESISTIVE AC CIRCUIT

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Series circuit and parallel circuits with pure resistance: The solution of series and parallel AC circuits that involve only resistance, follows the same principles as used for DC. As previously noted, the same equation for power and Ohm's Law can be applied if rms quantities are used throughout. In those problems which contain data with peak or peak-to-peak values, care must be taken to make the appropriate conversions, so that a consistent set of units results. The same laws of voltage division and current division hold for AC as they do for DC, provided that only pure resistances are involved. In AC circuits the values are rms values unless otherwise mentioned. (Fig 7)

In AC circuits that contain only resistance, the relationship between the current voltage, and resistance is that of Ohm's Law.

Fig 7

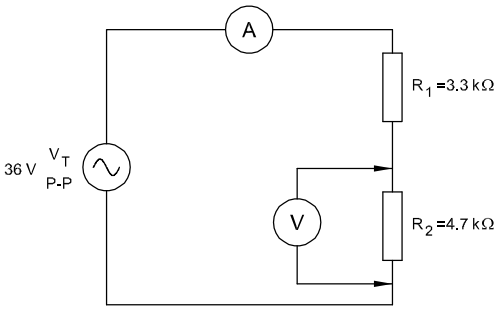


IN AC CIRCUITS THAT CONTAIN ONLY RESISTANCE, THE RELATIONSHIP BETWEEN THE CURRENT, VOLTAGE, AND RESISTANCE IS THAT OF OHM'S LAW.

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Example 2: Two series-connected resistors, 3.3k ohms and 4.7k ohms, have a 36-V peak-to-peak sinusoidal voltage connected to them as shown in Fig 8.

Fig 8



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Determine

A the reading of a series-connected ammeter

B the voltage across the 4.7k ohms resistor

C the power dissipated in the 3.3k ohms resistor.

Solution

A The rms applied voltage,

$$V_T = V_T = \frac{V_{P-P}}{2\sqrt{2}} = \frac{36}{2\sqrt{2}} = 12.73V$$

Total circuit resistance,

$R_T = R_1 + R_2 = 3.3k\ ohms + 4.7k\ ohms = 8k\ ohms.$

The ammeter indicates

$$I = \frac{V_T}{R} = \frac{12.73\ V}{8k\ ohms} = 1.59\ mA$$

B Voltage across the 4.7k ohms resistor,

$$V_2 = V \times \frac{R_2}{R_2 + R_1}$$

$$= 12.73V \times \frac{4.7k\ ohms}{4.7k\ ohms + 3.3k\ ohms} = 7.48V.$$

$$P = I^2R_1$$
$$= (1.59 \times 10^{-3})^2 \times 3.3 \times 10^3$$
$$= 8.3\ mW.$$

Example 3: Consider R_1 = 4.7k ohms and R_2 = 3.3kohms connected in parallel across a sinusoidal voltage, as shown in Fig 9. The resistors draw a total of 50mA.

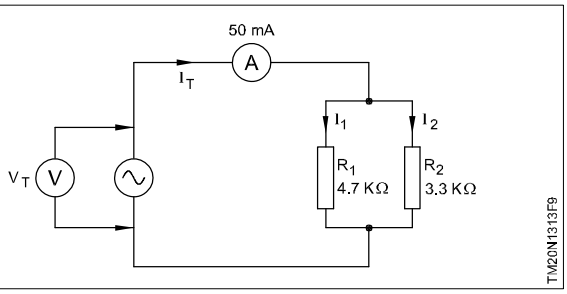
Calculate

a the current in the 3.3kohms resistor

b the peak-to-peak voltage across the source

c the total power dissipated in the two resistors.

Fig 9



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Solution

a Current in the 3.3k ohms resistor,

$$I_2 = I_T \times \frac{R_2}{R_2 + R_1}$$

$$= 50\text{mA} \times \frac{4.7\text{k ohms}}{4.7\text{k ohms} + 3.3\text{k ohms}}$$

$$= 50\text{ mA} \times \frac{4.7}{8} = 29.4\text{ mA.}$$

b Voltage across the circuit,

$V_T = I_T R = 29.4 \times 10^{-3}\text{A} \times 3.3 \times 10^{3}\text{ohms} = 97\text{V}$

$V_{P_P} = 2\sqrt{2}\,\text{V} = (2\sqrt{2} \times 97)\,\text{V} = 274.35\text{V}$

(Note that it is not necessary to find the total parallel resistance.)

c $P = V_T I_T$

$= 97\text{V} \times 50 \times 10^{-3}$

$= 4.85\text{W.}$

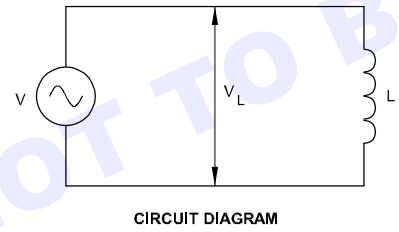
AC simple circuit with inductance only

Objectives: At the end of this lesson you shall be able to
- **state phase relation between V and I in a pure inductive circuit**
- **state what is inductive reactance**
- **state power in pure inductive circuit**
- **define power factor.**

Circuit with pure inductance only: Inductance affects the operation of pure DC circuits only at the instant they are opened and the instant they are closed. In an AC circuit, the current is always changing, and the inductance is always opposing the change. The inductance, therefore, has a constant effect on circuit operation.

A circuit with pure inductance alone can never be formed, because the source, the connecting wires, and the inductor all have some resistance. However, if these resistances are very small and have a much smaller effect on the circuit current than does the inductance, the circuit can be considered as containing only inductance. (Fig 1)

Fig 1



CIRCUIT DIAGRAM

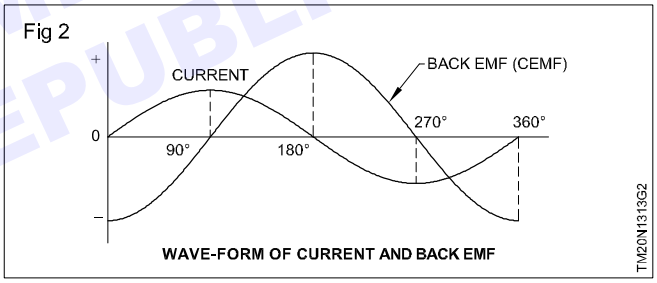
In any AC circuit that contains only inductance, there are three varying quantities. These are (1) the applied voltage, (2) the induced back emf, and (3) the circuit current.

Phase relationship between voltage and current: The phase relationships in an inductance can most easily be understood by considering first the current and the back emf. You know two things about the current and the back emf. One is that the counter emf is maximum when the rate of change of current is the greatest, and is zero when the current is not changing.

The second relationship is that the direction of the cemf is such that it always opposes the current change.

The wave-form in Fig 2 shows one cycle of AC current. The rate of change is greatest where the slope of the wave-form is greatest. You can see that this occurs at those points where the wave-form passes through zero; or at 0,180, and 360 degrees. This means that the highest cemf is generated at 0,180 and 360 degrees, as shown by the wave-forms in Fig 2. Around 90 and 270 degrees, the change is very little; as a matter of fact, at exactly 90 and 270 degrees, where the current change is from rising to falling, the current is momentarily steady. Therefore, the flux lines do not change at those points, and no cemf is induced.

Fig 2



WAVE-FORM OF CURRENT AND BACK EMF

What should be the amount and direction of counter emf (back emf) when the current is passing through zero and in the positive direction?

Since at 0 degrees the current is passing through zero in a positive direction, the cemf must be maximum in the negative direction, in as much as it always opposes the increase in current. Similarly, when the current begins to decrease at 90 degrees, the cemf must be increasing in the positive direction to aid the current flow. As shown, therefore, the cemf follows Lenz's Law by lagging the current by 90 degrees. You know that the applied voltage is 180 degrees out of phase with the cemf, and so the applied voltage must lead the current by 90 degrees. This is shown in the wave-form in Fig 3. The relationships between the three quantities (current, cemf, and applied voltage) is shown in the wave-forms in Fig 4. We know they are not in phase as in the case of resistive circuits.

In an inductance: (1) the applied voltage leads the current by 90°; (2) the back emf lags the current by 90° and (3) the applied voltage and the back emf are 180° out of phase.

This is known as 'phase difference'.

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Fig 3

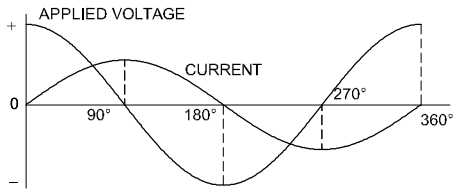
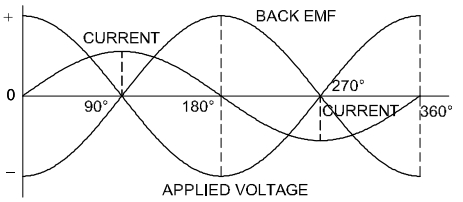


Fig 4



Phase difference: If two alternating quantities attain maximum value in the same direction after passing through zero value at different times, they are said to have a phase difference.

Phase difference can be expressed in fractions of a cycle. For more accuracy, phase difference is given in degrees. The terms `lead' and `lag' are used to describe the relative positions in time of two voltages or currents that are not in phase. The one that is ahead in time is said to lead, while the one behind lags. (Figs 5 and 6)

Fig 5

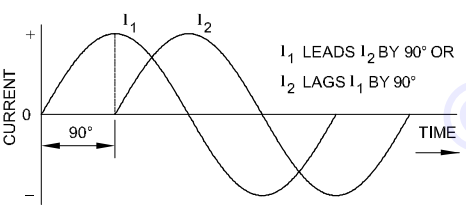
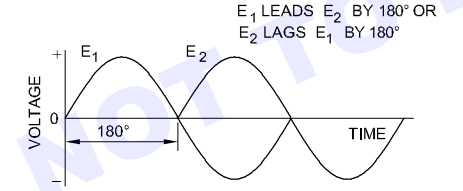


Fig 6



When maximum and minimum points of one voltage or current occur before the corresponding points of another voltage or current, the two are out of phase. When such a phase difference exists, one of the voltages or currents leads, and the other lags.

Phase difference can also be illustrated by a vector diagram. While representing phase difference, the reference quantity is shown on the +ve side of the x axis.(Figs 7&8)

The quantity of lead is shown by an angle in an anticlock-wise and a lagging quantity is shown by a clockwise angle.

Phase relationship between current and voltage in a circuit with inductance only

Fig 7

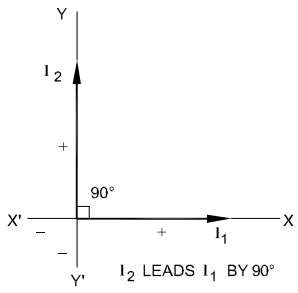
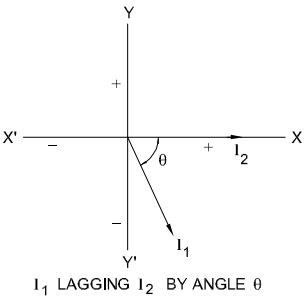
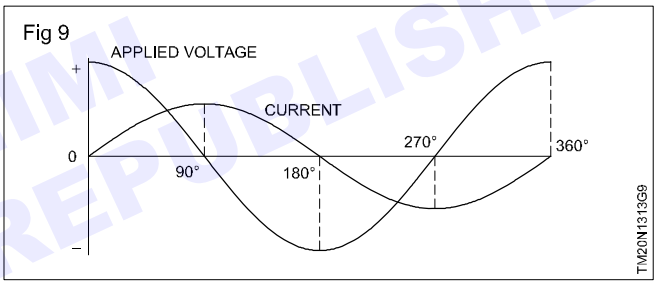


Fig 8



When AC voltage is applied to an inductive circuit, the current lags behind the applied voltage by a quarter cycle or by 90°. (Fig 9)

Fig 9



In a purely inductive circuit, the current lags behind the applied voltage by 90°. This is illustrated in the Fig 9 as wave-form. This also can be stated as voltage leads current. The vector diagram for both expressions is given in Figs 10 and 11.

Fig 10

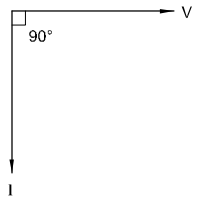
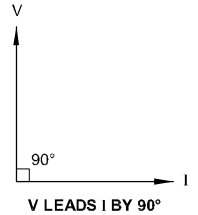


Fig 11



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Inductive reactance: The cemf acts just like a resistance to limit the current flow. But cemf is discussed in terms of volts, so it cannot be used in Ohm's Law to compute the current. However, the effect of cemf can be given in terms of ohms. This effect is called inductive reactance, and is abbreviated as X_L. Since the cemf generated by an inductor is determined by the inductance (L) of the inductor, and the frequency (f) of the current, the inductive reactance must also depend on these things. The inductive reactance can be calculated by the equation

$X_L = 2pfL$

where X_L is the inductive reactance in ohms; f is the frequency of the current in cycles per second; and L is the inductance in henrys. The quantity 2pf together actually represents the rate of change of the current, usually denoted by the Greek letter `w' (Omega).

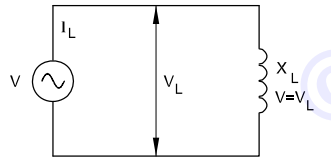
Since 2p = 2(3.14) = 6.28, the Eqn. becomes similarly

$$L = \frac{X_L}{6.28\ f}$$

$$f = \frac{X_L}{6.28\ L}$$

In a circuit containing only inductance, Ohm's Law can be used to find the current and voltage by substituting X_L for R. (Fig 12)

Fig 12



CIRCUIT WITH ONLY X_L

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$$I_L = \frac{V_L}{X_L}$$

$$X_L = \frac{V_L}{I_L}$$

$$V_L = I_L X_L$$

where I_L = current through the inductance, in amperes

V_L = voltage across the inductance, in volts

X_L = inductive reactance in ohms

Example: An AC circuit consists of a 20-mH coil operating at a frequency of 1000 kHz. What is the inductive reactance of the coil?

$X_L = 6.28fL$

$= 6.28(1000 \times 10^3)(20 \times 10^{-3})$

$= 12.56 \times 10^4 = 125600$ ohms.

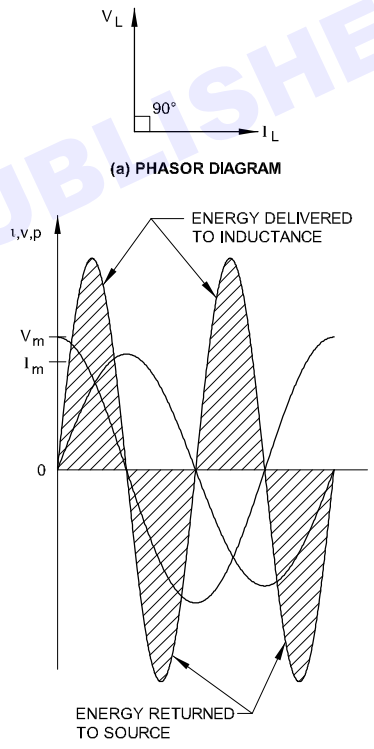
Example: What must the inductance of a coil be so that it has a reactance of 628 ohms at a frequency of 40KHz?

$$L = \frac{X_L}{6.28f} = \frac{628}{6.28(40 \times 10^3)} = 2.5 \times 10^{-3} = 2.5\text{mH}$$

Power in pure inductance: If an AC circuit contains only inductance, the voltage and current are 90° out of phase, as shown by the phasor and wave diagrams in Fig 13. The result of multiplying the v and i wave-forms is a power curve that again has a frequency twice that of the source is as shown in Fig 13. However, over a complete cycle of input voltage, the power curve has an average value of zero. That is, the power curve shows an equal alternation of positive and negative power above and below the zero time axis.

What is the meaning of positive and negative power? (Fig 13) The shaded portion of the power curve above the zero axis represents energy being delivered to the inductor (or load) from the source. This positive power actually represents a storage of energy in the magnetic field of the inductance. The shaded portion of the power curve below the zero axis represents energy returned to the source from the inductor. This negative power indicates that a flow of energy is taking place in the opposite direction (from load to source) when the coil's magnetic field collapses.

Fig 13



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The average true power, P, is zero, in a pure inductance.

In AC circuits,

Power = VI Cos f watts

where f is the phase angle between voltage and current.

As the phase angle between V & I in pure inductive circuit is 90°, Cos 90° is zero.

Therefore P = V x I x (zero) = zero.

The term Cos f is known as `power factor'.

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Reactive power: However, the source must be capable of delivering power for a quarter of a cycle, even though this power will be returned during the next quarter cycle. This stored or transferred power is called reactive power, P_q.

In the case of a purely inductive circuit, the reactive power is given by

$P_q = V_L I_L$ volt-amperes reactive (var)

where P_q is the reactive power in volt-amperes reactive, var

V_L is the voltage across the inductance in volts

I_L is the current through the inductance in ampere.

Since $V_L = I_L X_L$

then $P_q = I_L^2 X_L$ var.

where X_L is the inductive reactance in ohms. Note how the equations for relative power are similar to those for true power with X_L used in place of R. But we must remember to use var for the unit of reactive power, not watts.

Example: Calculate the reactive power of a circuit that has an inductance of 4 H when it draws 1.4 amps from a 50Hz supply.

Solution

$X_L = 2\pi fL = 2p \times 50Hz \times 4H = 1256$ ohms

$P_q = I_L^2 X_L = (1.4A)^2 \times 1256$ ohms $= 2462$ vars

$= 2.462$ kvar

Note that 1 kvar = 1 kilo-var = 1000 vars.

AC Simple circuit with capacitance only

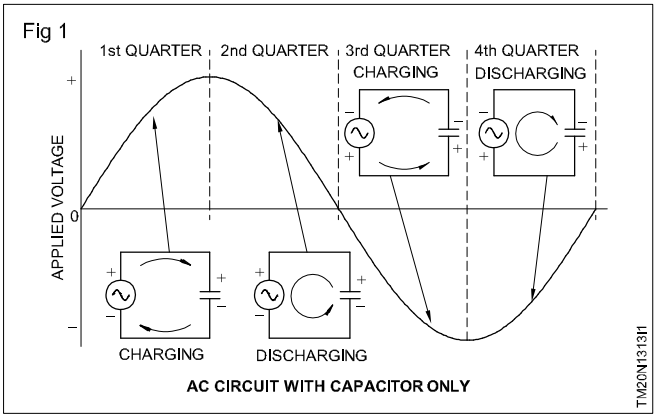
Objectives: At the end of this lesson you shall be able to

- **explain AC circuit with capacitance only**
- **state phase relation between V and I**
- **state power in pure capacitance only.**

Circuit with capacitance only: In an AC circuit, the applied voltage as well as the current it produces, periodically changes direction. (Fig 1) A capacitor in an AC circuit is first charged by the voltage being applied in one direction. Then, when the applied voltage starts to decrease, less current flows, but the capacitor is still being charged in the same direction. As a result, as the applied voltage continues to drop, the voltage developed across the capacitor becomes greater. The capacitor then acts as the source, and starts discharging. The capacitor becomes fully discharged when the applied voltage drops to zero and reverses its direction. Then the capacitor starts charging again, but in the same direction in which it was previously discharging. This continues until the applied voltage again starts to drop, and the events repeat themselves. This alternate charging and discharging, first in one direction, and then in the other, occur during every cycle of the applied AC. An AC current, therefore, flows in the circuit continuously.

It can be said, then, that although a capacitor blocks DC it passes AC.

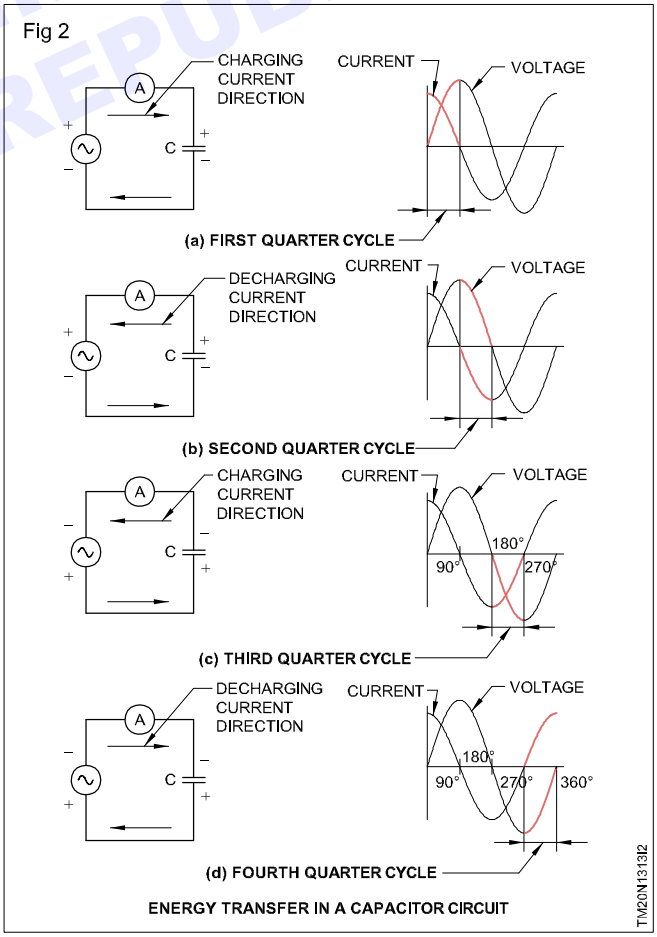
Fig 1



AC CIRCUIT WITH CAPACITOR ONLY

Voltage and current relationship: When an AC voltage source is connected across a capacitor, maximum current flows in the circuit the instant the source voltage begins its sinusoidal rise from zero. (Fig 2a)

Fig 2



ENERGY TRANSFER IN A CAPACITOR CIRCUIT

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This is because the plates are in neutral state and present no opposing electrostatic forces to the source terminals. Therefore, as you can see by Ohm's Law, if the opposition to the current flow is very, very low, a small applied voltage can cause considerable current to flow.

As the source voltage rises, however, the charges on the capacitor plates, (which result from the current flow) build up. The charge voltage, then, presents an increasing opposition to the source voltage and so the current decreases. When the source voltage reaches its peak value, the charge voltage across the capacitor plates is maximum. This charge is sufficient to completely cancel the source voltage, so that the current flow in the circuit stops.

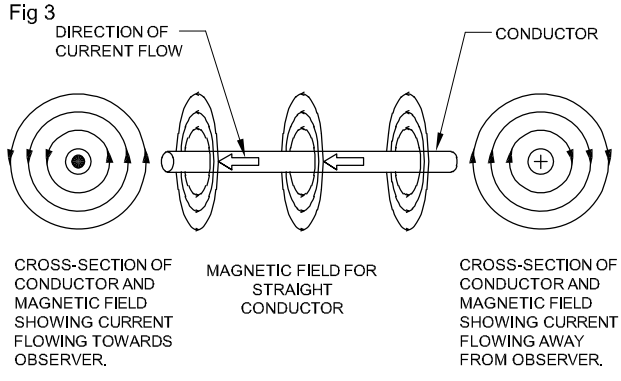
As the source voltage begins to decrease, the electrostatic charge on the capacitor plates becomes greater than the potential of the source terminals, and so the capacitor starts to discharge. (Fig 2b)

Is the current flow in the same direction when the voltage decreases?

The direction of electron flow is opposite to the direction taken by the electrons during capacitor charging. Thus, at the point that the applied voltage passes through its maximum value and begins decreasing, the current in the circuit passes through zero and changes direction. As can be seen from the graph, this constitutes a 90-degree phase difference, with the current leading the applied voltage. This 90-degree difference is maintained throughout the complete cycle of applied voltage. When the applied voltage has dropped to zero, the circuit current has increased to its maximum in the opposite direction, and when the voltage reverses the direction, the current begins decreasing. (Fig 2c) Therefore, the voltage applied to a capacitor is said to lag the current through the capacitor by 90 degrees. Or, the current through a capacitor leads the applied voltage by 90 degrees. Hence the current increases from zero to maximum when voltage starts decreasing from the peak value in the opposite direction to zero. (Fig 2d)

The phase relation between voltage and current in a pure capacitor circuit is shown in the wave-form and vector diagram. (Fig 3)

Fig 3



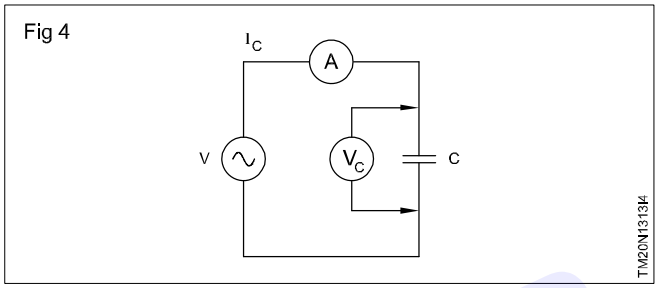
Capacitive reactance: The opposition offered to the flow of current by a capacitor is called capacitive reactance, and is abbreviated Xc. Capacitive reactance can be calculated by:

$$X_C = \frac{1}{2\pi fC} = \frac{1}{\omega c}$$

where 2p is approximately 6.28
f is the frequency in Hz
C is the capacitance in farad and w = 2.p.f.

Like its inductive counterpart - inductive reactance, capacitive reactance is expressed in ohms. Ohm's Law can also be applied to a circuit containing capacitive reactance only. (Fig 4)

Fig 4



$$V_C = I_c X_c$$

$$I_c = \frac{V_c}{X_c}, \qquad X_c = \frac{V_c}{I_C}$$

where, I_c is current through capacitor in amps
V_C is the voltage across the capacitor in volts
X_C is the capacitive reactance in ohms.

Example: A 10 micro-farad capacitor is connected to a 200V 50Hz supply. Find the current taken.
Solution

$$I_c = \frac{V_c}{X_c}, \qquad V_c = V$$

where X_c is the capacitive reactance.

$$X_c = \frac{1}{2\pi fc} = \frac{10^6}{2\pi \times 50 \times 10}$$

$$X_c = \frac{1000}{\pi} = 318.4 \text{ ohms}$$

$$I_c = \frac{200}{318.4} = 0.628 \text{ amps}$$

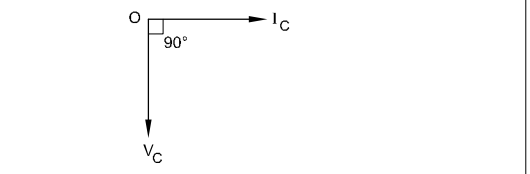
Power in pure capacitance: For pure capacitance, the voltage and current are 90^o out of phase with each other, the current leading as shown by the phase diagram in Fig 5a.

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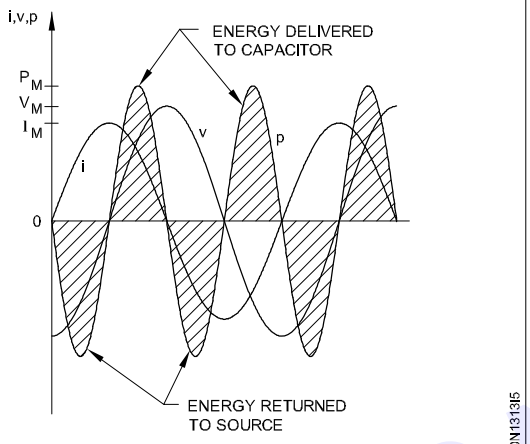
The product of v and i gives a power curve as shown in Fig 5b. We see that the energy delivered to the capacitor and stored in the electric field is represented as a positive quantity. A quarter of a cycle later, all of this energy is returned to the source, as the capacitor discharges. Thus the average true power, P, is zero in a pure capacitance.

However, reactive power P_q is drawn by the capacitor, and the source must be able to supply this power.

Fig 5



(a) VECTOR DIAGRAM OF CURRENT & VOLTAGE.



(b) CURRENT, VOLTAGE AND POWER FORMS.

For a purely capacitive circuit, the reactive power is given by

$P_q = V_c I_c$ volt-amperes reactive (var)

where P_q is the reactive power in volt-amperes reactive, var

V_c is the voltage across the capacitance in volts

I_c is the current through the capacitance in amperes.

Since $V_c = I_c X_c$

then $P_q = I_c^2 X_c$ var

and $P_q = \frac{V_c^2}{X_c}$

where X_c is the capacitive reactance in ohms.

Again the equations for reactive and true power are similar with X_c used in place of R. We must use vars, not watts, for the reactive power.

As in the case of pure inductive circuit, the power factor of the pure capacitive circuit is also zero.

Why is it so?

This is because the angle between the current and voltage in a capacitive circuit is 90°. Result cos ϕ = 0.

***Example**:* A reactive power of 100 vars is drawn by a 10 micro farad capacitor due to a current of 0.87A. Calculate the frequency.

Solution

$$X_c = \frac{P_q}{I_c^2} = \frac{100 \text{ vars}}{(0.87)^2} = 132 \text{ ohms}$$

$$\text{Therefore, } f = \frac{1}{2.\pi.X_c.C}$$

$$= \frac{1}{2\pi \times 132 \text{ ohms} \times 10 \times 10^{-6} \text{F}}$$

$$= 120 \text{ Hz.}$$

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Charging and discharging of a capacitor

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

- **state the method in which charging and discharging of a capacitor takes place**
- **list the precautions to be observed.**

Charging a capacitor: Let us examine now the rate at which a capacitor charges when connected suddenly across a DC voltage with a series resistance. (Fig 1a)

Assume that the capacitor is initially discharged so that the V_c is zero. This means that when the switch is first closed, all the voltage must appear across the resistor. The capacitor appears, momentarily, as a short circuit.) The initial charging current is determined only by the supplied voltage and the resistance.

$$I_{initial} = \frac{V}{R} = \frac{10V}{1K\Omega} = 10 \text{ mA.}$$

The current immediately increases from 0 to v/r at the instant the switch is closed, as shown in Fig 1a. This current causes a charge to be deposited on the capacitor so that some short time later, the capacitor voltage has increased above zero.

According to Kirchoff's law (Fig 1a)

$V = V_R + V_C$.

This means that with some charge on the capacitor, the resistor voltage, V_R is less than when the switch was first closed.

$$V_R = V - V_C.$$

And since $V_R = i_R$, the current must have some lower value now. We also know that $i = C\frac{\Delta V_C}{\Delta t}$.

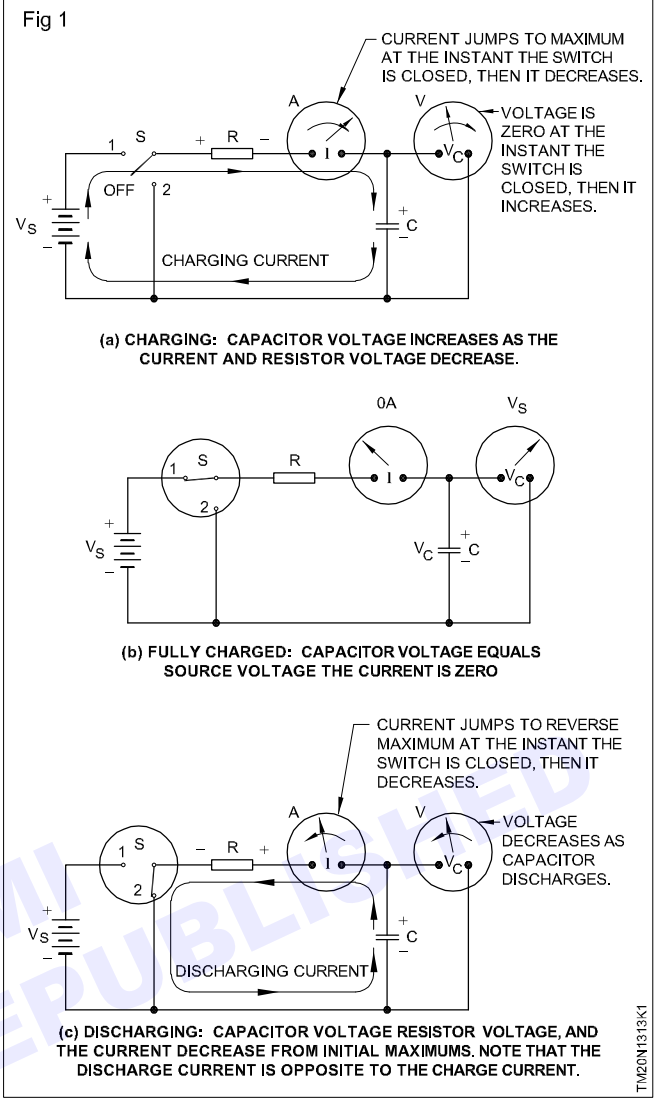
If i is lower than its initial value, the rate of change of the capacitor voltage $\frac{\Delta V_C}{\Delta t}$, is also lower. That is, the capacitor voltage is still increasing, but at a decreasing rate. Similarly, the charging current continues, but also at a decreasing rate.

When the capacitor voltage reaches the applied voltage V, there is no further change in voltage and the charging current drops to zero. If the switch is now opened (Fig 1b) the capacitor voltage remains at V.

When the source voltage is removed and the capacitor circuit terminals are shorted as shown in Fig 1c. it is found that the voltage across the capacitor falls to zero and the current which is maximum at the time of shorting in the reverse direction also falls to zero after some time showing capacitor is discharged.

To determine how long it takes for a capacitor to fully charge to its steady state value, we must consider the time constant, τ of the circuit.

Fig 1



(a) CHARGING: CAPACITOR VOLTAGE INCREASES AS THE CURRENT AND RESISTOR VOLTAGE DECREASE.

(b) FULLY CHARGED: CAPACITOR VOLTAGE EQUALS SOURCE VOLTAGE THE CURRENT IS ZERO

(c) DISCHARGING: CAPACITOR VOLTAGE RESISTOR VOLTAGE, AND THE CURRENT DECREASE FROM INITIAL MAXIMUMS. NOTE THAT THE DISCHARGE CURRENT IS OPPOSITE TO THE CHARGE CURRENT.

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R.L.C series circuit

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

- **calculate the resulting reactance in the RLC series circuit**
- **calculate the impedance of the RLC series circuit**
- **calculate the current in the RLC series circuit**
- **calculate the voltage drops across RLC in the RLC series circuit**
- **calculate the power factor of the RLC series circuit**
- **calculate active power, reactive power and apparent power in the circuit**
- **explain the necessary conditions for series resonance.**

Assume an AC single phase circuit consisting a resistance, inductor and capacitor in series. Various parameters could be calculated as shown in the example.

Example: The value of the components shown in Fig 1 is R = 40 ohms L = 0.3 H and C = 50mf. The supply voltage is 240 V 50 Hz. Calculate the inductive reactance, capacitance reactance, net reactance, impedance, current in the circuit, voltage drops across the R, L and C power factor, active power, reactive power and apparent power. Also draw the impedance triangle, voltage triangle and power triangle.

Calculate the resulting reactance in RLC circuit: Inductance and capacitance have directly opposite effects in an AC circuit. The voltage drop caused by the inductive reactance of the coil leads the line current by 90°. The voltage drop across the inductor coil and the capacitor are 180 degrees apart and oppose each other. To calculate the net reactance in the above example:

Inductive reactance

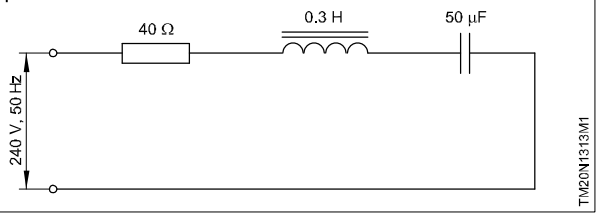
$$X = 2\pi\pi f = 314 \times 0.3 = 94.2\ \Omega$$

Capacitive reactance

$$X = \frac{1}{2\pi\pi f} = \frac{1}{314 \times 0.00005} = \frac{1}{0.0157} = 63.69\ \Omega$$

$$\text{Net reactance} = X_L - X_C = 94.2 - 63.69 = 30.51\Omega$$

Fig 1



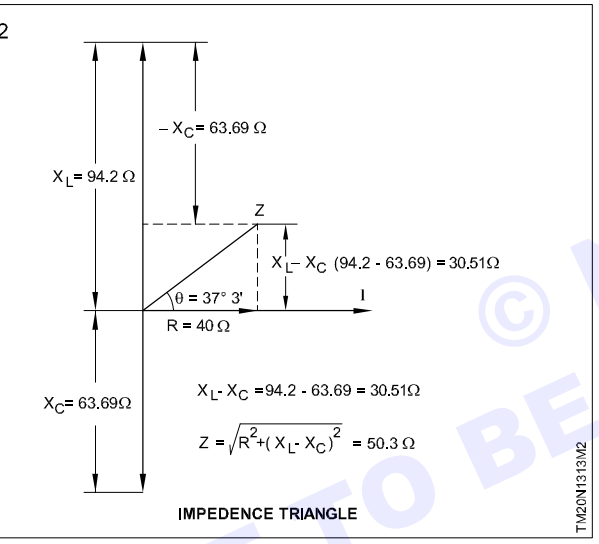
Calculate the impedance: From the circuit given above the impedance can be found. The impedance is the resultant combination resistance and reactance. In this circuit, the impedance is the combination of the 40 ohms resistance and 30.51 Ω resultant reactance. The impedance for this circuit is

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{40^2 + 30.51^2}$$

$$= \sqrt{1600 + 930.86} = \sqrt{2530.86} = 50.30\ \Omega$$

Draw the impedance triangle: Draw the horizontal line (X axis) indicating the circuit current.

Fig 2



Draw along with current vector the value of R to a suitable scale i.e. 1cm = y ohms.

Draw the vertical line perpendicular to the current vector in +y axis indicating the value of inductive reactance to the scale selected (1cm = y ohms)

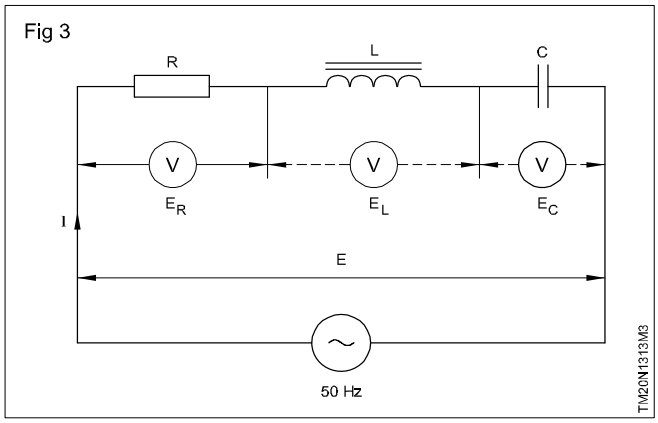
Draw a vertical the perpendicular to the current vector in _y axis indicating the value of capacitive reactance to the scale selected (1cm = y ohms).

Subtract the value of X_C from, X_L as shown in Fig 2 the net reactance value is equal to 30.51 ohms. Complete the vectors by closing the parallelogram the reactance of the parallelogram is the impedance of the series RLC circuit.

Mathematically what we determined the values of net reactance and impedance could also be determined by the above vectorial method.

Measurement of current and voltage drop in RLC circuit. The voltage drop across R = E_R across L = E_L and drop across C = E_C and the formula for finding their values and given below. (Fig 3)

Fig 3



$E_R = IR$

$E_L = IX_L$

$E_C = IX_C$

Current in given RLC series circuit: Current in this series circuit is I = E/Z = 240/50.3 = 4.77 amps.

Identifying whether the current flow is leading or lagging the voltage in a RLC series circuit: As this is a series circuit, the current is the same in all parts of the circuit, but the voltage drop across the resistor, the inductor coil and capacitor are

$E_R = IR$ = 4.77 x 40 = 190.8 volts

$E_L = IX_L$ = 4.77 x 94.2 W = 449.33 volts

$E_C = IX_C$ = 4.77 x 63.69 = 303.80 volts.

The vector sum of the voltage of 190.8 volts across the resistor and 145.53 volts across the net reactance of 30.51W is equal to the line voltage of 240 volts as shown below.

$$E = \sqrt{E^2_R + (E_L - E_C)^2}$$

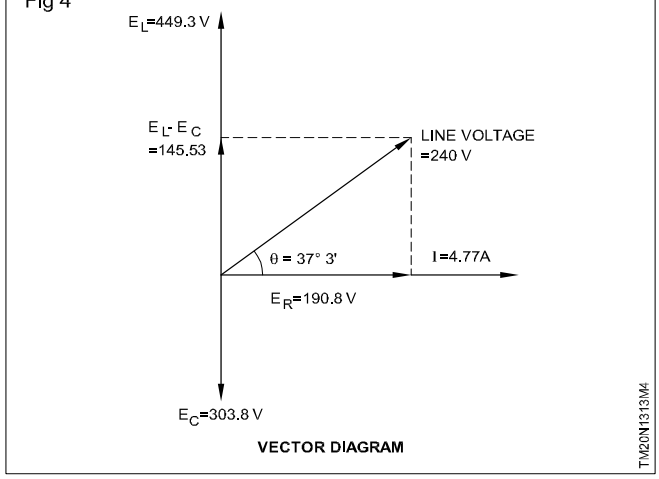
$$= \sqrt{190.8^2 + (449.33 - 303.80)^2}$$

$$= \sqrt{190.8^2 + 145.53^2}$$

$\therefore$ E = 240 volts.

The voltage vector diagram could be drawn as shown in Fig 4.

Fig 4



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In this type of series circuit, the current is used as a horizontal reference line. The voltage value of 145.53 volts across the portion of the inductive reactance which is not cancelled out by the voltage across the capacitive reactance. The PF = E_R/E = 190.8/240 = 0.795 lag or PF = R/Z = 40/50.30 = 0.795 lag PF. In this circuit the phase angle is 37.3° lagging. This means that current lags the line voltage.

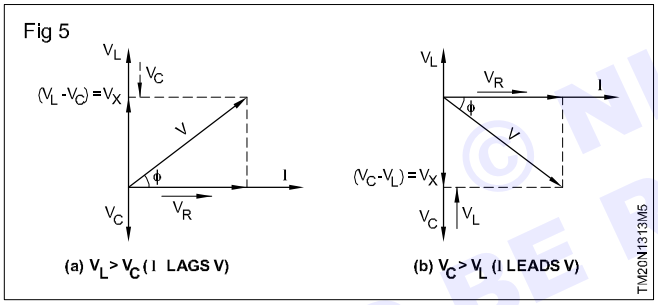
In an RLC series circuit, if X_L is greater then the voltage appearing across the inductor is high and that can be found out by IX_L. In the same way if the X_C value is greater in an RLC series circuit, the voltage appearing across the capacitor is more and can be found out by IX_C. The voltage vector diagram shown in Fig 5a and 5b represents the above conditions respectively.

In the example given above, the voltage drop across resistance 40 W = 190.8 volts.

Voltage drop across inductance 0.3 H = 449.33 volts. Voltage drop across capacitor of 50 mf = 303.80 volts.

From these values it is clear that the voltage drop across the inductor and capacitor is higher than the supply voltage. Hence while connecting the meter to measure the voltage drop across inductor and capacitor it should be noted that the range of this should be high (in this case 0 - 500 volts)

Fig 5



Calculate the power factor: Power factor of the RLC series circuit can be found from the impedance triangle or voltage triangle as shown below

$$\text{Power factor} = \text{Cos } \theta = \frac{R}{Z} \text{ or } \frac{E_R}{V}$$

$$\text{Power factor} = \frac{R}{Z} = \frac{40}{50.3} = 0.795$$

$$= \frac{E_R}{V} = \frac{190.8}{240} = 0.795$$

Calculate the active power (R_A): Active power can be calculated by using any one of the formulae given below

$P = EI \text{ Cos } q = I^2R$

$= EI \text{ Cos } q = 240 \times 4.77 \times 0.795$

= 910 walts

$= I^2R = 4.77^2 \times 40$

= 910 watts.

Calculate the reactive power P_q: Reactive power can be calculated using the formula

$P_q = EI \text{ sin } q \text{ Vars}$

$= 240 \times 6.77 \times 0.6074$

= 695 Vars

Cos q = 0.795

q = 37°3'

Sin q = Sin 37°3'

= 0.6074

Calculate the apparent power (P_{APP}): Apparent power can be calculated using the formula

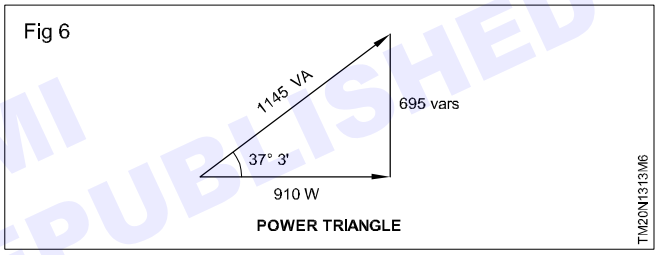
$P_{APP} = EI$ volt-amperes

$= 240 \times 4.77$

= 1145 Volt-amperes.

Draw the power triangle: Power triangle is shown in Fig 6.

Fig 6



Resonance circuit: When the value of X_L and X_C are equal, the voltage drop across them will be equal and hence they cancel each other. The value of voltage drops V_L and V_C may be much higher than the applied voltage. The impedance of the circuit will be equal to the resistance value. Full value of applied voltage appears across R and the current in the circuit is limited by the value of resistance only. Such circuits are used in electronic circuits like radio/ TV turning circuits. When $X_L = X_C$ the circuit is said to be in resonance. As current will be maximum in series resonant circuits it is also called acceptor circuits. For a known value of L and C the frequency at which this occurs is called as resonant frequency. This value can be calculated as follows when $X_C = X_L$

$$2\pi fL = \frac{1}{2\pi fC}$$

$$\text{Hence resonant frequency } f = \frac{1}{2\pi\sqrt{LC}}$$

Note: Power factor angle is commonly denoted by Theta q. In some pages of this text it is denoted by Phi f. As such these terms are used alternatively in this text.

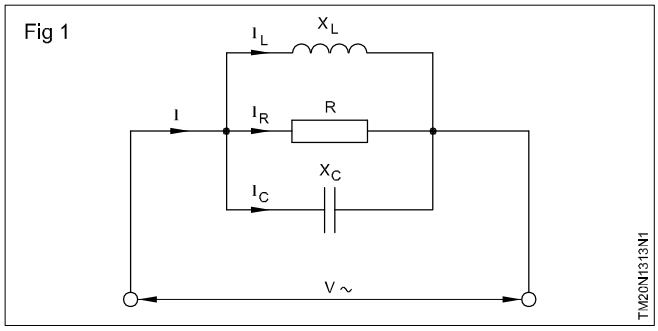
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R, L & C Parallel circuit - Vector diagram, power and power factor

Objectives: At the end of this lesson you shall be able to
- **explain the vector diagram for R, L & C parallel circuit**
- **state the an admittance triangle**
- **calculate the phase angle between I_L and the voltage applied.**

Parallel connection of R, X_L and X_C: X_L and X_C oppose each other, that is to say, I_L and I_C are in opposition, and partly annul one another.

Fig 1

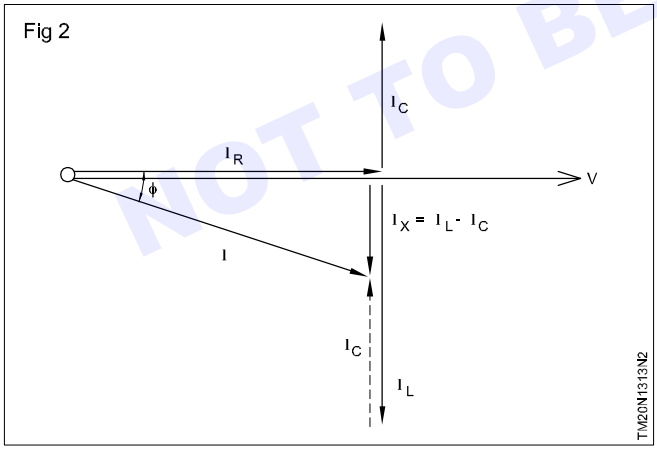


$I_X = I_C - I_L$ or $I_L - I_C$, depending on whether the capacitive or inductive current dominates.

Graphic solution: when $I_L > I_C$

1 V as common value
2 I_R in phase with V
3 I_C leads by 90°
4 I_L lags by 90°
5 $I_X = I_L - I_C$
6 I as resultant
7 <) ϕ (in this case inductive, I lags)

Fig 2



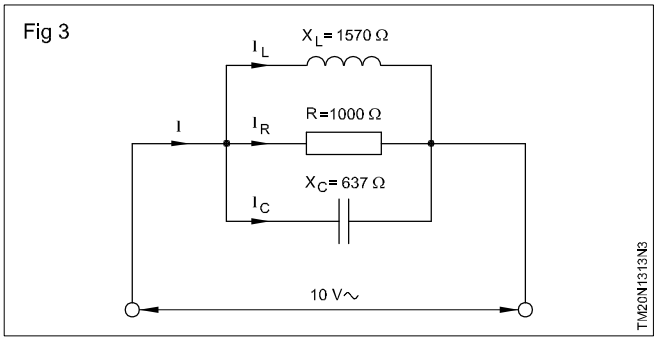
Particular case: X_L and X_C are equally large - I_L and I_C cancel each other. Z = R; parallel resonance occurs.

Currents in the reactances may be greater than the total current.

The calculation of the resonant frequency is the same as for the series connection.

Example: Calculate the value of I_T Z power factor and power for the circuit in Fig 3.

Fig 3



Given

$V_T = 10V$
$R = 1000\ \Omega$
$X_L = 1570\ \Omega$
$X_C = 637\ \Omega$

Known: Ohm's Law

$$I_T = \sqrt{(I_C - I_L)^2 + I_R^2}$$

Solution

$$I_C = \frac{10\ V}{637\ \Omega} = 0.0157\ A = 15.7\ mA$$

$$I_L = \frac{10\ V}{1570\ \Omega} = 0.0064\ A = 6.4\ mA$$

$$I_R = \frac{10\ V}{1000\ \Omega} = 0.01 = 10\ mA$$

$$I_T = \sqrt{(0.0157 - 0.0064)^2 + 0.01^2}$$

$$= 0.0137\ A = 13.7\ mA$$

$$Z = \frac{10V}{0.0137\ A} = 730\ \Omega$$

$$P.F = \frac{Z}{R} \qquad Y = \frac{1}{Z} \text{ and } g = \frac{1}{R}$$

$$= \frac{730}{1000} = 0.73$$

$$\text{PF in admittance triangle} = \frac{g}{Y} = \frac{1}{R} \times \frac{1}{1/Z} = \frac{Z}{R}$$

Power = $V I \cos\phi$

$= 10 \times 0.0137 \times 0.73$

$= 0.1$ Watt or 100 mw.

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Assignment

This assignment should be completed and handed over to the Instructor for valuation within 3 days on completion of the Exercise 135.

1 An inductive circuit, in parallel with a non-inductive circuit of 20 ohms is connected across a variable voltage 50 Hz supply. The inductive circuit current is 4.3 A and the non-inductive current is 2.7 A for a particular supply voltage. The total current is 5.8 A. Find:

   a the power observed by the inductive resistance

   b its inductance and

   c the power factor of the combined circuit.

2 A circuit connected to 115V, 50 Hz supply takes 0.8A at a power factor of 0.3 lagging. Calculate the resistance and inductance of the circuit assuming -

   a the circuit consists of a resistance and inductance in series

   b the circuit consists of a resistance and inductance in parallel.

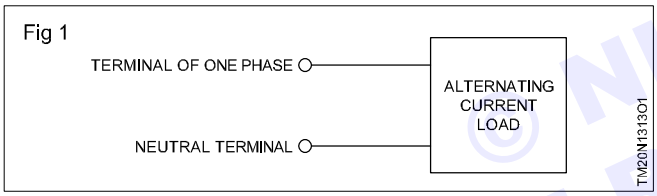
AC - 3 Phase fundamentals - systems of connection - measurement of power & energy in 3 phase

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 one of 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)

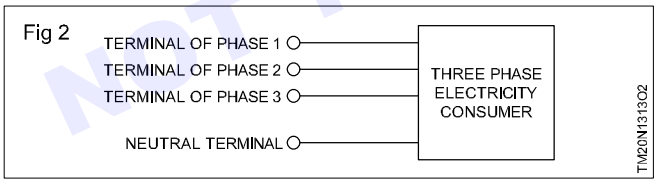
Fig 1



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.

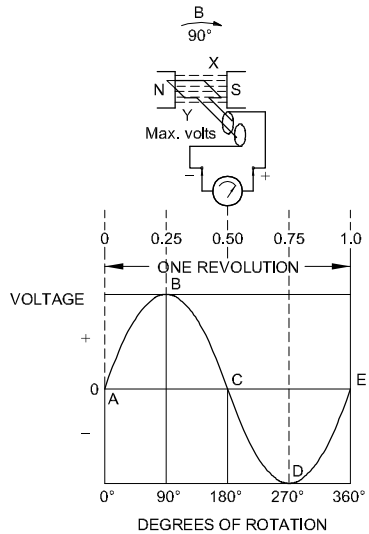
Further, lighting loads can be connected between any one of the three phases and neutral.

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

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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.

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 4

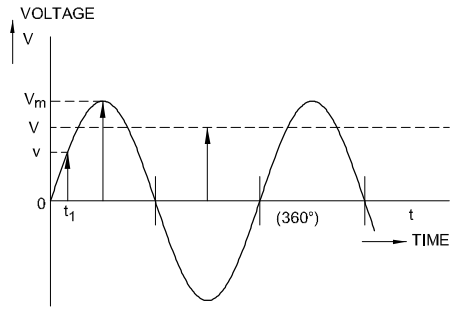
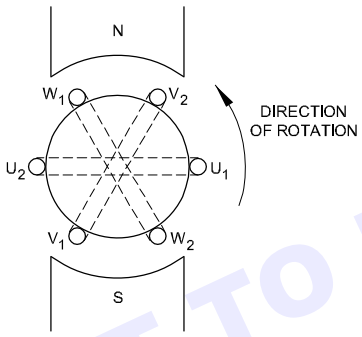


Fig 5

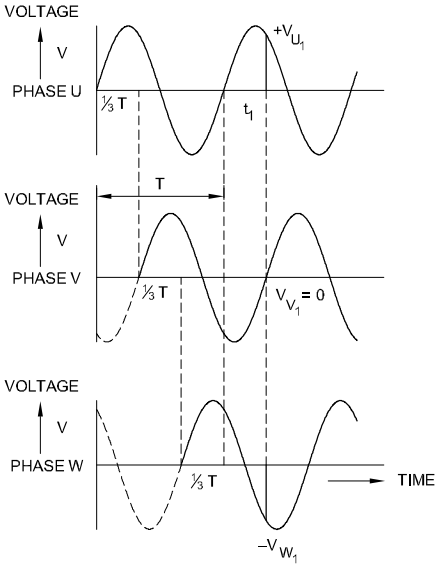


For each wire loop, the same result is obtained as for the alternating voltage generator. This means that an alternating voltage is induced in each wire loop. However, since the wire loops are displaced by 120° from each other, and a complete revolution (360°), takes one period, the three induced alternating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

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 6) 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)

Fig 6



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

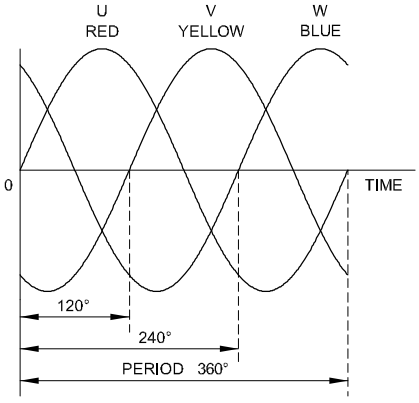
$$V_U + V_V + V_W = 0.$$

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.

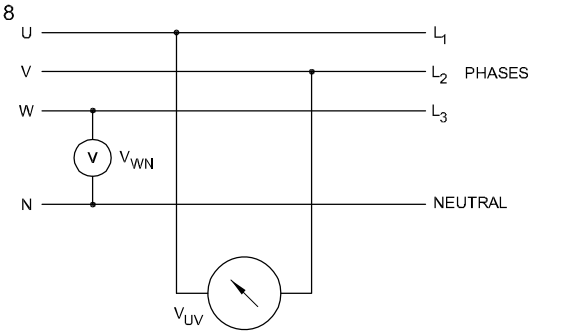
Fig 7



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.

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Fig 8

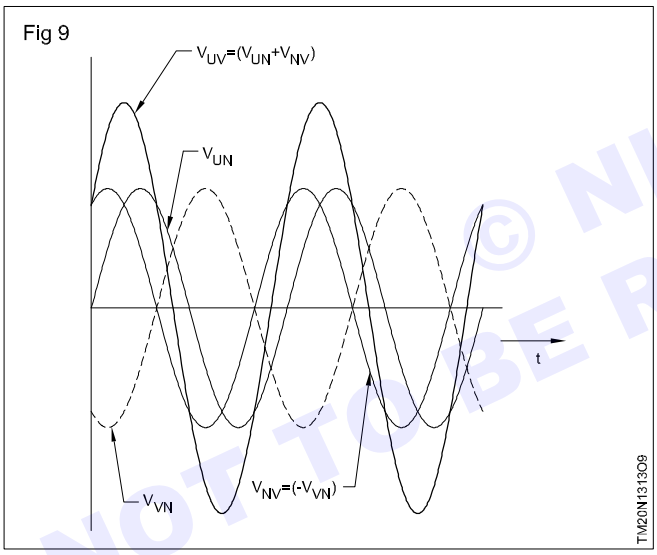


The return lead of the individual phases consists of a common neutral conductor N, which is described later in more detail. Voltmeters are connected between each of the lines U, V and W, and the neutral line N. They indicate the RMS (effective) values of the voltages between each of the three phases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

Fig 9



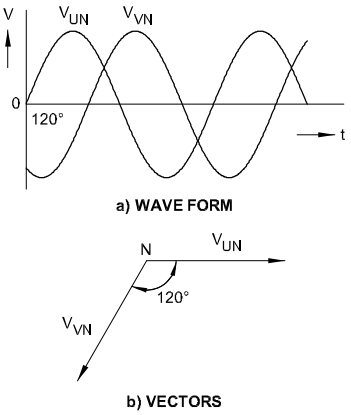
The individual instantaneous, peak and RMS values are the same as for a single-phase alternating voltage.

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.

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}.

Fig 10



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.

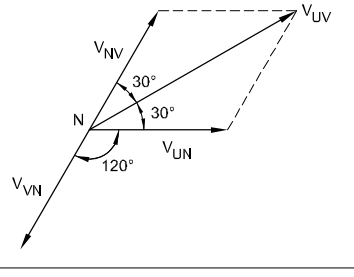
The phase voltages V_{UN} and V_{VN} are separated in phase by one third of a period, or 120° between the two phasors. (Fig 10)

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}.

Fig 11



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

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

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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

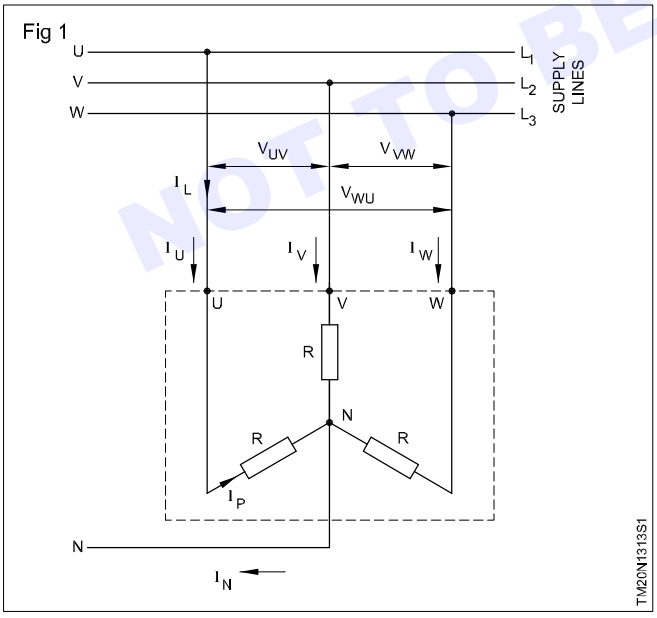
Objectives: At the end of this lesson you shall be able to

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

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).

Fig 1

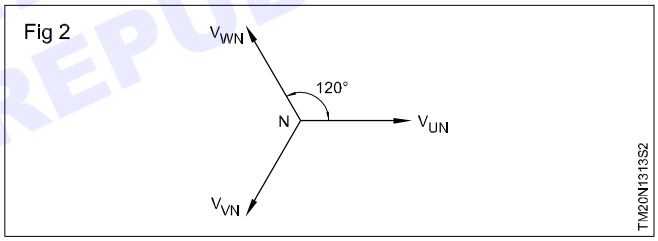


The potential difference for each phase, i.e. from a line to the star point, is called the phase voltage and designated as V_P. The potential difference across any two lines is called the line voltage V_L. Therefore, the voltage across each impedance of a star connection is the phase voltage V_P. The 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.

Thus

$$V_L = V_{UV} = (\text{phasor } V_{UN}) - (\text{phasor } V_{VN})$$
$$= \text{phasor } V_{UN} + V_{VN}.$$

Fig 2



In the phasor diagram (Fig 3)

$$V_L = V_{UV} = V_{UN} \cos 30^\circ + V_{NV} \cos 30^\circ$$

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

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

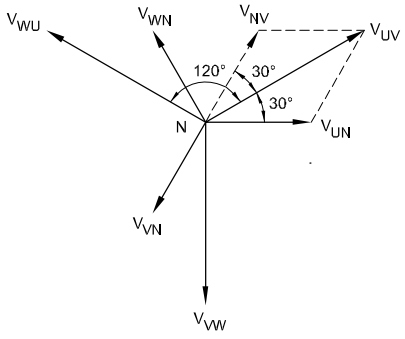
$$V_L = \sqrt{3}\ V_P.$$

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

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 $\sqrt{3}$.

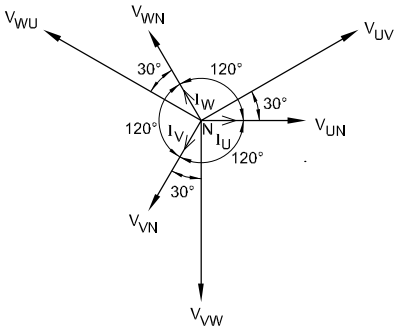
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Fig 3



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 120^0 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?

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

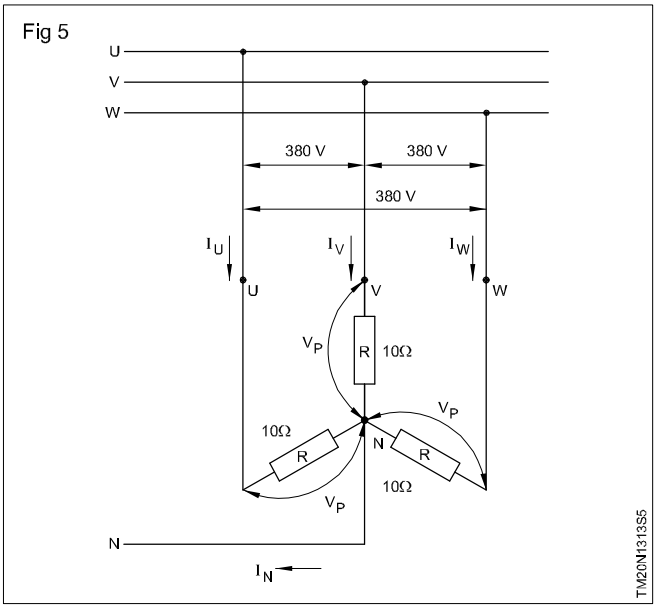
$$V_P = \frac{380}{173} = 220\ V$$

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

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

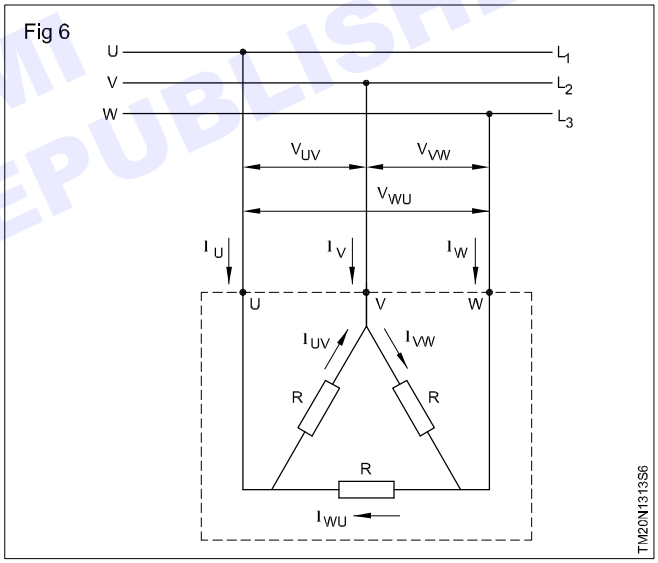
Fig 5



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 (D).(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.

Fig 6



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.

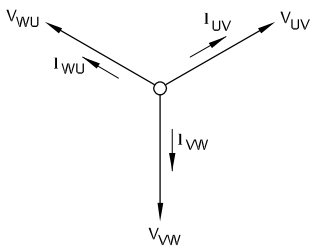
The phase currents through the elements in a delta arrangement are composed of I_{UV}, I_{VW} and I_{WU}. The currents from the supply lines are I_U, I_V and I_W, and one line current divides at the point of connection to produce two phase currents.

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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.

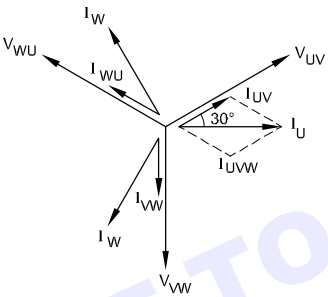
Because of the purely resistive load, the corresponding phase currents are in phase with the line voltages. (Fig 7) Their magnitudes are determined by the ratio of the line voltage to the resistance R.

Fig 7



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

But $\cos 30^o = \frac{\sqrt{3}}{2}$.

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

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

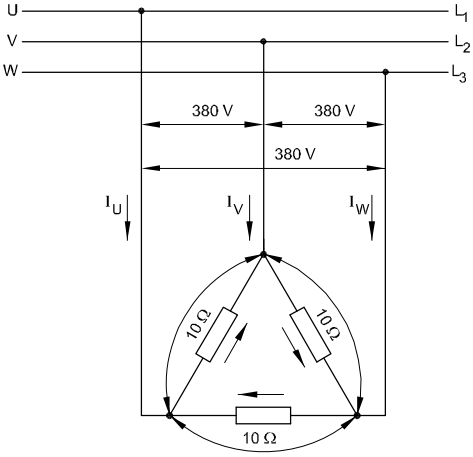
Thus, line current = $\sqrt{3}$ x phase current.

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

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

Fig 9



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

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 $X_L = 2\pi fL = 2 \times 3.142 \times 50 \times \frac{20}{1000} = 6.3$ 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,

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

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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 secondary 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.**

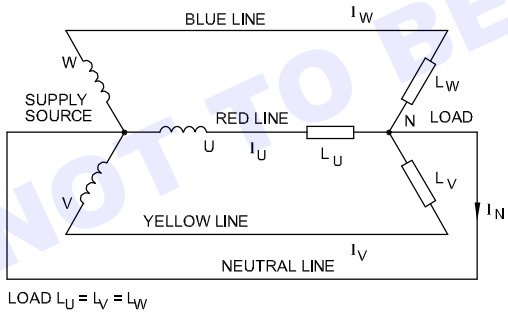
Neutral: In a three-phase star connection, the star point is known as neutral point, and the conductor connected to the neutral point is referred as neutral conductor.

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.

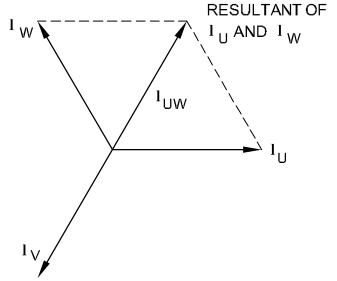
Fig 1



THREE-PHASE SUPPLY AND LOAD

TM20N1313U1

Fig 2

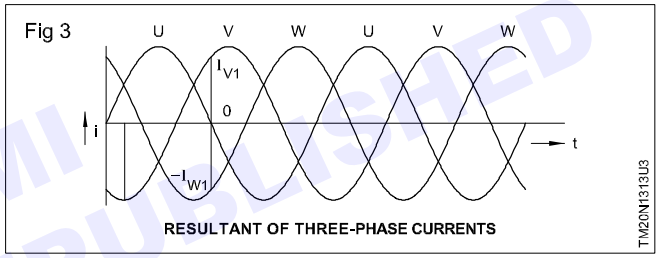


FOR A BALANCED LOAD THE RESULTANT OF I_W AND I_U IS EQUAL IN MAGNITUDE BUT OPPOSITE TO I_V.

TM20N1313U2

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 sum of the three phase currents to equal to zero.

Fig 3



RESULTANT OF THREE-PHASE CURRENTS

TM20N1313U3

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.

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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 400V is available. In this case, there is only 230V 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

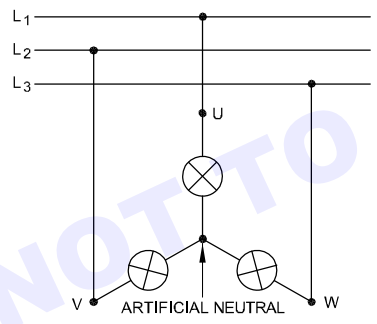
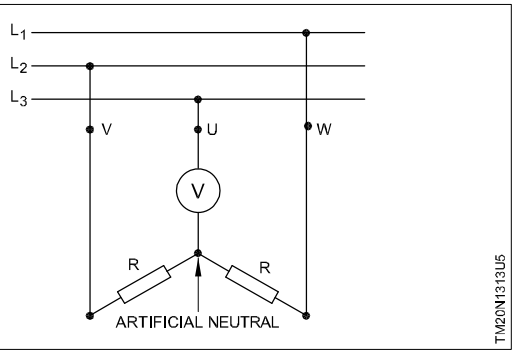


Fig 5



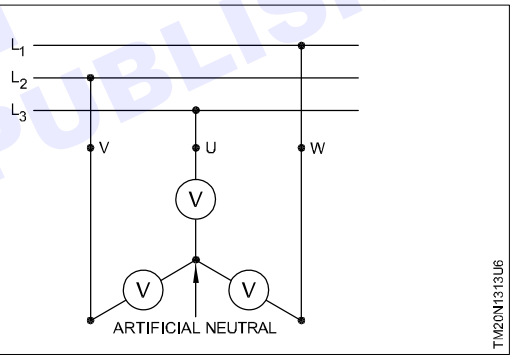
In this method, the value of R must be equal to the resistance of the voltmeter. The same method can be used while measuring power or energy by connecting resistors of equal resistance as of potential coil.

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

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.

Fig 6



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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.**

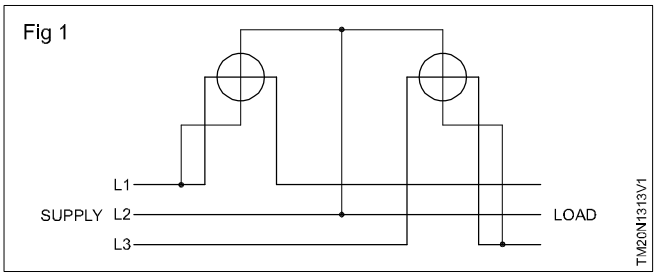
Power in a three-phase, three-wire system is normally measured by the `two-wattmeter' method. It may be used with balanced or unbalanced loads, and separate connections to the phases are not required. This method is not, however, used in four-wire systems because current may flow in the fourth wire, 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:

$$P_T = P_1 + P_2.$$

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.

Fig 1



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

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

$$P_T = V_{UN} i_U - V_{VN}(i_U + i_W) + V_{WN} i_W$$
$$= i_U(V_{UN} - V_{VN}) + i_W(V_{WN} - V_{UN})$$
$$= i_U V_{UV} + i_W V_{WV}$$

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

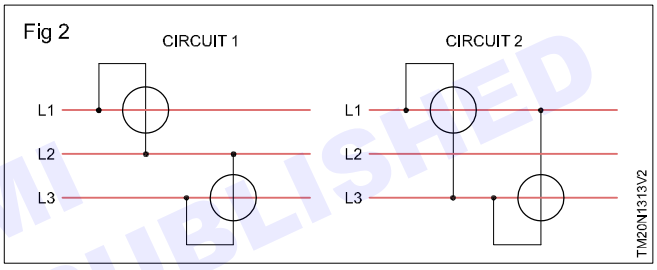
1 Draw a general wiring diagram for the two-wattmeter method of three-phase power measurement.

2 Why is it desirable, in practice, to use the two-wattmeter method?

3 Why can the two-wattmeter method not be used in a three-phase, four-wire system with random loading?

4 Which of the above circuits is used for the two-wattmeter method of power measurement?

Fig 2



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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

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

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

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

$P_1 = 4.5$ 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

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

$f = \tan^{-1} 0.3464 = 19^0 6'$

Power factor $\quad \cos 19^0 6' = 0.95$

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

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

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

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

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

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

$f = \tan^{-1} 8.66 = 83^{o}.27'$

since power factor (Cos 83^{o} 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

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

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

$f = \tan^{-1} 0.5774 = 30^{o}$

Power factor = Cos 30^{o} = 0.866.

2 a) P_1 = 25 KW

P_2 = 5 KW

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

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

$f = \tan^{-1} 1.1547 = 49^{o}6'$

Power factor (Cosϕ) = Cos $49^{o}6'$ = 0.6547

b) P_1 = 25 KW

P_2 = –5 KW

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

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

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

$f = \tan^{-1} 2.5980 = 68^{o}57'$

Power factor = Cos 68^{o} 57' = 0.3592

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Measurement of energy in 3-phase circuit

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

- **list the various types of 3-phase energy meters**
- **describe the construction and working of a 3-phase 3-wire induction type energy meter**
- **describe the construction and working of a 3-phase 4-wire induction type energy meter**
- **state the application of a 3-phase 3-wire and 3-phase 4-wire energy meter.**

3-phase energy meters: Even though different types of energy meters are available, the induction type energy meter is most commonly used because it is simple in construction, less in cost and requires less maintenance. The function of a 3-phase energy meter is similar to that of a single phase energy meter explained in Related Theory, Exercise 309 of the 1st year.

The three phase energy meter is required to measure the energy consumed in 3-phase loads whether balanced or unbalanced. The three phase energy can be measured by three separate single phase energy meters or by 3-phase energy meters.

Types of 3-phase energy meters

There are two types of 3-phase energy meters mainly.

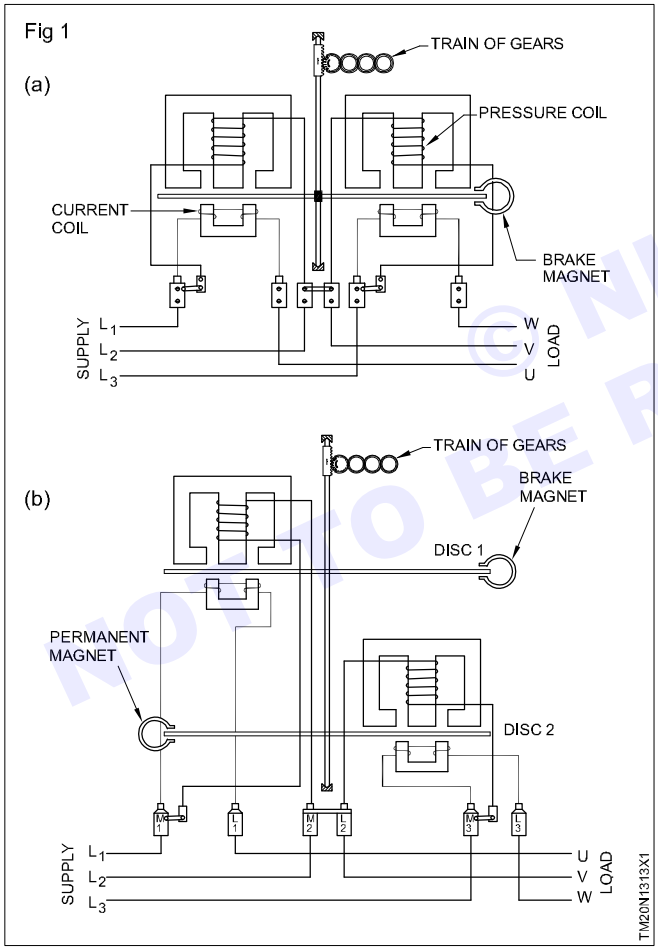
– Three phase 3-wire energy meters (3-phase 2- element energy meter)

– Three phase 4-wire energy meters (3-phase 3- element energy meter)

Two element 3-phase energy meters: This energy meter works on the principle of measurement of power by the two wattmeter method. Two elements of a current coil and two elements of a potential coil are used in this energy meter. These assemblies can be arranged on the different sectors in a horizontal position as shown in Fig 1a with a single aluminium disc which rotates between the poles of a single braking magnet.

The two elements can also have individual driving discs on a common spindle. In this case they will have individual braking magnets as shown in Fig 1b. The second type usually preferred by the manufacturers due to the construction simplicity. In both the cases the driving torque produced by individual elements are summed up. The recording mechanism which is attached to the train of gears i.e., cyclometer or counter type dial shows the sum of the energies that has passed through the elements. The two element energy meter is only suitable for a 3-phase 3-wire system but can be used for both balanced and unbalanced loads.

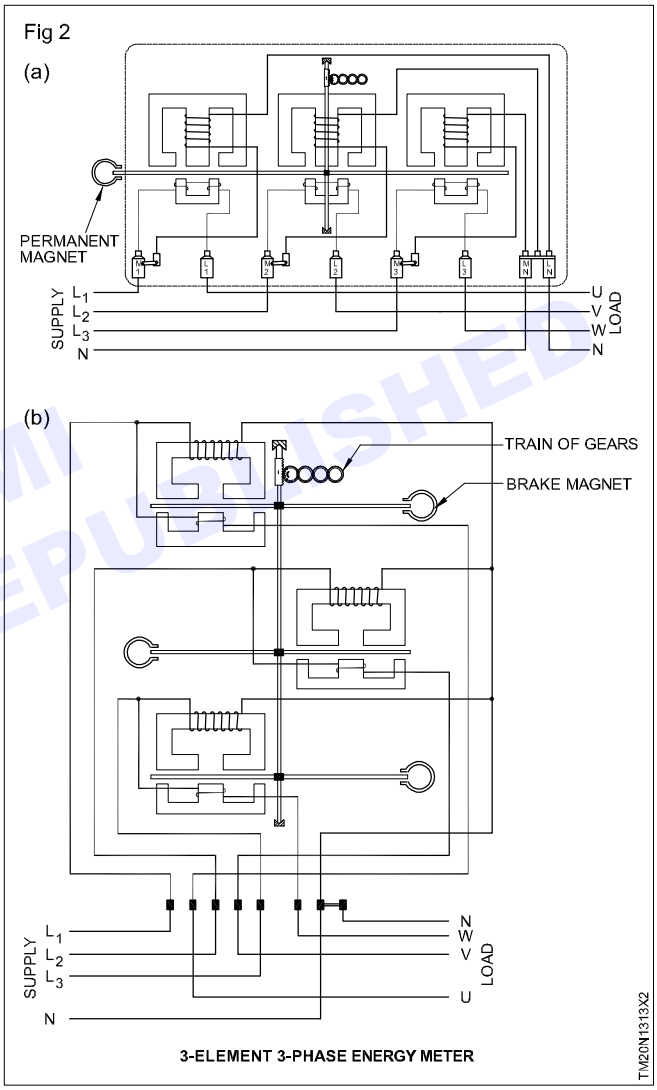
Fig 1



3-element 3-phase energy meter: This works on the same principle as that of the 3 wattmeter method of power measurement with a 3-phase load. Here 3 units, each with a current coil and a potential coil, are used. The potential coils of the 3 elements are connected in star to the supply lines with their common point connected to the neutral line of power supply. The current coils are connected in series to the individual lines. As is the case with the two element energy meter, these three elements can be arranged in the different sectors of a common single aluminium disc which serves as a rotating part connected to driving dial as shown in Fig 2a.

The three elements can also have a common spindle with three individual discs and braking magnets as shown in Fig 2b. Here also the 2nd type is usually preferred by manufacturers due to the easiness in construction. The driving torque produced by the three individual elements are summed up and the recording mechanism shows the sum of energies that has passed through the individual elements. This energy meter is suitable for the 3-phase 4-wire system.

Fig 2



Application of 3-phase energy meter: A two element 3-phase energy meter is used with three phase loads in which a neutral is not used such as for an industry or irrigation pumpset motors etc. having three phase loads only or with an 11kV 3-phase 3-wire supply to an industry.

A 3-phase 4-wire element energy meter is used with three phase load in which balanced or unbalanced loads are connected with individual phases and neutral such as for a large domestic consumer or for an industry having lighting loads also.

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Alternator - Principle - Types - E.m.f equations

Objectives: At the end of this lesson you shall be able to
- **explain the working principle of an alternator**
- **explain the method of production of sine wave voltage by a single loop alternator**
- **describe the relation between frequency, number of poles and synchronous speed.**

Principle of an alternator: An alternator works on the same principle of electromagnetic induction as a DC generator. That is, whenever a conductor moves in a magnetic field so as to cut the lines of force, an emf will be induced in that conductor. Alternatively whenever there is relative motion between the field and the conductor, then, the emf will be induced in the conductor. The amount of induced emf depends upon the rate of change of cutting or linkage of flux.

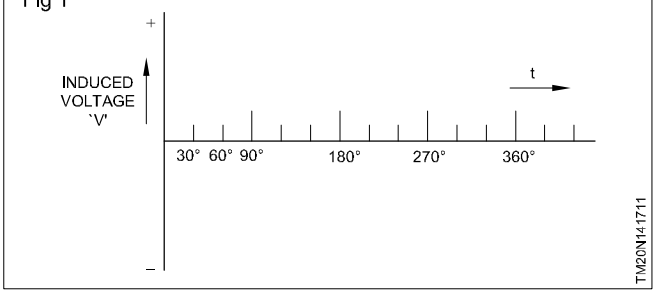
In the case of DC generators, we have seen that the alternating current produced inside the rotating armature coils has to be rectified to DC for the external circuit through the help of a commutator. But in the case of alternators, the alternating current produced in the armatrue coils can be brought out to the external circuit with the help of slip-rings. Alternatively the stationary conductors in the stator can produce alternating current when subjected to the rotating magnetic field in an alternator.

Production of sine wave voltage by single loop alternator: Fig 2a shows a single loop alternator. As it rotates in the magnetic field, the induced voltage in it varies in its direction and magnitude as follows.

To plot the magnitude and direction of the voltage induced in the wire loop of the AC generator in a graph, the electrical degrees of displacement of the loop are kept in the `X' axis as shown in Fig 1 through 30 electrical degrees. As shown in Fig 2c, three divisions on the `X' axis represent a quarter turn of the loop, and six divisions a half turn. The magnitude of the induced voltage is kept in the `Y' axis to a suitable scale.

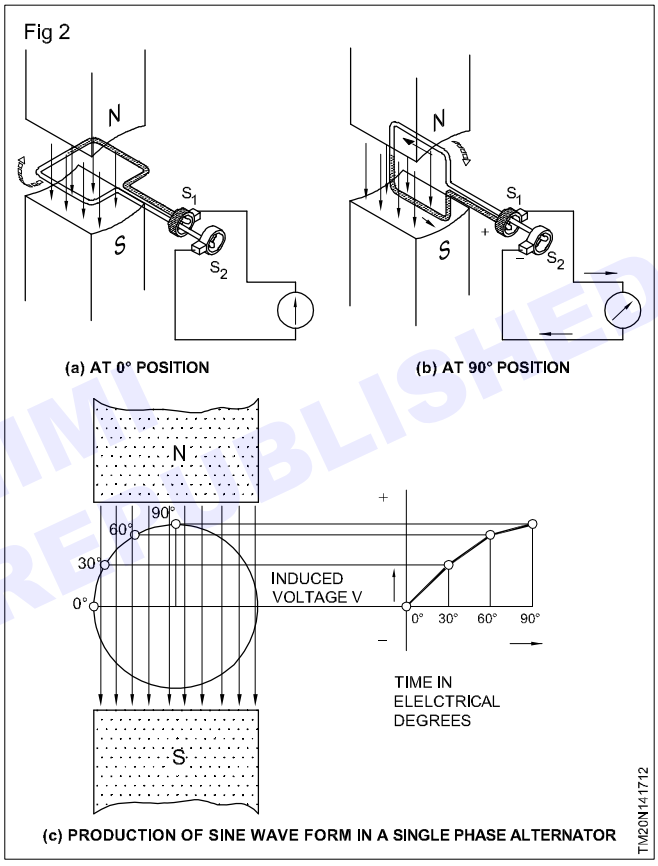
The part above the X-axis represents the positive voltage, and the part below it the negative voltage as shown in Fig 1.

Fig 1



The position of the loop at the time of starting is shown in Fig 2a and indicated in Fig 2c as `O' position. At this position, as the loop moves parallel to the main flux, the loop does not cut any lines of force, and hence, there will be no voltage induced. This zero voltage is represented in the graph as the starting point of the curve as shown in Fig 2c. The magnitude of the induced emf is given by the formula $E_o = BLV \sin\theta$

Fig 2



(c) PRODUCTION OF SINE WAVE FORM IN A SINGLE PHASE ALTERNATOR

where

B is the flux density in weber per square metre,

L is the length of the conductors in metres,

V is the velocity of the loop rotation in metres per second and

θ is the angle at which the conductor cuts the line of force.

As $\sin\theta = 0$

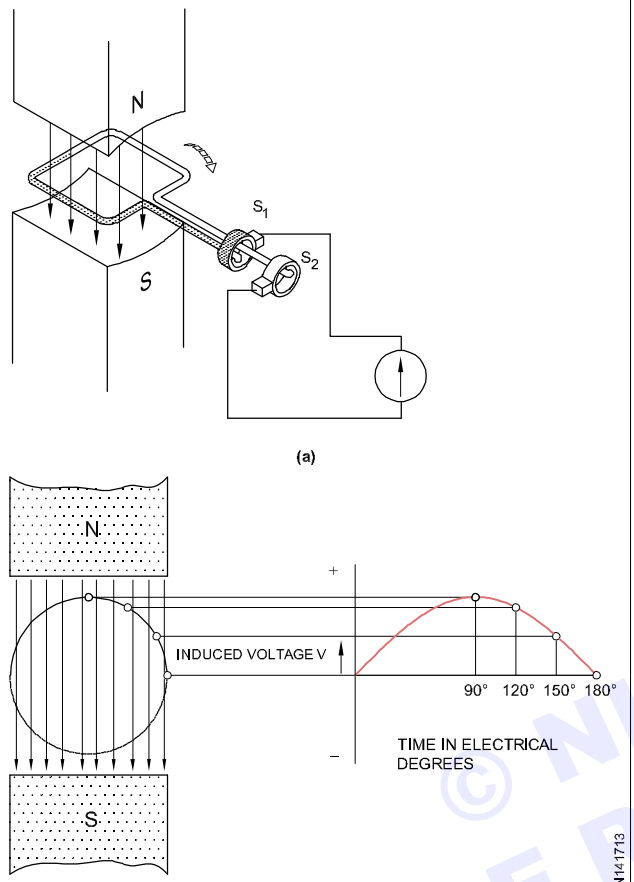
E at 0 position is equal to zero. As the loop turns in a clockwise direction at position 30° as shown in Fig 2c, the loop cuts the lines of force and an emf is induced (E_{30}) in the loop whose magnitude will be equal to $BLV \sin\theta$ where θ is equal to 30°.

Applying the above formula, we find the emf induced in the loop at 90° position will be maximum as shown in Fig 2c.

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As the loop turns further towards 180° it is found the number of lines of force which are cut will be reduced to zero value. If the quantity of emf induced at each position is marked by a point and a curve is drawn along the points, the curve will be having a shape as shown in Fig 3b.

Fig 3



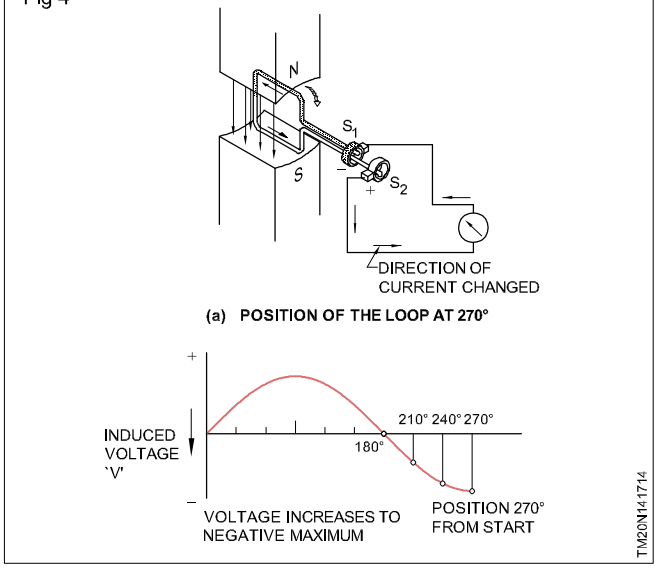
During the turn of the loop, from 0 to 180°, the slip ring S1 will be positive and S2 will be negative.

However, at 180° position, the loop moves parallel to the lines of force, and hence there is no cutting of flux by the loop and there is no emf induced in the loop as shown in Fig 3b.

Further during the turn of the loop from the position 180° to 270°, the voltage increases again but the polarity is reversed as shown in Fig 4b. During the movement of the loop from 180 to 360°, the slip ring S2 will be positive and S1 will be negative as shown in Fig 4a. However, at 270° the voltage induced will be the maximum and will decrease to zero at 360°. Fig 5b shows the variation of the induced voltage in both magnitude and direction during one complete revolution of the loop. This is called a cycle.

This type of wave-form is called a sine wave as the magnitude and direction of the induced emf, strictly follows the sine law. The number of cycles completed in one second is called a frequency. In our country, we use an AC supply having 50 cycles frequency which is denoted as 50 Hz.

Fig 4



Relation between frequency, speed and number of poles of alternator: If the alternator has got only two poles, the voltage induced in one revolution of the loop undergoes one cycle. If it has four poles, then one complete rotation of the coil produces two cycles because, whenever it crosses a set of north and south poles, it makes one cycle.

Fig 5

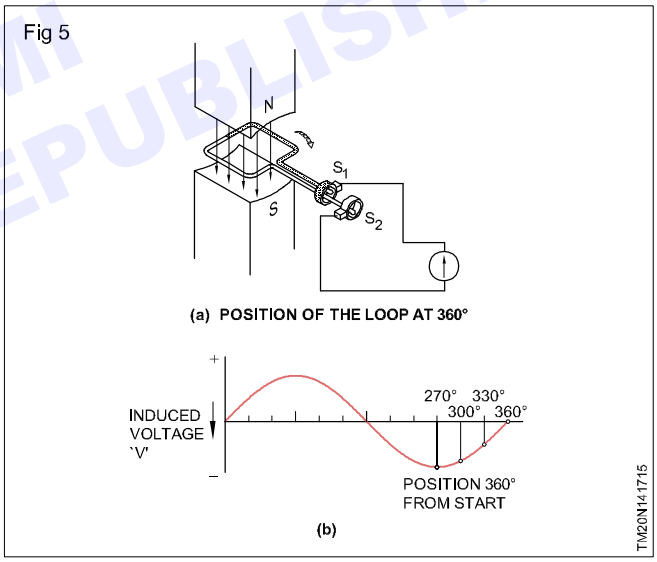


Fig 6 shows the number of cycles which are produced in each revolution of the coil, with 2 poles, 4 poles and 6 poles. It is clear from this that the number of cycles per revolution is directly proportional to the number of poles, `P' divided by two. Therefore the number of cycles produced per second depends on P/2, and the speed in revolutions per second.

Therefore frequency $F = \frac{P}{2} \times 'n'$

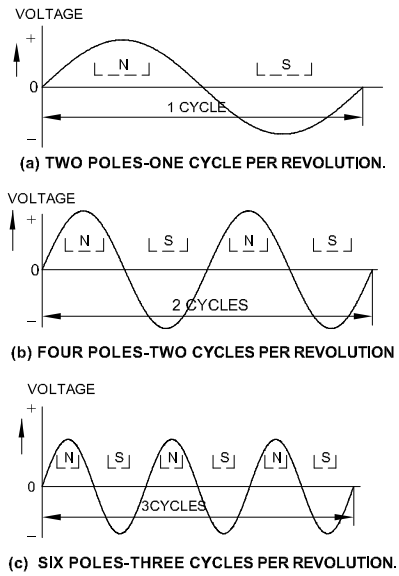
where `n' is in r.p.s.

`P' is the number of poles.

Generally speed is represented in r.p.m.

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Fig 6



Then we have requency $F = \frac{PN}{2 \times 60} = \frac{PN}{120}$

where P is number of poles and N is speed in r.p.m.

Accordingly we can state that the frequency of an alternator is directly proportional to the number of poles and speed.

Types and construction of alternators

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

- **explain the construction, and the various types of alternators.**

Types of alternators: DC and AC generators are similar in one important respect, that is, they both generate alternating emf in the armature conductors. The AC generator sends out the electrical energy in the same form of alternating emf to the external load with the help of slip rings.

AC generators, named as alternators, must be driven at a very definite constant speed called synchronous speed, because the frequency of the generated emf is determined by the speed. Due to this reason these machines are called `synchronous alternators or synchronous generators'.

Classification according to the type of rotating part: One way of classifying the alternator is the way in which the rotating part is chosen. In the earlier lessons, we discussed how an alternator can have either stationary or rotating magnetic field poles. Accordingly an alternator having a stationary magnetic field and a moving armature is called a rotating armature type, and an alternator with a stationary armature and moving magnetic field is called a rotating field type. There are definite advantages in using rotating field type alternators.

Advantages of using rotating field type alternators

Only two slip rings are required for a rotating field type alternator whatsoever the number of phases may be.

As the main winding is placed over the stator, more conductors can be housed in the stator because of more internal peripheral area. More conductors result in higher voltage/current production.

As the winding in which the emf is induced is stationary, there is no possibility of breaking or loosening the winding and its joints, due to rotational forces.

There is no sliding contact between the stationary armature and the external (load) circuit, as the supply could be taken direct. Only two slip rings are provided in the rotor for low power low voltage field excitation. Thus less sparking and less possibility of faults.

The main winding being stationary, the conductors can be easily and effectively insulated, and the insulating cost also will be less for higher output voltage (less dielectric strength insulation will be sufficient).

Stationary main conductors need less maintenance.

As the rotar has a field winding which is lighter for the given capacity than in the rotating armature type, the alternator can be driven at a higher speed.

Classification according to the number of phases: Another way of classifying the alternators is based on production of single or 3-phase by the alternator. Accordingly the types are 1) single-phase alternators 2) three-phase alternators.

Single-phase alternators: A single-phase alternator is one that provides only one voltage. The armature coils are connected in `series additive'. In other words, the sum of the emf induced in each coil produces the total output voltage. Single phase alternators are usually constructed in small sizes only. They are used as a temporary standby power for construction sites and for permanent installation in remote locations.

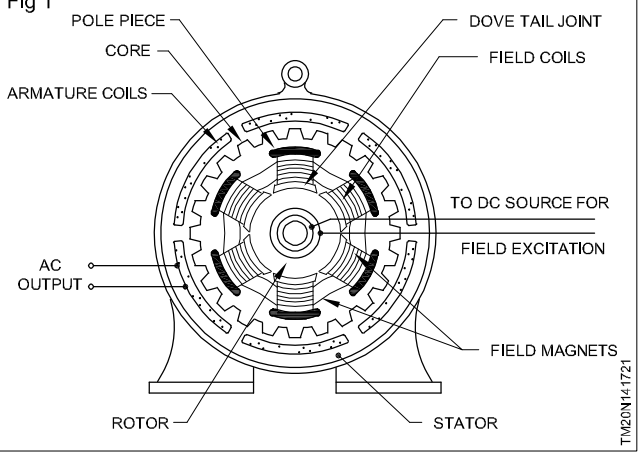
Three-phase alternators: This alternator provides two different voltages, namely, phase and line voltages. It has 3 windings placed at 120° to each other, mostly connected in a star having three main terminals U,V,W and neutral `N'.

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These alternators are driven by prime movers such as diesel engines, steam turbines, water wheels etc. depending upon the source available.

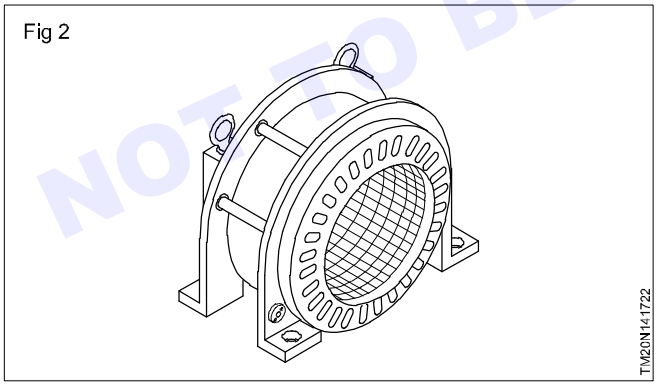
Construction of alternators: The main parts of a revolving field type alternator are shown in Fig 1.

Fig 1



Stator: It consists of mainly the armature core formed of laminations of steel alloy (silicon steel) having slots on its inner periphery to house the armature conductors. The armature core in the form of a ring is fitted to a frame which may be of cast iron or welded steel plate. The armature core is laminated to reduce the eddy current losses which occur in the stator core when subjected to the cutting of the flux produced by the rotating field poles. The laminations are stamped out in complete rings (for smaller machines) or in segments (for larger machines), and insulated from each other with paper or varnish. The stampings also have holes which make axial and radial ventilating ducts to provide efficient cooling. A general view of the stator with the frame is shown in Fig 2.

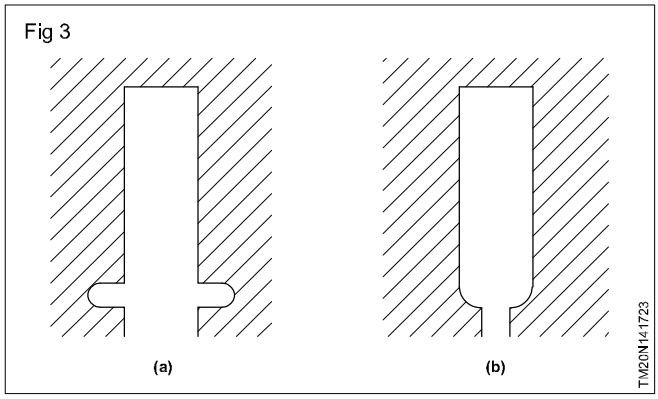
Fig 2



Slots provided on the stator core to house the armature coils are mainly of two types, (i) open and (ii) semi-closed slots, as shown in Fig 3(a) and (b) respectively.

The open slots are more commonly used because the coils can be form-wound and pre-insulated before placing in the slots resulting in fast work, less expenditure and good insulation. This type of slots also facilitates easy removal and replacement of defective coils. But this type of slots creates uneven distribution of the flux, thereby producing ripples in the emf wave. The semi-closed type slots are better in this respect but do not permit the use of form-wound coils, thereby complicating the process of winding. Totally closed slots are rarely used, but when used, they need bracing of the winding turns.

Fig 3



Rotor: This forms the field system, and is similar to DC generators. Normally the field system is excited from a separate source of low voltage DC supply. The excitation source is usually a DC shunt or compound generator, known as an exciter, mounted to the same alternator shaft. The exiting current is supplied to the rotor with the help of two slip- rings and brushes. The field poles created by the excitation are alternately north and south.

Rotating field rotors are of two types, namely (i) salient pole type as shown in Fig 4 and (ii) smooth cylindrical type or non-salient pole type, as shown in Fig 5.

Fig 4

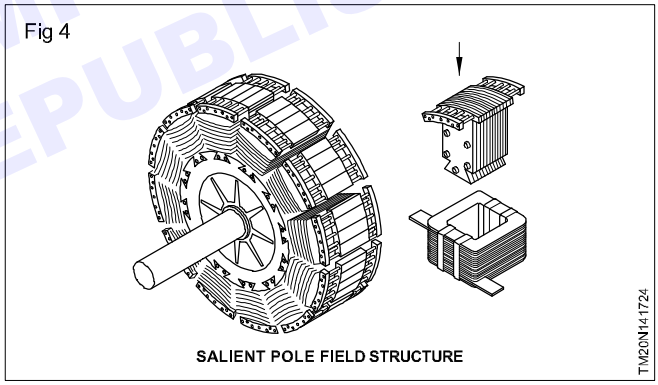
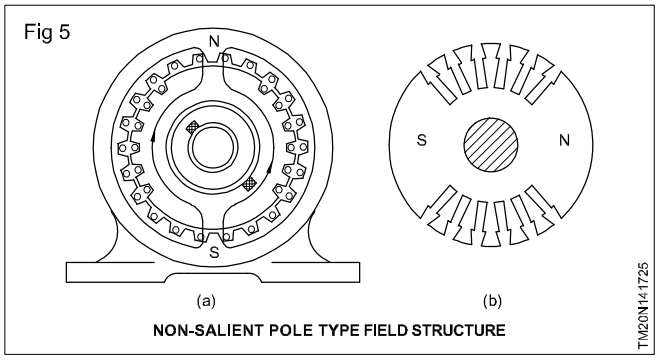


Fig 5



Salient pole type: This type of rotor is used only for slow and medium speed alternators. This type is less expensive, having more space for the field coils and vast heat dissipating area. This type is not suitable for high speed alternators as the salient poles create a lot of noise while running in addition to the difficulty of obtaining sufficient mechanical strength.

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Fig 4 shows the salient pole type rotor in which the riveted steel laminations are fitted to the shaft fitting with the help of a dovetailed joint. Pole faces are curved to have uniform distribution of the flux in the air gap leading to production of sinusoidal wave form of the generated emf. These pole faces are also provided with slots to carry the damper winding to prevent hunting. The field coils are connected in series in such a way as to produce alternate north and south poles, and the field winding ends are connected to the slip rings. The DC excitation source is connected to the brushes which are made to contact the slip rings with the required pressure.

Salient pole type alternators could be identified by their larger diameter, short axial length and low or medium speed of operation.

Smooth cylindrical or non-salient pole type rotor: This type is used in very high speed alternators, driven by steam turbines. To have good mechanical strength, the peripheral velocity is lowered by reducing the diameter of the rotor and alternatively with the increased axial length. Such rotors have either two or four poles but run at higher speeds.

To withstand such speeds, the rotor is made of solid steel forging with longitudinal slots cut as shown in Fig 5a which shows a two-pole rotor with six slots. The winding is in the form of insulated copper strips, held securely in the slots by proper wedges, and bound securely by steel bonds.

One part of the periphery of the rotor in which slots are not made is used as poles as shown in Fig 5b.

Smooth cylindrical pole type alternators could be identified by their shorter diameter, longer axial length and high speed of operation.

Emf equation of the alternator

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

- **explain the emf equation and apply the emf equation to calculate the induced emf in an alternator.**

Equation of induced emf: The emf induced in an alternator depends upon the flux per pole, the number of conductors and speed. The magnitude of the induced emf could be derived as stated below

Let Z = No.of conductors or coil sides in series/ phase in an alternator

P = No.of poles

F = frequency of induced emf in Hz

Ø = flux per pole in webers

k_f = form factor = 1.11 - if emf is assumed to be sinusoidal

N = rotative speed of the rotor in r.p.m.

According to Faraday's Law of Electromagnetic Induction we have the average emf induced in a conductor

= rate of change of flux linkage

$$= \frac{d\varnothing}{dt}$$

$$= \frac{\text{change of total flux}}{\text{time duration in which the flux change takes place}}$$

In one revolution of the rotor (ie in 60/N seconds), each stator conductor is cut by a flux equal to PØ webers.

Hence the change of total flux = dØ = PØ and the time duration in which the flux changes takes place

= dt = 60/N seconds.

Hence the average emf induced in a conductor

$$= \frac{d\varnothing}{dt} = \frac{P\varnothing}{\frac{60}{N}} \text{ volts}$$

Substituting the value for $N = \frac{120F}{P}$ in eqn 1

we have the average emf induced in a conductor =

$$= \frac{P\varnothing 120F}{P60} \text{ volts} = 2\varnothing F \text{ volts}$$

If there are Z conductors in series per phase we have the average emf per phase = 2ØFZ volts.

Then r.m.s. value of emf per phase = average value x form factor

$= V_{AV} \times K_F$

$= V_{AV} \times 1.11$

$= 2\varnothing FZ \times 1.11$

$= 2.22\varnothing FZ$ volts.

Alternatively r.m.s. value of emf per phase = 2.22ØF2T volts

$= 4.44\varnothing FT$ volts

where T is the number of coils or turns per phase

and Z = 2T.

This would have been the actual value of the induced voltage if all the coils in a phase were (i)full pitched and (ii) concentrated or bunched in one slot. (In actual practice, the coils of each phase are distributed in several slots under all the poles.) This not being so, the actually available voltage is reduced in the ratio of these two factors which are explained below.

Pitch factor (K_p or K_c.): The voltage generated in a fractional pitch winding is less than the full pitch winding. The factor by which the full pitch voltage is multiplied to get voltage generated in fractional pitch is called pitch factor,

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and it is always less than one; and denoted as K_p or K_c. Normally this value is given in problems directly; occasionally this value needs to be calculated by a formula $K_p = K_c = \text{Cos } a/2$

where a is the electrical angle by which the coil span falls short of full pitch.

Example: Calculate the pitch factor for a winding having 36 stator slots, 4 poles with a coil span of 1 to 8.

$$\text{For full pitch} = \frac{\text{Number of stator slots}}{\text{Number of slots}} = \frac{36}{4} = 9.$$

Hence winding should start at 1 and end at 10.

In actual practice the coil span is taken as 1 – 8.

Hence actual pitch = 8 – 1 = 7.

Hence the coil span is short pitched by = 9 – 7 = 2.

$$\text{The angle } \alpha = \frac{\text{difference in pitch}}{\text{full pitch}} \times 180°$$

$$= \frac{2}{9} \times 180° = 40°$$

where 180° is the complete angle for full pitch.

$$\text{Pitch factor } K_c = \text{Cos } \frac{\alpha}{2} = \text{Cos } \frac{40}{2} = \text{Cos } 20 = 0.94.$$

Distribution factor (K_d): It is imperative that the conductors of the same phase need to be distributed in the slots instead of being concentrated at one slot. Because of this, the emf generated in different conductors will not be in phase with each other, and hence, cannot be added together to get the total induced emf per phase but to be added vectorially. This has to be taken into account while determining the induced voltage per phase.

Therefore, the factor by which the generated voltage must be multiplied to obtain the correct value is called a distribution factor, denoted by K_d and the value is always less than one. The formula for finding the value of K_d is given below.

$$K_d = \frac{\text{Sin } m\beta/2}{m \text{ Sin } \beta/2}$$

where m is the number of slots per phase per pole

$$\beta = \frac{180°}{\text{No. of slots per pole}}$$

Example: A six-pole alternator rotating at 1000 r.p.m. has a single-phase winding housed in three slots per pole; the slots in groups of three being 20° apart. Find the distribution factor.

$$K_d = \frac{\text{Sin } m\beta/2}{m \text{ Sin } \beta/2}$$

where m = 3 slots per phase per pole

b = 20^0

$$K_d = \frac{\text{Sin } 3 \times 20/2}{3 \text{ Sin } 20/2} = \frac{\text{Sin } 30°}{3 \text{ Sin } 10°}$$

$$= \frac{0.5}{3 \times 0.1736} = 0.96$$

Example: A 3-phase, 12-pole, star-connected alternator has 180 slots with 10 conductors per slot, and the conductors of each phase are connected in series. The coil span is 144° (electrical). Find the distribution factor and the pitch factor K_p.

$$K_d = \frac{\text{Sin } m\beta/2}{m \text{ Sin } \beta/2}$$

$$m = \frac{180}{3 \times 12} = 5 \text{ slots per phase per pole.}$$

$$\beta = \frac{180°}{\frac{180}{12}} = 12°$$

$$K_d = \frac{\text{Sin } 5 \times \frac{12}{2}}{5 \text{ Sin } \frac{12}{2}} = \frac{\text{Sin } 30°}{5 \text{ Sin } 6°} = \frac{0.5}{5 \times 0.1045} = 0.957$$

$$K_p = \text{Cos } \frac{\alpha}{2}$$

= Cos (180-144)/2 = Cos 36/2 = Cos 18° = 0.95.

From the foregoing, it is found that the pitch factor and the distribution factor are to be used to multiply the induced emf to get the actual induced voltage. Thus emf induced in an alternator E_o per phase = 4.44 $K_p K_d$FØT volts.

In the case of a star-connected alternator, the line voltage = $E_L = \sqrt{3}E_P = \sqrt{3}E_0$ and in the case of a delta-connected alternator the line voltage $E_L = E_p = E_o$. However, if the value of either Kd or K_p is not given in the problem it can be assumed to be one.

Example: Calculate the effective voltage in one phase of an alternator, given the following particulars. F=60 Hz, turns/phase T = 240, flux per pole Ø = 0.0208 webber.

Solution: As K_c/K_p and K_d values are not given, we can assume they are equal to one.

Voltage/phase E = 4.44 ØFT volts

= 4.44 x 60 x 0.0208 x 240 volts

= 1329.86 V or 1330 volts.

Example: The following information is given in connection with a 3-phase alternator. Slots = 96, poles = 4, r.p.m. = 1500, turns/coil = 16 in single layer, Ø = 2.58 x 10^6 lines. Calculate the voltage generated/phase.

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$$F = \frac{PN}{120} = \frac{4 \times 1500}{120} = 50 \text{ Hz.}$$

$$\text{Coils per phase} = \frac{\text{No. of slots}}{\text{No. of phases}} = \frac{96}{3} = 32.$$

Therefore turns/phase = 32 x 16 = 512

$= 2.58 \times 10^6$ lines $= 2.58 \times 10^6 \times 10^{-8}$ weber

$V = 4.44 F\O T$

$= 4.44 \times 50 \times 512 \times 2.58 \times 10^6 \times 10^{-8} = 2932$ volts.

Example: The stator of a 3-phase, 16-pole alternator has 144 slots, and there are 4 conductors per slot connected in two layers, and the conductors of each phase are connected in series. If the speed of the alternator is 375 r.p.m. calculate the emf induced per phase. The resultant flux in the air gap is 5×10^{-2} webers per pole, sinusoidally distributed. Assume the coil span as 150° electrical.

Sinusoidal distribution, hence the wave form is sine wave and the emf induced

$E_o = E_p = 4.44 K_c K_d F\O T$ volts

$K_c = \text{Cos } \frac{\alpha}{2} = \text{Cos } (180\text{-}150)/2 = \text{Cos } \frac{30}{2}$

$= \text{Cos } 15 = 0.966$

$$m = \frac{144}{3 \times 16} = 3$$

$$\beta = \frac{180°}{\frac{144}{16}} = \frac{180}{9} = 20°$$

$$K_d = \frac{\text{Sin } 3 \times \frac{20}{2}}{3 \text{ Sin } \frac{20}{2}} = 0.96.$$

Number of slots/phase $= \frac{144}{3} = 48$

Number of conductors/slots = 4

Number of conductors in series per phase = 48 x 4

$$\text{Number of turns in series per phase} = \frac{48 \times 4}{2} = 96.$$

$$\text{Frequency} = \frac{PN}{120} = \frac{16 \times 375}{120} = 50 \text{ Hz.}$$

$E_{ph} = 4.44 K_c K_d F\O T$

$= 4.44 \times 0.966 \times 0.96 \times 50 \times 5 \times 10^{-2} \times 96$

$= 988$ volts.

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Single phase motors-types-resistance/induction-start, induction-run motor

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

- **explain briefly the types of AC single phase motors**
- **explain the necessity and methods of split-phasing the single phase to obtain a rotating magnetic field**
- **explain the principle, construction, operation characteristic and application of single phase resistance / induction-start / induction-run motors.**

Single phase motors perform a great variety of useful services at home, office, farm, factory, and in business establishments. These motors are generally referred to as fractional horsepower motors with a rating of less than 1 H.P. Most single phase motors fall into this category. Single phase motors are also manufactured in 1.5,2,3 and up to 10 H.P. as a special requirement.

Single phase motors may be broadly classified as split-phase induction motors and commutator motors according to their construction and method of starting.

Split-phase induction motors can be further classified as:

– resistance-start, induction-run motors

– induction-start, induction-run motors

– permanent capacitor motors

– capacitor-start, induction-run motors

– capacitor-start, capacitor-run motors

– shaded pole motors.

Commutator motors can be classified as:

– repulsion motors

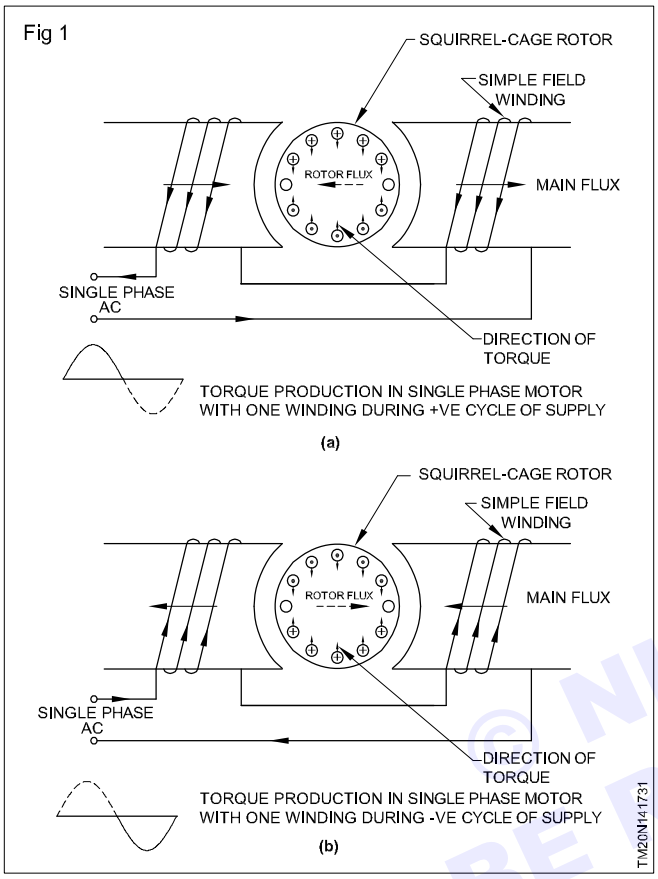
– series motors.

The basic principle of operation of a split-phase induction motor is similar to that of a polyphase induction motor. The main difference is that the single phase motor does not produce a rotating magnetic field but produces only a pulsating field. Hence to produce the rotating magnetic field, phase-splitting is to be done to make the motor to work as a two-phase motor for starting.

First, let us examine the behaviour of the magnetic field as set up by an AC current in a single-phase field winding. With reference to Fig 1, at a particular instant, the current flowing in the field winding produces the magnetic field as shown in Fig 1a. Since the produced magnetic field is varying, it will induce currents in the rotor bars which in turn will create a rotor flux. This stator-induced flux, according to Lenz's law, opposes that of the main field. By applying this principle, the current direction in the rotor bars can be determined as shown in Fig 1a, as well as the torque created between the field and rotor currents. It is apparent that the downward torque produced by the upper rotor conductors is counteracted by the upward torque produced by the lower rotor conductors; hence no rotation results.

In the next instant, as shown in Fig 1b, the voltage in the input supply changes its polarity, creating a main field with a change in direction. This main field produces a torque, downward in upper conductors, and upwards in bottom conductors resulting in the cancellation of torque with no movement of the rotor, in this case also. Since the field is pulsating, the torque is pulsating although no net torque is produced over a full cycle.

Fig 1



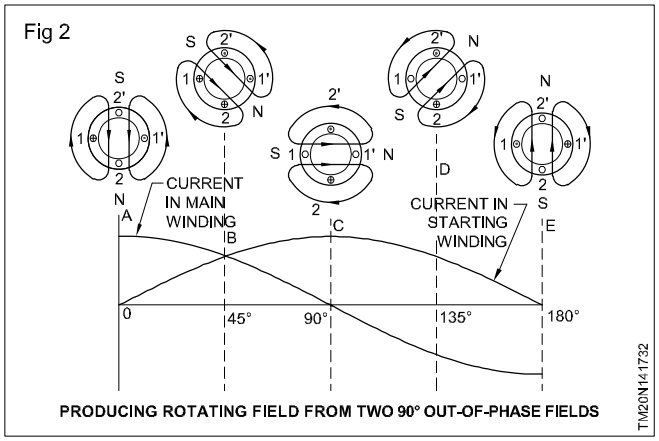
If the rotor is given a small jerk in any direction in the above mentioned cases, it will go on revolving, and will develop a torque in that particular direction due to interaction between the rotor and stator fluxes. Because of this effect, the split-phase motor, once started, needs only one winding to be connected to the supply for running. It is clear that a single phase induction motor, when having only one winding, is not self-starting. If the main field is made revolving instead of pulsating, a rotational torque could be produced in the rotor.

Producing a rotating field from two 90° out-of-phase fields: One of the methods of producing a rotating magnetic field is by split-phasing. This could be done by providing a second set of winding in the stator called the starting winding. This winding should be kept physically at 90 electrical degrees from the main winding, and should carry a current out of phase from the main winding. This, out of phase current, could be achieved by making the reactance of the starting winding being different from that of the main winding. In case both the windings have similar reactance and impedance, the resulting field, created by the main and starting windings, will alternate but will not revolve and the motor will not start.

By split-phasing, the two (main and starting) fields would combine to produce a rotating magnetic field as stated below.

Fig 2 shows that the main (1,1') and starting (2,2') windings are kept in the stator at 90° to each other. For consideration, only, one half cycle is shown with the effects at 45^0 increments.

Fig 2



At position `A', only the main winding is producing flux, and the net flux will be in a vertical direction, as shown in the stator diagram. At instant `B', 45° later, both windings are producing flux, and the net flux direction will also have rotated 45°. At position `C', the maximum flux is now in a horizontal direction because only the starting winding is producing flux. At instant `D', the current from the main winding is building up again, but in a new direction, while that from starting winding is now decreasing. Therefore, the net flux at this instant will be as shown in position D. At position `E', the maximum flux is just the opposite of what it was at instant `A'. It should now be evident that the two out-of-phase fields are combining to produce a net rotating field effect.

Working of split-phase motor: At the time of starting, both the main and starting windings should be connected across the supply to produce the rotating magnetic field. The rotor is of a squirrel cage type, and the revolving magnetic field sweeps past the stationary rotor, inducing an emf in the rotor. As the rotor bars are short-circuited, a current flows through them producing a magnetic field. This magnetic field opposes the revolving magnetic field and will combine with the main field to produce a revolving field. By this action, the rotor starts revolving in the same direction of the rotating magnetic field as in the case of a squirrel cage induction motor, which was explained earlier.

Hence, once the rotor starts rotating, the starting winding can be disconnected from the supply by some mechanical means as the rotor and stator fields form a revolving magnetic field.

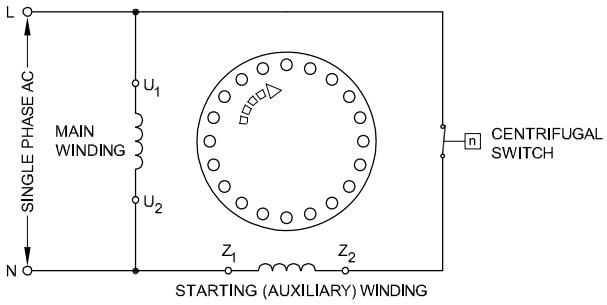
Resistance-start, induction-run motor: As the starting torque of this type of motor is relatively small and its starting current is high, these motors are most commonly used for rating up to 0.5 HP where the load could be started easily.

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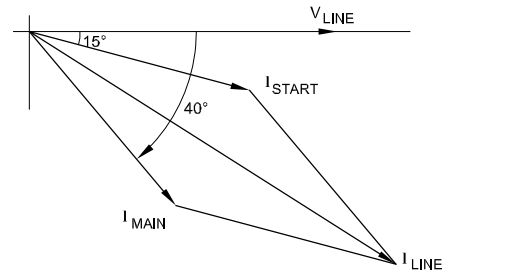
The essential parts are as shown in Fig 3a.

– Main winding or running winding
– Auxiliary winding or starting winding
– Squirrel cage type rotor
– Centrifugal switch

Fig 3



(a) RESISTANCE START INDUCTION RUN MOTOR



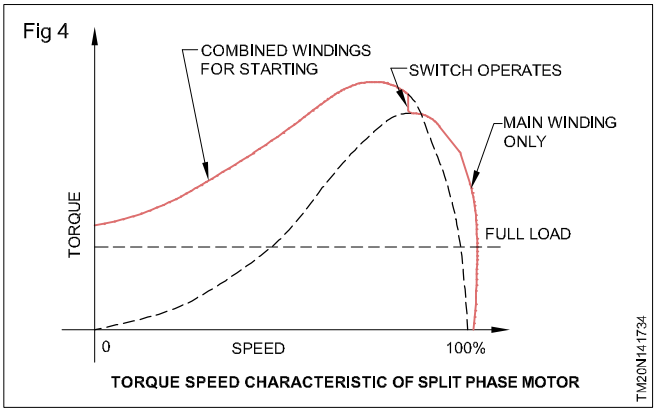
(b) PHASOR DIAGRAM AT THE INSTANT OF STARTING

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The starting winding is designed to have a higher resistance and lower reactance than the main winding. This is achieved by using smaller conductors in the auxiliary winding than in the main winding. The main winding will have higher inductance when surrounded by more iron, which could be made possible by placing it deeper into the stator slots. It is obvious that the current would split as shown in Fig 3b. The starting current `I start' will lag the main supply voltage `V' line' by 15° and the main winding current. `I main' lags the main voltage by about 40°. Therefore, these currents will differ in time phase and their magnetic fields will combine to produce a rotating magnetic field.

When the motor has come up to about 75 to 80% of synchronous speed, the starting winding is opened by a centrifugal switch, and the motor will continue to operate as a single phase motor. At the point where the starting winding is disconnected, the motor develops nearly as much torque with the main winding alone as with both windings connected. This can be observed from the typical torque-speed characteristics of this motor, as shown in Fig 4.

Fig 4



TORQUE SPEED CHARACTERISTIC OF SPLIT PHASE MOTOR

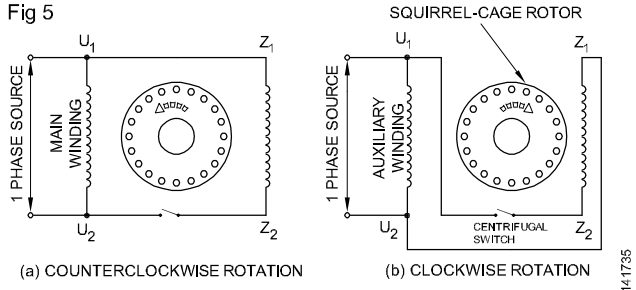
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The direction of rotation of a split-phase motor is determined by the way the main and auxiliary windings are connected. Hence, either by changing the main winding terminals or by changing the starting winding terminals, the reversal of direction of rotation could be obtained. Rotation will be, say counter-clockwise, if Z_1 is joined to U_1 and Z_2 is joined to U_2 as per Fig 5a. If Z_1 is joined to U_2 and Z_2 is joined to U_1, then the rotation will be clockwise, as shown in Fig 5b.

Application of resistance-start, induction-run motor: As the starting torque of this type of motors is relatively small and its starting current is high, these are manufactured for a rating up to 0.5 HP where the starting load is light. These motors are used for driving fans, grinders, washing machines and wood working tools.

Induction-start, induction-run motor: Instead of resistance start, inductance can be used to start the motor through a highly inductive starting winding. In such a case, the starting winding will have more number of turns, and will be imbedded in the inner areas of the stator slots so as to have high inductance due to more number of turns, and the area will be surrounded by more iron. As the starting and main windings in most of the cases are made from the same gauge winding wire, resistance measurement has to be done to identify the windings. This motor will have a low starting torque, higher starting current and lower power factor.

Fig 5



(a) COUNTERCLOCKWISE ROTATION (b) CLOCKWISE ROTATION

METHOD OF CHANGING THE DIRECTION OF ROTATION OF RESISTANCE START INDUCTION RUN MOTOR

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Centrifugal switch

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

- **explain the working, the method of maintenance and testing of a centrifugal switch**
- **explain the necessity of a manual D.O.L. starter and its working.**

The centrifugal switch: The centrifugal switch is located inside the motor and is connected in series with the starting winding in the case of capacitor-start, induction-run motors, and for disconnecting the starting capacitor in the case of a two value, capacitor-start, capacitor-run motor. Its function is to disconnect the starting winding after the rotor has reached 75 to 80% of the rated speed. The usual type consists of two main parts. Namely, a stationary part as shown in Fig 1, and a rotating part as shown in Fig 2. The stationary part is usually located on the front-end plate of the motor and has two contacts, so that it is similar in action to a single-pole, single-throw switch. When the rotating part is fitted in the rotor, it rotates along with it. When the rotor is stationary, the insulator ring of the rotating part is in an inward position due to spring tension. This inward movement of the insulator ring allows the stationary switch contacts to be closed which is due to the movable lever pressure against the leaf-spring tension in the switch.

Fig 1

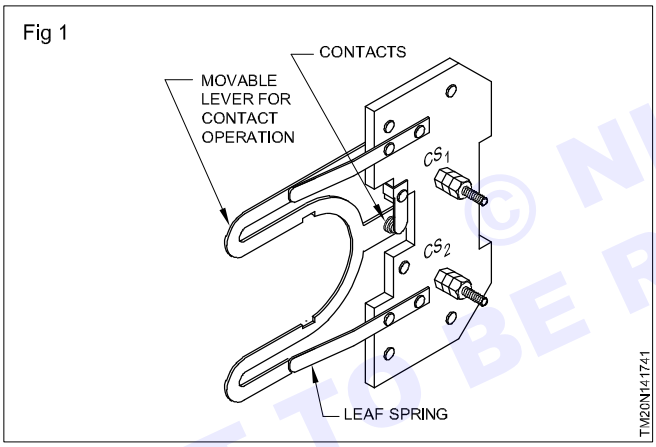
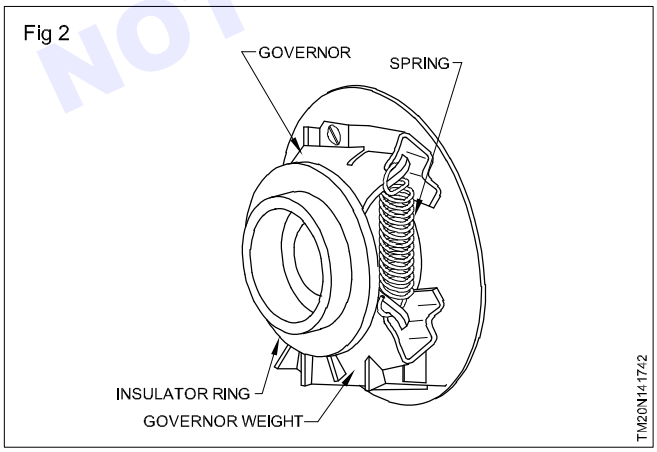


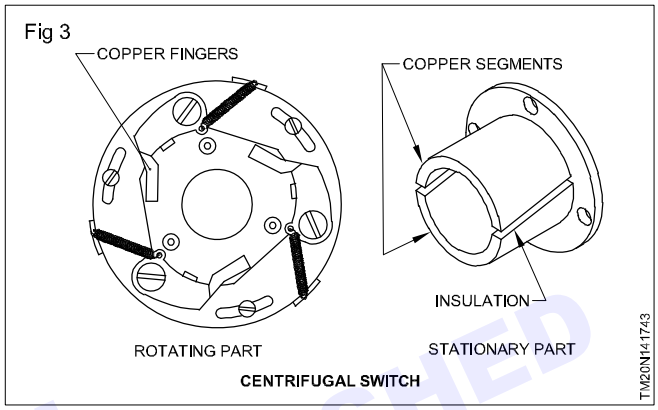
Fig 2



When the rotor attains about 75% of the rated speed, due to centrifugal force, the governor weights fly out, and this makes the insulator ring to come outward. Due to this forward movement of the insulated ring, it presses the movable lever, and the contacts connected through terminals CS_1 and CS_2 open the starting winding.

In older types of centrifugal switches, the stationary part consists of two copper, semicircular segments. These are insulated from each other and mounted inside the front-end plate. The centrifugal switch connections are given to these segments. The rotating part is composed of three copper fingers that ride around the stationary segments, while the motor is at rest or running at lower than 75% of the rated speed. These parts are illustrated in Fig 3.

Fig 3



At the time of starting, the segments are shorted by the copper fingers, thus causing the starting winding to be included in the motor circuit. At approximately 75 percent of the full speed, the centrifugal force causes the fingers to be lifted from the segments, thereby disconnecting the starting winding from the circuit.

Maintenance of centrifugal switch: Access to the centrifugal switch could be had by removing the inspection plate, located in the end covers of the motor. In very many cases, the switch is accessible only when the end plate is removed. These switches need to be checked atleast once in six months to ensure their proper operation. Look for broken or weak springs, for improper movement, for dirt or corrosion or pittings in the contact points. Make sure all parts work freely without binding. Replace the switch, if found defective.

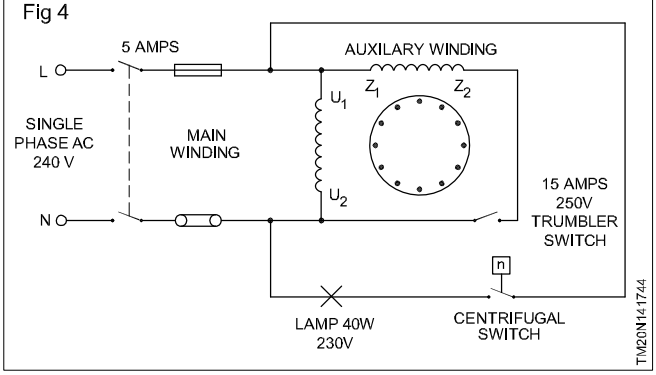
Testing the operation of a centrifugal switch: Though the centrifugal switch could be tested in a static condition, it will be very difficult to assess its operation at dynamic condition. As most of these switches cannot be checked without opening the end plate, the procedure becomes lengthy and cumbersome. To check the dynamic operation of the switch the following method is suggested. Disconnect the interconnecting terminals of the centrifugal switch from the supply and the starting winding. Connect the starting (auxiliary) winding through a 15 amps, single-pole, tumbler switch to the rated supply as shown in Fig 4, and keep the tumbler switch in the `ON' position.

Connect the terminals of the centrifugal switch, through a lamp as shown in Fig 4. Switch `ON' the motor. When the centrifugal switch is in the closed position, the lamp will light. As the motor picks up speed, say in about 20

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seconds, open the tumbler switch to disconnect the starting winding. When the speed of the motor attains about 75% of the rated value, the centrifugal switch, if it operates correctly, will open its contacts which could be observed from the lamp going `off'. Soon after switching `on' the main supply, if the lamp is not lighted, or if it lights up but does not go out after 30-40 seconds (75 % of the rated speed) then the centrifugal switch is deemed to be not working, and should be repaired or replaced.

Fig 4



Manual D.O.L. starter: A starter is necessary for starting and stopping the motor, and for providing overload protection.

A manual starter, as it appears, is shown in Fig 5, an open view of the starter is shown in Fig 6, and the internal parts are shown in Fig 7, as a schematic diagram. A manual starter is a motor controller with a contact mechanism operated by hand. A push-button operates the mechanism through a mechanical linkage. As shown in Figs 6 & 7, the starter may have both a thermal overload relay and a magnetic overload relay for overload protection and short circuit protection respectively. Both the relays are made to operate independently, in case of overload or short circuit, to release the start-button for disconnecting the motor from supply. Most of the present day, manual starters have either of the two relays only. Basically, a manual starter is an ON-OFF switch with overload relay only.

Manual starters are simple and they provide quiet operation.

Operation: Pushing the `ON' button closes the contacts. The contacts remain closed until the STOP button is pushed or the overload relay or the short circuit relay trips the starter.

Fig 5

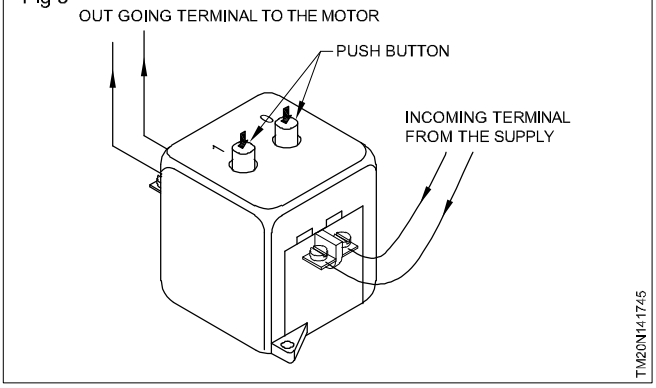
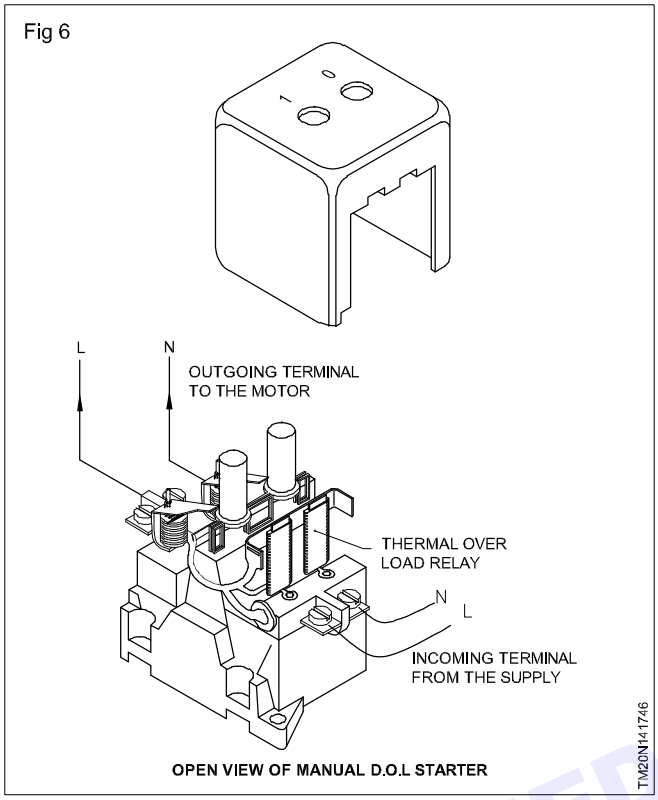


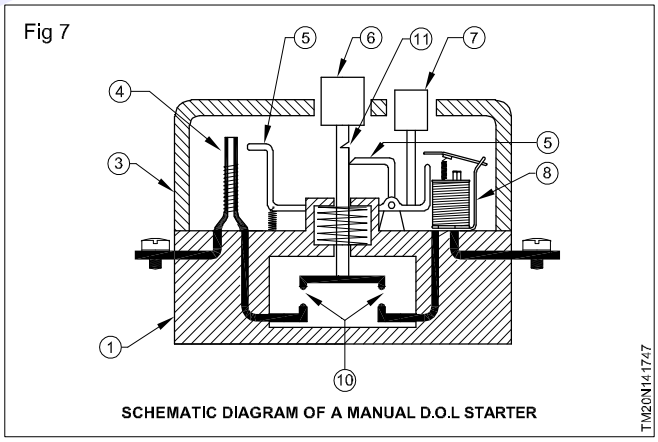
Fig 6



OPEN VIEW OF MANUAL D.O.L STARTER

As shown in Fig 7, when the `ON' push-button (6) is pressed, the switching contact (10) gets closed, and remains in a closed position, as the mechanical lever system (5) holds the stem of the `ON' button by the cavity (11) against the spring tension. By operating the stop button (7), the mechanical lever system (5) gets disengaged from the stem cavity, making the stem of the `ON' button to spring back, thereby opening the switching contacts (10).

Fig 7



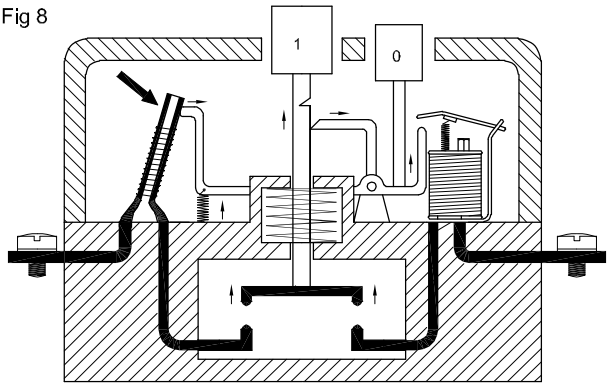
SCHEMATIC DIAGRAM OF A MANUAL D.O.L STARTER

Operation of overload relay: In the case of sustained overloads, the heavy currents passing through the heating element of the thermal overload relay heats up the bimetallic strip, making it to bend as shown by the arrow in Fig 8, thereby activating the mechanical lever system to open the switching contacts.

The current setting of the thermal overload relay can be changed by adjusting the setting screw, provided for this purpose (not shown in the figure.)

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Fig 8



OPERATION OF O/L RELAY IN A MANUAL D.O.L. STARTER

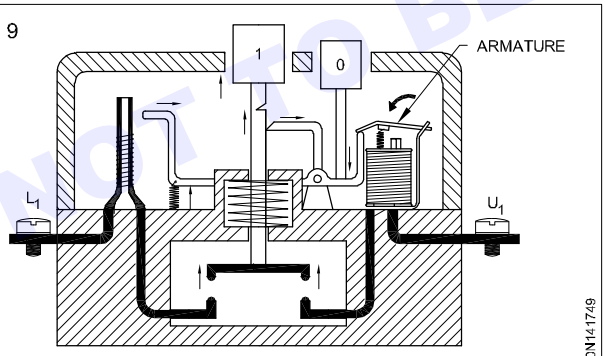
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Operation of short-circuit relay: In the case of a short circuit in the motor circuit, the short circuit current will be very high in value. Though the thermal overload relay is also in series with such a short circuit current, it is sluggish in operation and takes considerable time to operate. On the other hand, the short circuit current within such time of delayed operation, will sufficiently damage the motor winding, power cables or the connected supply line.

The magnetic relay will operate faster than the thermal overload relay in such cases.

During normal load current the magnetic field produced by the coil will not have sufficient pull to attract the armature. But in case of short circuit, the current will be very high and the coil produces sufficient magnetism to attract the armature. Downward movement of the armature activates the mechanical lever mechanism as shown by the arrow in Fig 9 and the switching contact opens. These contacts cannot be reclosed until the starter mechanism has been reset by pressing the Stop button.

Fig 9



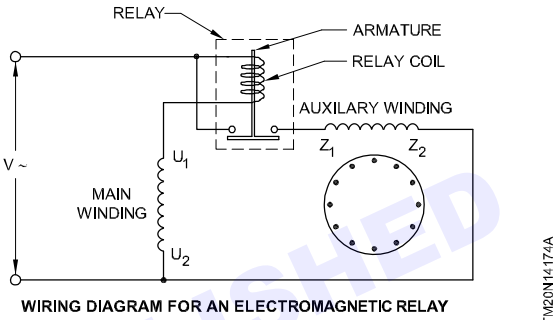
OPERATING OF MAGNETIC RELAY DURING SHORT CIRCUIT

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Manual starters are used for fractional horsepower motors. They usually provide across-the-line starting. Manual starters cannot provide low-voltage protection or no-volt release. If power fails, the contacts remain closed, and the motor will restart when the power returns. This may be an advantage for pumps, fans, compressors, and oil burners. But in the case of machinery it can be dangerous to people operating the equipment, and hence, such manual starters are not recommended to be used in these places.

Electromagnetic relay: Single phase induction motors, like poly phase induction motors takes heavy current from the time during starting when started direct on line Advantage of this high starting current is taken to operate electromagnetic type relay which performs the same function as the centrifugal device. Connection diagram for such a relay is shown in Fig 10.

Fig 10



WIRING DIAGRAM FOR AN ELECTROMAGNETIC RELAY

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The relay has a coil which is connected in series with the main winding. The auxiliary winding is connected across the supply through a normally open contact of the relay. Since split-phase motors are usually started direct on line, the initial current inrush may be as high a five to six times the rated current. During the starting period, when the main winding current is high, the armature of the relay will be drawn upwards, thereby closing the relay contacts. The auxiliary winding will, therefore, get connected across the supply, thus helping the motor to start rotating. As the rotor starts rotating, the line current gradually goes on decreasing. After the motor reaches proper speed, the main winding current drops to a low value and causes the armature of the relay to fall downwards and open the contacts, thereby cutting out the auxiliary winding from the supply. Such relays are located outside the motor so that they can be easily serviced or replaced. As centrifugal switches are mounted internally, their servicing or replacement is not as simple as an externally mounted over-current relay.

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A.C Capacitor - start - induction run motor

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

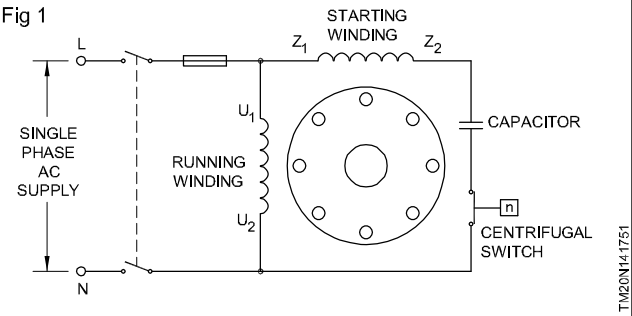
- **explain with a diagram the working of an AC single phase, capacitor-start, induction-run motor**
- **explain the characteristic and application of a capacitor- start, induction-run motor.**

A drive which requires a higher starting torque may be fitted with a capacitor-start, induction-run motor as it has excellent starting torque as compared to the resistance-start, induction-run motor.

Construction and working: Fig 1 shows the schematic diagram of a capacitor-start, induction-run motor. As shown, the main winding is connected across the main supply, whereas the starting winding is connected across

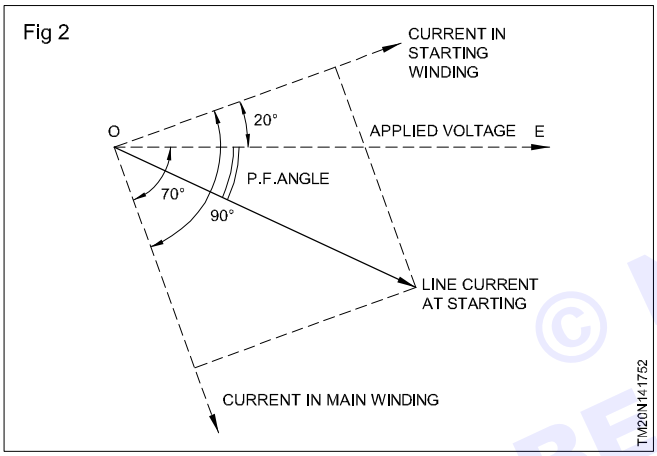
the main supply through a capacitor and a centrifugal switch. Both these windings are placed in a stator slot at 90° electrical degrees apart, and a squirrel cage type rotor is used.

Fig 1



As shown in Fig 2, at the time of starting, the current in the main winding lags the supply voltages by about 70° degrees, depending upon its inductance and resistance. On the other hand, the current in the starting winding due to its capacitor will lead the applied voltage, by say 20° degrees.

Fig 2



Hence, the phase difference between the main and starting winding becomes near to 90 degrees. This in turn makes the line current to be more or less in phase with its applied voltage, making the power factor to be high, thereby creating an excellent starting torque.

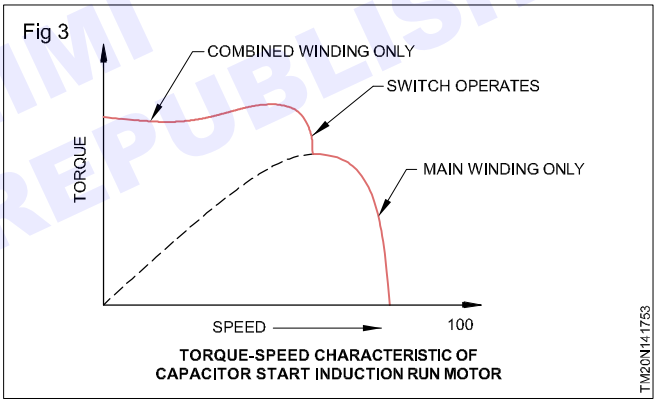
However, after attaining 75% of the rated speed, the centrifugal switch operates opening the starting winding, and the motor then operates as an induction motor, with only the main winding connected to the supply.

Reversing the direction of rotation: In order to reverse the direction of rotation of the capacitor start, induction-run motor, either the starting or the main winding terminals should be changed. This is due to the fact that the direction of rotation depends upon the instantaneous polarities of the main field flux and the flux produced by the starting winding. Therefore, reversing the polarity of any one of the fields will reverse the torque.

Characteristic: As shown in Fig 2, the displacement of current in the main and starting winding is about 80/90 degrees, and the power factor angle between the applied voltage and line current is very small. This results in producing a higher power factor and an excellent starting torque, several times higher than the normal running torque, as shown in Fig 3. The running torque adjusts itself with load by varying inversely with respect to speed as shown in the characteristic curve in Fig 3.

Application: Due to the excellent starting torque and easy direction-reversal characteristic, these machines are used in belted fans, blowers, dryers, washing machines, pumps and compressors.

Fig 3



TORQUE-SPEED CHARACTERISTIC OF CAPACITOR START INDUCTION RUN MOTOR

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Capacitors used in single phase capacitor motors

Objectives: At the end of this lesson you shall be able to
- **state the precautions to be followed while using a capacitor in a single phase capacitor motor**
- **explain the methods of testing capacitors.**

A capacitor is a device which can store electrical energy in the form of electrostatic charge. However the main purpose of the capacitor in the single phase motors is to split the phase for producing the rotating magnetic field. In addition, they also draw the leading current, thereby improving the power factor.

Precautions to be followed while using a capacitor in a single phase capacitor motor: Paper or electrolytic capacitors of non-polarized types are used for starting AC capacitor type motors. These capacitors have special marking for use in AC circuits, and will not have polarity marking. Paper or electrolytic capacitors for use in DC circuits have polarity markings. They must not be used in AC circuits as the reversal of AC voltage will heat up the capacitor, producing enormous gas inside the can, thereby blowing it into pieces.

The AC voltage rating inscribed on the capacitor will have two ratings. One for working voltage and another for the maximum value of voltage. Working voltage refers to the normal R.M.S. rating of the supply mains while the maximum rating will be AC peak voltage which will be $\sqrt{2}$ times the rated R.M.S. voltage. Hence, while replacing a capacitor, a careful scrutiny of voltage rating is essential, as otherwise the capacitor may fail and may also explode.

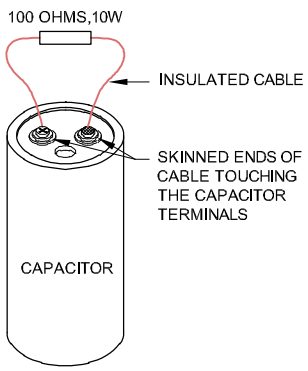
The duty cycle is another important point to be checked. In most of the capacitors, the marking will indicate whether it is for intermittent (short duty) or continuous (long duty) rating. Though continuous rated capacitors can be used for intermittent rating, never an intermittent (short duty) rating capacitor should be used for continuous rating. This has some relation with the centrifugal switch operation, frequency of starting and stopping and load. When the load is heavy or the centrifugal switch is not proper, there will be a chance for the starting winding, along with the capacitor, to be in the main circuit for a long time. In such cases the capacitor, which is intermittent rated, will fail due to overheating. This should be checked when the capacitor fails often in a specified capacitor-start motor.

The capacity of the capacitor, which is given in microfarads, should be the same as is specified by the manufacturer of the motor. A lower value will result in poorer starting torque and high starting currents, whereas a higher rating may not allow the speed to reach the rated value resulting in the starting winding to be in main line for a long time there by ending in poor operation and efficiency. In capacitor-start, capacitor-run motors, there will be two capacitors. As the starting capacitor will be 5 to 15 times of the rating of the running capacitor, and will also be of intermittent-rated electrolytic type, when compared to the running capacitor, which will be of continuous-rated, oil-filled type. Due care should be taken while connecting these capacitors in the motor, avoiding wrong selection and connection.

While handling a capacitor, due care should be taken to avoid shocks. A good capacitor can hold its charge for several days, and when touched, may give a severe shock. Hence, before touching any terminal of the capacitor, which is in use, the electrical charge should be discharged through a test lamp or through a 100 ohms 10 watts resistor as shown in Fig 1. Direct shorting of the capacitor terminals for discharging should be avoided as far as possible as this results in creating an enormous strain to the inner parts of the capacitor and it may fail.

Method of testing capacitors: Before removing a capacitor from the motor connection for testing, it should be discharged to avoid fatal shocks. The following methods are recommended for testing the large value paper, electrolytic or oil-filled capacitors.

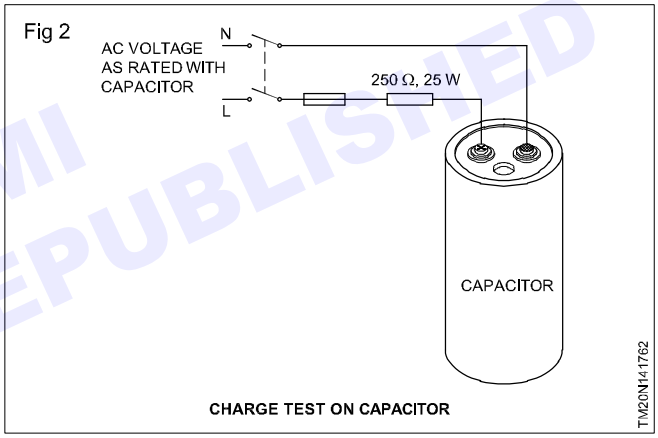
Fig 1



METHOD OD DISCHARGING A CAPACITOR

Charge-discharge test: Check the working voltage indicated on the capacitor. If the value is equal or more than that of the usual, single phase voltage, say 230V AC 50 Hz, we can connect it to the supply through a 100 ohms, 25 watts resistor as shown in Fig 2. Preferably, keep the capacitor, while testing on line voltage, inside a covered cardboard box or in a wooden box. Sometimes, if the capacitor is defective, it may explode and cause injury to you. Switch on the circuit for about 3-4 seconds. Then switch `OFF' the supply, and remove the supply terminals carefully with the help of an insulated pliers, without touching the capacitor terminals. Then, short the capacitor terminals with the help of a screwdriver. A bright spark is an indication that the capacitor is working. A dull spark or no spark indicates the capacitor is weak or open. On the other hand, no sparks while touching with the supply terminals indicate that the capacitor is opened. In the case of low capacity capacitors, the spark will be very feeble even if the capacitor is in good condition. Further, this check or the ohmmeter test described in the next para, does not indicate the de-rated value of the capacitor. Hence a capacity check is necessary as will be explained later.

Fig 2



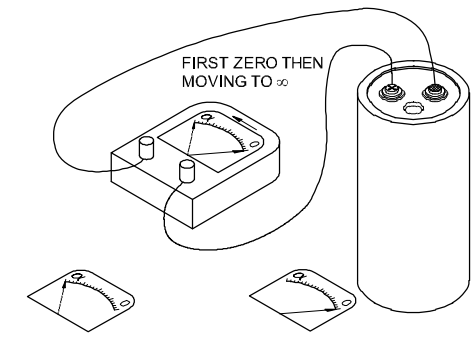
CHARGE TEST ON CAPACITOR

Ohmmeter test: Before using the ohmmeter, the capacitor should be thoroughly discharged to avoid damage to the ohmmeter. Set the range of the ohmmeter to resistance and adjust to zero ohms. Touch the terminals of the capacitor and watch the deflection of the meter. If the needle deflects towards zero and then moves towards infinity, the capacitor is working. Reverse the test leads and test it again, the needle will do the same thing again in a good capacitor. If the capacitor is open, the needle will not go to zero position but will remain in infinity side. On the other hand, in a shorted capacitor, the needle will be in zero position but will not go to infinity side at all. These results are illustrated in Fig 3.

Capacity test: Connection should be as shown in Fig 4. Keep the resistance value maximum at the time of switching `on' to protect the ammeter. Keep the capacitor inside a cardboard or wooden box to avoid injury in case of explosion. The ammeter (I) and voltmeter (V) readings are to be taken when the resistor is completely cut out from the circuit. From the meter readings, the capacity rating of the capacitor in microfarads can be calculated.

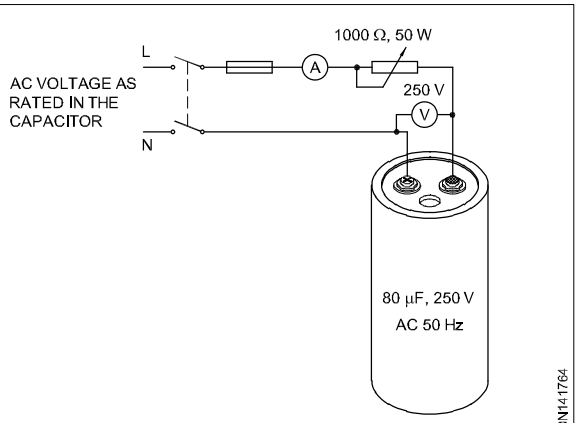
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Fig 3



TESTING A CAPACITOR WITH A MULTIMETER

Fig 4



CAPACITY TEST ON CAPACITOR

Capacity of capacitor in C_F Farad = $\frac{I}{2\pi FV}$

Capacity in microfarad C_{mf} = $\frac{I \times 10^6}{2\pi FV}$

= $\frac{3182 \times I}{V}$ microfarads.

If the capacity is 20 percent more or less than the notified value, replace it.

Insulation test on capacitors: According to BIS 1709-1984 recommendations, the insulation test conducted between the shorted capacitor terminals and the metal can, when measured by a 500V megger/insulation tester, should not be less than 100 megohms. If the can is of insulating material, the measurement could be made between the capacitor terminals and the metal strap holding the can.

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A.C Capacitor-start, capacitor - run motor

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

- **distinguish between the single and two-value, capacitor-start, capacitor-run motors**
- **explain the schematic diagram of a permanent capacitor motor, state its characteristic and use**
- **explain the schematic diagram of a capacitor-start, capacitor-run motor, state its characteristic and use.**

Capacitor-start, capacitor-run motors are of two types as stated below.

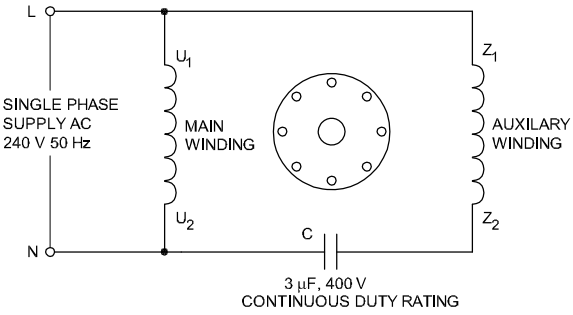
– Permanent capacitor motor (Single value capacitor motor)

– Capacitor-start, capacitor-run motor (Two-value capacitor motor)

Permanent capacitor motor: This type of motor is shown in Fig 1 which is most commonly used in fans. This motor is preferred in drives where the starting torque is not required to be high, while at the same time elimination of the centrifugal switch in the motor is necessary for easy maintenance. The capacitor is connected in series with the auxiliary winding, and remains so throughout the operation. These capacitors should be of oil-type construction and have continuous duty rating.

To avoid low efficiency, the capacity of the condensers is kept low, which, in turn, brings down the starting torque to about 50 to 80% of the full-load torque.

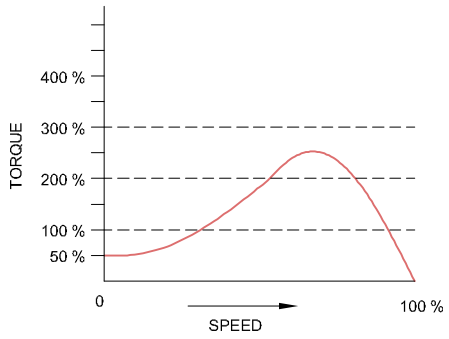
Fig 1



CIRCUIT DIAGRAM OF PERMANENT CAPACITOR MOTOR

The torque-speed characteristic of the motor is shown in Fig 2. This motor works on the same principle as the capacitor-start, induction-run motor with low starting torque but with higher power factor, during starting as well as in running.

Fig 2



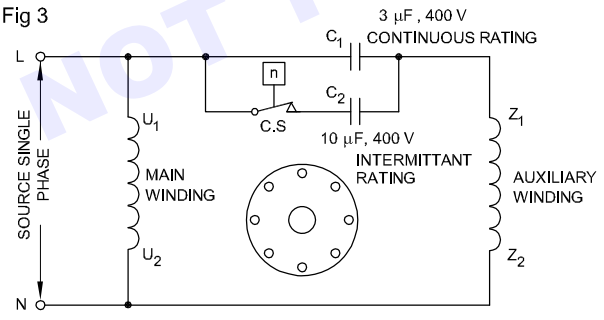
TORQUE-SPEED CHARACTERISTIC OF PERMANENT CAPACITOR MOTOR

This motor is most suitable for drives, which require a lower torque during start, easy changes in the direction of rotation, stable load operation and higher power factor during operation. *Examples* - fans, variable rheostats, induction regulators, furnace control and arc welding controls. This motor is cheaper than the capacitor-start, induction-run motor of the same rating.

Capacitor-start, capacitor-run motors: As discussed earlier capacitor-start, induction-run motors have excellent starting torque, say about 300% of the full load torque, and their power factor during starting is high. However, their running torque is not good, and their power factor, while running, is low. They also have lesser efficiency and cannot take overloads.

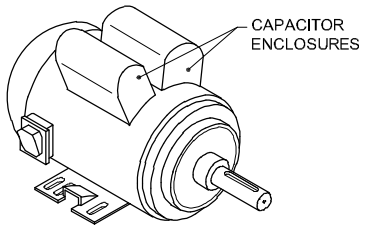
These problems are eliminated by the use of a two-value capacitor motor in which one larger capacitor of electrolytic (short duty) type is used for starting, whereas a smaller capacitor of oil-filled (continuous duty) type is used for running, by connecting them with the starting winding as shown in Fig 3. A general view of such a two-value capacitor motor is shown in Fig 4. This motor also works in the same way as a capacitor-start induction-run motor, with the exception, that the capacitor C1 is always in the circuit, altering the running performance to a great extent.

Fig 3



SCHEMATIC DIAGRAM OF A CAPACITOR-START CAPACITOR-RUN MOTOR

Fig 4



CAPACITOR-START CAPACITOR-RUN MOTOR

The starting capacitor which is of short-duty rating will be disconnected from the starting winding with the help of a centrifugal switch, when the starting speed attains about 75% of the rated speed.

Characteristic

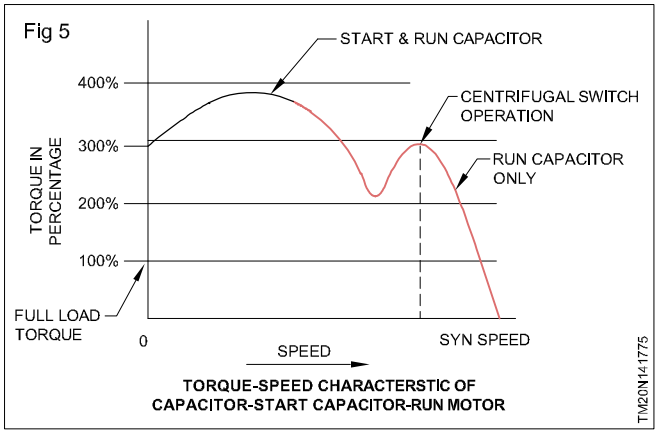
The torque-speed characteristic of this motor is shown in Fig 5. This motor has the following advantages.

- The starting torque is 300% of the full load torque.
- The starting current is low, say 2 to 3 times of the running current.
- Starting and running P.F. are good.
- Highly efficient running.
- Extremely noiseless operation.
- Can be loaded up to 125% of the full-load capacity.

Application

These motors are used for compressors, refrigerators, air-conditioners etc. where the duty demands a higher starting torque, higher efficiency, higher power factor and overloading. These motors are costlier than the capacitor-start, induction- run motors of the same capacity.

Fig 5



TORQUE-SPEED CHARACTERSTIC OF
CAPACITOR-START CAPACITOR-RUN MOTOR

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Universal motor

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

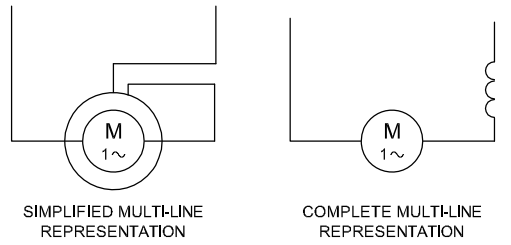
- **compare a universal motor with the DC series motor with respect to its construction**
- **explain the characteristic and application of a universal motor**
- **explain the method of changing the direction of rotation**
- **describe the methods of controlling the speed of a universal motor.**

Comparison between a universal motor and a DC series motor: A universal motor is one which operates both on AC and DC supplies. It develops more horsepower per Kg. weight than any other AC motor, mainly due to its

high speed. The principle of operation is the same as that of a DC motor. Though a universal motor resembles a DC series motor, it requires suitable modification in the construction, winding and brush grade to achieve sparkless commutation and reduced heating when operated on AC supply, due to increased inductance and armature reaction.

A universal motor could, therefore, be defined as a series or a compensated series motor designed to operate at approximately the same speed and output on either direct current or single phase alternating current of a frequency not greater than 50 Hz, and of approximately the same RMS voltage. Universal motor is also named as AC single phase series motor, and Fig 1 shows the multi-line representation according to B.I.S. 2032, Part IV.

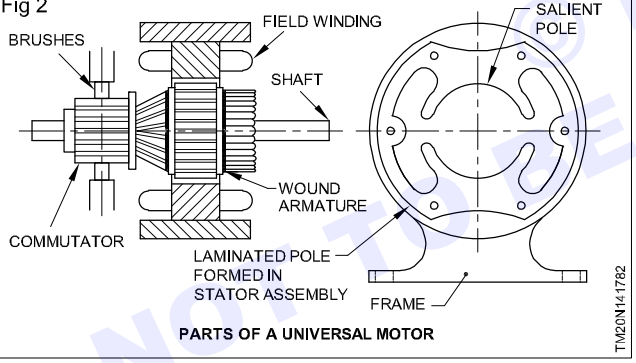
Fig 1



MULTIPLE REPRESENTATION OF AC SINGLE PHASE SERIES MOTOR (BIS 2032-PART IV.)

The main parts of a universal motor are an armature, field winding, stator stampings, frame, end plates and brushes as shown in Fig 2.

Fig 2



PARTS OF A UNIVERSAL MOTOR

The increased sparking at the brush position in AC operation is reduced by the following means.

– Providing compensating winding to neutralize the armature M.M.F. These compensating windings are either short-circuited windings or windings connected in series with the armature.

– Providing commutating inter-poles in the stator and connecting the inter-pole winding in series with the armature winding.

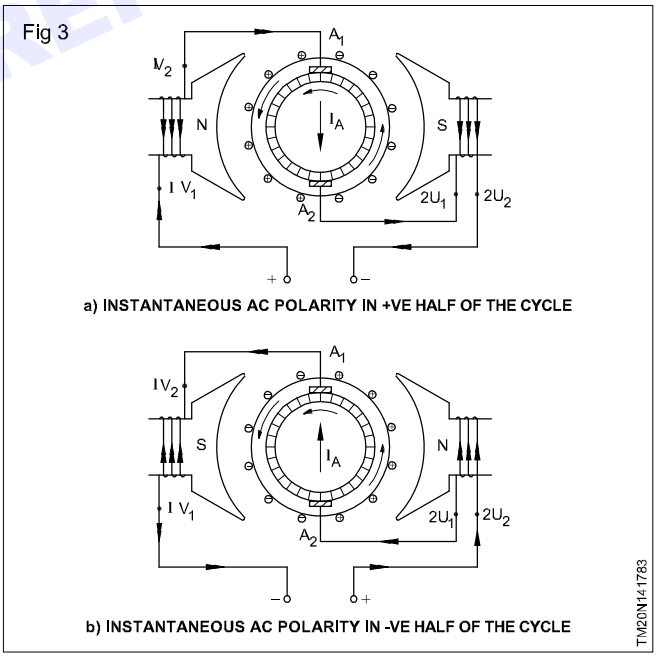
– Providing high contact resistance brushes to reduce sparking at brush positions.

The table given below indicates the differences between a universal motor and a DC series motor.

Universal motor	DC series motor
1 Can run on AC and DC supplies.	Can run smoothly on DC supply. However when connected to AC supply, it produces heavy sparks at brush positions and becomes hot due to armature reaction and rough commutation.
2 Compensating winding is a must for large machines.	Does not require compensating winding.
3 Inter-poles provided in machines.	Does not require inter-poles normally.
4 High resistance grade brushes are necessary.	Normal grade brushes will suffice.
5 Air gap is kept to the minimum.	Normal air gap is maintained.

Operation: A universal motor works on the same principle as a DC motor, i.e. force is created on the armature conductors due to the interaction between the main field flux and the flux created by the current-carrying armature conductors. A universal motor develops unidirectional torque regardless of whether it operates on AC or DC supply. Fig 3 shows the operation of a universal motor on AC supply. In AC operation, both field and armature currents change their, polarities, at the same time resulting in unidirectional torque.

Fig 3

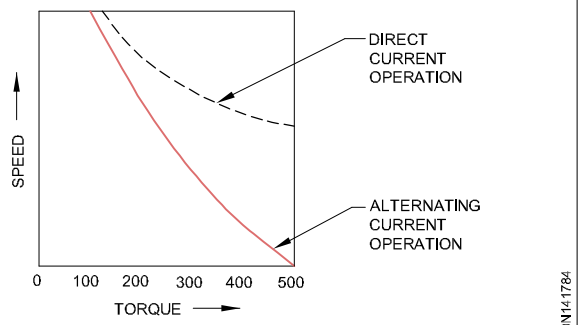


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Characteristic and application: The speed of a universal motor is inversely proportional to the load, i.e. speed is low at full load and high on no load. The speed reaches a dangerously high value due to low field flux at no loads. In fact the no-load speed is limited only by its own friction and windage losses. As such these motors are connected with permanent loads or gear trains to avoid running at no-load, thereby avoiding high speeds.

Fig 4 shows the typical torque speed relation of a universal motor, both for AC and DC operations. This motor develops about 450 percent of full load torque at starting, as such, higher than any other type of single phase motor. Universal motors are used in vacuum cleaners, food mixers, portable drills and domestic sewing machines.

Fig 4



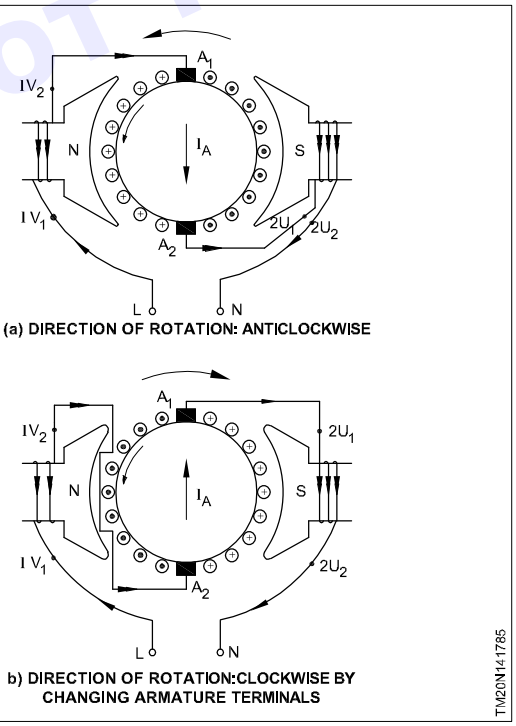
TORQUE-SPEED CHARACTERISTIC OF A UNIVERSAL MOTOR

Speed control of universal motor: The following methods are adopted to control the speed of a universal motor.

Series resistance or applied voltage control method: The motor speed is controlled by connecting a variable resistance in series with the motor. Foot-pedal operated

Change of rotation: Direction of rotation of a universal motor can be reversed by reversing the flow of current through either the armature or the field windings. It is easy to interchange the leads at the brush holders as shown in Fig 5.

Fig 5

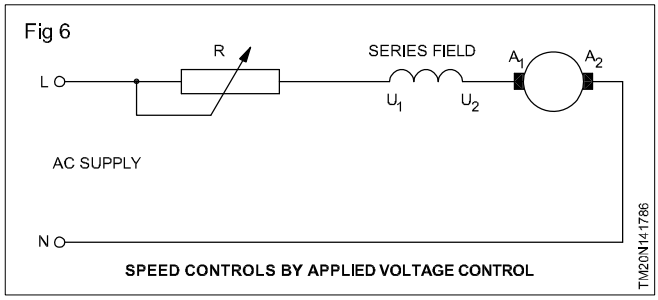


(a) DIRECTION OF ROTATION: ANTICLOCKWISE

b) DIRECTION OF ROTATION:CLOCKWISE BY CHANGING ARMATURE TERMINALS

However, when the armature terminals are interchanged in a universal motor having compensating winding, care should be taken to interchange the compensating winding also to avoid heavy sparking while running, sewing machines incorporate such a control. Fig 6 shows the connections.

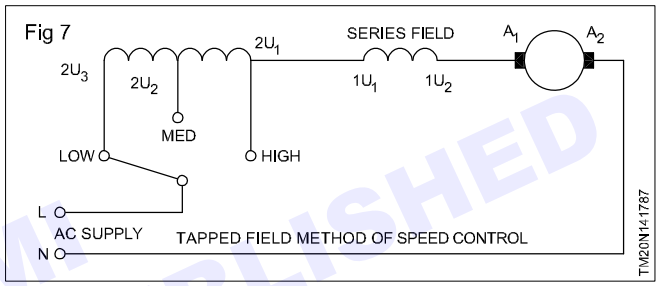
Fig 6



SPEED CONTROLS BY APPLIED VOLTAGE CONTROL

Tapped field method: In this method, the field winding is tapped at 2 or 3 points and the speed is controlled by the varying field MMF. Fig 7 shows such a connection. Most of the domestic food mixers employ this method of speed control.

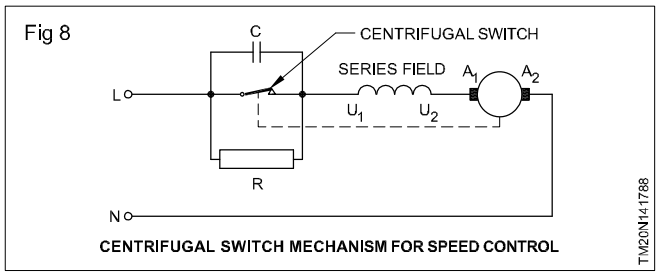
Fig 7



TAPPED FIELD METHOD OF SPEED CONTROL

Centrifugal switch method: A centrifugal mechanism adjusted by an external lever is connected in series with the motor as shown by Fig 8. If the speed reaches beyond a certain limit, according to the lever setting, the centrifugal device opens the contacts and inserts the resistance R in the circuit, which causes the motor speed to decrease. When the motor speed falls and reaches a predetermined value, the centrifugal switch contact closes, the motor gets reconnected to the supply and the speed rises. Some advanced type of food mixers employ this sort of speed control. A capacitor is used across the centrifugal switch to reduce the switching spark and to suppress the radio interference. Apart from the above methods of speed control, a thyristor is used in certain food mixers to control the speed electronically.

Fig 8



CENTRIFUGAL SWITCH MECHANISM FOR SPEED CONTROL

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Installation of a pump set

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

- **list the type of pump and capacity of the motor taking into consideration the height and quantity of water to be lifted**
- **explain the types of pumps and use the table for selecting a proper type and capacity for requirement**
- **select a proper location of pump installation and select proper control devices**
- **operate and check the pumps while running**
- **plan a schedule for the maintenance of the pump**
- **troubleshoot in pumps.**

Selection of pump: The following points are to be considered before selecting a pump for lifting the water.

– The quantity of water to be lifted

– Height of water to be delivered

– The time for lifting.

Based on the above considerations the pump has to be selected along with the motor to lift the water from a well/ sump.

An illustration is given below to show how to calculate the required HP of the motor to a particular height and quantity of water to be lifted within a specified time.

Example: Calculation of HP for domestic pump set.

A pump driven by a single phase AC motor of 230V, 50 Hz has to deliver 1000 litre to a height of 30 metre within 15 minutes. Find the HP of the motor if the efficiency of the motor is 80%.

Given

Working voltage - 230V, 50 Hz

Quantity of water to be delivered - 1000 litre

Height of the water delivered - 30 m

Efficiency of motor - 80%

Time of delivery - 15 minute

SOLUTION

$$\text{Work done by the pump / minute} = \frac{\text{weight of the water x Height}}{\text{Time}} = \frac{1000 \times 30}{15} \text{kg/min.}$$

since 1 litre of water = 1 kg. of water
and 4500 kgm/minute = 1HP

$$\text{Pump output in HP} = \frac{1000 \times 30}{15 \times 4500} = 0.44 \text{ or } 0.5 \text{ HP}$$

$$\text{Input of the pump} = \frac{0.5 \times 100}{80} = 0.625 \text{ HP}$$

Next nearest HP of the motor recommended is 0.75 HP.

Pumpset for agricultural purposes

Example 2: Calculation of HP required.

A pump is to be driven by a 3-phase 415V, 50 Hz induction motor to deliver 45,000 litre of water to a height of 50 metres in 25 minutes. Calculate the HP of the motor assuming the efficiency of the pump is 70% and that of the motor is 95%.

Given

Working voltage - 415V, 50 Hz

Quantity of water to be delivered - 45,000 litre

Height of the water delivered - 50 m

Efficiency of the pump - 70%

Efficiency of the motor - 95%

Time of delivery - 25 min.

SOLUTION

$$\text{Work done by the pump / minute} = \frac{\text{weight of the water x Height}}{\text{Time}} = \frac{45000 \times 50}{25} \text{kg/min.}$$

since 1 litre of water = 1 kg. of water
and 4500 kg/min = 1 HP

$$\text{Pump output in HP} = \frac{45000 \times 50}{25 \times 4500} = 20 \text{ HP}$$

$$\text{Input of the pump} = \frac{20 \times 100}{70} = 28.6 \text{ HP}$$

$$\text{HP of the motor} = \frac{\text{Input of the pump}}{\text{Efficiency of the motor}}$$

$$\frac{28.6 \times 100}{95} = 30.1 \text{HP}$$

Say approx. 30 HP motor will be suitable.

Pumps: Pumps can be classified mainly into two categories. They are

– Reciprocating pumps

– Rotary pumps.

Reciprocating pumps: In this type of pump, the main moving part has reciprocating motion only and hence the name. Fig 1 shows the main parts of a reciprocating pump.

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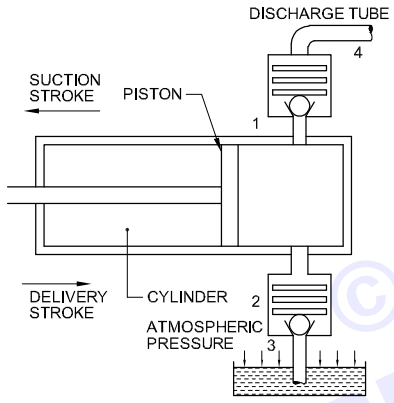
When the piston moves towards left, a partial vacuum is created inside the cylinder. The check valve shown as 1 in Fig 1 closes due to the suction effect of the vacuum, spring action and head of water in the discharge tube 4 but valve 2 shown in Fig 1 opens and allows the water to fill the cylinder through the suction pipe 3 due to atmospheric pressure outside. This stroke of the piston is called suction stroke.

On the other hand when the piston moves towards right ie discharge or delivery stroke the liquid inside the cylinder is pushed out through check valve 1 and delivery pipe 4. During the delivery stroke valve 2 remains closed by the action of spring and the water pressure inside the cylinder.

However, as the discharge of water takes place in this type of pump only during the discharge stroke, the pump creates a pulsating flow of water and not a continuous flow. This type of pump is called a piston pump.

Rotary pumps: There are very many varieties of this pump in the market. However centrifugal pumps and jet pumps are the commonly used pumps for lifting water in houses.

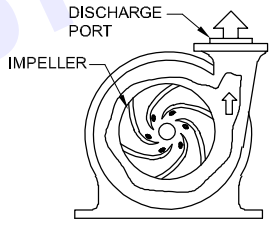
Fig 1



RECIPROCATING PUMP

Centrifugal pumps: The construction and operation of a centrifugal pump as shown in Fig 2.

Fig 2



FLUID FLOW IN A CENTRIFUGAL PUMP

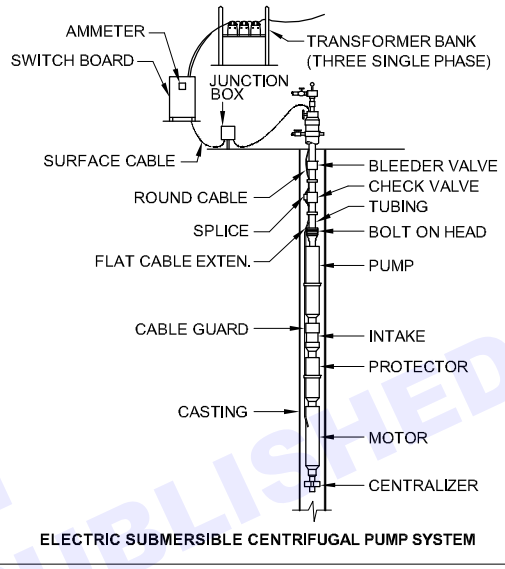
The operation of a centrifugal pump is based on centrifugal force. As the fluid being pumped enters the inlet or central section of the pump, the rotating action of the impeller vanes forces it to the outside of the pump casing as shown in Fig 2. Because the fluid moves faster at the outer edge of the impeller the momentum increases. As more fluid enters the pump, more fluid momentum is built up in the casing that encloses the impeller. This momentum forces the fluid out of the pump discharge port.

The centrifugal pumps are used where large volumes of water are to be pumped at relatively low pressure.

Submersible pumps: This pump also comes under the category of centrifugal pumps and is found in use at places where water is found in great depth.

Submersible pumps have motor and pump in an axial length are submerged in water as shown in Fig 3. Generally such pumps are used for borewells where the volume of water to be lifted exceeds the capacity of reciprocating pumps. The motor used in such types of pumps is of 3-phase.

Fig 3



ELECTRIC SUBMERSIBLE CENTRIFUGAL PUMP SYSTEM

The cables and motor windings have water proof sealing as they are immersed in water. Such pump sets will have following advantages.

- Diameter is smaller.
- Motor and pump are submerged in water. Hence needs no space on ground level.
- The motor and pump are entirely connected through metal pipes for delivering water.
- Efficiency is more as the motor with the pump will be to the level of water or inside the water.
- Cooling is effectively done by water only.
- Can be used for lifting water from any depth of sump or borewell as suction pipe is not used.

Disadvantages

- Erection cost and initial cost of purchasing will be high.
- In case of any defects, it is necessary to remove entire unit along with the pipe line.
- Requires skilled worker for both erection and maintenance work.

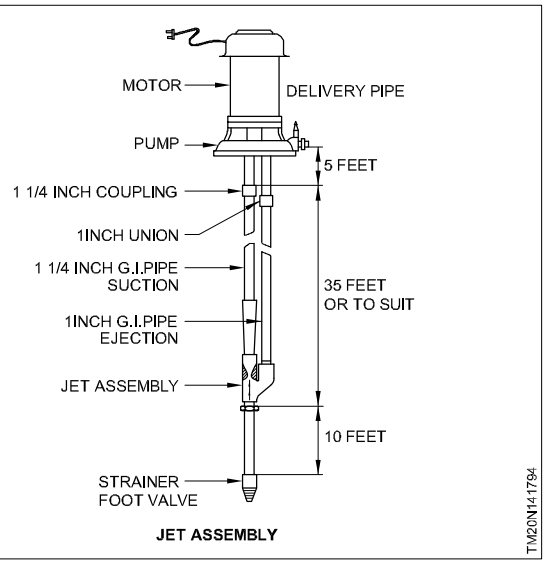
Jet pumps : Another variety of centrifugal pump commonly used in the domestic wells an d borewells is the jet pump.

In jet pumps, the motor and pump are assembled together in one block as shown in Fig 4.

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The bottom portion of the pump has two connecting pipes. One is called suction pipe and the other is called ejection pipe. A portion of the water is sent through the ejection pipe to the jet assembly and it aids the water in the suction pipe to be lifted upwards as shown in Fig 4 by Venturi principle.

Fig 4



JET ASSEMBLY

Suction, ejection and delivery pipes and motor capacity could be selected with the help of the performance Table 1.

Almost all types of pumps may be independent units to be coupled with an electric motor through belts or couplings or may be single(mono) blocks comprising both motor and pumps.

Location of pump set : The pump should be installed as near as possible to the water source in order to reduce the suction lift and to achieve better performance.

Note: For suction lifts up to 20 feet the pumpsets can work without jet assembly.

Controlling devices

- A switch and starter of a suitable type and capacity may be purchased as per calculated HP of motor.
- Proper size of cable should be used between supply and motor terminals to minimize voltage drop.
- Nuts at connecting terminals should be tightened properly to avoid any chance of the motor burning out.
- Proper double earthing connections should be made at bolts provided for earthing at motor, starter and switch

Ample space should be provided around the pump for easy inspection and maintenance whenever required.

Table 1

Performance with AC 50 Hz, 2880 rpm electric motors for 220/240V single phase and 400/440V 3-phase

Motor rating Kw (HP)	Discharge in litres per hour at various suction lifts										Pipe sizes in inches				Minimum bore diameter (inches)
	30'	40'	50'	60'	70'	80'	90'	100'	120'	140'	at discharge pressure of	Suc-tion	Ejec-tion	Deli-very	
0.37(1/2)															
Single phase only	2370	1690	1200	900	700						20 lbs/ Sq.in.	1"	¾"	¾"	3
	2500	1820	1370	1100	820						(46 ft)	1¼"	1"	1"	4" & Well
0.75(1.0) Single phase & 3-phase	3650	2600	2140	1700	1525	1370	1200	1050	700		30 lbs/Sq.in.	1¼"	1"	1"	4" & Well
	3870	2730	2275	1820	1640	1460	1275	1100			(69 ft)	1½"	1¼"	1¼"	5" & Well
1.5(2.0)	4550	3180	2730	2160	1660	1550	1300	1070	910	730	40 lbs/	1¼"	1"	1"	4"
3-phase	6350	4460	3550	2900	2460	2260	2000	1730	1370	910	Sq.in.	1½"	1¼"	1¼"	5" & Well
only	8400	5700	4800	3800	3200	2910	2460	1820			(92 ft)	2"	1½"	1½"	6" & Well
2.2(3.0) 3-phase	8900	6000	4840	3820	3250	2960	2530	2180	1820	1250	40 lbs/Sq.in.	1½"	1¼"	1¼"	5"
only	10000	7050	5640	4550	4000	3640	3250	2700	2100		(92 ft)	2"	1½"	1½"	6" & Well

Operational instructions

Before starting the pump ensure that.

- Shaft rotates freely by hand.
- The gland box is properly tightened.
- The valve, if there is any on the delivery branch, is opened.

Check the following during running condition.

- The direction of rotation is correct.
- Pump is running smoothly.
- Leakage of stuffing box is normal ie 50 to 60 drops per minute in gland packed pump.
- The ball bearings do not get excessively hot.

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To get optimum performance from any pump, the following maintenance schedule is suggested.

Quarterly check.

– Pump noise.
– Pipe connections and nut/bolts.
– Foot valve strainer.
– Moving parts for lubrication.

Yearly check.

– Remove impeller, replace if vanes are worn out totally.
– Replace shaft sleeves, if worn out.
– Replace gland packing, if worn out.
– Replace any other worn out part.
– Replace mechanical seal if damaged.

Trouble shooting in pumps: In case of trouble in pumps, with the help of the trouble shooting chart given in Table 2 locate the fault and rectify the defects.

Table 1

Troubleshooting chart

Sl.No.	Problems	Probable reason
1	Pump does not deliver water.	Pump casing and suction pipe is not primed.
2	Delivered water is not enough.	Delivery head is too high. Suction lift is too high.
3	Not enough pressure.	Impeller/suction pipe choked. Wrong direction of rotation. Leakage in suction pipe. Gland packings/mechanical seal worn out. Foot valve choked/not immersed in water. Impeller damaged. Wearing of shaft sleeve.
4	Pump takes too much power.	Damaged ball bearing. Head is much lower. Mechanical friction is more in the rotating part. Shaft bent. Stuffing box is too tight (gland is too tight).
5	Pump leaks excessively.	Gland packings/mechanical seal worn out. Shaft sleeve worn out. Gland packings/mechanical seal are not in proper position.
6	Pump is noisy.	Hydraulic cavitation. Foundation is not rigid. Shaft bent. Rotating parts are loose or broken. Bearing worn out.

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Rotary type forward/reversing switches manual star-delta starter

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

- **explain the type of rotary switches - specifications like voltage rating, current rating, poles, function, position, type of mounting, type of handle, number of operations per hour and special requirement, if any**
- **explain the schematic diagram of rotary switches along with connection diagram of motors for ON/OFF three-pole switch, forward, stop and reverse three-pole switch, star-delta switch and pole changing switch.**

Rotary switches are most commonly used in lathes, milling and drilling machines due to their exact visual position and easiness in operation. These switches are operated by levers or knobs which in turn operate cams inside the switch to contact various terminals in sequence by the internal contact blocks. These cams and blocks are made of hard P.V.C. and are designed to withstand many operations. It is possible to get many circuit combinations by combining various cams and contact blocks. As the contact blocks, terminals and cams are spring-loaded, these switches should not be opened by inexperienced persons for repairs.

These rotary switches are classified according to

– poles
– function
– position

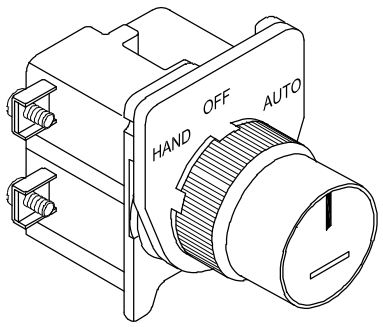
– mounting type

– handle design, and

– frequency of operations.

Poles: According to the number of independent connecting terminals and operation, they are called 2-pole (single phase, refer to Fig 1) or 3-pole (3-phase, refer to Fig 2) switches.

Fig 1



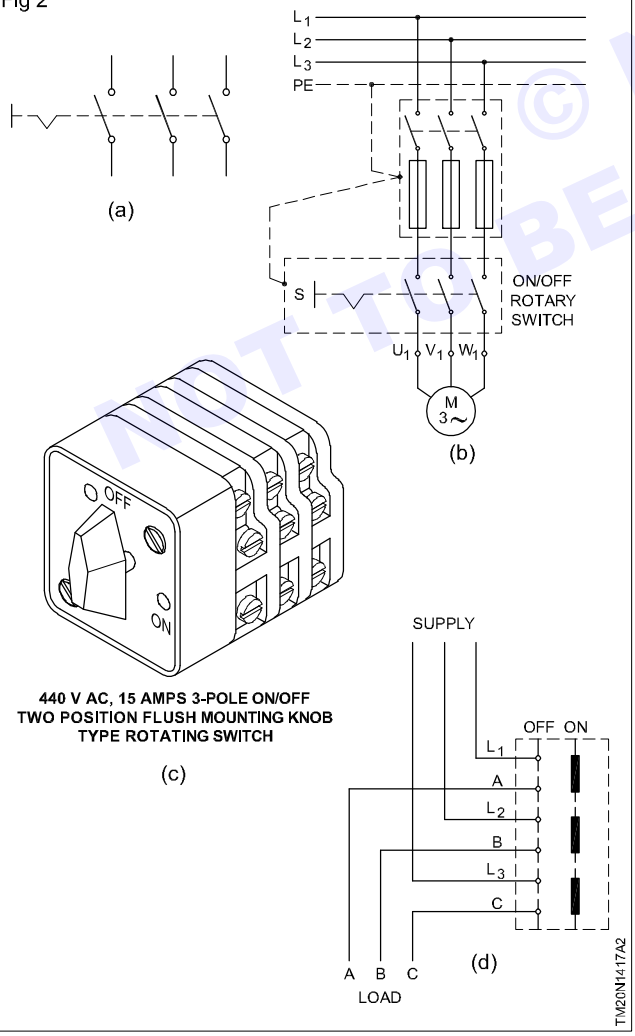
250 V AC 15 AMPS 2-POLE THREE POSITION FLUSH MOUNTING COIN-SLOT OPERATOR

TM20N1417A1

Function: Rotary switches can do a number of functions depending upon the cam and contact block combinations. Accordingly they can be

– ON/OFF switches (Fig 2)

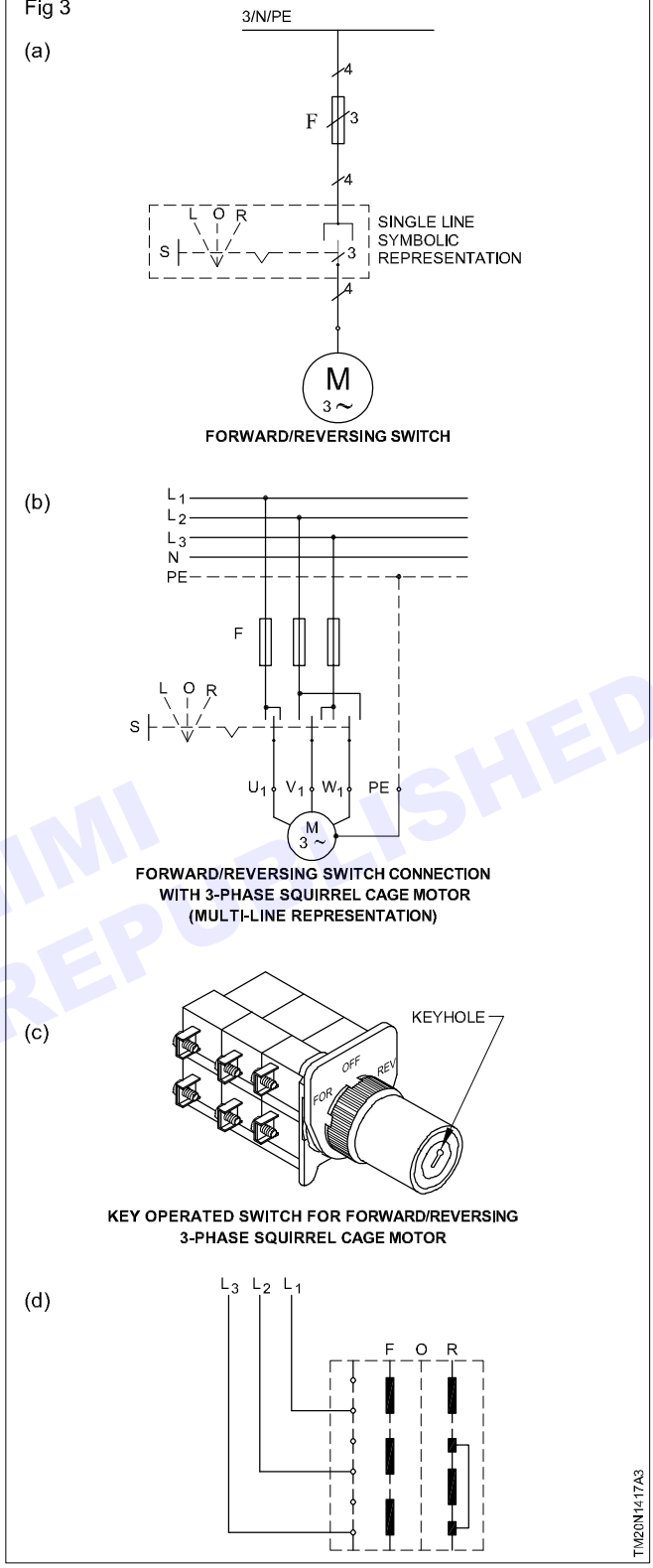
Fig 2



TM20N1417A2

– manual forward/reversing switches (Fig 3)

Fig 3



TM20N1417A3

– manual star-delta switches (Fig 4)

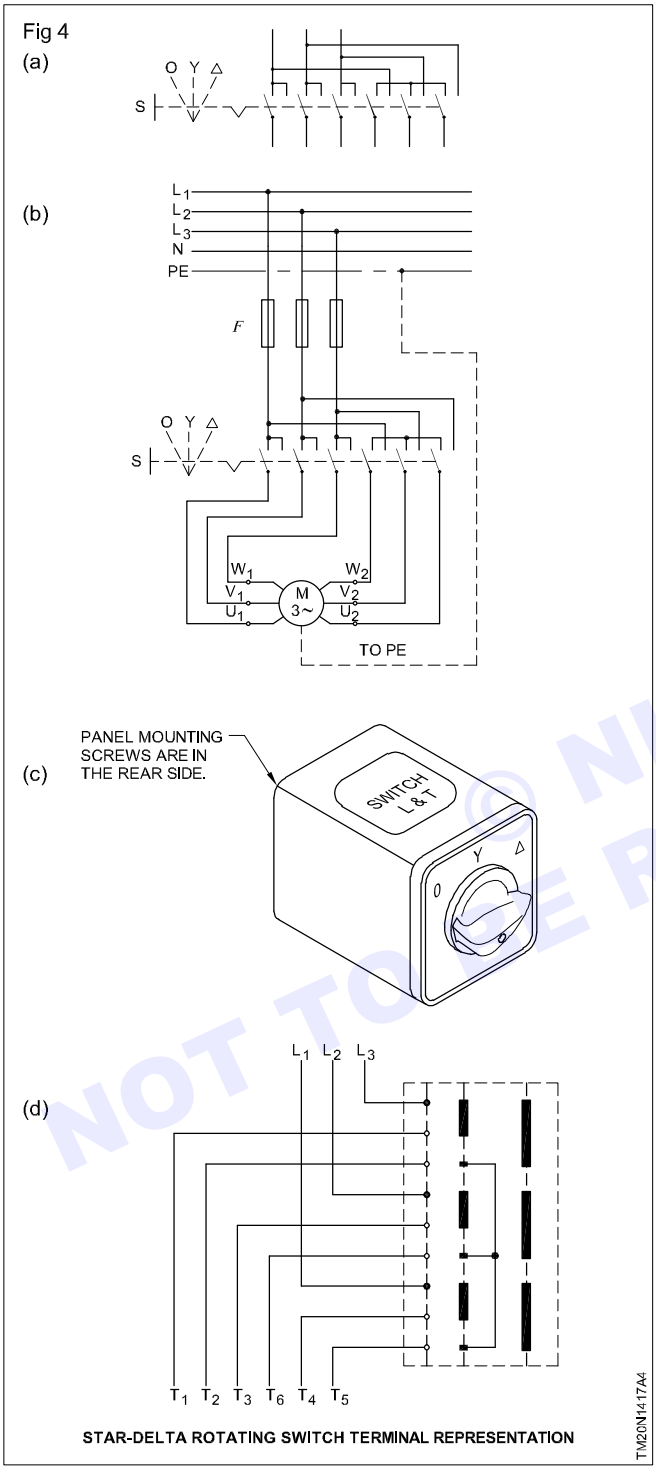
– pole changing switches for speed control. (Fig 5)

In addition to the above voltmeter/ammeter selector switches, 4-position, air-conditioner switches are also available.

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Position: Selector switches of rotary type are available in two (Fig 2), three (Figs 1, 3 and 4) and four positions. They provide maintained or spring-return (momentary) control operation. Two-position and three-position switches can be either maintained or spring-returned whereas four-position switches are maintained in all four positions.

Fig 4



STAR-DELTA ROTATING SWITCH TERMINAL REPRESENTATION

Mounting type: According to requirement, we may select any one of the following types for mounting.

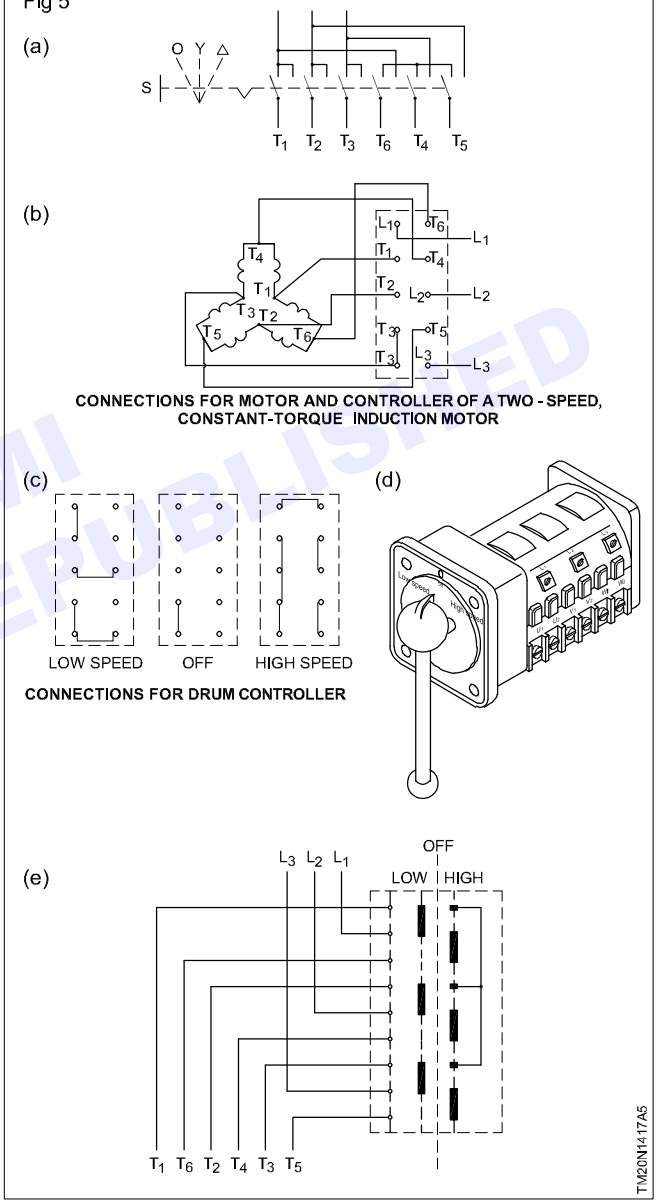
- Surface mounting type
- Flush mounting type (Fig 1)
- Box mounting type (Fig 4)

Handle design: According to the nature of operation it could be done by

- a knob (Fig 2c)
- a lever (Fig 5d)
- a coin slot (Fig 1)
- key operation. (Fig 3c)

Frequency of operation: The number of operations of these switches per hour is specified in B.I.S. 10118 (Part II) 1982. The details given below are taken from the B.I.S. as per the reference cited.

Fig 5



CONNECTIONS FOR MOTOR AND CONTROLLER OF A TWO - SPEED, CONSTANT-TORQUE INDUCTION MOTOR

CONNECTIONS FOR DRUM CONTROLLER

Sl. No.	Description	Operations per hour
1	On-off and system selector switch	Up to 150 times
2	Pole-changing switch	Up to 150 times
3	Manual star-delta switch	Up to 30 times
4	Speed control switch	Up to 150 times

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Specification: Specification of rotary switches should contain the following information, for procurement in the market.

- Working voltage and kind of operation - AC or DC
- Load current
- Poles
- Function
- Position of operation
- Type of mounting
- Desired handle type
- Frequency of operation
- Accepted maximum dimensions
- Type of casing

Schematic diagram of rotary switches

ON/OFF switch: These switches are used for a 3-phase squirrel cage motor for direct starting, which is symbolically represented in Fig 2a. The complete connection diagram shown in Fig 2b and Fig 2c shows the normal appearance of such a switch, with a knob type handle, having a box mounting type body.

Fig 2d shows the manufacturer's catalogue representation of an ON/OFF switch.

Manual forward/reversing switch: These switches are used for forward and reverse running operation of the squirrel cage induction motors. A symbolic representation is shown in Fig 3a. The complete diagram is shown in Fig 3b and Fig 3c shows the normal appearance of such a switch with a key- operated type switch, having box-type enclosure mounting.

Fig 3d shows the manufacturer's catalogue representation of a forward|reversing rotary switch.

Manual star-delta starter switch: These switches are used for starting a 3-phase squirrel cage induction motor in star position and to run it in delta position.

Fig 4a shows the symbolic representation of the star-delta manual switch, the complete diagram of connection to the 3-phase induction motor is shown in Fig 4b, and Fig 4c shows the normal appearance of such a starter switch with knob operation having a box-type body. Fig 4d shows the manufacturer's catalogue representation of a manual star-delta rotary switch.

Pole-changing rotary switch: This is used for changing the speed of a three-phase squirrel cage induction motor from one speed to another with the help of either two separate windings or by six windings arranged for series delta (low speed) or parallel star (high speed) connection. (Fig 5)

Fig 5a shows the symbolic representation of the pole-changing rotary switch, Figs 5b and 5c show the complete connection diagram of the pole-changing switch with motor connection, and Fig 5d shows the normal appearance of such a switch with lever operation.

Fig 5e shows the manufacturer's catalogue representation of the pole-changing rotary switch - shown in Figs 5a,b and c.

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Manual star-delta switch/starter

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

- **state the necessity of a star-delta starter for a 3-phase squirrel cage induction motor**
- **explain the construction, connection and working of a star-delta switch and starter**
- **specify the back-up rating of the fuse in the motor circuit**
- **compare voltages across the windings of the motor, current taken, power absorbed and torque produced in star and delta positions of the starter.**

Necessity of star-delta starter for 3-phase squirrel cage motor: If a 3-phase squirrel cage motor is started directly, it takes about 5-6 times the full load current for a few seconds, and then the current reduces to normal value once the speed accelerates to its rated value. As the motor is of rugged construction and the starting current remains for a few seconds, the squirrel cage induction motor will not get damaged by this high starting current.

However with large capacity motors, the starting current will cause too much voltage fluctuations in the power lines and disturb the other loads. On the other hand, if all the squirrel cage motors connected to the power lines are started at the same time, they may momentarily overload the power lines, transformers and even the alternators.

Because of these reasons, the applied voltage to the squirrel cage motor needs to be reduced during the starting periods, and regular supply could be given when the motor picks up its speed.

Following are the methods of reducing the applied voltage to the squirrel cage motor at the start.

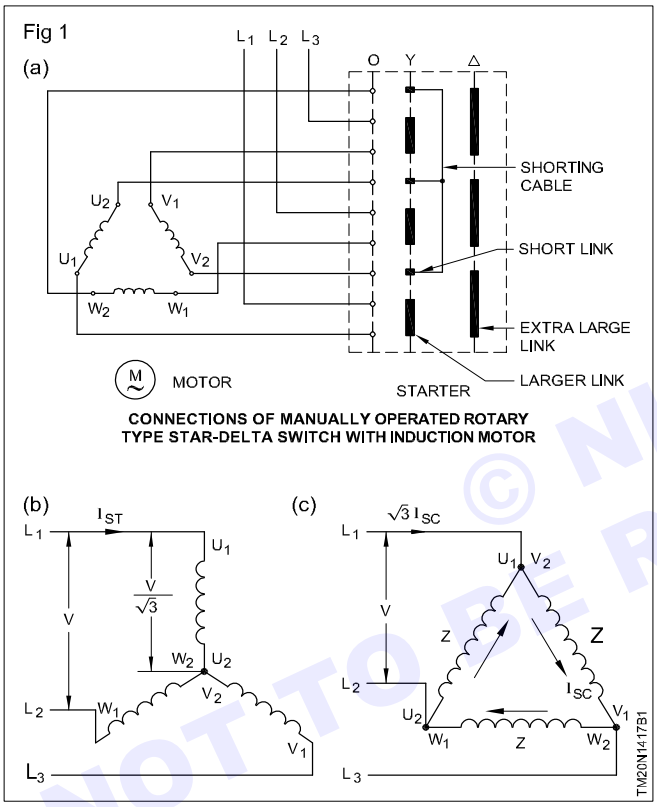
- Star-delta switch or starter
- Auto-transformer starter
- Step-down transformer starter

Star-delta starter: A star-delta switch is a simple arrangement of a cam switch which does not have any additional protective devices like overload or under-voltage relay except fuse protection through circuit fuses, whereas the star-delta starter may have overload relay and under voltage protection in addition to fuse protection. In a star-delta switch/starter, at the time of starting, the squirrel cage motor is connected in star so that the phase voltage is reduced to $1/\sqrt{3}$ times the line voltage, and then when the motor picks up its speed, the windings are connected in delta so that the phase voltage is the same

as the line voltage. To connect a star-delta switch/starter to a 3-phase squirrel cage motor, all the six terminals of the three-phase winding must be available.

As shown in Fig 1a, the star-delta switch connection enables the 3 windings of the squirrel cage motor to be connected in star, and then in delta. In star position, the line supply L_1, L_2 and L_3 are connected to the beginning of windings U_1, W_1 and V_1 respectively by the larger links, whereas the short links, which connect V_2 U_2 and W_2, are shorted by the shorting cable to form the star point. This connection is shown as a schematic diagram. (Fig 1b)

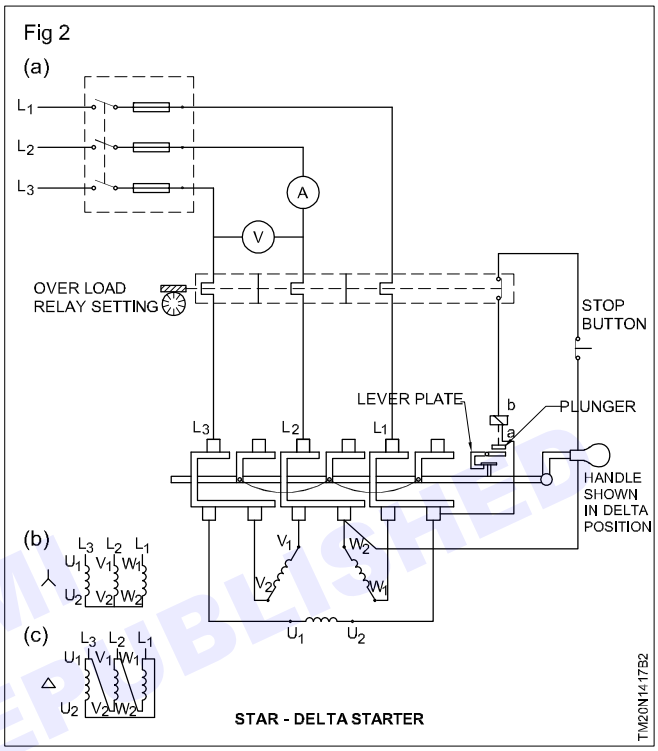
When the switch handle is changed over to delta position, the line supply L_1, L_2 and L_3 are connected to terminals U_1 V_2, W_1 U_2 and V_1 W_2 respectively by the extra large links to form a delta connection. (Fig 1c)



Manual star-delta starter: Fig 2 shows the conventional manual star-delta starter. As the insulated handle is spring-loaded, it will come back to OFF position from any position unless and until the no-volt (hold-on) coil is energised. When the hold-on coil circuit is closed through the supply taken from U_2 and W_2, the coil is energised and it holds the plunger, and thereby the handle is held in delta position against the spring tension by the lever plate mechanism. When the hold-on coil is de-energised the plunger falls and operates the lever plate mechanism so as to make the handle to be thrown to the off position due to spring tension. The handle also has a mechanism (not shown in Fig) which makes it impossible for the operator to put the handle in delta position in the first moment. It is only when the handle is brought to star position first, and then when the motor picks up speed, the handle is pushed to delta position.

The handle has a set of baffles insulated from each other and also from the handle. When the handle is thrown to star position, the baffles connect the supply lines L_1, L_2 and L_3 to beginning of the 3-phase winding W_1, V_1 and U1 respectively. At the same time the small baffles connect V_2, W_2 and U_2 through the shorting cable to form the star point. (Fig 2b)

When the handle is thrown to delta position, the larger end of the baffles connect the main supply line L_1, L_2 and L_3 to the winding terminals W_1U_2, V_1W_2 and U_1V_2 respectively to form the delta connection. (Fig 2c)



The overload relay current setting could be adjusted by the worm gear mechanism of the insulated rod. When the load current exceeds a stipulated value, the heat developed in the relay heater element pushes the rod to open the hold-on coil circuit, and thereby the coil is de-energised, and the handle returns to the off position due to the spring tension.

The motor also could be stopped by operating the stop button which in turn de-energises the hold-on coil.

Back-up fuse protection: Fuse protection is necessary in the star-delta started motor circuit against short circuits. In general, as a thumb rule for 415V, 3-phase squirrel cage motors, the full load current can be taken as 1.5 times the H.P. rating. For example, a 10 HP 3-phase 415V motor will have approximately 15 amps as its full load current.

To avoid frequent blowing of the fuse and at the same time for proper protection, the fuse wire rating should be 1.5 times the full load current rating of the motor. Hence for 10 HP, 15 amps motor, the fuse rating will be 23 amps, or say 25 amps.

Comparison of impact of star and delta connections on starting current and torque of the induction motor: When the three-phase windings of the squirrel cage motor are connected in star by the starter, the phase voltage across each winding is reduced by a factor of $1/\sqrt{3}$ of the

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applied line voltage (58%), and hence the starting current reduces to 1/3 of that current which would have been drawn if the motor were directly started in delta. This reduction in starting current also reduces the starting torque to 1/3 of the starting torque which would have been produced in the motor, if it were started directly in delta.

The above statement could be explained through the following example.

Example

Three similar coils of a 3-phase winding of a squirrel cage induction motor, each having a resistance of 20 ohms and inductive reactance of 15 ohms, are connected in (a) star (b) delta through a star-delta starter to a 3-phase 400V 50 Hz supply mains.

Calculate the line current and total power absorbed in each case. Compare the torque developed in each case.

Solution

Impedance per phase

$$Z_{ph} = \sqrt{20^2 + 15^2}$$

Star connection

$$E_{Ph} = \frac{E_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 231 \text{ volts}$$

$$I_{Ph} = \frac{E_{ph}}{Z_{ph}} = \frac{231}{25} = 9.24 \text{amps}$$

$$I_L = I_{sh} = 9.24 \text{amps.}$$

$$\text{Power absorbed} = \sqrt{3}\, E_L I_L \cos\theta$$

$$= \sqrt{3} \times 400 \times 9.24 \times 1$$

Assuming PF = 1, we have = 6401 watts.

Delta connection

$$E_{ph} = E_L = 400V$$

$$I_{Ph} = \frac{E_{ph}}{Z_{ph}} = \frac{400}{25} = 16A$$

$$I_L = \sqrt{3}\, I_{ph} = 1.732 \times 16 = 27.7 \text{ A}$$

$$\text{Power absorbed} = \sqrt{3}\, E_L I_L \cos\theta$$

(assume PF = 1)

$$= \sqrt{3} \times 400 \times 27.7 \times 1$$

$$= 19190 \text{ W.}$$

The torque developed is proportional to the square of the voltage across the winding.

In the case of star, the voltage across the winding E_{ph}

$$E_{ph} = \frac{E_L}{\sqrt{3}}$$

$$= \frac{E^2_L}{\sqrt{3}} K \text{ in star}$$

In the case of delta, the voltage across the E_{ph} winding

$$E_{ph} = E_L.$$

Hence torque

$$(E_L)^2 K = E^2_L K.$$

By comparison the torque developed in star connection at the time of starting is 1/3 of the torque developed in a delta connection (running).

As the torque is 3 times less in starting due to the star connection, whenever a motor has to be started with heavy loads, the star-delta starter is not used. Instead an auto-transformer or step-down transformer starter could be used as the voltage tapping can be changed to more than 58% of the line voltage to suit the torque requirement.

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A.C 3 phase squirrel cage induction motor

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

- **state the squirrel cage bar arrangement for different classes of induction motors say class A, B, C, D**
- **compare the starting torque, starting current and slip for different types of squirrel-cage motors**
- **state the relation between starting and full load torque in star-delta starting**
- **describe the influence of supply voltage on torque/ speed characteristic curve.**

The three-phase squirrel cage motors have been standardised according to their electric characteristics into six types designated as design A, B, C, D, E and F. Standard squirrel cage induction motors which were of shallow, slot types are designated as class A. For this reason class A motors are used as a reference and are referred to as 'normal starting-torque', normal starting current, normal slip motors.

Classes of squirrel-cage motors
(According to starting characteristics)

Class	Starting torque	Starting	Current Slip
A	Normal	Normal	Normal
B	Normal	Low	Normal
C	High	Low	Normal
D	High	Low	High
E	Low	Normal	Low
F	Low	Low	Normal

Out of these six, four specific designs A through D are common squirrel cage motors. These four classes, however, cover nearly all practical applications of induction machines.

Class A motors: These motors are characterised by having a low rotor-circuit resistance and reactance. Its locked rotor current with full voltage is generally more than 6 times the full load current. Because of their low resistance, starting currents are very high. They operate at very small slips ($s < 0.01$) under full load. Machines in this class are suitable only in situations where very small starting torques are required. The rotor bar construction of such motor is shown in Fig 1.

Class B motors: These are general purpose motors of normal starting torque and starting current. The speed regulation at full load is low (usually under 5%) and the starting torque is in the order of 15% of the rated speed being lower for the lower speed and larger motors. It should be realised that although the starting current is low, it generally is 600% of full load value.

Fig 1

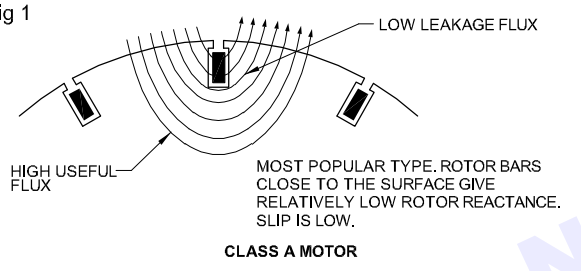
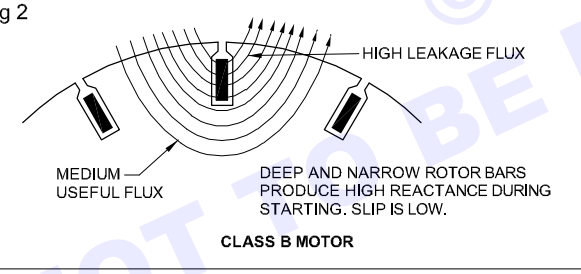


Fig 2



Class C motors: Compared to class B motors, class C motors have higher starting torque, normal starting current and run at slips of less than 0.05 at full load. The starting torque is about 200% of the rated speed and the motors are generally designed to start at full-load. Typical application of this class motor is driving conveyors, reciprocating pumps, and compressors.

Class D motors: These are high slip motors with high starting torque and relatively low starting current. As a result of the high full load slip, their efficiency is generally lower than that of the other motor classes. The peak of the torque speed curve, resulting in a starting torque of about 300%, is identical to the starting torque.

Now when the motor is stationary, the frequency of the rotor current is the same as the supply frequency. But when the rotor starts revolving, then the frequency depends upon the relative speed or on slip speed. Let at any slip speed, the frequency of the rotor current be f', then

Fig 3

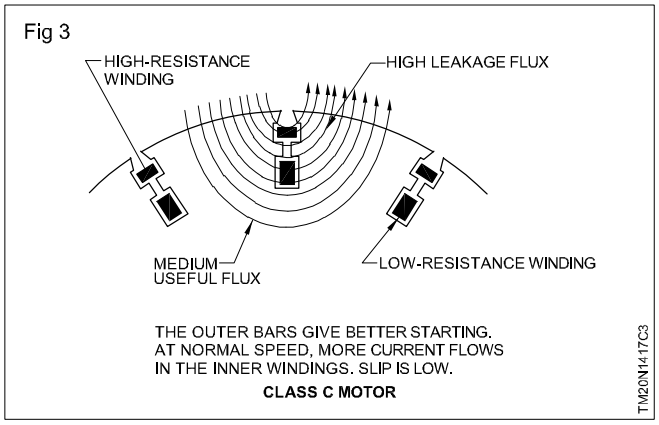


Fig 4

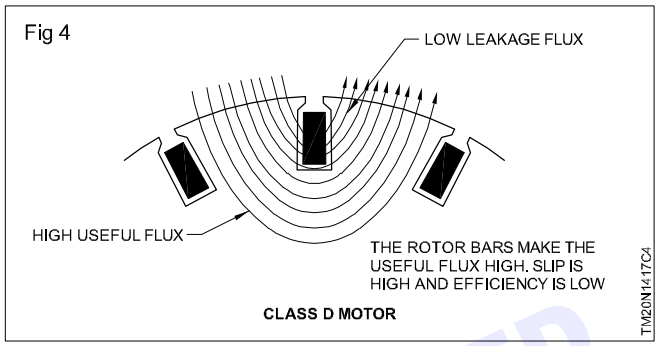
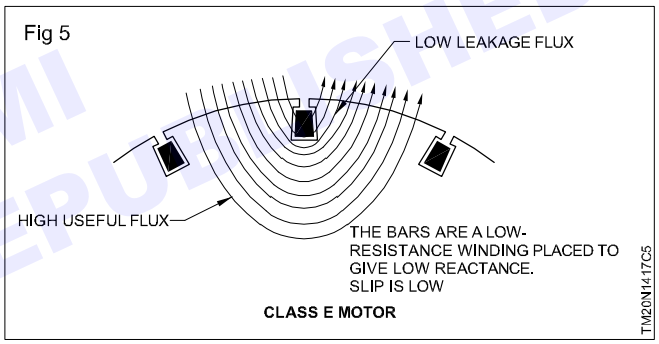


Fig 5



$$N_s - N = \frac{120f'}{p}$$

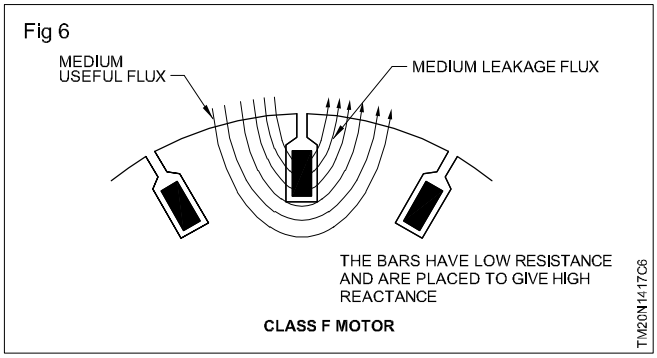
$$\text{also, } N_s = \frac{120f}{p}$$

Dividing one by the other, we get

$$\frac{f'}{f} = \frac{N_s - N}{N_s} = s$$

$$f' = sf$$

Fig 6



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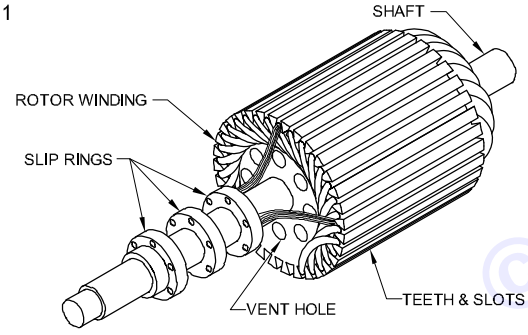
A.C - 3 phase slip ring induction motor

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

- **explain briefly the construction and working of a three-phase, slip-ring induction motor**
- **explain how the starting torque is high due to insertion of rotor resistance**
- **explain the relation between rotor emf and reactance under running condition**
- **state the characteristic of the slip-ring induction motor**
- **compare the slip-ring induction motor with the squirrel cage induction motor.**

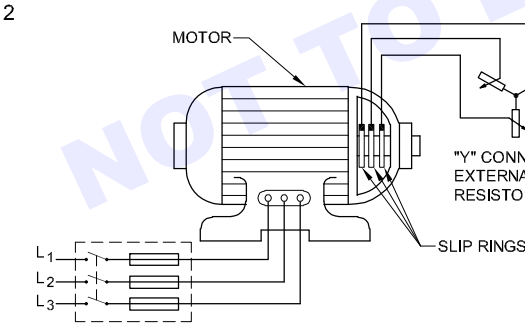
Construction: The slip-ring induction motor could be used for industrial drives where variable speed and high starting torque are prime requirements. The stator of the slip-ring induction motor is very much the same as that for a squirrel cage motor but the construction of its rotor is very much different. Stator windings can be either star or delta connected depending upon the design. The rotor consists of three-phase windings to form the same number of poles as in a stator. The rotor winding is connected in star and the open ends are connected to three slip-rings mounted in the rotor shaft, as shown in Fig 1. The rotor circuit is, in turn, connected to the external star-connected resistances through the brushes, as shown in Fig 2.

Fig 1



WOUND ROTOR FOR SLIP RING INDUCTION MOTOR

Fig 2



CIRCUIT FOR A WOUND - ROTOR INDUCTION MOTOR

Working: When the stator-winding of the slip-ring motor is connected to the 3-phase supply, it produces a rotating magnetic field in the same way as a squirrel cage motor. This rotating magnetic field induces voltages in the rotor windings, and a rotor current will flow through the closed circuit, formed by the rotor winding, the slip-rings, the brushes and the star-connected external resistors.

At the time of starting, the external resistors are set for their maximum value. As such, the rotor resistance is high enabling the starting current to be low. At the same time, the high resistance rotor circuit increases the rotor power factor, and thereby, the torque developed at the start becomes much higher than the torque developed in squirrel cage motors.

As the motor speeds up, the external resistance is slowly reduced, and the rotor winding is made to be short-circuited at the slip-ring ends. Because of the reduced rotor resistance, the motor operates with low slip and high operating efficiency. The motor could be started for heavy loads with higher resistance or vice versa. However at increased rotor resistance, the motor's slip will be greater, the speed regulation poorer and it will have low efficiency. The resistance in the external circuit could be designed and varied to change the speed of the slip-ring motor between 50 to 100 percent of the rated speed. However, the I^2R losses in the rotor due to increased resistance is inevitable.

Starting torque: The torque developed by the motor at the instant of starting is called the starting torque. In some cases it is greater than the normal running torque whereas in some other cases it is somewhat less.

Let E_2 be the rotor emf per phase at standstill

X_2 be the rotor reactance per phase at standstill

and R_2 be the rotor resistance per phase.

Therefore $Z_2 = \sqrt{(R_2)^2 + (X_2)^2}$ = rotor impedance per phase at standstill.

$$\text{Then } I_2 = \frac{E_2}{Z_2}, \cos\theta_2 = \frac{R_2}{Z_2}$$

Standstill or starting torque $T_{st} = K_1 E_2 I_2 \cos\theta_2$ or

$$T_{st} = K_1 E_2 = \frac{E_2}{\sqrt{(R_2)^2 + (X_2)^2}} \times \frac{R_2}{\sqrt{(R_2)^2 + (X_2)^2}}$$

If the supply voltage V is constant, then the flux, ϕ and hence E_2 is constant.

Therefore $T_{st} = K_2 \frac{R_2}{Z_2}$ where K_2 is another constant.

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The starting torque of such a motor is increased by adding external resistance in the rotor circuit. The resistance is progressively cut out as the motor gain speed.

Rotor emf and reactance under running condition: When the starter is stationary i.e. S = 1, the frequency of the rotor emf is the same as that of the stator supply frequency. The value of emf induced in the rotor at standstill is maximum because the relative speed between the rotor and the rotating stator flux is maximum.

When the rotor starts running, the relative speed between the rotor and the rotating stator flux is decreased. Hence the rotor induced emf is also decreased. The rotor emf become zero if the rotor speed become equal to the speed of stator rotating flux.

Hence, for a slip (s), the rotor induced emf will be s times the induced emf at standstill.

Therefore, under running condition $E_r = sE_2$.

The frequency of induced emf will likewise become $f_r = sf_2$ where f_2 is the rotor current frequency at standstill.

Due to decrease in frequency of the rotor emf, the rotor reactance will also decrease.

Therefore $X_r = sX_2$.

Characteristic and application of slip-ring induction motor: Insertion of higher, external resistance alters the starting torque to a higher value, as shown in Fig 3, by the torque speed characteristic.

By inserting the suitable value rotor resistance, the speed of the slip ring motor could be controlled inspite of power less in resistance.

As shown in the curve, higher, external resistance improves the starting torque to a higher value. However the maximum torque remains constant for the variation of the rotor resistance.

By these curves, it is clear that the slip-ring motor could be used to start heavy loads by insertion of high resistance in the rotor to facilitate higher starting torque. At the same time the running efficiency of the motor could be achieved by cutting out the external resistance when the motor picks up its speed.

This motor could be used for drive which demands a higher starting torque and also a variable speed control - like compressors, conveyors, cranes, hoists, steel mills and printing presses.

Comparison between squirrel cage and slip-ring induction motors is given below:

Sl. No.	Property	Squirrel cage	Slip-ring motor
1	Rotor construction	Bars are used in rotor. Squirrel cage rotor is very simple, rugged and long lasting. No slip-rings.	Winding wire is used. Wound rotor requires attention Slip-ring and brush gear need frequent main-tenance.
2	Starting	Can be started by DOL star-delta, auto-transformer starters.	Rotor resistance starter is required.
3	Starting torque	Low	Very high
4	Starting current	High	Low
5	Speed variation	Not easy, but could be varied in larger steps by pole-changing or smaller incre--mental steps through thyristors or by frequency variation.	Easy to vary speed, but speed change through pole-changing is not possible. Speed change possible by - insertion of rotor resistance - using thyristors - using frequency variation - injecting emf in the rotor circuit - cascading
6	Acceleration on load	Just satisfactory	Very good
7	Maintenance	Almost nil	Requires frequent maintenance
8	Cost	Low	Comparatively high

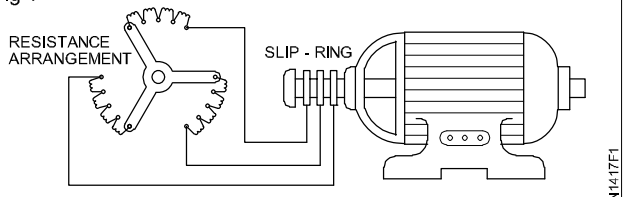
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Resistance starter for 3-phase, slip-ring induction motor

Objectives: At the end of this lesson you shall be able to
- **explain the circuits of rotor resistance starters used for a 3-phase, slip-ring induction motor.**

Slip-ring induction motors are started with full-line voltage across the stator winding. However, to reduce the heavy rush of the starting current, a star-connected external resistance is added in the rotor circuit as shown in Fig 1. The external resistances are cut out, and the rotor winding ends are shorted once the motor picks up its speed.

Fig 1



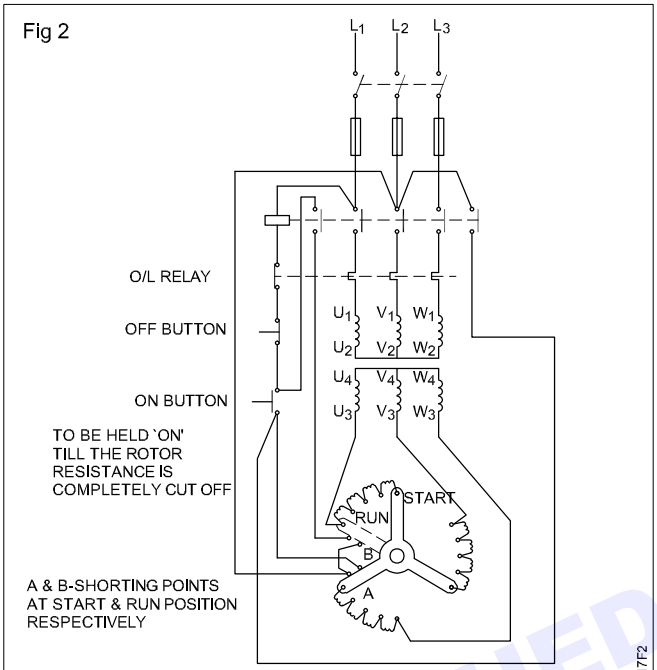
SLIP RING INDUCTION MOTOR WITH RESISTANCE STARTER

If such a manual starter is used, there is a possibility that someone may apply full voltage to the stator when the rotor resistance is in a completely cut-out position, resulting in heavy rush of the starting current and poor starting torque. This could be eliminated by the use of a protective circuit in the resistance starter; thereby motor cannot be started until and unless all the rotor resistances are included in the rotor winding. Such a semi-automatic starter is shown in Fig 2.

By pressing the 'ON' button, the contactor will close, only when the shorting point 'A' at the rotor resistance is in a closed position. This is possible only when the handle is in the start position. Once the motor starts running, the handle of the rotor resistance should be brought to 'run' position to cutout the rotor resistance.

The position of the handle clearly indicates that at the start position, the contact 'A' is in the closed position, and at the run position, contact 'B' is in the closed position, but both cannot close at the same time. The 'ON' push-button

Fig 2



ROTOR RESISTANCE STARTER FOR SLIP RING INDUCTION MOTOR

needs to be held in the pushed-position till the handle is brought to the run-position. During the run-position, the handle contact 'B' closes the no-volt coil circuit, and the pressure on the 'ON' button can be released.

In general, for small machines, the rotor resistance is air-cooled to dissipate the heat developed during starting. For larger machines, the rotor resistance is kept in an insulating oil tank for cooling. The starter shown is intended to start the motor only. As speed regulation through the rotor resistance needs intermediate positions, they are specially designed and always oil-cooled.

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Transformers - construction principle - transformation ratio - E.m.f equation

Objectives: At the end of this lesson you shall be able to
- **define the primary and secondary of a transformer**
- **state the constructional features of a power transformer and the function of each part**
- **state the reasons for laminated silicon steel being used as core material.**

Introduction

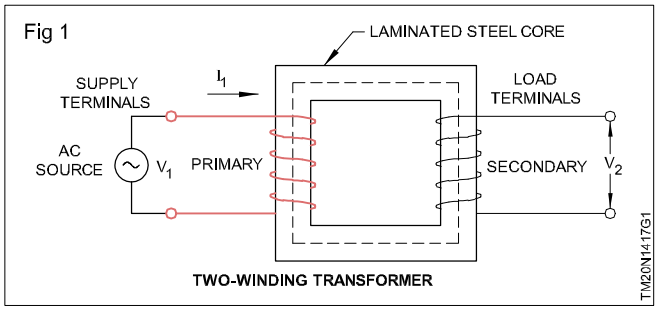
The three-phase synchronous generator is used extensively to generate bulk power. The voltage levels at which this power is generated is typically in the range 13.8 kV to 28 kV. Electrical power is to be provided at a considerable distance from a generating station. It is possible to transmit the generated power directly but this results in unacceptable power losses and voltage drops.

Transmission voltages vary in many hundreds of thousands of volts, up to the 400 kV level. This is made possible by power transformers. At the receiving end this high voltage must be reduced because ultimately it must supply three phase load at 415V or single phase load at 240V.

The transformer makes it possible for various parts of a power system to operate at different voltage levels.

Two-winding transformers: A transformer in its simplest form consists of two stationary coils coupled by a mutual magnetic flux (Fig 1). The coils are said to be mutually coupled because they link a common flux.

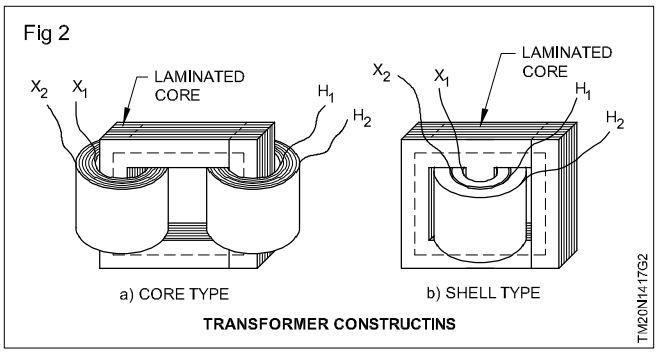
Laminated steel core transformers are used in power applications. As shown in Fig 1, the current flowing in the coil connected to the AC source is called the primary winding or simply primary. The primary is the input to a transformer. It sets up the flux in the core, which varies periodically both in magnitude and direction. The flux links the second coil, called the secondary winding or simply the secondary.



The flux is changing; therefore, it induces a voltage in the secondary by electromagnetic induction. Thus the primary receives its power from the source while the secondary supplies this power to the load. This action is known as transformer action. There is no electrical connection between these two coils.

Transformers are efficient and reliable devices used mainly to change voltage levels. Transformers are efficient because the rotational losses are absent; so little power is lost when transforming power from one voltage level to another. Typical efficiencies are in the range of 92 to 99%. The higher values apply to the large power transformers. There is no change in frequency of voltage.

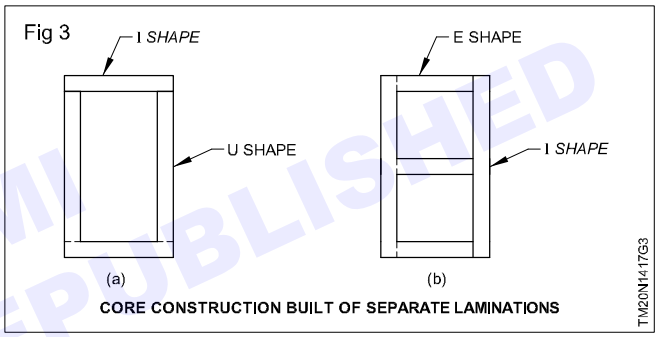
Construction: There are basically two types of iron-core construction. They differ in the way the core is constructed to accommodate the windings. Fig 2a shows core type already represented in Fig 1. It consists of two separate coils, one on each of the two opposite legs of a rectangular core. Normally, this is not a desirable design. Its disadvantage is the large leakage fluxes associated with it. The large leakage fluxes cause poor voltage regulation. Therefore, to ensure that most of the flux set by the primary will link the secondary, the construction shown in Fig 2b is employed. This is called shell type construction.



Here the two windings are wound concentrically. The higher voltage winding is wound on top of the lower voltage winding. The low-voltage winding is then located closer to the steel. This arrangement is preferable from an electrical insulating point of view. From the electrical viewpoint there is not much difference between the two constructions.

Cores may be built up of lamination cut from silicon steel. Most laminating materials have an approximate alloy content of 3% silicon and 97% iron. The silicon content reduces the magnetizing losses. Particularly, the loss due to hysteresis is reduced. The silicon makes the material brittle. The brittleness causes problems in stamping operation. Most laminated materials are cold-rolled and often specially annealed to orient the grain or iron crystals. This provides very high permeability and low hysteresis to the flux in the direction of rolling. Transformer laminations are usually 2.5 to 0.27 mm thick for 50 Hz. operation. The laminations are coated on one side by a thin layer of varnish or paper to insulate them from each other.

Coils are pre-wound, and the core design must be such that it permits placing the coil on the core. Ofcourse, the core must then be made in atleast two sections. The laminations for the core-type transformer of Fig 2a may be made up of E and I shaped laminations, as shown in Fig 3. The core for the shell type transformer of Fig 2b is normally made up of E and I shaped laminations.



Core construction built of separate laminations

Many other popular types of core constructions are in existence, depending upon the manufacturers' preferences. As a rule, the number of butt joints is to be limited.

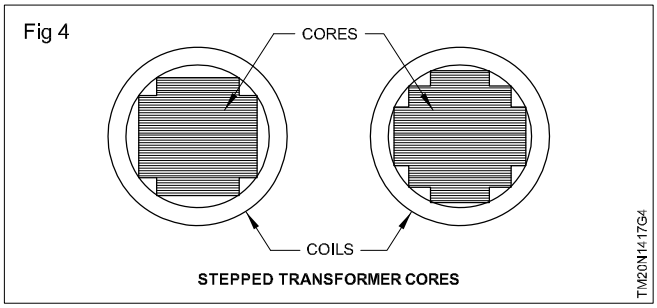
The joints are tightly made and laminations interleaved so as to minimize the reluctance of the magnetic circuit. The whole core is stacked to the proper dimension and the laminations are bolted together firmly. The stacking of laminations to the required core cross-section results in the core legs of square or rectangular cross-section. This permits coils to be fitted on the core legs with either square, rectangular, or circular coil spools or forms.

In larger transformers, a stepped-core arrangement is used to minimise the use of copper and reduce copper loss. (Fig 4) This construction guarantees that each length of copper conductor embraces the maximum cross-sectional area of steel.

In practice, the primary and secondary windings of a transformer have two or more coils per leg. They may be arranged in series or parallel. The laminations are pressed together by clamping in such a way as to prevent any fluttering or shifting. The forces due to alternating magnetic field and forces that exist between parallel conductors (carrying current) act on the core laminations and windings.

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The coils are impregnated. Insufficient clamping of laminations usually results in a humming sound. This generates objectionable and audible noise by the iron core of the transformer.



Transformers are usually air-cooled. Larger transformers are placed in tanks with a special transformer oil. The oil serves a dual purpose as an insulating medium as well as a cooling medium. The heat generated in the transformer is removed by the transformer oil surrounding the source and is transmitted either to atmospheric air or water. No matter what size of transformer is dealt with, they all operate on the same principle.

Transformer principle

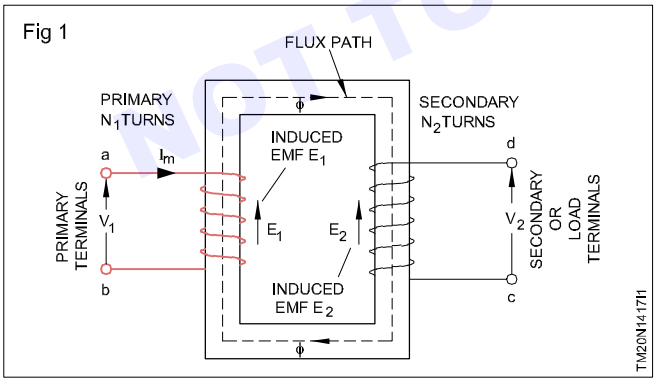
Objectives: At the end of this lesson you shall be able to

- **describe an ideal transformer**
- **represent the instantaneous rms values of primary and secondary**
- **explain the principle of the operation of a transformer**
- **state the emf equation of a two-winding transformer**
- **define the transformation ratio of a transformer.**

An ideal transformer: An ideal transformer is one which has no losses, ie. its windings have no ohmic resistance and there is no magnetic leakage. An ideal transformer consists of two coils which are purely inductive and wound on a loss-free core.

However, it may be noted that it is impossible to realize such a transformer in practice; yet for convenience, we will first analyse such a transformer and then an actual transformer.

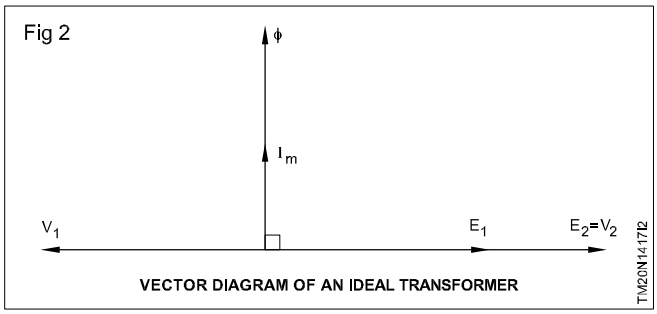
Let us consider an ideal transformer (Fig 1) whose secondary is open and whose primary is connected to a sinusoidal voltage V_1.



The impressed voltage causes a small current to flow in the primary winding. This no-load current is meant to build up a counter-electromotive force equal and opposite to the applied voltage. Since the primary winding is purely inductive and there is no output, the primary draws the magnetizing current I_m only. The function of this current is merely to magnetise the core. The I_m is small in magnitude and lags V_1 by 90^o. This alternating current I_m produces an alternating flux ϕ which is proportional to the current and hence is in phase with it (I_m). This changing flux is linked with both the windings. Therefore, it produces self-induced emf E in the primary which lags the flux 'ϕ' by 90^0. This is shown in vector diagram Fig 2.

The flux 'ø' produced by the primary links with the secondary winding and induces an emf 'E_2' by mutual induction which lags behind the flux 'ø' by 90° as shown in Fig 2. As the emf induced in primary or secondary per turn is the same the secondary emf will depend on the number of turns of the secondary.

When secondary is on open circuit, its terminal voltage 'V_2' is the same as the induced emf 'E_2'. On the other hand, the primary current at no load is very small, hence the applied voltage 'V_1' is practically equal and opposite to the primary induced emf 'E_1'. The relationship between primary and secondary voltages is shown in Fig 2.



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Hence we can say that

$$\frac{\text{Total emf induced in secondary } 'E_2}{\text{Total emf induced in primary } 'E_1'} = \frac{N_2 \times \text{emf per turn}}{N_1 \text{ x emf per turn}} \quad \text{OR}$$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

as $E_1 = V_1$ and $E_2 = V_2$

We have $\frac{V_2}{V_1} = \frac{N_2}{N_1}$

Ideal Transformer on Load: When the secondary is connected to a load, secondary current flows this in turn makes the primary current to increase. How this happens is explained below.

The relationship between primary and secondary currents is based upon a comparison of the primary and secondary ampere turns. When the secondary is on open circuit, the primary current is such that the primary ampere turns are just sufficient to produce the flux 'ø' necessary to induce an emf 'E_1' that is practically equal and opposite to the applied voltage 'V_1'. The magnetising current is usually about 2 to 5 percent of the full load primary current.

When a load is connected across the secondary terminals, the secondary current - by Lenz's law - produces in demagnetising effect. Consequently the flux and the emf induced in the primary are reduced slightly. But this small change may increase the difference between applied voltage 'V_1' and the induced emf 'E_1' by say 1 percent in which case the new primary current would be 20 times the no load current.

The demagnetising ampere turns of the secondary are thus nearly neutralized by the increase in the primary ampere turns and since the primary ampere turns on no load are very small compared with the full load ampere turns.

Therefore Full load primary ampere turns $\simeq$ full load secondary ampere turns

i.e $I_1N_1 \simeq I_2N_2$

so that $\frac{I_1}{I_2} \simeq \frac{N_2}{N_1} \simeq \frac{V_2}{V_1}$

From the above statement, it is clear that the magnetic flux forms the connecting link between the primary and secondary circuits and that any variation of the secondary current is accompanied by a small variation of the flux and therefore of the emf induced in the primary, thereby enabling the primary current to vary approximately, proportional to the secondary current.

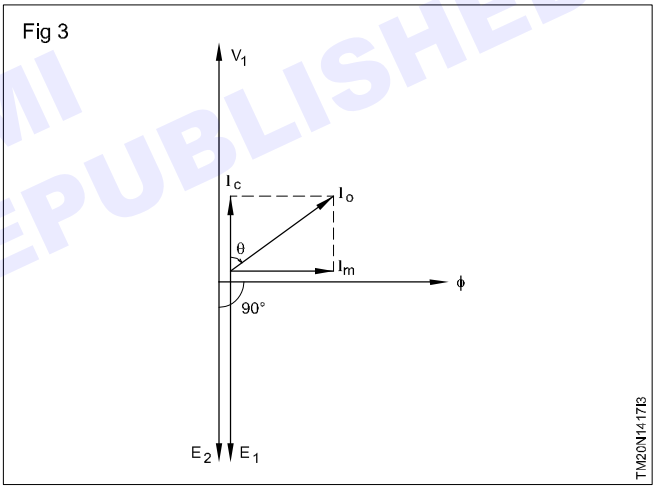
Theory of No-load Operation: With the secondary winding open-circuited, the no-load current I_o flows in the primary winding. This no-load current has two functions: (1) it produces the magnetic flux in the core, which varies sinusoidally between zero and ± $ø_m$ where $ø_m$ is the maximum value of the core flux; and (2) it provides a component to account for the hysteresis and eddy current losses in the core. These combined losses are normally referred to as the core losses or iron losses.

The no-load current I_o is usually a small percentage of the rated full load current of the transformer (about 2 to 5%). Since at no-load the primary winding acts as a large reactance due to the iron core, the I_o will lag the primary voltage 'V_1' by nearly 90°. Fig 3 illustrates this relationship where θ^0 is the no-load power factor angle.

Magnetising current = $I_m = I_o \sin\theta^0$ is 90° in phase behind the primary voltage V_1. It is this component that sets up the flux in the core; ø is therefore in phase I_m.

The second component, $I_c = I_o \cos ø_o$ is 90° is in phase with the primary voltage V_1. It is the current component that supplies the iron-loss plus a small quantity of primary Cu-loss. As I_o is very small, the no-load primary copper-loss is negligibly small.

Fig 3



EMF equation of a transformer: Since the magnetic flux set up by the primary winding links the secondary winding, there will be an induced emf E_2, in the secondary in accordance with Faraday's law, namely, E = N (δø/δt). The same flux also links the primary itself, inducing in it an emf, E_1. The induced voltage must lag the flux by 90°, therefore, they are 180° out of phase with the applied voltage V_1.

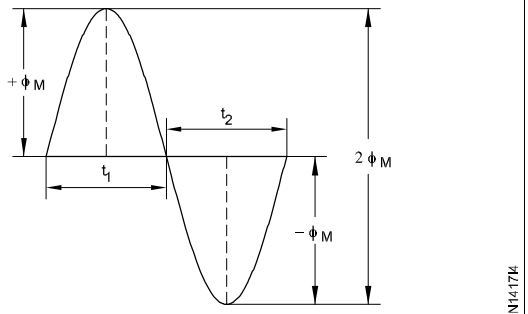
Since there is no current in the secondary winding, $E_2 = V_2$. The primary voltage and the resulting flux are sinusoidal; thus the induced quantities E_1 and E_2 vary as a sine function. The average value of the induced voltage is given by

$$E_{avg} = \text{turns} \times \frac{\text{change in flux in a given time}}{\text{given time}} \quad ...(1)$$

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Referring to Fig 4, it is seen that the flux change in time interval t_1 to t_2 is $2ø_m$ where $ø_m$ is the maximum value of the flux, in webers. The time interval represents the time in which this flux change occurs and equals one-half cycle of 1/(2f) seconds, where f is the supply frequency, in hertz. It follows that

Fig 4



SINUSOIDAL FLUX WAVE IN CORE

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$$E_{avg} = N \times \frac{2\phi_m}{\frac{1}{2f}} = 4fN\phi_m \quad ...(2)$$

where N is the number of turns on the winding.

From AC circuit theory, the effective or rms voltage for a sine wave is 1.11 times the average voltage, thus

$$E = 4.44\ f\ N ø_m \quad ...(3)$$

Since the flux links with the primary and secondary windings, the voltage per turn in each winding is the same. Hence

$$E_1 = 4.44\ f\ N_1 ø_m \quad ...(4)$$

and

$$E_2 = 4.44\ f\ N_2 ø_m \quad ...(5)$$

where N_1 and N_2 are the number of turns in the primary and secondary windings respectively.

Voltage Transformation Ratio (K): From the equations 4 and 5, we get

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K \text{ (Constant)} \quad ...(6)$$

This constant is known as voltage transformation ratio. Although the true transformation ratio is constant, the ratio of terminal voltages varies somewhat depending on the load and its power factor. In practice, the transformation ratio is obtained from the name plate data, which list the primary and secondary voltages under full load condition.

When the secondary voltage V_2 is less compared to the primary voltage, the transformer is said to be step down transformer. If the secondary voltage is higher it is called a step-up transformer. In other words

(a) $N_2 < N_1$ i.e K<1, then the transformer is called a step-down transformer

(b) $N_2 > N_1$ i.e K>1, then the transformer is called a step-up transformer

Assume that the power output of a transformer is equal to its input i.e we are dealing with an ideal transformer.

Thus $P_{in} = P_{out}$ OR

$V_1 I_1$ x primary PF = $V_2 I_2$ x secondary PF

where PF is the power factor. For the above stated assumption it means that the power factor on primary and secondary sides are equal. (It is possible when I_o is neglected). Therefore,

$V_1 I_1 = V_2 I_2$ OR

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{E_2}{E_1} = \frac{N_2}{N_1} = K \quad ...(7)$$

Equation 7 shows that as an approximation the terminal voltage ratio equals the turns ratio.

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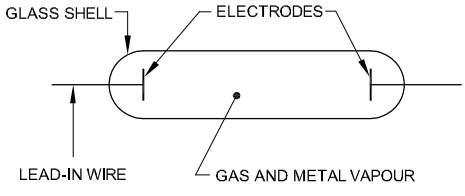
Fluorescent lamps

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

- **draw the circuit diagram of single tube fluorescent lamp with its components**
- **state the function of each component in the circuit**
- **state probable causes for different problems in the circuit malfunctioning.**

Principle of a discharge lamp : The basic principle of a gas-discharge lamp is explained in Fig 1. Gases are normally poor conductors, especially at atmospheric and higher pressures, but application of suitable voltage (known as ignition voltage) between two electrodes in a sealed envelope containing gas at low pressure ionises the gas, and current passes from one electrode to the other through the gas medium.

Fig 1



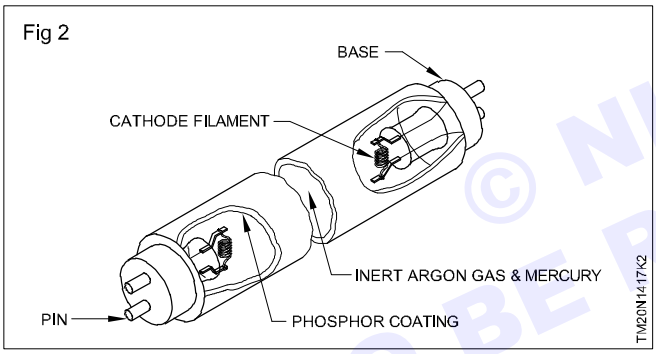
GAS-DISCHARGE LAMP

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A glass shell with two electrodes apart is connected through lead in wires to the voltage source. The space within the shell is filled with low pressure vapour. When the voltage applied to the electrodes is increased to a certain value, the gas inside gets ionised and starts conducting. When once the ionisation takes place and current is conducted from one electrode to the other, the resistance in the circuit drops very rapidly. It causes heavy current drawal. A device to limit the excess current must be provided. The current flow through the low pressure gas is called discharge. This causes the gas/vapour to emit radiation in the ultraviolet region. The UV radiation cannot be perceived by the human eye. Certain phosphors have the property of emitting light in the visible spectrum when the phosphor is exposed to UV rays.

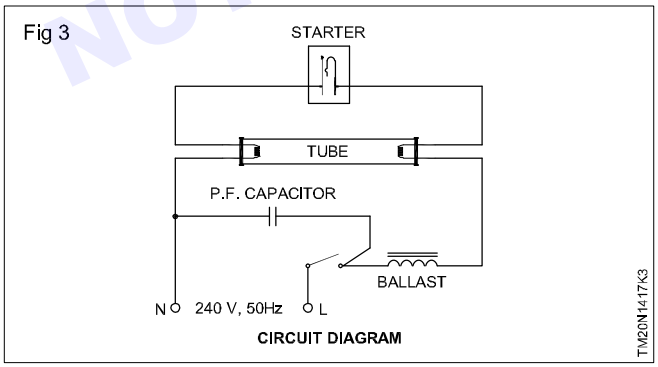
Construction of fluorescent tubes: A fluorescent light bulb is basically a glass tube capped by two bases. (Fig 2) These bases are fitted with pins to carry current to internal components called cathodes. Contained inside the tube are minute droplets of mercury and an inert gas. The inner surface of the tube is coated with a fluorescent powder or phosphor. This phosphor emits light when exposed to ultra-violet rays. Cathodes or electrodes are made up of coiled tungsten filaments coated with a mixture of barium and strontium oxides.

Fig 2



Circuit diagram: The method of connecting the starter, ballast and the tube's electrodes at its either end is shown in Fig 3.

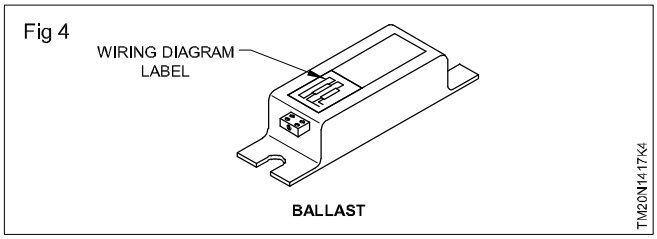
Fig 3



Function of the various parts in a fluorescent light circuit

Ballast (Choke)**:** The ballast is basically a coil of many turns wound on a laminated iron core (Fig 4). It steps up the supply voltage to start the fluorescent tube conducting. Once the tube is conducting, it regulates the flow of current to the tube cathodes to keep them from burning out.

Fig 4



Starters: A starter in the fluorescent tube circuit performs two functions.

– It completes the circuit at first for preheating the electrodes.

– It opens the circuit to provide voltage kick for ignition.

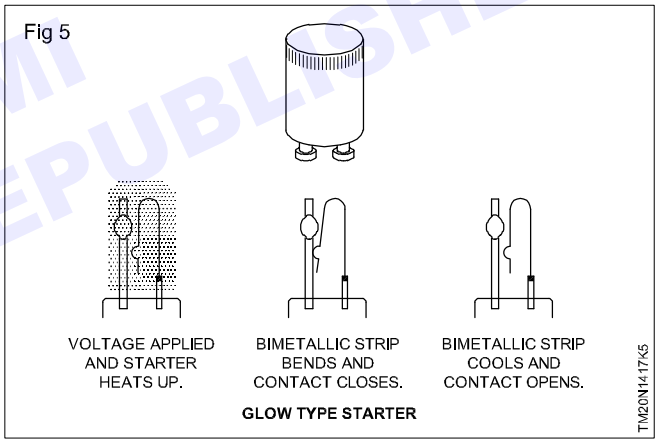
There are two types of starters.

– Glow-type

– Thermal type

Glow type starters: A glow-type starter switch (Fig 5) is the one most widely used. It consists of a gas-filled glass tube containing two electrodes, one of which is a bimetallic strip. When voltage is applied to the starter, a glow discharge occurs between the two contacts. The heat thus developed causes the bimetallic strip to deflect and close the circuit.

Fig 5



Current for preheating the electrodes starts flowing. At the same time the glow discharge ceases resulting in the cooling of the bimetallic strip. The contacts reopen and the voltage induced in the choke coil provides the ignition voltage.

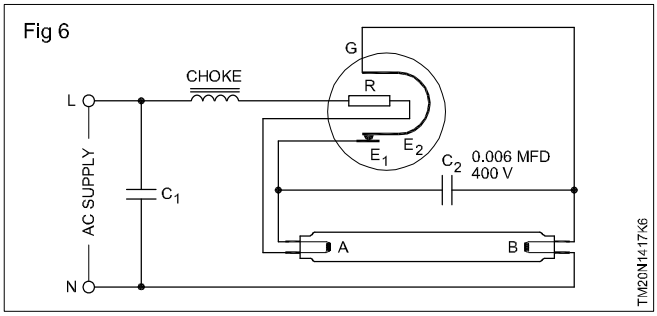
Thermal type starter: The switch has a bimetallic strip close to the resistance R which produces heat.

Thermal type starters are generally enclosed in a hydrogen - filled glass bulb G. The two switch electrodes E_1 and E_2 are normally closed when the lamp is not in operation. When normal supply is switched on, the lamp filament electrodes A and B are connected together through the thermal switch and a large current passes through them. Consequently, they are heated to incandescence. Meanwhile the heat produced in resistance R causes the bimetallic strip E_2 to break contact. The inductive surge of about 1000V produced by the choke is sufficient to start discharge through mercury vapours as explained.

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The heat produced in R keeps the switch contacts E_1 and E_2 open during the time as shown in Fig 6.

Fig 6



A 0.006 MFD capacitor (C_2) is connected across the electrodes of the starter contacts (bimetals) in the case of both thermal and glow type starters, to eliminate any radio interference effects that may be caused by the opening and closing of the bimetallic contacts.

Fluorescent tube: When the circuit in Fig 3 is energised, a small current passes through the series reactor, the two tube filaments, and the glow-tube. At the instant when the circuit is energised, the current is very small because of the high resistance of the glow-tube.

Because of the high resistance of the glow-tube, the current is small, and there is little voltage drop across the series reactor. Therefore, there is sufficient voltage at the glow-tube to produce a glow discharge between the U-shaped bimetallic strip to expand and close the contacts. Preheating takes place at both cathodes. The current through the two filaments is relatively high but the series reactor limits the current to a safe value. In the period that the contacts of the glow-tube are closed, the temperature of the fluorescent tube electrodes increases rapidly. However, when the contacts close in the glow-tube, the glow discharge is stopped, the bimetallic U-strip cools and the contacts open. At the instant these contacts open, an inductive voltage-kick generated by the series reactor coil starts conduction of current between the main electrodes of the fluorescent tube.

A stream of electrons flows between the filament electrodes. These electrons collide with the electrons of the argon and mercury vapour in the tube. The two gases radiate ultraviolet light. These rays bombard the phosphor coating on the tube wall. The phosphor-coating radiates visible light.

The fluorescent lamp continues to operate as long as the circuit is energised. The usual operating voltage for satisfactory operation is 110 to 125 volts AC. Once the circuit is in operation, the reactor limits the current to the rated value so that the fluorescent tube fluoresces at the proper light intensity.

Power factor correction capacitor: The reactor or voltage ballast in series with the fluorescent tube causes the power factor of fluorescent units to range between 50 and 60 percent lag. The power companies, therefore, have requested the various fluorescent lamp manufacturers to install capacitors in fluorescent lighting units. They have such a capacitor connected in the lamp circuit so that the operating power factor of most fluorescent lamp units is near 100 percent or unity.

Standard sizes of fluorescent lamps available in the market: The light output of a fluorescent lamp amounts to about 70 lumens per watt. The usual sizes are 10, 20, 40 and 80 watts; 1 foot (30 cm), 2 feet (60 cm), 4 feet (120 cm) and 5 feet (150 cm) respectively at 230 volts.

Comparison of a fluorescent lamp with incandescent lamps: Fluorescent lamps or tubes have several advantages over standard incandescent lamps. Their main advantage is that they can produce light at a much lower cost. Fluorescent tubes produce about four times as much light per watt of power than do incandescent lamps. This makes them much cheaper to operate. Glare level is low.

Fluorescent tubes produce less heat than incandescent lamps due to their higher light efficiency. If you touch a fluorescent tube after it has been `ON' for some time, you will note that it is cool to touch. Large incandescent bulbs will cause burns to the anyone trying to remove them after they have been in operation for some time.

Under ordinary operating conditions, fluorescent lamps last five to fifteen times longer than standard incandescent lamps. However, the more often a fluorescent lamp is turned on and off, the shorter its life span. The major disadvantage of fluorescent lighting is the higher initial cost of the fixture. This extra cost is due to the auxiliary hardware required to operate the fluorescent lamp circuit. The disadvantage is the small wattage of these lamps require a large number of fittings.

Life of fluorescent lamps: Their normal life span is 7500 hours. They are affected by both high and low voltage, frequency of switching. The average life is for three burning hours per switching operation. The actual life may vary from 5000 to 10000 hours, depending upon the operating conditions. Light output is reduced by 15 to 20% after 4000 hours operation, and it is, therefore, a good practice to replace the fluorescent lamps after 4000 - 5000 hours of burning, on economic grounds.

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Fluorescent light - troubleshooting chart

Problem	Possible causes	Solution
The tube fails to start	Bulb burnt out. Defective starter. Broken lamp-holder. Incorrect bulb for ballast Fixture wired incorrectly. Line voltage too low. Air temperature too low. Defective ballast.	Replace bulb. Replace starter. Replace lamp-holder. Check ballast label for correct bulb. Check wiring diagram on ballast label. Contact electricity board. Install special low-temperature, ballast. Replace ballast.
Ends of the bulb glow but centre does not	Defective starter. Fixture wired incorrectly. Fixture not adequately grounded	Replace starter. Rewire according to ballast wiring diagram. Check ground connection on fixture.
Ends of bulb are black.	Bulb nearly burnt out.	Replace bulb.
Bulb flickers or blinks.	Tube pins making poor contact. Bulb nearly burnt out. Defective or incorrect starter. Air temperature too low.	Clean the prongs and tighten the tube in the lamp-holder. Replace bulb. Replace starter. Warm room; if necessary install special low temperature ballast.

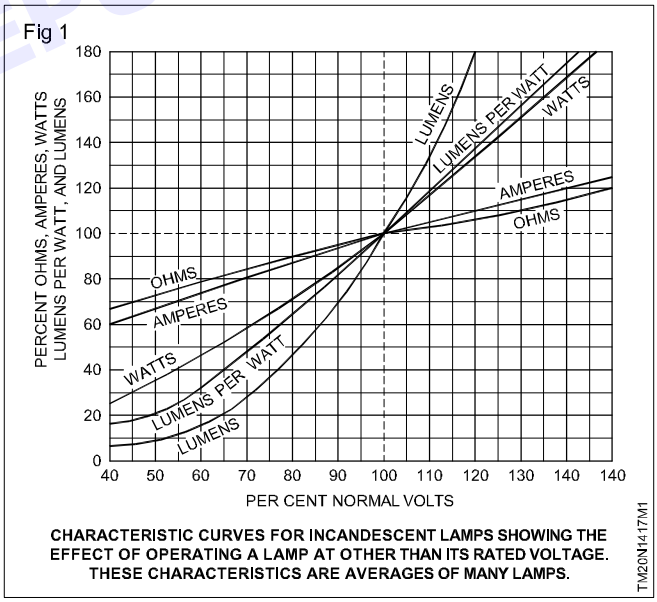
Low voltage lamps

Objectives: At the end of this lesson you shall be able to
- **calculate and compare the hot resistance of the same voltage but of different wattage/current lamps**
- **state the conditions of a lamp of low voltage when it carries less current or more current through it**
- **describe the method of measuring 'hot resistance'.**

Purpose: In quite a few places we use low voltage supply i.e. 6V, 12V or 24V, such as in automobile vehicles. Automobile vehicles are equipped with many lights to provide an efficient lighting system for both day and night driving conditions. The various lights require the use of different wattage and types of light lamps to provide the amount of illumination desired.

Glow conditions of low wattage lamps with current flow through it: An electric lamp changes electrical energy into heat and light, when current flows through its filament and causes it to become incandescent. The filament is made of tungsten wire. The low voltage lamps are generally of low wattage because at a low voltage, the current taken by the filament for a given wattage is much more as compared to the domestic light. The performance characteristics of tungsten-filament lamp is affected by voltage. The effect of operating a lamp at other than its rated voltage is shown in Fig 1. The decrease in voltage across the lamp lowers the current flow thus lowering the filament temperature. At 50% of the rated voltage, current decreases to about 68% and the resistance of the filament to 75%. The temperature of the filament lowers to an extent to give a light out of less than 10% lumens.

Fig 1



CHARACTERISTIC CURVES FOR INCANDESCENT LAMPS SHOWING THE EFFECT OF OPERATING A LAMP AT OTHER THAN ITS RATED VOLTAGE. THESE CHARACTERISTICS ARE AVERAGES OF MANY LAMPS.

Calculating the resistance (Hot)**:** The lamp filament operates at a very high temperature, 1800°C to 2200°C. Therefore, there is a very big difference between 'cold resistance' and 'hot resistance'. Hot resistance (when the lamp is ON) is nearly 12 times more than the cold resistance (when the lamp is OFF).

Hot resistance

a Wattage = 12

Voltage = 12

$$\text{Current} = \frac{W}{V} = \frac{12}{12} = 1 \text{ amp.}$$

$$\text{Resistance} = \frac{V}{I} = \frac{12}{1} = 12 \text{ ohms (hot)}$$

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b Wattage = 40

Voltage = 24

$$\text{Current} = \frac{W}{V} = \frac{40}{24} = 1.667 \text{ amps.}$$

$$\text{Resistance} = \frac{V}{I} = \frac{24}{1.667} = 14.4 \text{ ohms (hot)}$$

c

(i) Voltage = 6

Current = 0.1 ampere

$$\text{Resistance} = \frac{V}{I} = \frac{6}{0.1} = 60 \text{ ohms (hot)}$$

(ii) Voltage = 6

Current = 0.15

$$\text{Resistance} = \frac{V}{I} = \frac{6}{0.15} = 40 \text{ ohms (hot)}$$

(iii) Voltage = 6

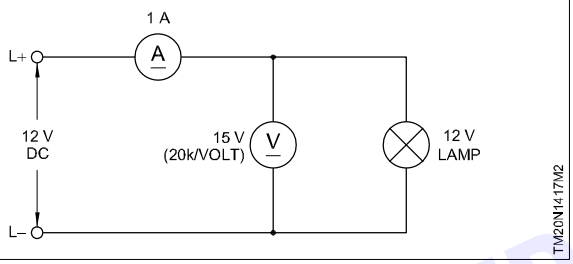
Current = 1 ampere

$$\text{Resistance} = \frac{V}{I} = \frac{6}{1} = 6 \text{ ohms (hot)}$$

The resistances calculated above are always hot resistance. To find out the cold resistance, it is measured with the ohmmeter when the lamp is OFF and at room temperature.

Measuring 'hot resistance': The hot resistance of a low voltage lamp could be measured by connecting the lamp as per the circuit given, Fig 2. The lamp must operate at its rated voltage. A voltmeter of high sensitivity not less than 20 k ohms per volt is used such that the current taken by the voltmeter is negligible. The reading of the ammeter and voltmeter must be taken accurately.

Fig 2



$$\text{Hot resistance} = \frac{\text{Voltmeter reading}}{\text{Ammeter reading}}$$

Designing a decorative serial lamp for a given supply voltage

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

- **calculate the number of bulbs to be connected in series for a given supply voltage**
- **state the condition of glow of all the lamps in series.**

We have to design a row of 6 or 9 volts lamps. If these lamps are connected directly to the 230V supply, the lamps will get fused immediately. Therefore the lamps are to be connected in series. The calculation as shown will be -

1 6 volts lamps

$$\text{Total No. of lamps required} = \frac{230}{6} = 38 \text{ lamps.}$$

Taking 5% allowance for fluctuations in the supply voltage

Total No. of lamps = 38 + (5% of 38)

= 38 + 2 = 40 lamps.

2 For 9 volts lamps

$$\text{Total No. of lamps required} = \frac{230}{9} = 26 \text{ lamps.}$$

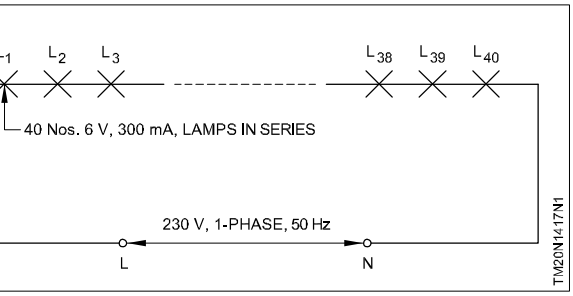
Taking 5% allowance for fluctuations in the supply voltage

Total No. of lamps = 26 + (5% of 26)

= 26 + 2 = 28 lamps.

The circuit for a series lamp connection of 6V lamp and supply voltage 230V is shown in Fig 1.

Fig 1



Precautions

– Never connect the low volt lamps directly to the mains.

– Never touch the exposed wires.

In the above case we discussed for 6V and 9V lamps. In the market we get for 6 volts different current ratings viz. 100mA, 150mA, 300mA, 500mA. The shape of the lamp for the above current ratings however remains the same.

For the series lamps to work satisfactorily the current rating of all the lamps should be the same.

We can prepare serial lamps with different voltages but of the same current rating. Let us consider an example.

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You have 25 lamps of 6V, 300mA rating and 20 numbers of 9V,300mA lamps. How will you design a 'serial lamp' circuit for 230V supply mains

a using all the available 6V lamps and for the rest of 9V lamps

b using all the available 9V lamps and for the remaining 6V lamps?

The important factor is that the sum of the voltages of the lamps in series should be equal to or slightly greater than the supply voltage.

Calculation

a Voltage drop across 25 lamps of 6 volts rating in series = 25 x 6 = 150V

Supply voltage : 230V

Voltage to be dropped by 9 volts lamps

= 230 –150 = 80 volts

Number of 9V lamps in series

$$= \frac{80}{9} \cong 9 \text{ say } 10$$

25 Nos. of 6V lamps and 10 Nos. of 9V lamp in series.

b Voltage drop across 20 Nos. of 9 volt lamps

20 x 9 = 180

Voltage to be dropped by 6V lamps in series

= 230 – 180 = 50V

Number of 6 volt lamps in series $\frac{50}{6} \cong 9$

20 Nos. of 9 volt lamps and 9 Nos. of 6 volt lamps in series.

The number of bulbs in series is always kept more than the calculated value. The purpose is to reduce the current through each lamp slightly. The reduced current makes the fusing of the lamps rather remote.

Mercury vapour lamp

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

- **describe the working of a `high pressure' mercury vapour lamp**
- **name the three different types of mercury vapour lamps**
- **name the parts of a mercury vapour lamp**
- **identify the circuit elements in a mercury vapour lamp**
- **list the features of a mercury vapour lamp like standard wattage, voltage etc.**

Discharge lamps: When an arc is struck in gas or metallic vapour, it radiates energy in characteristic wave-bonds. For example, neon gives red light, sodium yellow and mercury vapour four distinct lines in the visible, and two in the ultraviolet region of the spectrum.

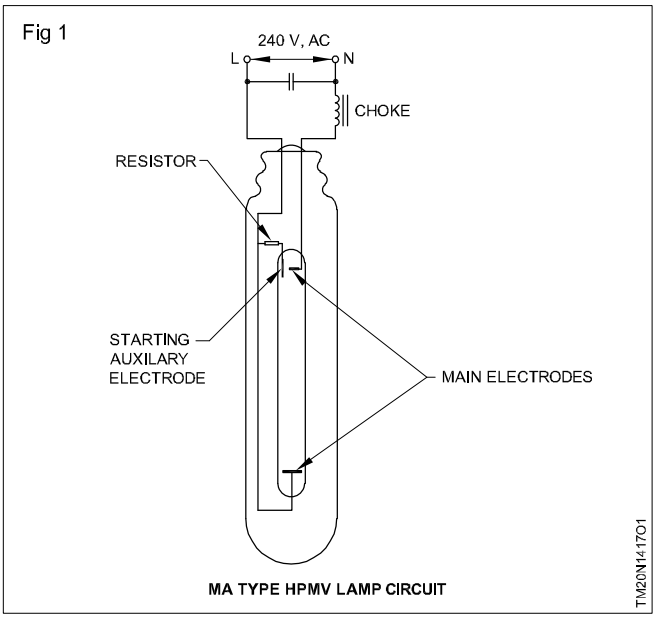
All modern discharge lamps operate in a translucent enclosure. The initial discharge is usually struck in argon or neon.

The discharge occurs in an inner tube enclosed in an outer evacuated tube. (Fig 1) The inner tube of glass or quartz contains mercury and a small amount of argon to assist in the starting of the discharge. The electrodes are rich in electron-emitting materials in order to permit ease in the release of electrons.

The lamp operates at high pressure. To start a discharge, an auxiliary electrode is positioned quite close to the main electrode. The auxiliary electrode is connected to the lamp terminal through a high resistor. The high resistor limits the current. When switched on, the normal mains voltage is not sufficient to start the discharge between the main electrodes but it can start over the very short distance between the main and auxiliary electrodes.

At the beginning, the discharge current passing through the high resistance causes a potential difference to develop between the starting electrode and one of the main electrode through the argon gas. The discharge now spreads rapidly until it takes place between the main electrodes. The argon discharge then warms up the tube and vaporises the mercury. Soon the gas content is mainly mercury vapour and the argon has less and less effect. The discharge then takes place in the mercury vapour.

Fig 1



MA TYPE HPMV LAMP CIRCUIT

Three different types of high pressure mercury vapour lamps are:

– MA type (MV lamp with auxiliary electrode)

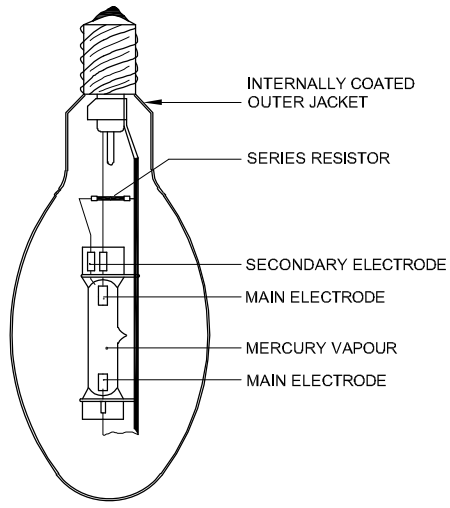
– MAT type (MV lamp with tungsten filament)

– MB type. (MV lamp with auxiliary electrode and Bayonet cap)

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MA type HPMV lamp: The discharge tube is made of borosilicate which is quite hard. The tube consisting of the main and auxiliary electrodes is sealed with an inside pressure of one and a half atmospheres. The lamp has a screw cap and is connected to the mains through the choke. (Fig 2) The lamp takes about 5 minutes to start giving full output.

Fig 2



MA TYPE HPMV LAMP

This lamp, once switched off, will not restart again until the pressure developed inside the tube falls back. It takes about 7 minutes to start again. There is no harm in keeping the switch on. The lamp should always be hung vertically, otherwise the inner tube will be damaged.

The efficiency is 45 lm/watt for 400 watts lamp.

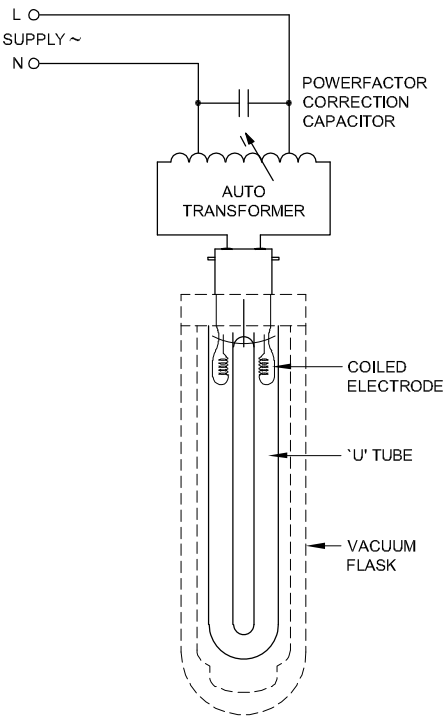
MAT type lamp: This type of lamp is almost similar to the MA type, but the outer glass envelope, instead of being empty, consists of a tungsten filament. The tungsten filament, similar to the one in an ordinary lamp, is in series with the discharge tube. It acts as a ballast. This lamp requires no external choke (or ballast) and capacitor. (Fig 3)

When the lamp is switched on, it works as a filament lamp does and its full output is given by the outer tube. At the same time, the discharge tube starts warming up, and when a particular temperature is attained, a thermal switch operates. The thermal switch cuts off a part of the filament so that the voltage across the discharge tube increases.

The light output is a mixture of light produced by a filament lamp and a discharge lamp.

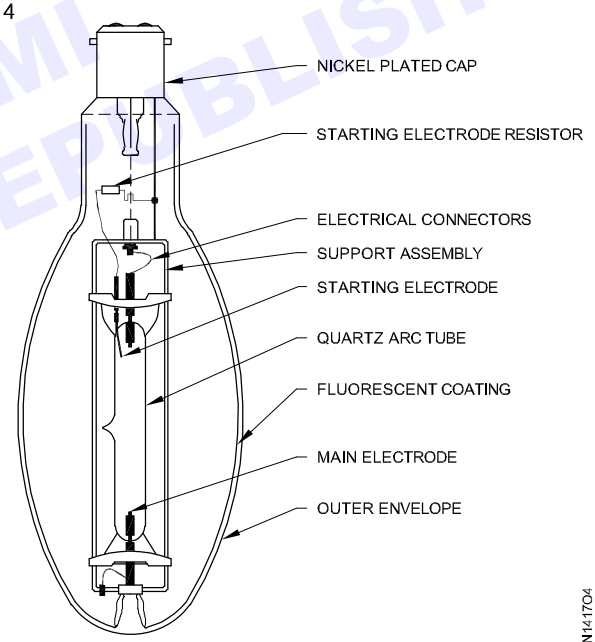
MB type lamp: This lamp operates at an extra high pressure of 5 to 10 atmospheres. The discharge tube of this type is of quartz, about 5 cm long and has three electrodes, two main and one auxiliary. This lamp has a 3-pin bayonet cap and it cannot be put into an ordinary holder as it requires a choke and capacitor. (Fig 4)

Fig 3



SODIUM DISCHARGE LAMP

Fig 4



MB TYPE HPMV LAMP

The functioning of the tube is similar to that of a MA type lamp. Since a quartz tube can withstand high temperature, it can be used in any position.

The wattages available are 80 watts 125 W, 250 W, 400 W, 700 W and 1000 watts operating in 230V/250V, 50 Hz main supply.

The efficiency is about 50 lm/W.

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Sodium vapour lamp

Objectives: At the end of this lesson you shall be able to
- **identify a sodium vapour lamp and its types**
- **describe the construction of a sodium vapour lamp**
- **state the functions of the parts in the circuit**
- **specify the standard sizes of sodium vapour lamps available**
- **compare a sodium vapour lamp with a mercury vapour lamp.**

Sodium vapour lamp and its types: Sodium vapour lamp is a gas discharge lamp. It gives a yellow colour light. Sodium lamps are not suitable for locations where colour rendition is important, but due to their higher efficiency (110 lumens/watt), they are used for the lighting of streets, railways, storage yards etc. where human traffic is less and colour rendition unimportant. Sodium lamps are particularly suitable in fog as their yellow light can penetrate fog better.

The average life of a sodium vapour lamp is well over 6000 hours. There are two types of sodium vapour lamps as given below:

– low pressure SV lamp

– high pressure SV lamp.

Construction

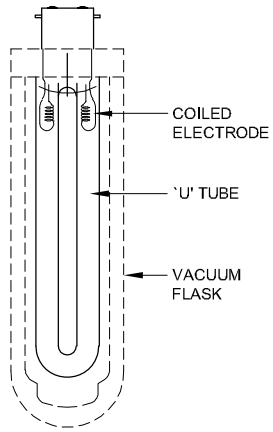
Low pressure sodium vapour lamp: In the sodium vapour lamps efficiency decreases rapidly as the current density is increased above a certain value. Consequently the lamp has to be operated at a low current density and this necessitates a large surface area of the tube. This lamp posseses a brightness of 7.5 candle per sq.cm. Because of these points the length of this tube has to be very long. Moreover its efficiency is very sensitive to change in tube temperature. For maximum efficiency the temperature of the lamp has to be maintained at about 220^0C. So the whole tube is placed in a detachable double walled vacuum jacket.

As stated above low pressure sodium vapour lamps require a long tube, but as there is limit to the practicable size of such a jacket of the vacuum flask type, the long lamp tube is bent to a `U' shape to suit the jacket.

The low pressure sodium vapour lamp posseses a `U' shaped glass tube internally coated with fluorescent powder, consisting of sodium together with neon and one percent of argon, the function of the argon being to reduce the initializing voltage. In a cold lamp the sodium is in the form of solidified drops on the inner walls. The tube contains two barium and strontium coated, coiled tungsten electrodes at both ends. The two ends of the electrodes are fixed to the bayonet cap. (Fig 1) Connection diagram is shown in Fig 3.

High pressure sodium vapour lamp: A high pressure sodium vapour lamp operates at a much higher current which flows through a much shorter arc tube (discharge

Fig 1

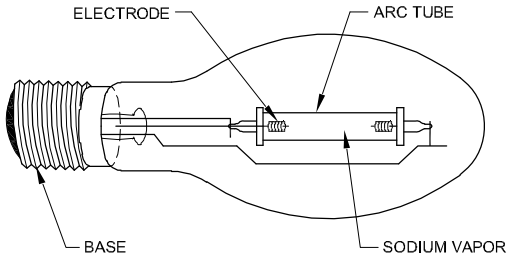


SODIUM DISCHARGE LAMP

TM20N1417S1

tube). This discharge tube is made of sintered aluminium ceramic discharge arc tube which is resistant to hot ionised sodium vapour up to a temperature of about 1600^0C which transmits over 90% of visible radiation. The discharge tube operates at a pressure of about half an atmosphere, and is enclosed in an evacuated hard glass envelope of elliptical shape to maintain the tube at the correct temperature. (Fig 2) The lamp gives a rich golden light which enables colours to be easily distinguished. This discharge tube contains sodium and mercury, with argon or xenon added at a low pressure for starting purposes at low pressure.

Fig 2



HPSV LAMP

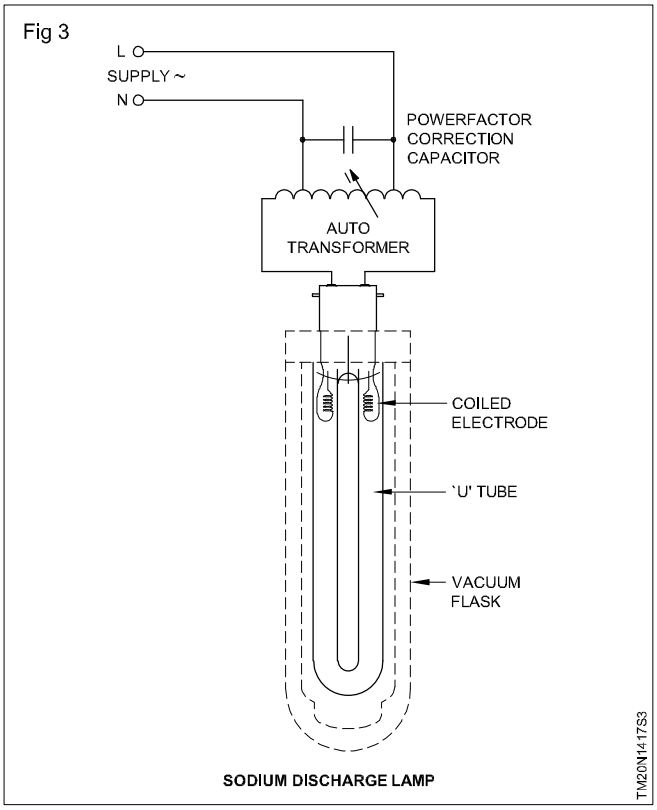
TM20N1417S2

A voltage pulse of about 2.5 KV is required to initiate the discharge (Fig 4) in higher pressure sodium vapour lamp. This high voltage pulse is generated by high external igniter or by built in thermal starter.

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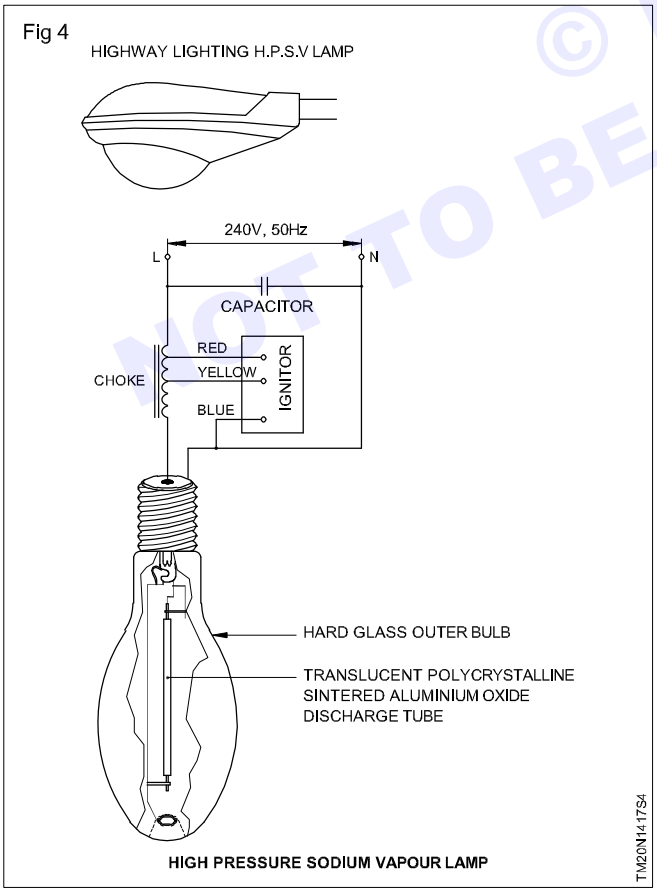
Circuit diagram

Low pressure sodium vapour lamp



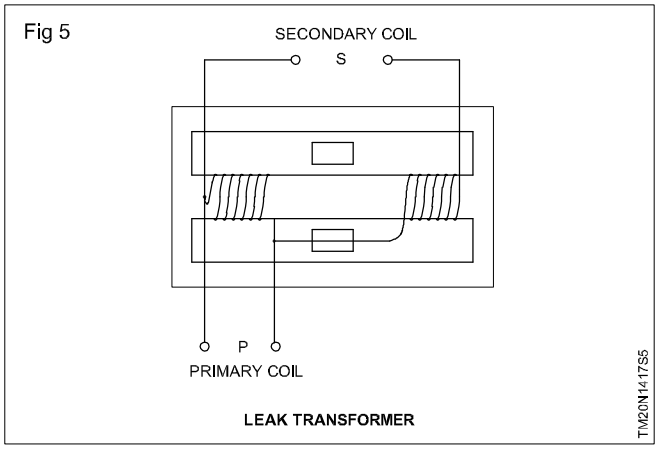
SODIUM DISCHARGE LAMP

High pressure sodium vapour lamp



HIGH PRESSURE SODIUM VAPOUR LAMP

Functions of the parts in the circuit



LEAK TRANSFORMER

Leak transformer: The ignition voltage of sodium lamps varies from 400 to 600V. A `leak transformer' performs the dual role of providing the ignition voltage initially, and acting as a choke for limiting the current subsequently when the lamp starts conducting. The diagram of a leak transformer is shown in Fig 5.

The primary and the secondary windings are connected in series and placed around the centre limb of a 3-core yoke. Between the coils, a loose iron core is clamped in the yoke on either side, which acts as a shunt for the magnetic field.

Under no-load conditions, the resistance of the shunt is large due to air gaps, with the result the magnetic field moves through the limbs of the yoke, and the device acts as an auto-transformer. But when the lamp ignites and consumes current, a part of the magnetic field leaks away through the shunt due to the counter-acting field of the secondary.

The device now a acts a choke coil reducing the voltage across the lamp electrodes to the required value.

Sodium vapour lamp (Bulb)**:** Before the lamp starts, the sodium is usually in the form of a solid deposited on the sides of the tube walls. So in the initial stage when the potential is applied to the lamp it operates as a low pressure neon lamp with pink colour (characteristics of the neon gas); but as the lamp warms up it vaporizes the sodium, and slowly it radiates out yellow light ,and after about ten minutes the lamp starts giving its full output.

Now the resistance of the lamp decreases and the

current increases but the voltage drop across the high leakage transformer controls the current to safe values.

The lamp works at low voltage, and the working temperature is about 300^0C.

Operating position of sodium lamps: Sodium lamps of 45W and 60W may be operated in horizontal or any other position. The cap of the lamp should always be higher than the lamp itself, so that the sodium does not settle behind the electrodes. For sodium lamps of

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higher wattage, the deviation from the horizontal position should not exceed 20°; otherwise, the distribution of the sodium will be altered, affecting the life and performance of the lamp.

Life of sodium lamps: The average life of a sodium lamp is well over 6000 hours for three or more burning hours per switching operation. At the end of this period the light output will be less by about 15% due to ageing.

Details of sodium vapour lamps (Std sizes)

Data on sodium lamps

Watts	Lamp voltage V	Minimum starting voltage V	Current A	Light output (lumens)	Dimensions mm
45	80	340	0.6	3500	257 x 51
60	105	340	0.6	5000	300 x 51
85	160	400	0.6	8000	414 x 51
140	160	410	0.9	13000	525 x 10
200	260	600	0.9	22000	785 x 60

Data on tin-oxide sodium lamps

Watts	Voltage	Current	Light output (lumens)	Dimensions
40	75	0.5	4400	310 x 51
60	115	0.7	7800	425 x 51
100	125	0.95	12500	528 x 64.5
150	185	0.94	20500	775 x 64.5
200	265	0.90	30000	1120 x 61.5

Comparison of Sodium vapour lamp with Mercury vapour lamp

Sl.No.	Sodium vapour lamp	Mercury vapour lamp
1	It is provided with a high leakage reactance transformer.	It is provided a with choke. (Ballast)
2	Higher light efficiency: 160 lm/w.	Lower light efficiency: 50 lm/w.
3	Ignition voltage of sodium vapour lamp varies from 400 to 600V.	Ignition voltage of mercury vapour lamp is less.
4	Burning position critical.	Burning position not critical.
5	Yellowish light.	Greenish blue light.
6	It posses only two main electrodes.	It posses two main electrodes and one auxiliary electrode.

Study the applications of norms for illumination in Textile mills

Objectives: At the end of this lesson you shall be able to
- **describe the norms for illumination in Textile mills**
- **apply norms for illumination in Textile mills.**

Lighting is an essential requirement in textile industries as well as all other industries. Light is a radiant energy from a hot body which produces the visual sensation upon the human eye. It is required for practical purposes as well as aesthetic purposes. Illumination differ from light very much, through generally, these terms are used more or less synonymously. Light is the cause and illumination is the result of that light on surfaces on which it falls. The power consumption by the industrial lighting varies between 2 to 10% of the total power depending on the type of industry. Proper and adequate lighting in the textile industry improves the visibility of an object, enhances work performance, improve the job satisfaction and reduce loss and compensation payment due to accidents in the industry.

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Light is just one portion of the various electromagnetic waves travels through space. These waves have both a length and a frequency, the values of which distinguish light from other forms of energy on the electromagnetic spectrum. Visible light represents a narrow band (380 to 780 nm wavelength) between ultraviolet light (UV) and infrared energy (heat). The light waves are capable of exciting the eye's retina, which results in a visual sensation called sight. Therefore, seeing requires a functioning eye and visible light .

Lighting can be classified in following three categories

i **Accent lighting:** This lighting is mainly decorative and used for interior design. Landscaping or "highlighting pictures or plants.

ii **Task Lighting:** This type of lighting is required for performing various activities such as: reading,"writing, production process or inspection.

iii **General lighting:** General lighting or ambient light is fall in between abovementioned two lighting and is used for general illumination of an area.

Characteristics and benefits of good lighting

In textile industry, poor lighting at work place can cause of eye strain, fatigue, stress, headaches and accidents. On the other hand, too much light 'glare' can also cause health and safety problems. Both can lead to mistakes at work, poor quality and low productivity. Characteristics of good lighting are as under:

- Light should be of adequate in tensity for the particular job,
- It should be equally bright throughout the workshop.
- Light should not allow marked shadows.
- It should be diffused and not glare (excessive luminance).
- It should not be dazzle {bright confusing light)

Good illumination (Adequate and balanced levels) in textile industry have following benefits:

i Increase production

ii Enhance quality of product

iii Protecting health, eyes and nervous system of workers

iv Improved safety and security

v Reduce workers fatigue

vi Reduce accidents

vii Improve satisfaction and morale of employees.

Recommendation illumination level

The illuminance required for particular task depends on visual requirements of the job, satisfaction of the user, practical experience and cost effective use of energy. The table-1 gives the recommended luminance range for different areas, tasks and activities.

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Table1: Recommended Il luminance levels

Area/task/ process	illuminance level (lux}
General Industries	
Exterior circulating, walkways, stores, entrances and exit roads, car parking, internal factory roads etc.	20-20
Boiler house, transformer yards, furnace rooms, entrances, corridors, stairs etc.	70-100
Circulation areas in industry, stores and stock rooms, canteen	100-150
Coarse work	200-300
Medium work	300-500
Fine work	500-1500
Very fine minute and precise work	1500-3000
Cotton Textile Mills	
Bale breaking, washing, Stock dyeing, tinting, Mixing, Blowing	200-300
Carding, drawing, roving	300-500
Spinning, doubling, reeling, winding	300-750
Warping	300-400
Sizing	400-500
Healing (drawing in)	750-1000
Weaving (plain gray fabrics)	200-300
Weaving- (light coloured)	300-750
Weaving (dark coloured)	500-1000
Knitting	300-750
Dyeing	200-450
Calendaring, chemical treatment	300-750
Grey cloth inspection	700-1000
Final inspection	1000-2000

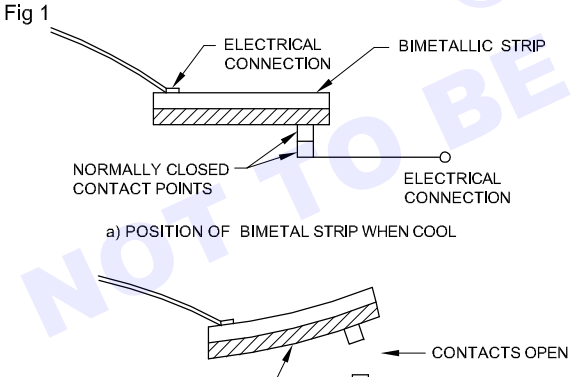
Thermostat heat controls in automatic electric iron

Objectives: At the end of this lesson you shall be able to
- **describe the construction of a bimetal thermostat**
- **illustrate the working of an adjustable thermostat**
- **list the applications of a thermostat**
- **explain the cause of pitting and oxidation of contacts.**

Thermostats Thermostat is a device for keeping the temperature steady. One of the simplest and most dependable components in the modern heating appliances is a bimetal thermostat. It controls the temperature in stoves, toasters, food warmers, irons and so on. When combined with some other small components, it forms the basis for automatic and variable heat switches. It serves as a safety device to prevent overheating in many appliances when used by themselves with no adjustment provisions.

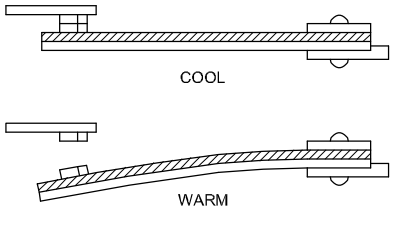
Bimetal thermostat: It is made of two strips of metal with different expansion rates welded together. Metal strips expand when heated and contract when cooled. One metal in the bimetal strip has a high rate of expansion when heated, and the other has a low rate. When a bimetal strip is heated, both the metals in the strip expand but the one at the bottom (with a higher rate of expansion) expands faster and forces the upper half to curl up or bend away from the contact point. (Fig 1) The strip curls or bends enough to break contact, opening the circuit. As the strip cools, it straightens and restores contact with the stationary point. The bending of the bimetal strip on heating is towards the side that has the smaller expansion rate. (Fig 2)

Fig 1



A SIMPLE BIMETAL THERMOSTAT

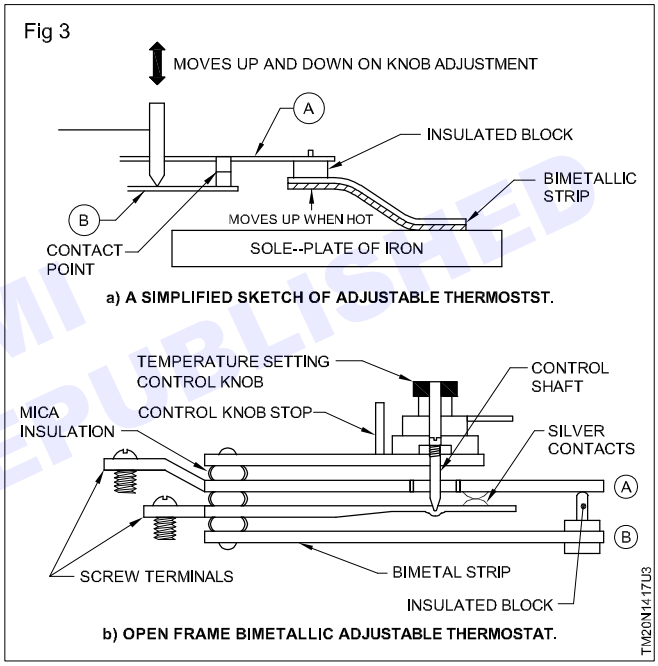
Fig 2



A FIXED BIMETALLIC BLADE BENDS AS IT IS HEATED.

Adjustable thermostat: The operating temperature of a small, thermostatically - controlled heating appliance (e.g. electric iron) is varied by altering the distance the bimetallic blade must travel to close or open a set of contacts. By sliding or turning a control knob, the user adjusts the heat of the appliance only within specified limits. That is, through a linkage from the user's control knob, the distance between the thermostat's bimetallic blade and its associated electric contacts is varied. (Fig 3)

Fig 3



The user adjustment does not determine the amount of current that flows into the appliance but usually controls the ON-OFF cycle of the unit.

The bimetallic blade of the thermostat seldom is the source of a problem. Most often, trouble occurs because of contact points getting pitted and oxidised through repeated use. Remember that thermostats, as employed in small appliances, are switches.

Bimetal thermostats open and close slowly, and as a result, contacts are prone to arcing. Each time the contacts open, they cause a small arc which leaves a deposit of oxide on the contact surface. Arcing corrodes the contacts, increases through the point and causes even more severe arcing. Eventually the contacts no longer allow the current to flow. This can occur even though the contacts may seem to be touching each other.

Generally, a good thermostat will show zero ohms resistance, or at most a few ohms. When a thermostat indicates high resistance or infinity, it should be replaced. Remember to isolate the thermostat from the circuit.

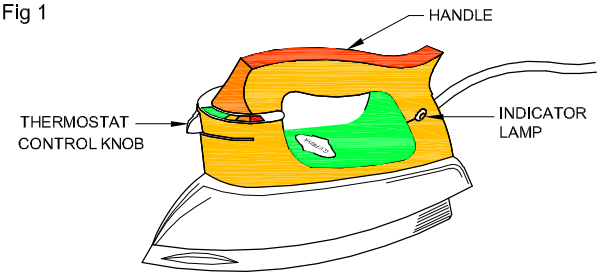
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Automatic electric iron

Objectives: At the end of this lesson you shall be able to
- **name the different parts of an automatic iron from its constructional diagram**
- **list the possible faults, the causes and corrective action to be taken in an automatic iron.**

The difference between an automatic iron and the ordinary one (non-automatic) is that the automatic type has a thermostatic device to regulate the temperature. The principal parts are the same as in an ordinary iron except that it has a thermostat and a setting knob. (Fig 1)

Fig 1



AUTOMATIC ELECTRIC IRON

Parts of an automatic iron

Handle: Scientifically designed bakelite handle with thumb hollows for right or left handers and pilot lamp.

Sole-plate and cover: Surface ground, chrome plated, cast iron sole-plate resists corrosion and heat damage. Heavily plated steel cover.

Thermostat: Built in for automatic heat adjustment to suit different types of fabrics. Construction is identical to the one shown in Fig 3 of thermostat heat controls.

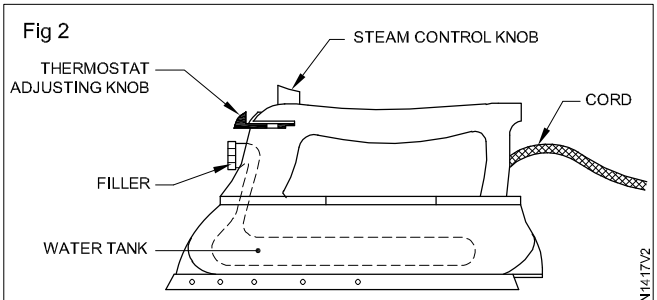
Heating element: Made of ribbon shaped, nickel-chromium, resistance element wound on high grade mica affords maximum electrical contact with connecting leads and thermal contact with the sole- plate, giving longer element life.

Flex: Cotton-braided 3-core, unsinkable flex with provision for earthing.

Automatic irons are fitted with a thermostatic switch to regulate the heat to a specific predetermined value, thus disconnecting it when sufficiently hot and reconnecting when cold. A turning dial just below the handle, marked as rayon, cotton, silk, wool, operates at a pre-set temperature, depending upon the particular fabric to be ironed. A lamp fitted into the handle goes off when the desired temperature is attained.

The electric components of the dry iron include a heating element, a thermostat, terminals, a terminal insulator and a cord-set.

Fig 2



OUTLINE OF A TYPICAL STEAM IRON

The main causes of trouble in an iron are the cord-set, thermostat, heating element and connections to the element and thermostat.

The sole-plate needs to be cleaned and maintained as prescribed by the manufacturer.

Steam/spray irons (IS 6290)**:** Electrically there is no difference between steam irons and dry irons. A steam iron has a small reservoir mounted above the heating element. A control valve on this allows the water to drip in to recess in the sole plate. Check valve prevents the water and stem going back to the reservoir. When the water drips on the hot sole plate it is converted into steam and goes out through the holes in the bottom of the sole plate. The heating element s concealed with the sole plate. The amount of steam can be controlled by the contact knob on the iron located on the handle. Like automatic iron a thermostat is also provided to control the temperature.

When the element is found to be defective, sole plate along with the sealed heating element has to be replaced.

Distilled water is recommended for filling in to the tank. Ordinary water, if used, may result in deposition of salts in the tank and clog the entry and exit ports.

It is recommended to flush the water in the tank by pressing the steam control knob fully for some time before the iron is switched off for keeping it till next use.

Salt deposits can be removed by filling the tank with water diluted vinegar and plugging the iron to supply. A number of attempts may be made to flush the iron by pressing steam control knob.

Some of the common problems, possible causes and suggested corrective actions are given in the chart.

Troubleshooting Chart

Dry Iron

Problem	Possible cause	Corrective action
No heat	No power at outlet. Defective cord or plug.	Check outlet for power. Repair or replace.

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	Broken lead in iron.	Repair or replace the lead.
	Loose thermostat control knob	Clean and tighten.
	Defective thermostat.	Replace the thermostat.
	Defective heater element	Replace the heater if separate. If cast in, replace the sole-plate assembly.
	Open thermal fuse.	Replace.
Insufficient heat	Low line voltage.	Check voltage at the outlet.
	Incorrect thermostat setting.	Adjust and re-calibrate the thermostat.
	Defective thermostat.	Replace the thermostat.
	Loose connection.	Clean and tighten connections.
Excessive heat	Incorrect thermostat setting	Adjust and re-calibrate the thermostat.
	Defective thermostat.	Replace the thermostat.
Blisters on the sole-plate	Excessive heat.	After repair of the control replace or the sole-plate, depending on its repair condition.
Tears clothes.	Rough spot, nick, scratch, burr on the sole-plate.	Remove with fine emery; then buff polish the area.
Shocks user.	Electric circuit grounded to iron.	Check: Cord and wiring for bare spot, thermostat for insulation breakdown, heater element for ground. Repair or replace as indicated.
Cord sparks.	Loose connection.	Clean and tighten.
	Broken wire.	Repair or replace.
Sticks to clothes.	Dirty sole-plate	Clean.
	Excessive starch in clothes.	Iron at a lower temperature. Use less starch next time. Iron too hot for the fabric being ironed.
		Lower the thermostat setting.
Iron does not turn off automatically	• Welded thermostat contacts • defective thermostat	Replace thermostat

Testing the iron

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

- **test the automatic iron in a systematic way to find the defective part.**

Besides the obvious physical damages, such as a broken handle, dented shell (a leak tank), or a scratched sole-plate, you will have to make electrical tests to locate the trouble spot. All electrical tests can be made with an appliance tester or ohmmeter. When an iron does not heat or when it operates erratically, the first part to suspect is the cord. Test it by plugging it into the outlet with a lamp in series. Turn the thermostat all the way on, and the bulb should light. If it does not, then connect the jumper lead across the two terminals of the cord to short them. If the cord is good, the bulb will light and remain lighted while you shake, wiggle or work over the cord with your hands. If the light flickers or goes out while you are working over the cord, it means that there is an intermittent break in the cord, and it should be replaced. Having checked the condition of the cord, we move on to the iron itself.

The next part to test is the thermostat. Remove the jumper from the cord terminals and connect it across the heating element terminals. Turn the thermostat from OFF to ON and rotate its entire range. The test bulb light should come on somewhere in the first third of the control's rotation and remain ON steadily throughout the rest of the turning. It should go OFF at about the same point it came ON. Look the thermostat over carefully. Note the condition of the contact-points, leaf springs and insulators. Clean out any lint or other foreign matter that may have collected. Make certain that the terminals are tight and that contact areas are clean. A defective thermostat must be replaced. Contact points can be cleaned to some extent but generally such repairs are not satisfactory. The next step in electrical testing is the heater element. Remove the jumper lead from the heater element terminals and turn the thermostat all the way ON. The bulb should light. If it does not and everything else up to this point is good, the heater is defective. To double check this diagnosis, remove the plug of the iron cord from your tester and plug in the tester leads. Connect the test leads, one to each heater terminal. The bulb will light if the element is all right. No light, or a dim light, will indicate a defective element. There is no repair for this problem. The heater element must be replaced.

Finally, all parts and the assembled iron must be ground-tested before you can say that the iron is electrically workable.

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Soldering/desoldering

Objectives : At the end of this lesson you shall be able to
- **state the soldering process and types of soldering**
- **list the uses of lug boards**
- **state the method of connecting wires to lug boards**
- **list the different tools used for soldering**
- **state method of desoldering using different tools.**

Soldering

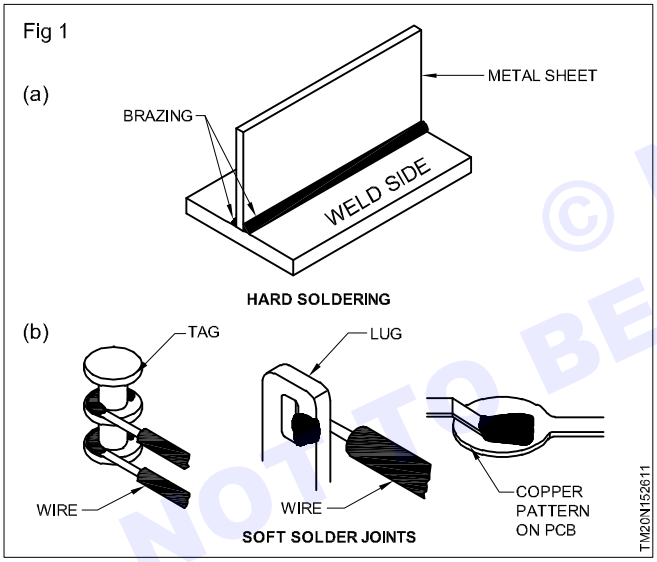
Soldering is a process of connecting any two metallic surfaces such as copper, brass and alloys of these metals. Some types of solder joints are shown in Fig 1.

There are two types of soldering,

1 Hard soldering or brazing used for joining large metal parts as shown in Fig 1a.

2 Soft soldering used to form good electrical joints/ connections between electrical/electronic parts as shown in Fig 1b.

Fig 1



Soft soldering is used extensively for electronic circuit wiring. In this lesson only soft soldering is discussed. Hard soldering or brazing is out of scope of this lesson.

From now on in this book, soldering means soft soldering.

Need for soldering

Requirements of an electrical joint

1 The electrical joint must provide ideally zero resistance or at least a very low resistance path, for the flow of current.

2 The electrical joint made should be strong enough to withstand vibrations, physical shock, bumps etc, without causing any deterioration to the quality and strength of the joint.

3 The electrical joint should be able to withstand corrosion and oxidation due to adverse atmospheric conditions.

All the above requirements of an electrical joint can be achieved by making a solder joints.

Solder

In a soldered joint, the solder is a mixture of metals, generally TIN and LEAD. It is made to melt at a certain temperature. It acts as a filler between the parts of the connection/joint to form a continuous, low resistance metallic path for conduction of electricity.

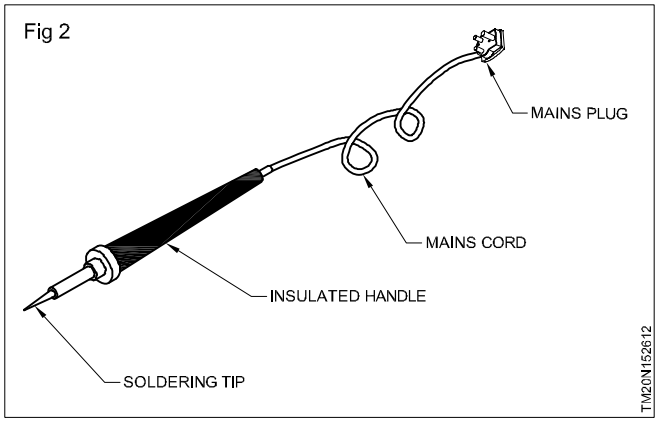
In soldering, as the metal surface is wetted (free flow of liquid solder over a surface) by the solder, a complex chemical reaction, bonds the solder to the metal surface.

The tin content of the solder diffuses with the metal surface to form a layer of a completely new alloy. The alloy so formed will have the same structure as the constituent metals and retain their metallic properties and strength.

Soldering and soldering irons

While soldering, the solder is made to melt between the metallic surfaces of the joint, using a soldering iron, as shown in Fig 2. A **soldering iron** is an instrument used to produce the required heat to carry out soldering.

Fig 2



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 230V, 50Hz ac mains supply. There are special type irons which work on dc supply also. For soldering delicate components, soldering

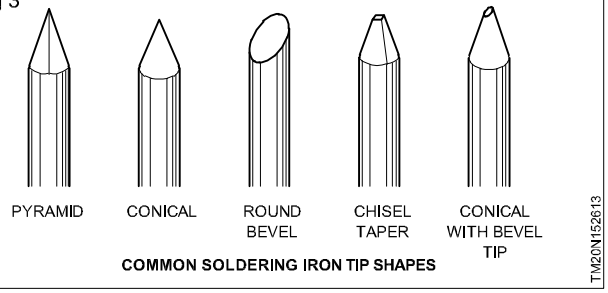
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irons with temperature controlling facility are used. These are known as soldering stations.

Soldering iron tips

Soldering irons are designed to take, a variety of tip sizes and shapes as shown in Fig 3. 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 3

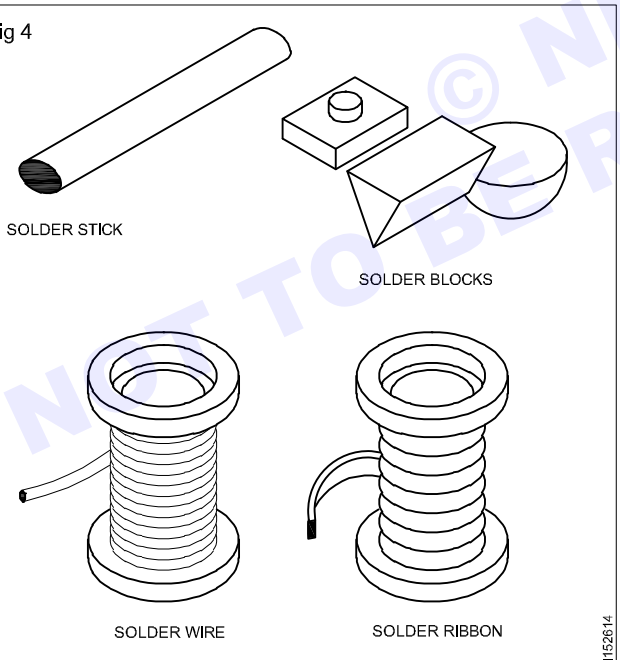


COMMON SOLDERING IRON TIP SHAPES

Types of solders

Solders are available in many forms as shown in Fig 4. The type to be chosen depends on, the type of soldering to be carried out. The wire type solder shown in Fig 4 is the most commonly used solder for hand soldering work, using low wattage soldering iron.

Fig 4



FORMS OF SOLDER

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 they are 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 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 as shown in Fig 5. This is known as **cored solder**.

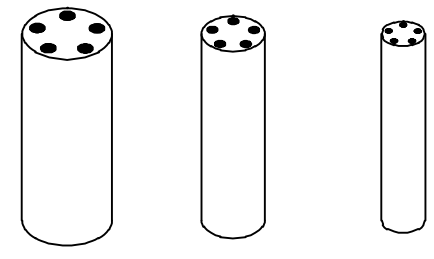
The most popular type of cored solder for electronic hand soldering contains rosin type flux. Such solder is known as rosin cored solder.

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.

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Rosin-cored solder is available in different gauges as shown in Fig 5. It is important to choose a size suitable for the job at hand as given below;

Fig 5



VARIOUS GAUGES OF CORED SOLDER

– use 22 gauge for small joints

– use 18 gauge for medium joints

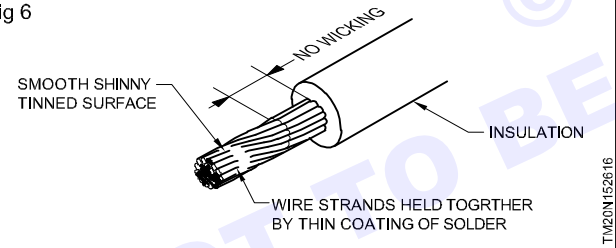
– use 16 gauge for large joints.

Tinning wires

When wires are to be connected to lugs or any other type of terminations, after skinning the wire, it is preferred to apply a thin coating of solder using a soldering iron. This process is known as tinning the wire.

When tinned, the solder penetrates the wire strands and holds them together as shown in Fig 6. This holding of strands prevents the strands from becoming separate while soldering the wire onto terminations.

Fig 6



Tinning of the wire is advised to be done soon after stripping of the wire end, so that the wire strands do not tarnish.

Care must be taken when tinning a wire to ensure that capillary action does not draw the solder under the unstriped insulation. This action is called wicking. A special tool known as anti-wicking tweezers shown in Fig 7 can be used to help prevent wicking. A wire that has wicked under the insulation must be cut off and the tinning process repeated.

Inspecting tinned wires

When a wire has been tinned, it is necessary to inspect the tinned wire to ensure that:

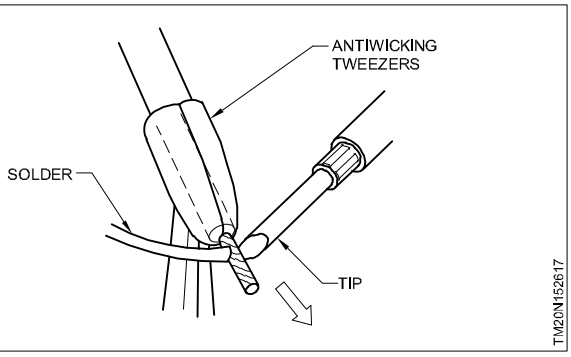
– the solder has not wicked under the insulation

– the insulation on the wire is not melted or burnt

– the wire strands are visible beneath the solder

– the tinned surface is smooth and shiny.

Fig 7

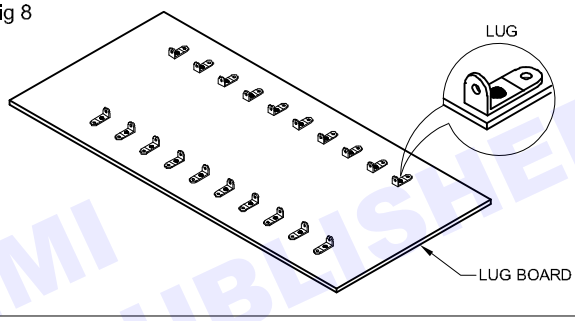


If the tinned wire does not meet these standards, that portion of the wire must be cut. The wire must be re-skinned and tinned.

Lug Boards

A typical lug board shown in Fig 8 is made up of lugs generally riveted on hylam sheet. Lugs are generally made of tinned copper or brass for the ease of soldering.

Fig 8



Boards with lug terminals are often used to wire

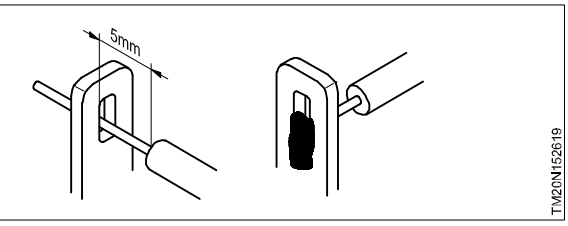
- small circuits for test purposes
- circuits using large/heavy components
- circuits expected to carry heavy current.

On lug boards, the circuit components are connected directly on to the lugs, and lug-to lug interconnections are carried out by single strand or multi-strand wires. In many cases, several components or wires are connected to one lug terminal.

There are two methods of connecting a component or wire to the lugs.

1 The component lead or wire enters the lug at right angles. This is called side entry method as shown in Fig 9.

Fig 9

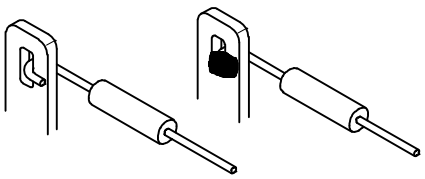


2 This component lead or wire entres in line with the lug. This called edge entry method as shown in Fig 10.

Side entry method: It is easier to de-solder the component or wire without much damage to the component or wire. Hence the side entry method is more commonly used compared to the edge entry method.

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Fig 10



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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 **De--Soldering the connection -** this action involves removal of the solder from a joint

2 **Removal of the component -** this action involves removing the component lead from the joint.

De-soldering the connection: De-soldering is a process of heating a soldered joint, to melt the existing solder and removing the molten solder from the joint.

De-soldering makes it easy to separate or pull-out the components, wires from the joint without unnecessary damage to the components and wires.

The heat required to melt the solder is supplied by a soldering iron. But removal of the molten solder from the joint requires the use of one of the following;

– Plunger de-soldering tool or desoldering pump

– Wicking braid

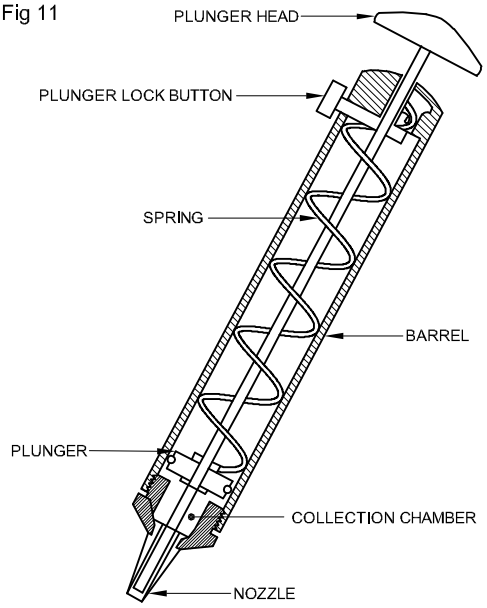
But, in many cases, desoldering is done using a nose player and a soldering iron. First, the joint to be disconnected is heated using the soldering iron. Once the solder at the joint melts, the component lead is pulled away using a nose player. This method of desoldering can be used for heavy components 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 likely hood of component getting overheated or the leads getting cut or leads getting detached from the body of the component.

Plungerde-soldering tool

A typical plunger de-soldering tool is shown in Fig 11.

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 as shown in Fig 12, it gets locked inside with the help of the plunger button. This is known as cocking tool.

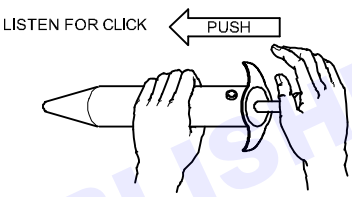
Fig 11



PLUNGER DESOLDERING TOOL

TM20N15261B

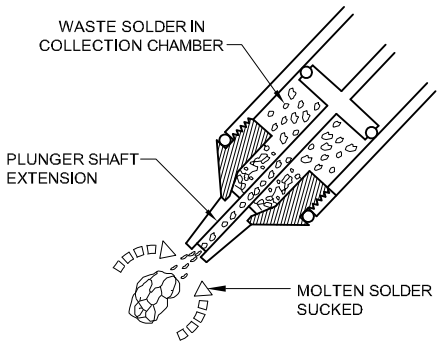
Fig 12



TM20N15261C

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 as shown in Fig 13.

Fig 13



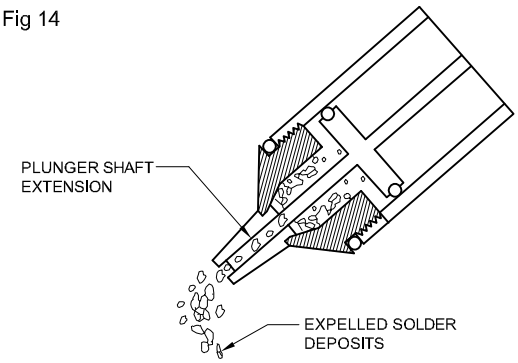
TM20N15261D

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 as shown in Fig 14.

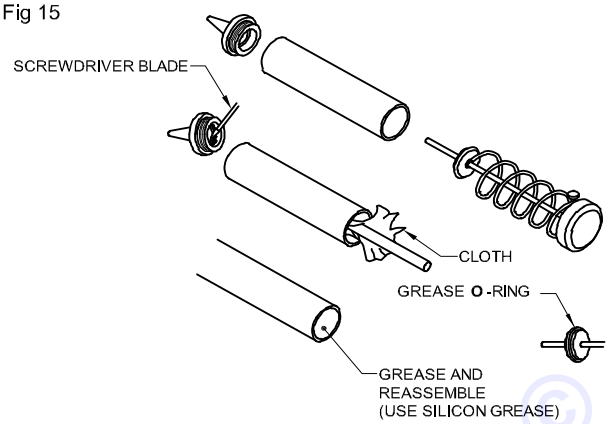
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Fig 14



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 as shown in Fig 15.

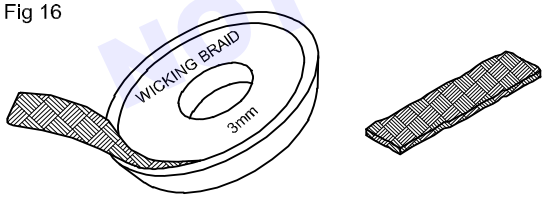
Fig 15



Wicking braid

Wicking braid as shown in Fig 16 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 as shown in Fig 16.

Fig 16



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 17a, the molten solder gets drawn into the wicking braid as shown in Fig 17b. 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 as shown in Fig 18.

Fig 17

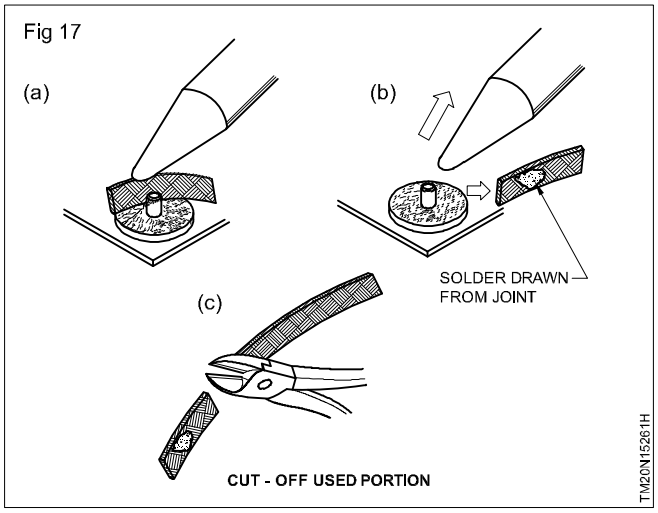
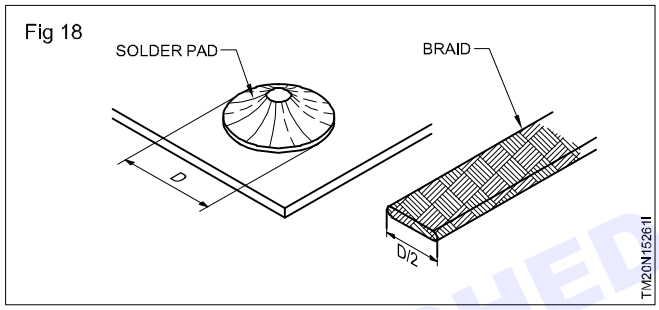


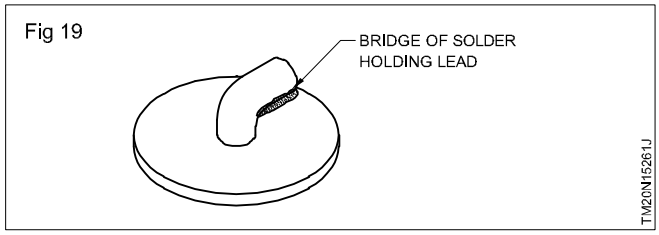
Fig 18



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* as shown in Fig 19, it is essential to remove the bridge of solder holding the lead.

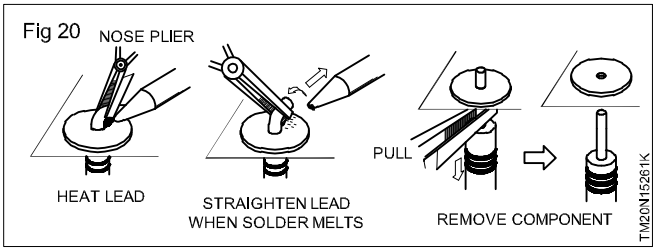
Fig 19



To remove the solder bridge, follow the steps shown in Fig 20

There are other special tools used for de-soldering such as De-soldering iron and multi-contact de-soldering block.

Fig 20



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Single range electric meters/panel meters

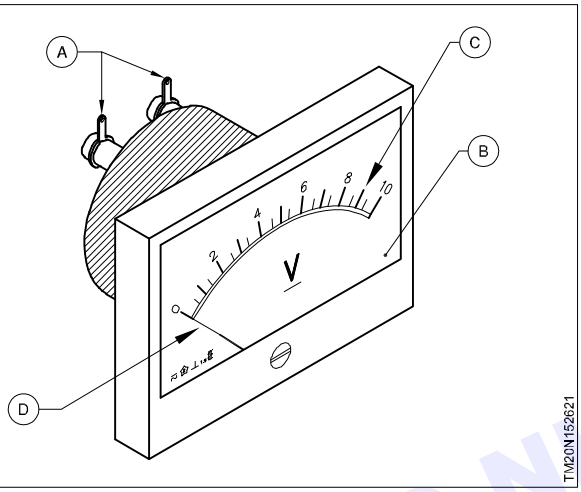
Objectives: At the end of this lesson you shall be able to
- **state the use of meters**
- **list the basic parts of a simple meter**
- **list the minimum specifications that go with any meter**
- **list the symbols used on meter dial and interpret their meaning.**

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

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

A simple meter is shown in Fig 1.

Fig 1



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

Any simple meter must have the following minimum specifications.

1 The electrical parameter it can measure.

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

2 The maximum quantity that it can measure.

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

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

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

V for measuring voltage

~ for measuring AC.

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

Example 2: A symbol $\underset{\sim}{V}$ on the meter dial indicates,

V for measuring voltage

~ for measuring $\tilde{A}C$

_ for measuring DC.

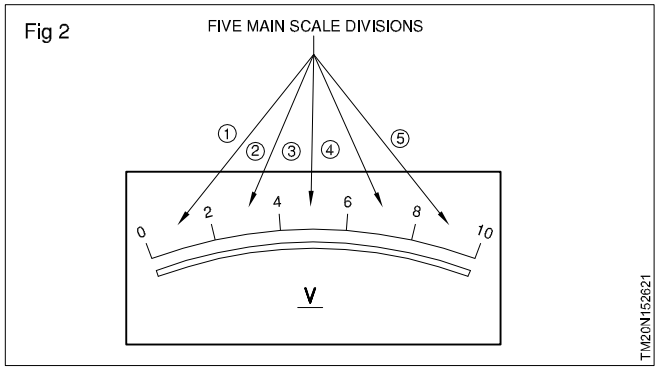
This means, a meter with $\underset{\simeq}{\mathbf{V}}$ symbol is for measuring AC and DC voltages.

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

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

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

Fig 2



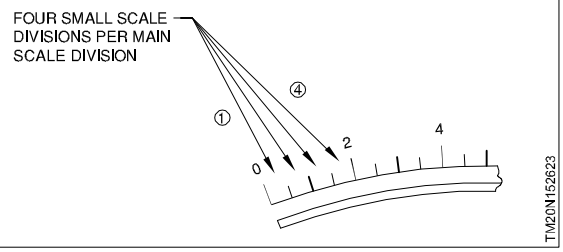
Each small scale division therefore corresponds to,

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

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

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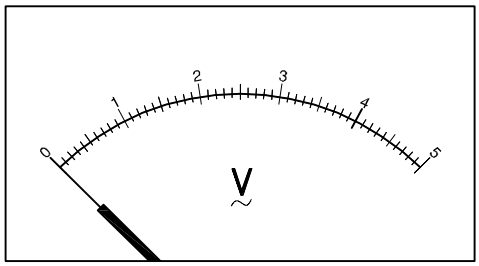
Fig 3



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

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

Fig 4



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

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

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

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

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

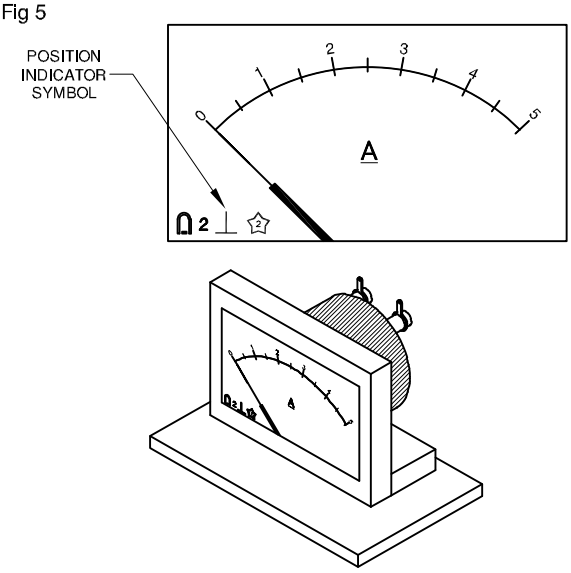
On the dial scale of any meter, in addition to the symbols indicating the electrical parameter (voltage, current etc) it can measure and the type of parameter (AC, DC, AC/DC), there are several other symbols. One of the important symbols to be identified before using the meter is the **position symbol**.

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

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

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

Fig 5



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

Classroom exercise

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

i the nature and type of electrical parameter it can measure

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

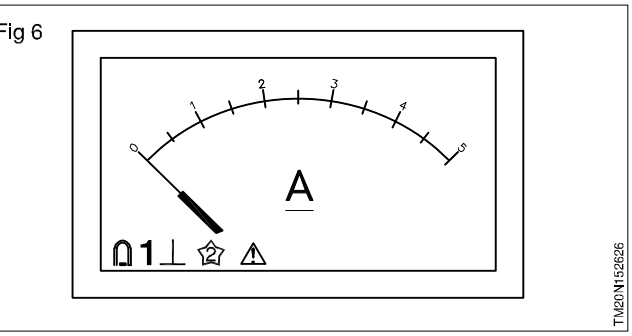
iii the type of mechanism used for the pointer movement

iv the percentage of error indicated in the meter reading

v the maximum test voltage that can be applied

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

Fig 6

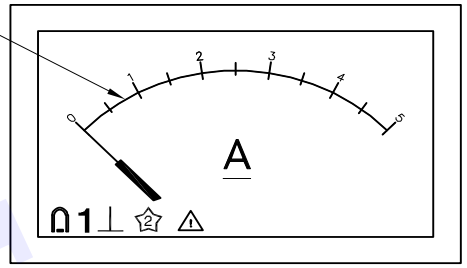


The meters discussed so far, can measure only one range of values. The meter shown in Fig 1 can measure 0 to 10 volts. The meter shown in Fig 4 can measure 0 to 5 volts. Such meters are called **Single range meters**. These meters are generally mounted on electrical panels, and on the front panel of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

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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
	VERTICAL POSITION PERMISSIBLE DEPARTURE ± 2° FROM VERTICAL POSITION
	HORIZONTAL POSITION
	HORIZONTAL POSITION PERMISSIBLE DEPARTURE ± 10 ° FROM HORIZONTAL POSITION
60°	INCLINED POSITION ANGLE OF INCLINATION 60° FROM HORIZONTAL

Indicates special instructions that go with the meter.

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

Indicates special instructions that go with the meter.

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

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Multi-range meters and multi-function meters/multimeters

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

- **state the advantages of multi-range meters over single range meters**
- **state the basic working principle of a multimeter**
- **state the steps to be followed while using multi-range and multi-meters**
- **state the method of identification of the different scales of a multi-meter**
- **state the difference between mechanical and resistance zero setting in multimeters.**

Multi-range meters

Test instruments used to measure the most common electrical parameters are;

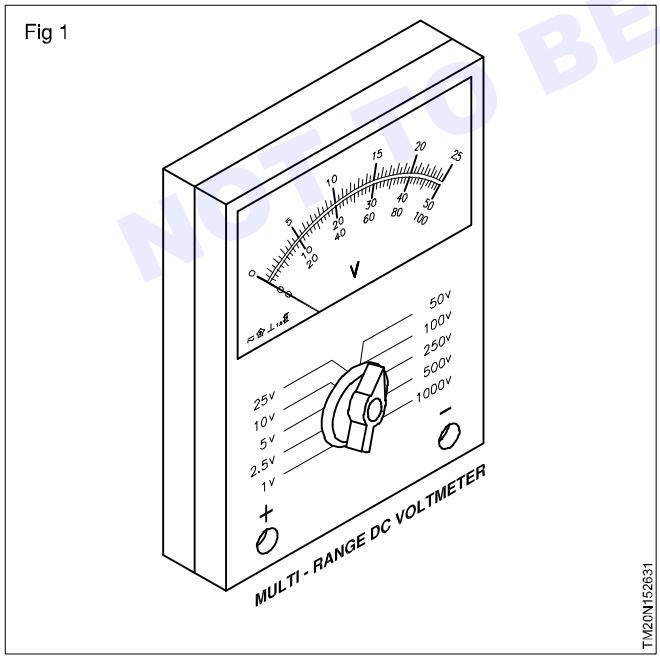
Voltmeter	-	to measure	- **voltage**
Ammeter or current meter	-	to measure	- **current**
Ohmmeter	-	to measure	- **resis-tance.**

Single range meters discussed in lesson 3.08 had the draw-back that one single range meter can be used for measuring only one range of voltage, current or resistance. For example: A 0-5V DC single range meter, used to measure 1.5 volt cells, cannot be used to measure a 9 volt battery. A separate 10 volts range meter has to be used to measure a 9V cell.

In general, to measure a wide range of values, several single meters need to be used. To overcome this limitation, meters are designed, which can measure a wide range of values with the help of a range switch. Such meters are called **multi range meters**. Fig 1 shows a typical multi-range DC voltmeter.

The meter shown in Fig 1 can be used as *ten independent single range voltmeters* as given below:

Fig 1



With a control switch put in,

1 volt position - the meter can measure from 0 to 1 V.

2.5 volt position - the meter can measure from 0 to 2.5 V.

10 volt position - the meter can measure from 0 to 10 V.

.....

.....

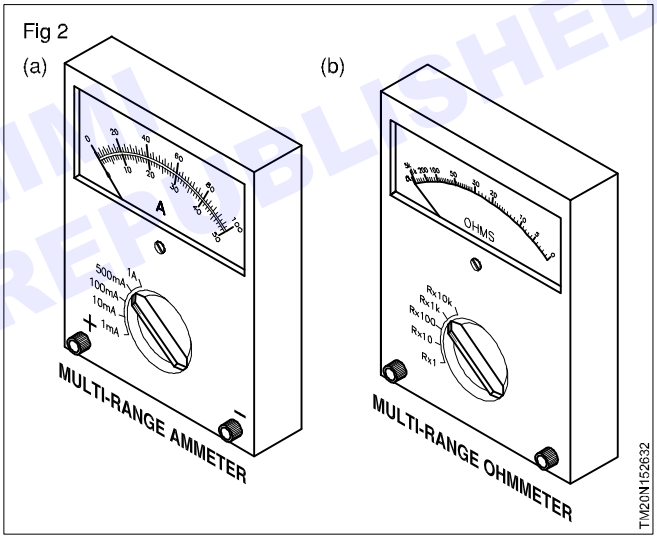
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1000 volt position - the meter can measure from 0 to 1000 V.

Such multi-range meters are preferred when wide range of voltages are to be measured.

Multi-range ammeters and ohmmeters are also available in the market for the measurement of a wide range of currents and resistances as shown in Fig 2a and Fig 2b

Fig 2



Meter scales of multi-range meters

Multi-range meters may have more than one graduated scale as shown in Fig 1. Some multi-range meter may have a single common scale has to be used for all ranges while taking readings as shown in Fig 3.

In the meter at Fig 3, when the control switch is put to 1 volt range position, the meter gives full scale deflection(FSD) for 1 volt. Hence the scale end marking of 100 on the meter scale should be treated as 1 volt.

Similarly when the control switch is put to 10 volts position, the scale end marking of 100 should be taken as 10 and so on...

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The other method of taking readings is by using the table given below.

Range switch position	Scale reading shown	X or ÷	Correct reading
100	36	X 1	36
1000	36	X 10	360
10	36	÷ 10	3.6
1	36	÷ 100	0.36

Readings given in Table above is for the pointer position as shown in Fig 3.

Fig 3

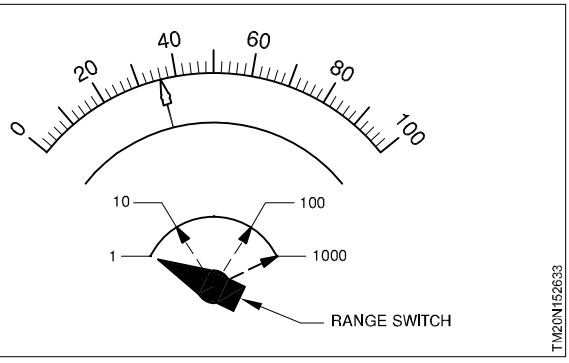
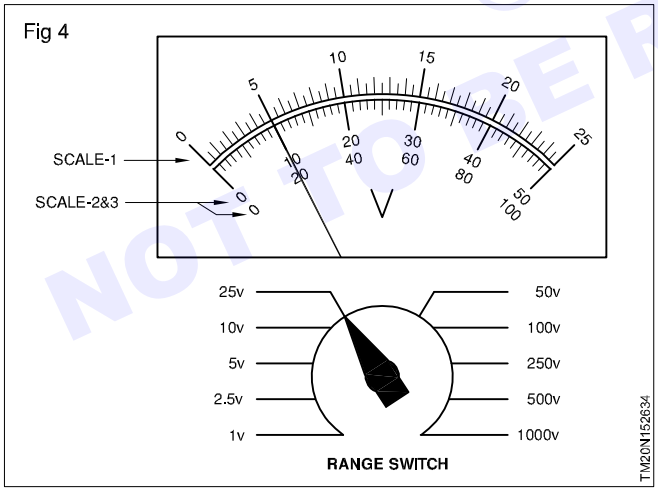


Fig 4 shows a multi-range meter having more than one scale.

In the meter at Fig 4, depending upon the range selected, the most suitable scale is to be chosen for taking the readings.

Fig 4



For example: If the range switch is put to 25 volts, the topmost scale, wherein, the number at the end of the scale is 25, is to be chosen. If the range switch is set to 2.5 volts or 250 volts, still the scale with 25 at the end is the most suitable because instead of reading the end scale as 25, it can be treated as 2.5 or 250 volts respectively and the readings can be taken easily.

Similarly

– Use the scale with 50 at the end(FSD) for the control switch settings of 5 , 50 and 500.

– Use the scale with 100 at the end (FSD) for control switch settings of 1 , 10 , 100 and 1000.

Multi-meter

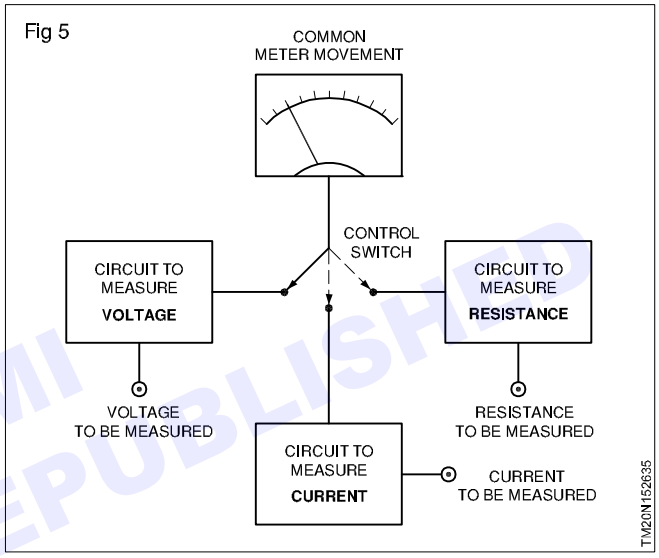
The voltmeter, ammeter and ohmmeter although used for measuring different electrical parameters - all these metres use the same basic type of meter movement called the D'Arsonval movement (named after its inventor). The difference between these instruments while measuring different electrical parameters are;

– the circuit associated with the meter movement

– the graduations/markings on its meter scale.

It is, therefore, possible to design an instrument having a common meter movement, with three different circuits, for measuring voltage, current, resistance. A control switch will be necessary to connect any one of the three circuits to the common meter movement as shown in Fig 5.

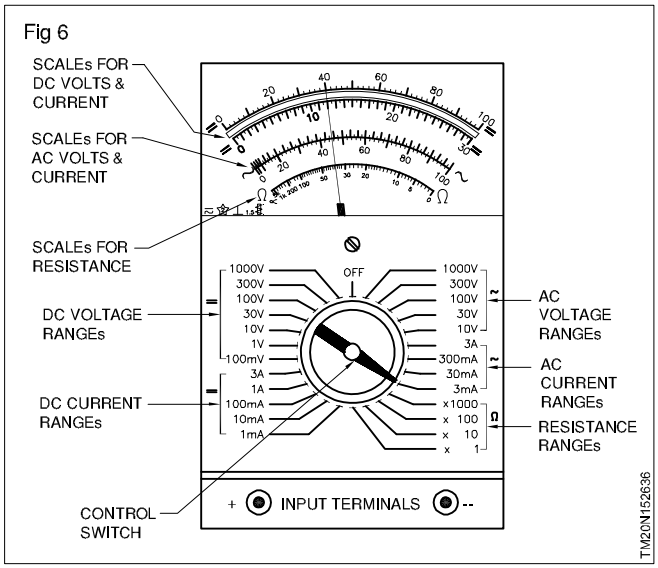
Fig 5



Such an instrument which can be used to measure voltage, current and resistance is called a **Volt - Ohm - milliammeter** or **VOM** or more commonly known as **multi-meter**. Fig 6 shows a typical multi-meter.

The multimeter used in your institute may have a different front panel design than shown in Fig 6. But the function will remain almost same.

Fig 6



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In the multimeter shown in Fig 6, following steps are to be followed to measure DC voltages.

First : Know the approximate voltage to be measured.

Second: Put the control switch to the most suitable DC volts range.

While measuring unknown voltage levels, always set the range switch to the highest available range and work down from there. This avoids damage to meter.

Third: Identify the most suitable scale on which the readings are to be taken corresponding to the chosen range.

Fourth: Find the value of one small scale division of the scale.

Fifth: Give the voltage to be measured to the meter using the meter probes with correct polarity.

Sixth: Read the indicated voltage on the scale.

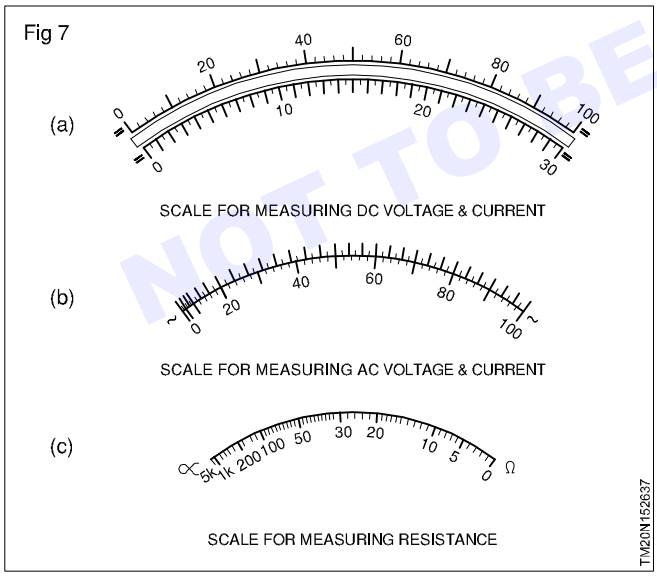
Identifying the scale to take readings

In almost all meters, the symbol of the electrical parameter for which the particular scale is to be used will be given either at the beginning, or at the end, or at both places as shown in Figs 7a, b, c.

The symbol "=" at the beginning and end of scale shown in Fig 7a indicates that this scale should be used for DC voltages and current.

Similarly, Fig 7b shows the scale to be used for AC voltage and current and Fig 7c for resistance.

Fig 7

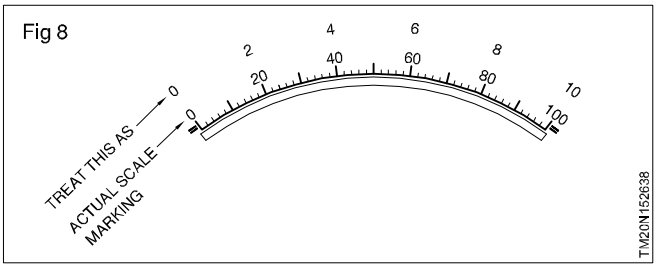


In the scale meant for taking readings for a particular parameter (say DC voltage) may itself have more than one scale for the convenience of taking readings in different range positions.

For example, the scale to be used for DC voltages shown in Fig 7a itself has two scales 0-100 and 0-30. Of these two scales, depending upon the range switch position selected, readings will have to be taken on any one scale.

Example 1: In the multimeter at Fig 6, if the range switch is put to 10 V position, choose 0-100 scale. Treat the maximum marking 100 as 10 as shown in Fig 8.

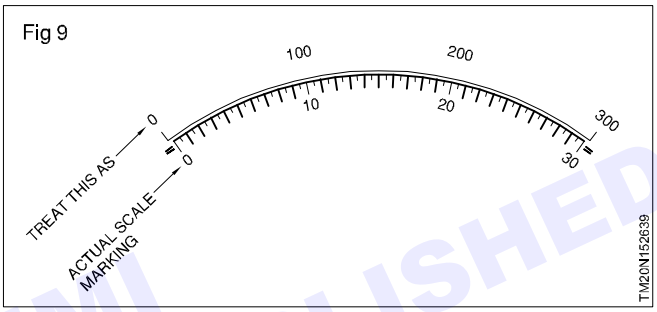
Fig 8



Here each SSD on meter scale corresponds to 0.2 volts and hence it is accurate as well as easy to take the readings.

Example 2: Referring to Fig 6, if the range switch is put to 300 volts position, choose 0-30 scale. Treat the maximum marking 30 as 300 as shown in Fig 9.

Fig 9



Using multi-meters as voltmeter, ammeter and ohmmeter

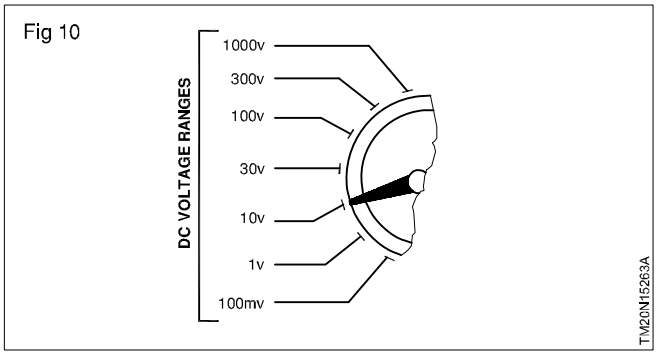
Multimeter as DC VOLTMETER

To measure a wide range of voltages the multi-meter will have several ranges under **DC volts** as shown in Fig 10. This is similar to a multi-range voltmeter. Depending on the quantity of voltage being measured the control switch can be put to the most suitable range position. Corresponding to the range selected the most suitable scale has to be chosen for taking the readings.

Example 1: Referring to Fig 10, to measure the voltage of a 1.5 V dry cell, the control switch should be put to 10 V position. This is because, the battery voltage is greater than 1 V and less than 10 V.

Since the range selected is 10 V, the most suitable scale to take reading is the scale with the marking 0 - 100.

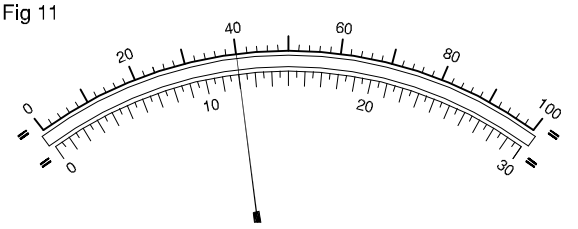
Fig 10



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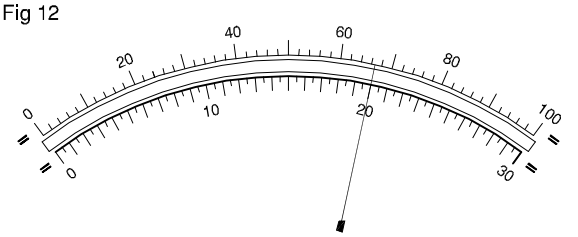
Hence, with the control switch in 10V position, if the pointer indication is as in Fig 11 the voltage indicated will be 4 volts.

Fig 11



Example 2: With the control switch in 300 volts position, if the pointer indication is as in Fig 12, the voltage indicated will be 200 volts.

Fig 12

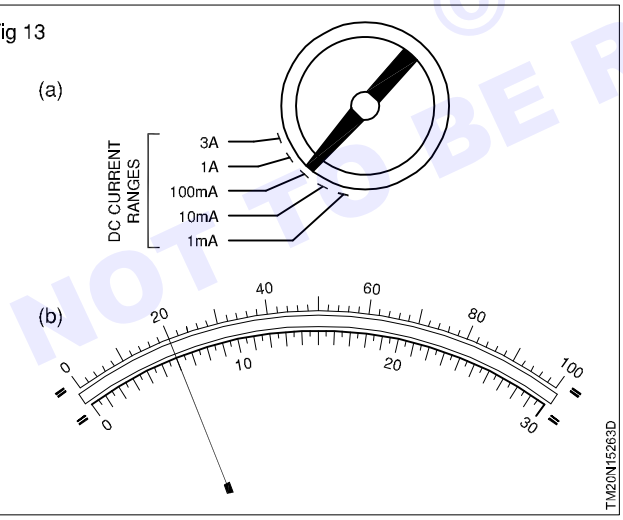


Multi-meter as DC AMMETER

To use a multi-meter as a DC ammeter, the control switch should be put to the most suitable DC current position as shown in Fig 13a. This depends upon the quantity of DC current to be measured. If in doubt put to maximum range position.

Choose the scale shown in Fig 13b to read the DC current.

Fig 13

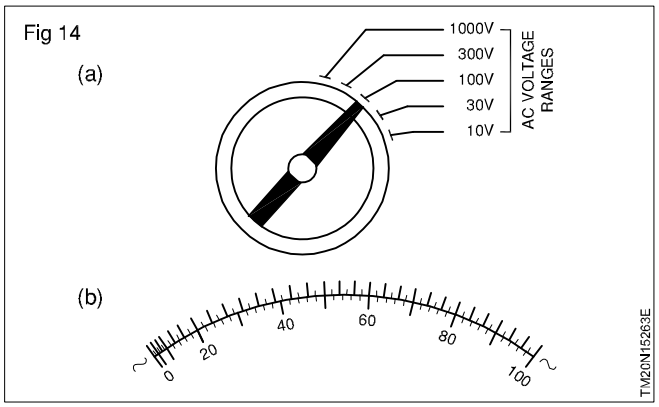


Multi-meter as AC voltmeter

To use a multi-meter as an AC voltmeter, the control switch should be put to AC volts position as shown in Fig 14a.

Choose the scale shown in Fig 14b to read the AC voltages.

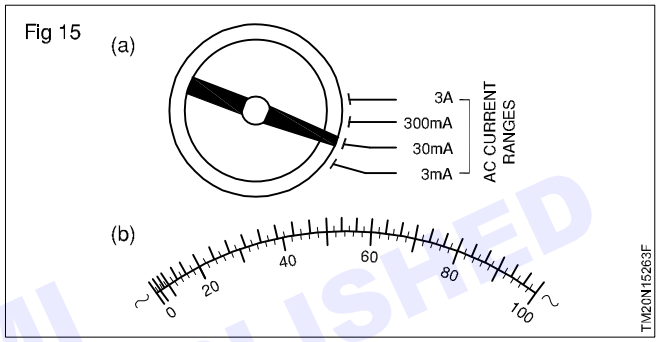
Fig 14



Multi-meter as AC ammeter

Put the control switch to AC current position and the most suitable current range as shown in Fig 15a and choose scale shown in Fig 15b.

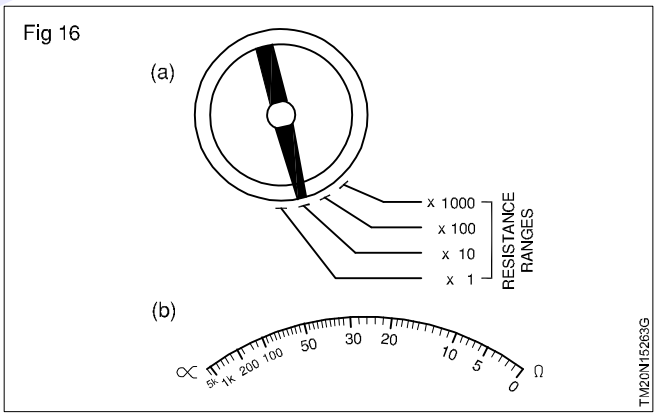
Fig 15



Multi-meter as ohm meter

Put the control switch to the most suitable OHMS (W) position as shown in Fig 16a and use the scale shown in Fig 16b.

Fig 16

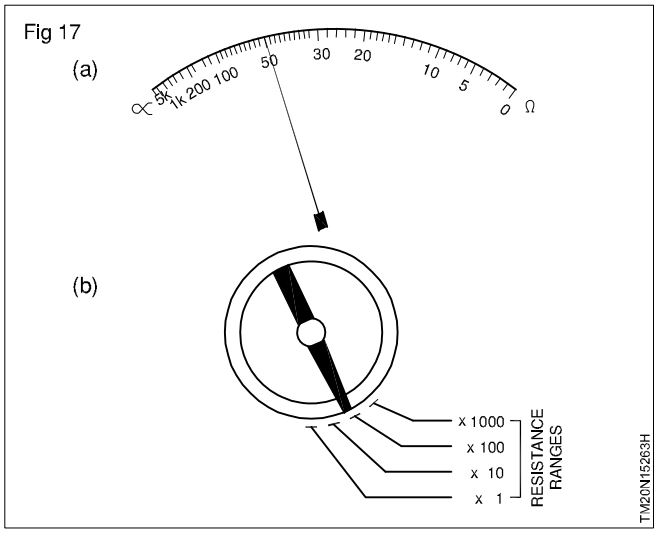


The range switch in resistance range also has different range positions to enable the measurement of a wide range of resistance values. But unlike in voltage and current range positions, these ranges are marked **x 1000, x 100** and so on. This means, whatever is the value of resistance pointed by the meter needle should be multiplied by this factor.

Example: If the meter needle shows a reading as shown in Fig 17a with the control switch in position as in Fig 17b the value indicated by the meter will be;

Meter reading = (50) x 100 = 5000 W or 5 KW.

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Resistance zero setting: One important thing to note in the scale for measuring resistance is that, the zero of the scale is on the right hand end of scale. When the meter prods are shorted, the resistance across the meter terminals is zero and the meter should indicate 0W. Sometimes the pointer may not be exactly at zero. Then, it is required to set the pointer to indicate zero. To set the pointer to zero short the meter prods and turn the *Resistance zero set knob* provided on the meter such that the pointer goes to zero. This procedure is called *resistance zero setting* of the meter.

Mechanical zero setting is to adjust errors arising due to the mechanical parts of the meter whereas **Resistance zero setting** is to adjust the meter full scale deflection due to low voltage of battery inside the meter. This adjustment is required to be carried out only when using the meter to measure resistance.

While using a multi-meter as ohmmeter, whenever you change the multiplier range position, it is advised to carry out the **Resistance zero setting** of the meter to get accurate readings.

There are several manufacturers of multi-meters and the meters differ from one another in the provided ranges and meter scales. Therefore, before using any multi-meter it is worth spending some time in studying the various ranges and scales available on the meter.

In some low cost multi-meters there will be no control knob for changing the meter range. Instead they will have a common -ve socket where the black meter prod should always be plugged in. Depending upon the range required, the +ve meter prod should be plugged into the socket provided for each range.

Resistive Circuits

Objectives: 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**
- **calculate the power dissipated in a 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.**

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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 other hand, if the applied voltage (V) across a fixed value resistor is increased, the current flowing through the resistor also increases. In other words current (I) through a resistor is directly proportional to the applied voltage(V) across the resistor.

Combining the above two relationships between resistance(R), current (I) and applied voltage(V), it can be written as,

$$I = \frac{V}{R}$$

This relationship of I = V/R was found by the scientist *George Simon Ohm* and hence this is referred to as *ohm's law.*

The relationship of I = V/R can be expressed mathematically in different forms as

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

These formulas are used invariably while designing or testing electrical/electronic circuits.

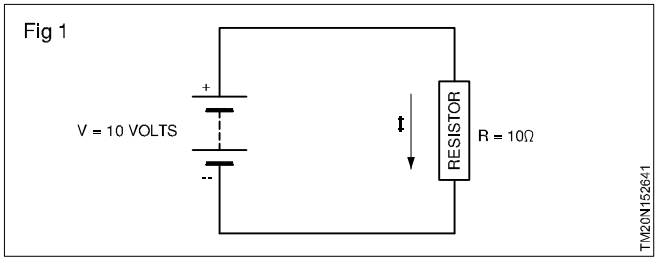
Generalising, ohm's law can be stated as follows

Under a given constant temperature, the current flowing through a resistor is directly proportional to the voltage across the resistor and inversely proportional to the value of resistance.

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

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

Fig 1



Solution

Applied voltage across the resistor is : 10 volts

Resistance value of the resistor is given as 10 ohms.

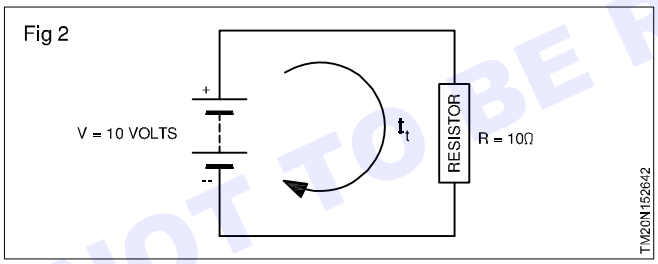
Therefore current(I) through the resistor by Ohm's law is;

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

Current through the resistor is 1 ampere.

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

In the given circuit ,

total applied voltage = 10 volts.

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

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

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

Resistors in series

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

Total resistance of resistors in series

When resistors are connected in series, the total resistance of the series connection will be equal to, the sum of individual resistance values. In Fig 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,

(R_1 and R_2 are connected in series).

$= R_1 + R_2$

$= 1.0 \text{ K W} + 2.2 \text{ K W} = 3.2 \text{ K W.}$

Current through a series circuit

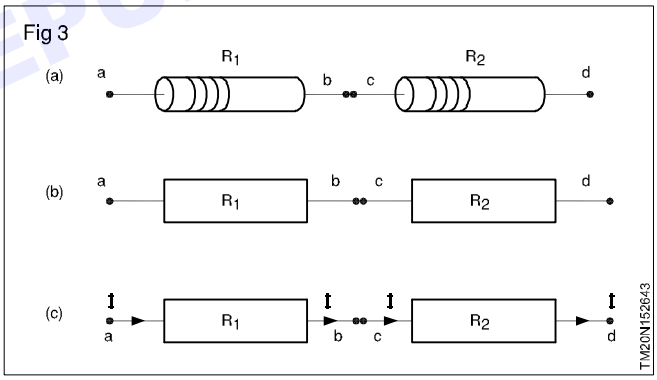
When resistors are connected in series as shown in Fig 3, the current that flows through R_1 can only flow through R_2 . This is because

– 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.

Fig 3



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.

Circuit current I_t

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

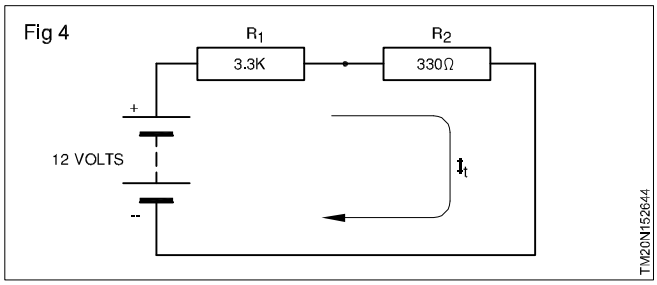
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Example: Calculate the voltage drops across R_1 and R_2 for the circuit at Fig 4.

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.

Fig 4



From Ohm's Law

Therefore the voltage drop across R_1

= I x R_1 volts

= 3.3 mAmps x 3.3 kilo ohms

= $(3.3 \times 10^{-3}) \times (3.3 \times 10^{3})$

= 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.

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

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

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

= 1000×10^{-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.

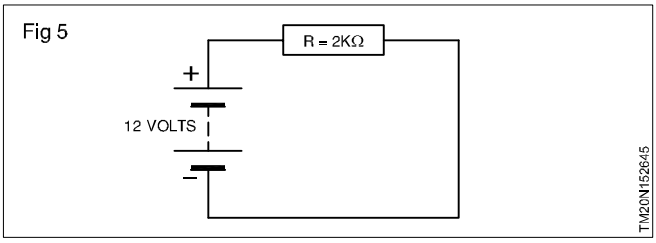
Solution

Method 1

Current through the circuit is I_t = V/R

= 12V/ 2 KW = 6 mA

Fig 5



Power dissipated by the circuit is

= (circuit current)^2 x circuit resistance

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

= 72×10^{-3} watts

= 72 milli-watts = 0.072 watts.

Method 2

Power dissipated is given by,

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

From Ohm's law

substituting this in equation .....[1]

$$I = \frac{V}{R}$$

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 = (6×10^{-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.

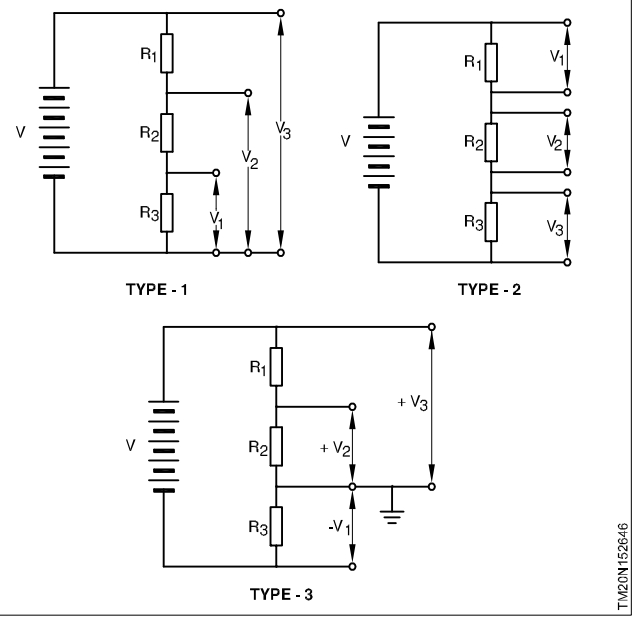
Try to derive alternative formulas for calculating power.

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.

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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.

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

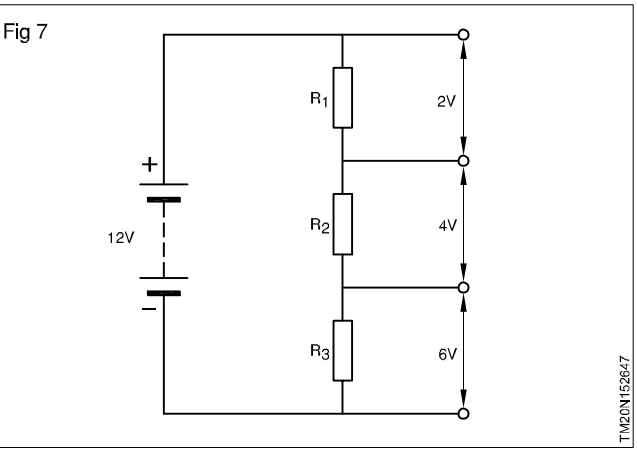
Easier method [Ratio method]

Find the ratio of the three different voltages required:

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

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

Fig 7



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.

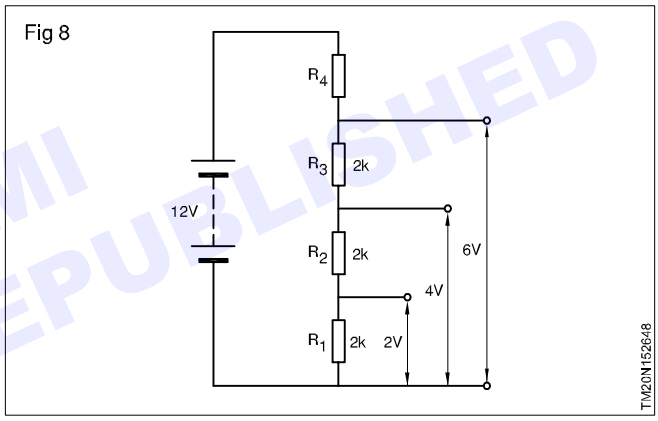
2x3K ohms = 6 K ohms. This is the value required to drop 6 volts.

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.

Discuss merits and demerits of the above two designs.

Fig 8

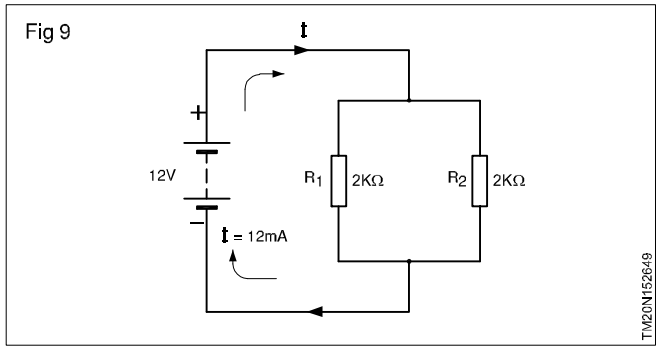


Resistors in parallel

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.

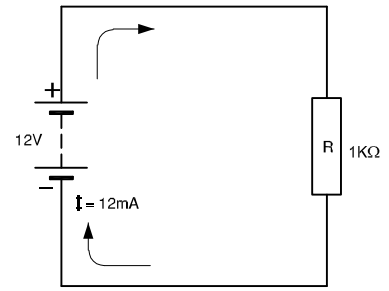
This means that, the two resistors connected in parallel as shown in Fig 9 has effective or total resistance equal to that of a single resistor that is shown in Fig 10.

Fig 9



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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,

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

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

or

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 1KW 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 KW and 100 W each are connected in parallel, from the thumb rule, the effective resistance will less than 100W.

Verification

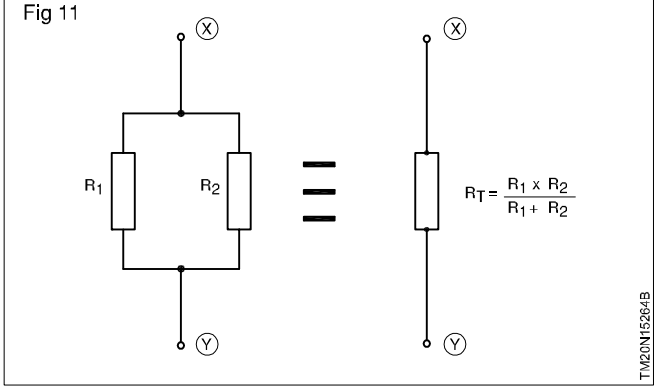
From the formula derived above, $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$

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

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?

Fig 11



Solution

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

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

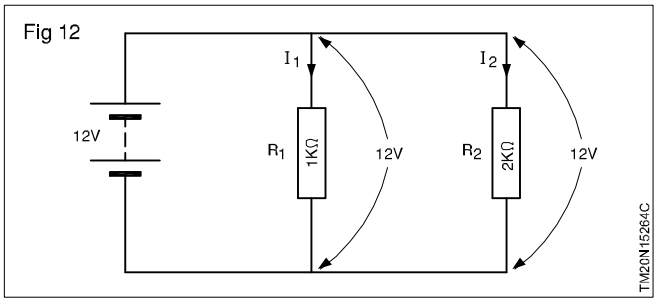
Effective resistance of 10 ohms & 1 K ohm in parallel is 9.9 ohms or approximately 10 ohms. From this, it can be understood when a very small value resistor is connected in parallel with a very large resistor, the effective resistance of the parallel connection will be approximately equal to the values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

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

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

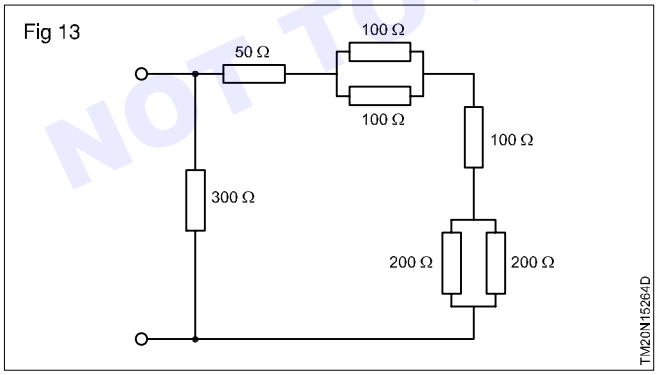
Circuit current $I_t = I_1 + I_2$

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

Power consumed by the circuit = $I_t^2 \times R_T$
$= (0.018)^2 \times (666.7)$
= 0.216 watts
= 216 mwatts

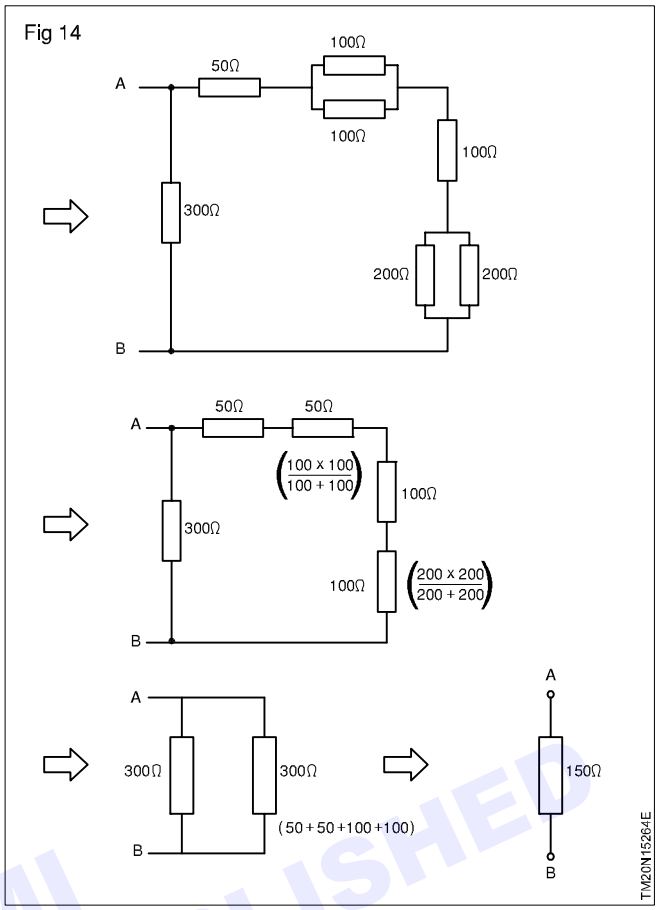
Series - parallel resistor circuits

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.



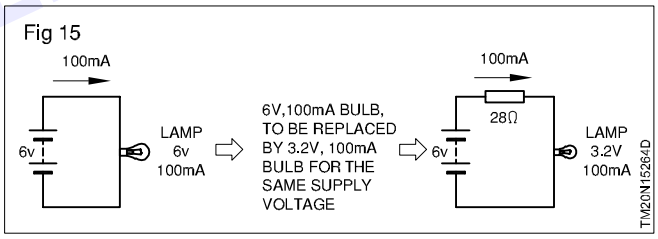
To find the effective resistance of such series-parallel circuits, follow the steps illustrated in Fig 14.

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.

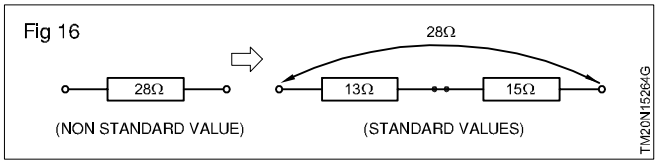


Some applications of series, parallel and series-parallel connection of resistors in circuit.

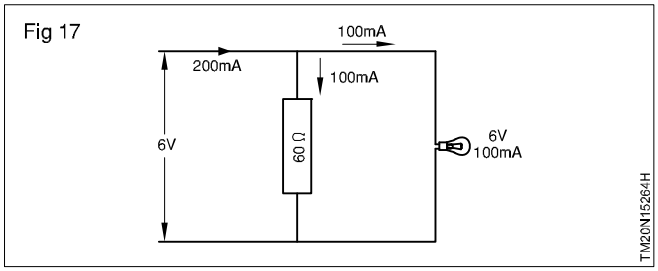
1 Series resistor to drop excess voltage. (Fig 15)



2 Series resistor to obtain non-standard resistor values. (Fig 16)

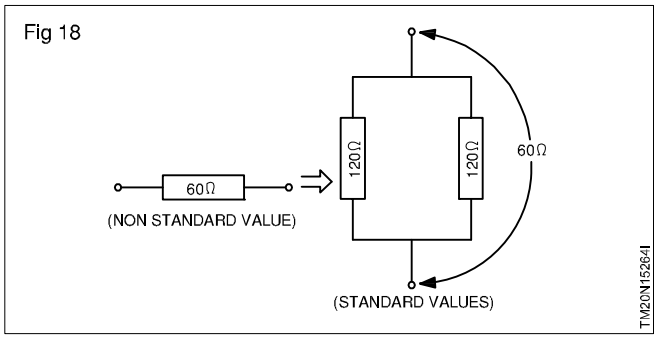


3 Parallel resistor used to divert excess circuit current. (Fig 17)



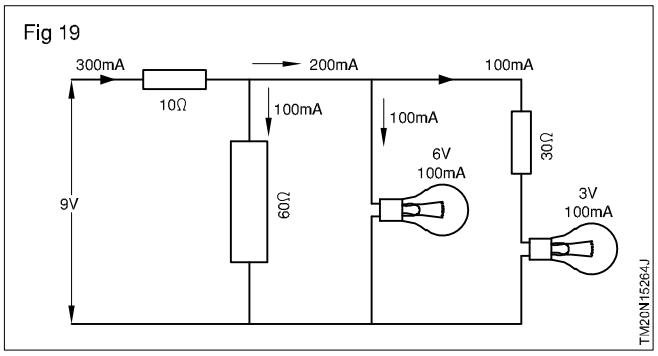
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4 Parallel resistor to obtain non-standard resistor values. (Fig 18)



5 Resistors in series, parallel to drop voltage and divert current. (Fig 19)

[H.I.Discus the circuit given at Figs 15 to 19.]



Passive electronic components

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

- **state difference between the passive and active components**
- **explain the types of resistors, and their coding**
- **explain the types of capacitors and methods of testing (R)**
- **explain the types of inductors and their applications**

Resistors: The Components used in electronic circuits can broadly grouped under two headings.

– passive components

– active components

Passive components: Components like resistors, capacitors, and inductors used in electronic circuit are called as passive components. These components by themselves are not capable of amplifying or processing an electrical signal. However these components are equally important in electronic circuit as that of active components, without the aid of passive components, a transistor (active components) cannot be made to amplify electrical signal.

Circuits formed with passive components obey the electrical circuits laws such as ohm's law, Kirchoff's Laws etc.,

Active components: In electronic circuit, the components, other than passive are known as active components. Namely, transistors, diodes, SCRs Vacuum tubes etc.,

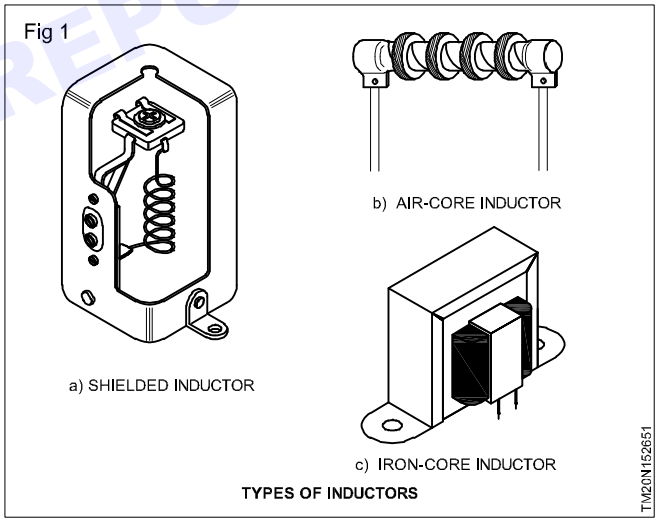
Resistors : The components whose purpose to introduce resistance in the circuit is called as resistors. Other details of resistors are dealt in earlier lessons.

Capacitor: The components whose purpose to introduce capacitance in the circuit is called as capacitor. The unit of capacitance is 'FARAD'. Commercially capacitors are available in micro farad (μF), nanofarad (nf) and pico farads (pf).

The colour coding of capacitors and resistors are same. Where as, in the case of fixed capacitors, the colour coded unit shall be in pico farads.

For letter coding, in case of capacitor, the letter 'p', 'n', 'm' shall be used as multipliers. Where p = 10^{-12}, n= 10^{-9} and m = 10^{-6} farads, and letter code for tolerance on capacitor is the same as in resistor.

Inductor: The ability of the conductor to induce voltage in itself, when the current changes in it is called as self inductance (or) simply inductance. A coil introduced in a circuit to have inductance is called as inductor. Different type of inductors as shown in Fig 1. The unit of inductance is "Henry". Commercially a coil may have inductance in milli/henry (10^{-3}H), or in micro henry (10^{-6}H).



While specifying the inductance the following factors to be considered

- nominal value of inductance in Henry / milli/henry / micro (m) henry
- tolerance in percentage (±5/10/20%)
- type of winding like single layer, double layer, multilayer and pie (p) etc.
- type of core like air core, iron core, ferrite core
- type of application like audio frequency (AF), Radio frequency (RF) coupling coil, filter coil etc.,

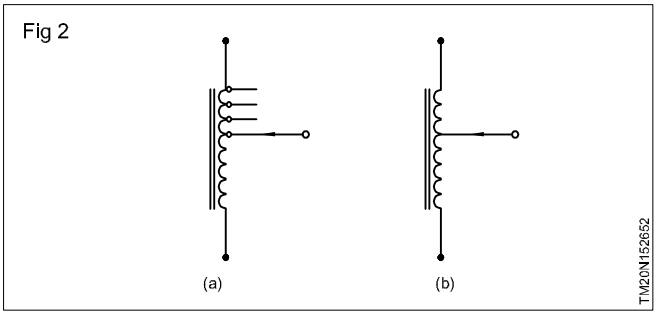
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In an electronic circuit some time, it is also required to vary the inductance.

The inductance of a coil can be varied by

– providing tapped inductive coil, as shown in Fig 2 or

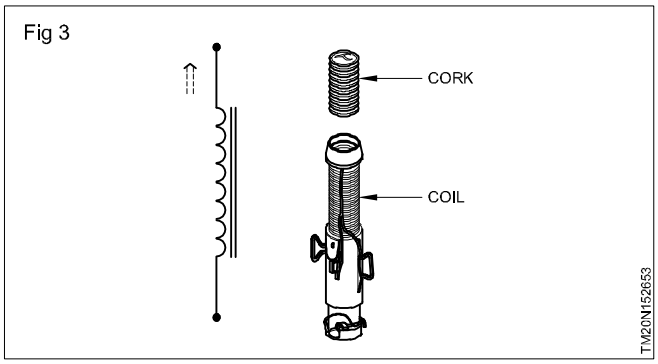
Fig 2



– adjusting the core of a coil as shown in Fig 3.

However, all inductor coils have inherent resistance due to the resistance of the winding wire in the coil. Further the maximum current that can be safely carried by an inductor depends upon the size of the winding wire used.

Fig 3



Semi conductors - Atomic structure

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

- **define the terms: intrinsic and extrinsic semiconductor, N type and P type material, dopping, holes, electrons impurity**
- **describe the atomic structure of semiconductor materials - silicon and germanium**
- **name the three types of bonding in solids with one example.**

The very tiny fundamental unit of an element which is capable of independent existence is the atom. An atom of any element consists of a central core called Nucleus. A number of small particles called electrons move around the central core. The nucleus contains protons and neutrons. A proton in the nucleus possess a positive electrical charge. An electron in an atom possess negative electrical charge. In normal state, the atom is electrically neutral, that is the number of electrons is equal to the number of protons in the nucleus.

For stability of materials (solids), the valence (outer most) shell of an atom should contain either 8 or more number of electrons, if it is to be complete. The above stability keeps the atoms and the molecules together in a solid state.

There are three important kinds of bonding amongst the atoms and the molecules of a solid. They are i) ionic ii) covalent and iii) metallic bonds.

Examples of solids under different bondings are,

Ionic bond	:	sodium chloride
Covalent bond	:	silicon and germanium
Metallic bond	:	metals like copper

Difference between conductors insulators and semi conductors: We are familiar with conducting and insulating materials. Conducting materials are good conductors of electricity. Insulating materials are bad conductors of electricity. There is another group of materials called as semiconductors, such as Germanimum and silicon. These are neither good conductors nor good insulators. On conductors the valence electrons are always free. In an insulator the valence electrons are always bound. Whereas in semi conductors 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.

Semi conductors - Atomic structure : Germanium (Ge) and silicon (Si) are examples of semi conductors. Fig 1a shows a germanium atom. In the centre is a nucleus with 32 protons. The revolving electrons have distributed themselves in different orbits. There are 2 electrons in the first orbit, 8 electrons in the second orbit, and 18 electrons in the third orbit. The fourth orbit is the outer or valence orbit which contains 4 electrons.

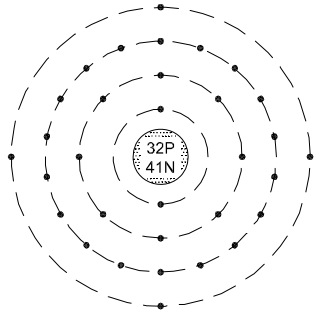
Fig 1b shows a silicon atom. It has 14 protons in the nucleus and 14 electrons in orbit. There are 2 electrons in the first orbit and 8 in the second orbit. The remaining 4 electrons are in the outer or valence orbit.

In semiconductor materials, the atoms are arranged in an orderly pattern called a crystal lattice structure. If a pure silicon crystal is examined we find that the four electrons in the outer (valence) shell of an atom is shared by the neighbouring atoms as shown in Fig 2.

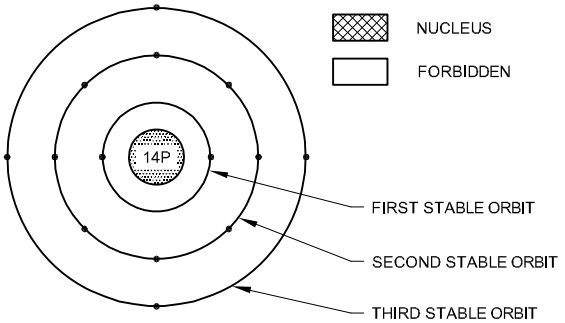
The union of atoms sharing the valence electrons is called a **covalent band**. That means a valence electron being shared by two adjacent atoms. Each atom appears to have a full outer shell of eight electrons.

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Fig 1



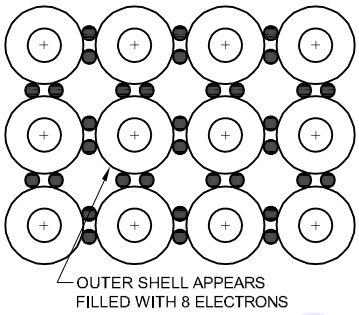
(A) GERMANIUM ATOM (32)



(B) SILICON ATOM (14)

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Fig 2



CRYSTAL LATTICE STRUCTURE OF SILICON ATOMS

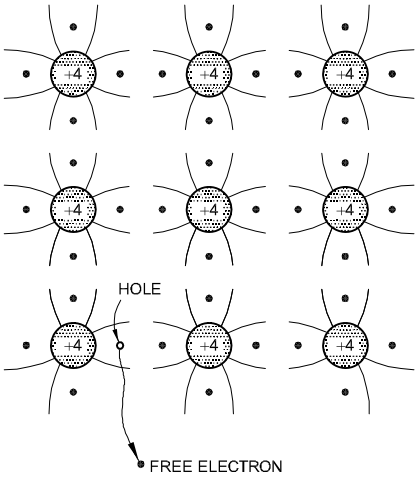
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Types of semiconductors: A pure semiconductor is called an intrinsic semiconductor. For example, a silicon crystal is an intrinsic semiconductor because every atom in the crystal is a silicon atom. One way to increase conductivity in a semiconductor is by **'doping'**. This means adding impurity atoms to an intrinsic semiconductor. The doped semi-conductor is known as an extrinsic semiconductor.

The residual heat at room temperature (300K) is sufficient to make a valence electron of an intrinsic semiconductor to move away from the covalent bond and then the covalent bond is broken, and the electron becomes a free electron to move in the crystal. This is shown in Fig 3. When an electron breaks a covalent bond and moves away, a vacancy is created in the broken covalent bond. This vacancy is called a 'hole'. A hole has a positive charge. When a free electron is liberated, a hole is created.

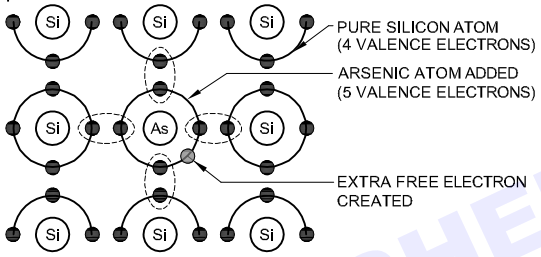
N - type semiconductor: A semiconductor with excess of electrons is called N-type. To obtain excess free electrons, the element doped with the semiconductor material is arsenic, or antimony or phosphorus. Each of these atoms has five electrons in its outer orbit. (Fig 4)

Fig 3



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Fig 4



FORMATION OF 'N' TYPE SEMICONDUCTOR

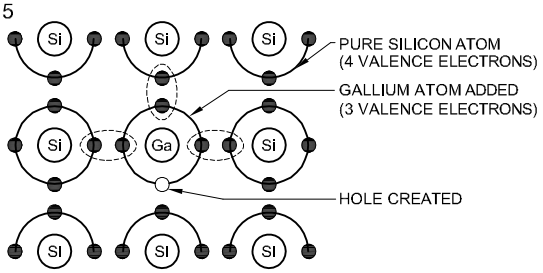
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Because the outer orbits of the atoms can hold eight electrons, no hole is available for the fifth electron in the arsenic atoms to move into. It, therefore, becomes a free electron. The number of such free electrons is controlled by the amount of arsenic added to the crystals.

In N-type, the free electrons are called the **majority** carriers, and the holes minority carriers.

P-type semiconductor: To obtain more holes, a pure silicon crystal is doped with elements such as aluminum or boron or gallium. The atoms of each of these elements have three electrons only in their outer orbit. Adding gallium to pure silicon crystals allows the atoms of the two elements to share seven electrons. (Fig 5) A hole is created in the place of the eighth electron. Now that the number of holes exceeds the number of free electrons the substance becomes 'P' type material. The holes in P-type are the **majority** carriers, and the free electrons are the minority carriers.

Fig 5



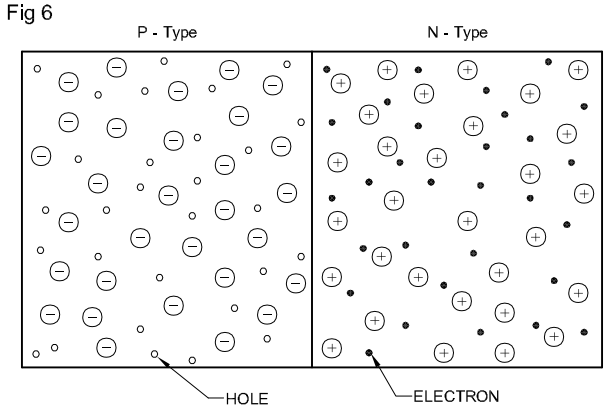
FORMATION OF 'P' TYPE SEMICONDUCTOR

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PN Junction: A PN junction is formed by combining P and N type materials. The surface where they meet is called the PN junction. A PN junction is illustrated in Fig 6.

Fig 6

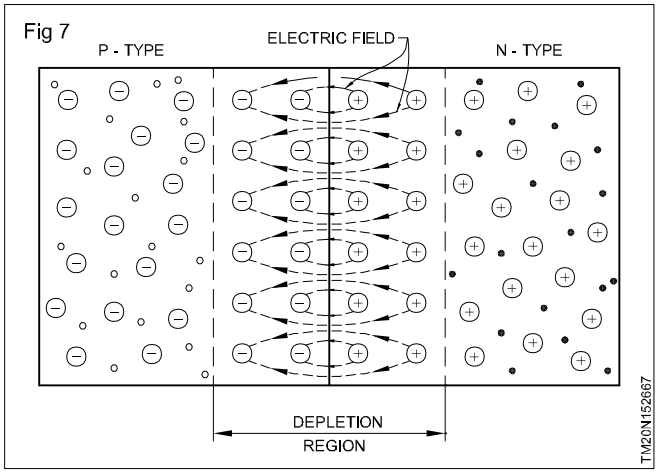


The free electrons in the N-regions diffuse across the junctions into the P-region. The free electrons lose energy and recombine with the holes in the P-regions. This recombination eliminates a free electron and a hole. When the electron moved from the N-region and diffused across the junction, it leaves the atom to be a positive ion. The positive ion is not balanced by a negative charge in the N-region. The hole is eliminated in the P-region by recombination. The elimination of the hole and its positive charge leaves the atom to be a negative ion in the P-region.

The ions in the crystal structure are fixed and cannot move. Thus, a layer of fixed charges is formed on the two sides of the junctions. This is shown in Fig 7.

There is a layer of positively charged ions on the N-side and on the P-side of the junction there is a layer of negatively charged ions. An electric field is created across the junction between the oppositely charged ions. This is called a junction field. The junction field is also known as 'barrier'. The distance between the sides of the barrier is the 'width' of the barrier.

Fig 7



Depletion region: The carrier in the vicinity of the junction are involved in forming the junction. Once the junction field is established, no carriers can move through the junction. Hence the junction field is called 'depletion region' or 'space charge region'. This layer is called the depletion layer, because there are neither free electrons nor holes present. This depletion region prevents further movement of electrons from the N-material to the P-material and thus an equilibrium is reached. The intensity of the field is known as 'barrier height' or 'potential' hill'. The internal voltage set up due to positive and negative ions at the junction is called barrier potential. If any more electrons have to go over from the N-side to P-side, they have to over come 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 order to cancel of the barrier potential and the electrons to cross over a potential difference of 0.7 V in required for a silicon diode and 0.3 V for a germanimum diode. The barrier voltage is more for silicon because its lower atomic number allows more stability in the covalent bonds. The barrier potential decreases at higher temperatures.

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Active components

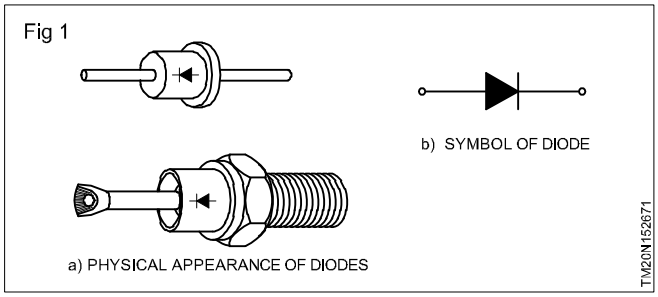
Objectives: At the end of this lesson you shall be able to

- **explain about the active components**
- **represent the components - diodes, transistors, SCRs, diac, triac, zener diode, diode bridges, UJT, FET - with standard symbols.**

Active components: In electronic circuits, components other than resistors, capacitors and inductors are also used. Namely, transistors, diodes, vacuum tubes, SCRs, diacs, zener-diode etc. The application of electrical circuit laws (Ohm's law etc.) in the circuit containing the above components will not give correct results. i.e. these components do not obey. Ohm's law, Kirchoff's law etc. These components are called active components.

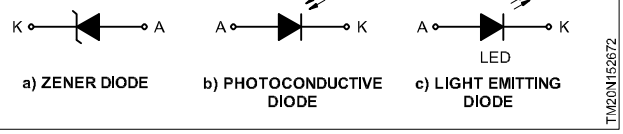
The different active components and the method of representing them by symbols in the circuit diagram are given below.

Fig 1



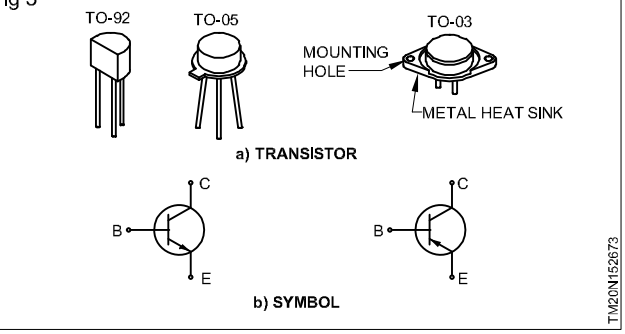
The different types of diodes (Fig 2) used for specific purposes are represented by the symbols given.

Fig 2



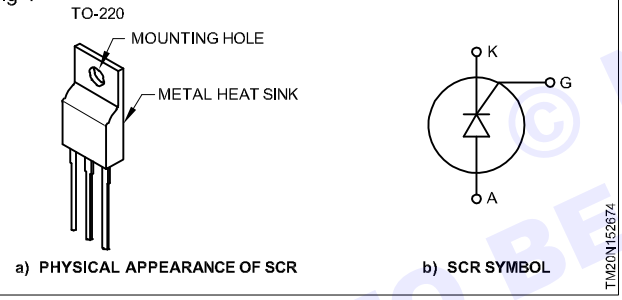
Transistor: Fig 3a shows the physical appearance of transistors. There are two symbols to represent a transistor. (Fig 3b). The selection of a symbol is based on either the NPN or the PNP type of transistor.

Fig 3



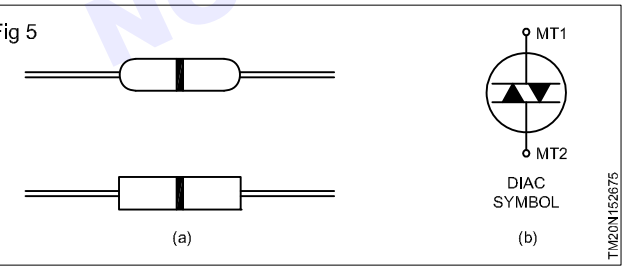
SCR (Silicon controlled rectifier): Fig 4a shows the physical appearance of one type of SCR and the symbol is shown in Fig 4 b. SCRs are also called thyristors and used as switching devices.

Fig 4



Diac: A diac (Fig 5a) is a two-lead device like a diode. It is a bidirectional switching device. Its symbol is shown in Fig 5b.

Fig 5



Triac: A triac is also a semiconductor device with three leads like two SCRs in parallel. The triac can control the circuit in either direction. (Fig 6)

Bridge rectifier or diode bridge: It is a single package of four semiconductor diodes connected in bridge circuit. The input AC and the output DC leads are marked and terminated as shown in Fig 7.

Fig 6

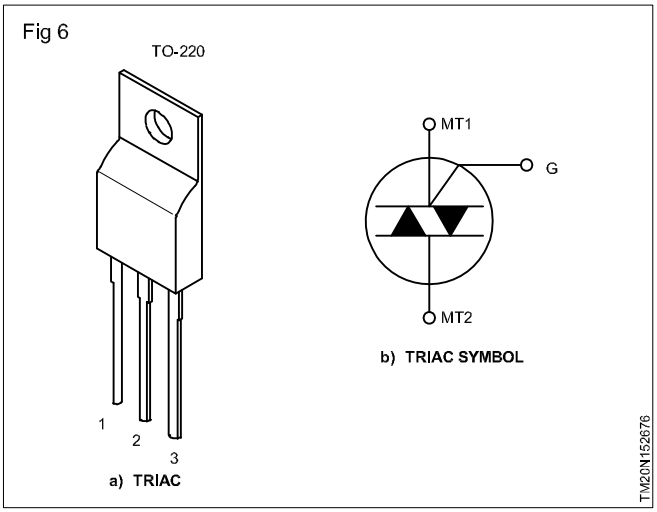
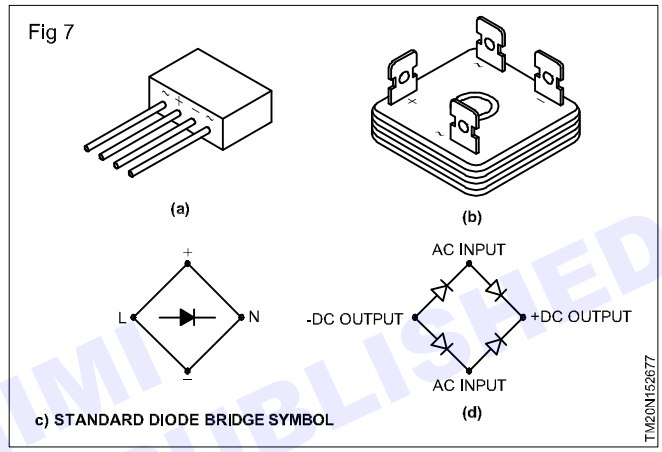
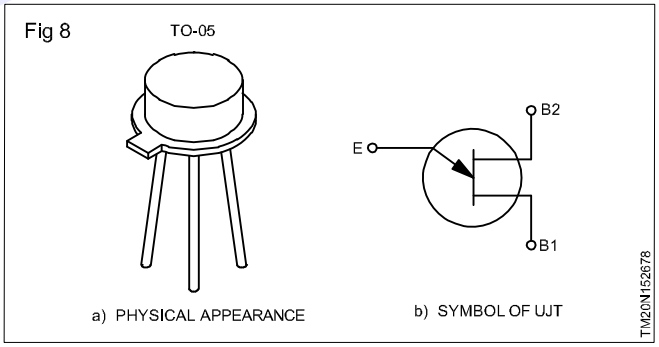


Fig 7



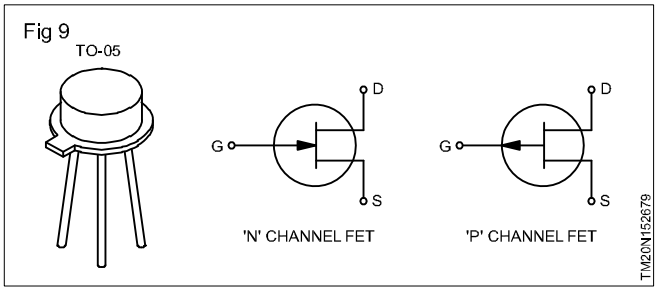
UJT (Uni-junction transistor): It has two doped regions with three leads and has one emitter and two bases. (Fig 8)

Fig 8



FET (Field effect transistor): Fig 9a give a pictorial view of the component, and the related symbol to represent the field effect transistor is shown in Fig 9b. The selection of the symbol is based on whether the FET is a 'N' channel or a 'P' channel one.

Fig 9



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Note: The devices like transistor, SCR triac, UJT & FET may look alike due to similarity in encapsulation. They can be identified only by the code numbers and relevant data books.

Coding of semiconductor devices

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

- **state the purpose of letters used in the old systems of coding semiconductors, by referring to the manual**
- **describe the meaning of 1N, 2N, 3N in semiconductor coding.**

Old system: Some earlier semiconductor diodes and transistors have type numbers, consisting of two or three letters followed by group of one, two or three figures. The first letter is always 'O', indicating a semiconduct device.

The second (and third) letter(s) indicate the general class of the device.

A – diode or rectifier

AP – photo-diode

AZ – voltage regulator diode

C – transistor

CP – phototransistor

The group of figures in a serial number indicating a particular design or development.

Present system: This system consists of two letters followed by a serial number. The serial number may consists of three figures of one letter and two figures depending on the main application of the device.

The first letter indicates the semiconductor material used.

A Germanium

B Silicon

C Compound materials such as gallium arsenide

R Compound materials such as cadmium sulphide

The second letter indicates the general function of the device.

A detection diode, high speed diode, mixer diode

B variable capacitance diode

C transistor for I.F. applications (not power types)

D power transistor for A.F. applications (not power types)

E tunnel diode

F transistor for A.F. applications (not power types)

G multiple of dissimilar devices, miscellaneous devices

L power transistor for a.f. applications

N photo-coupler

P radiation sensitive device such as photo-diode, photo-transistor, photo-conducive cell, or radiation detector diode

Q radiation generating device such as light-emitting diode

R controlling and switching devices (e.g. thyristor) having a specified breakdown characteristic (not power types)

S transistor for switching applications (not power types)

T controlling and switching power device (e.g. thyristor) having a specified breakdown characteristic.

U power transistor for switching applications

X multiplier diode such as varactor or step recovery diode

Y rectifier diode, booster diode, efficiency diode

Z voltage reference or voltage regulator diode, transient suppressor diode.

The remainder of the type number is a serial number indicating a particular design or development, and is in one of the following two groups.

a Devices intended primarily for use in consumer applications (radio and television receivers, audio-amplifiers, tape recorders, domestic appliances, etc.) The **serial number** consists of three figures.

b Devices intended mainly for applications other than (a) e.g. industrial, professional and transmitting equipments.

The serial number consists of one letter (Z,Y,X,W etc) followed by two numbers (digits)

The international system follows letters 1N, 2N, 3N etc followed by four numbers.

1N indicates single junction

2N indicates two junction

3N indicates three junctions.

The number indicates internationally agreed manufacturer's code e.g. 1N 4007, 2N 3055, 3N 2000.

Again, manufacturers use their own codes for semiconductor devices. Manufacturers in Japan use 2SA, 2SB, 2SC, 2SD etc. followed by a group of numbers e.g. 2SC 1061, 2SA 934, 2SB 77. Indian manufacturers have their own codes too.

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Resistors

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

- **state the function of a resistor in a circuit**
- **state the unit of resistance**
- **name the two broad classifications of resistors**
- **state the meaning of fixed value resistors**
- **list the classifications of fixed value resistors based on their construction and material used**
- **state meaning of power rating of resistors**
- **name the two methods to indicate ohmic value of a resistor on its body.**
- **state the meaning of tolerance in a resistor**
- **give examples to find the value of a resistor using colour code**
- **state the two important points to remember while bending resistor leads**
- **state the constructional details of important types of 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

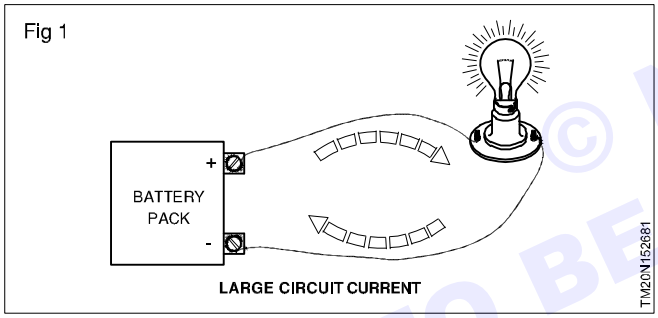
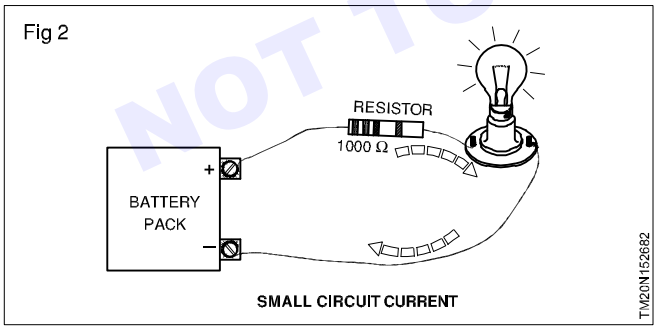


Fig 2



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 W.

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 W = 1 x 1000 W = 1 x kiloW = 1 K W

10,000 W = 10 x 1000 W = 10 x kiloW = 10 K W

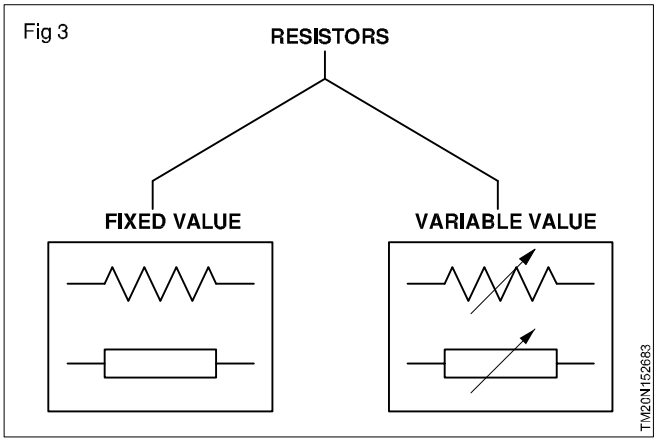
100,000 W = 100 x 1000 W = 100 x kilo W = 100 K W

1000,000 W = 1000 x 1000W = 1000 x kiloW = 1000 KW
= 1Mega W = 1MW

Classification of Resistors

Resistors can be classified under two main categories as shown in Fig 3.

Fig 3

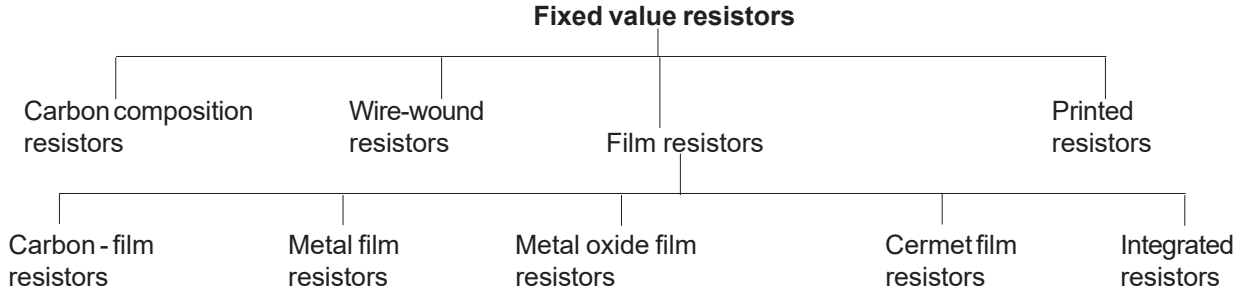


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Its ohmic value is fixed. This value cannot be changed by the user. Resistors of standard fixed values are manufactured for use in majority of applications.

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.

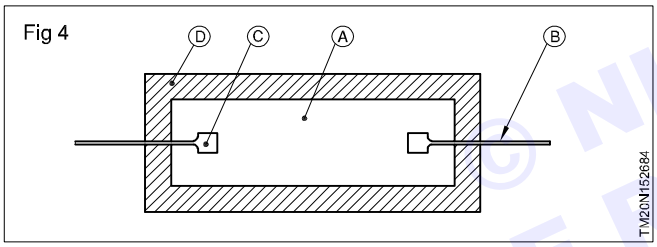


Physical appearance of some types of fixed value resistors is shown in Chart 1 at the end of this lesson.

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 4.



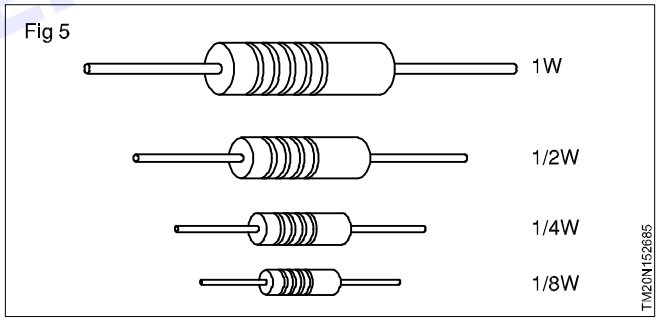
A mixture of finely powdered carbon or graphite (A), filler and binder is made into rods or extruded into desired shapes. Leads (B) made of tinned copper are then attached to the body either by soldering or embedding (C) in the body. A protective layer/tube (D) of phenolic or Bakelite is moulded around the assembly. Finally its resistance value is marked on the body.

Refer reference books listed at the end of this unit for further details on resistor manufacturing techniques.

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 manufacturers to withstand different power ratings. Fig 5 illustrates comparative physical sizes of different wattage resistors. 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 IW resistor is much less. Therefore, the resistor will get overheated and gets charred due to overheat.



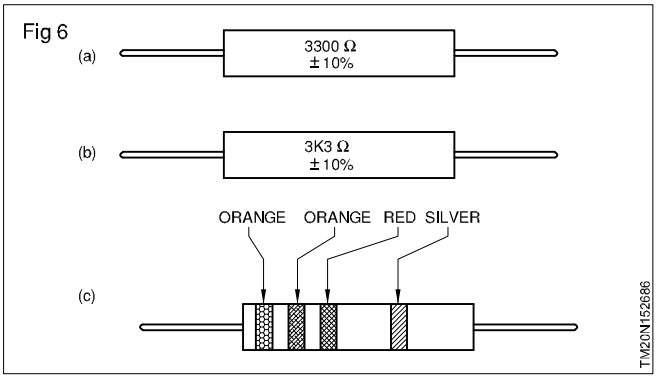
Hence, before using a resistor, in addition to its ohmic value, it is important to choose the correct wattage rating. If in doubt, choose a higher wattage resistor but never on the lower side. The power rating of resistors are generally printed on the body of the resistor.

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.

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Selection of a particular type of resistor is possible based on its physical appearance. Chart 1 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 6A or using a typographic code as shown in Fig 6B or using a colour code as shown in Fig 6C.



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.6 of pocket table book gives a list of commercially available standard resistor values.

Refer to the Pocket Table book, table nos 2, 3 and 4 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. A few examples of the generally used typographical codes and their meanings with examples are given in Table No.5.

Some resistance manufacturers use a coding scheme of their own. In such cases it will be necessary to refer to the manufacturer's guide.

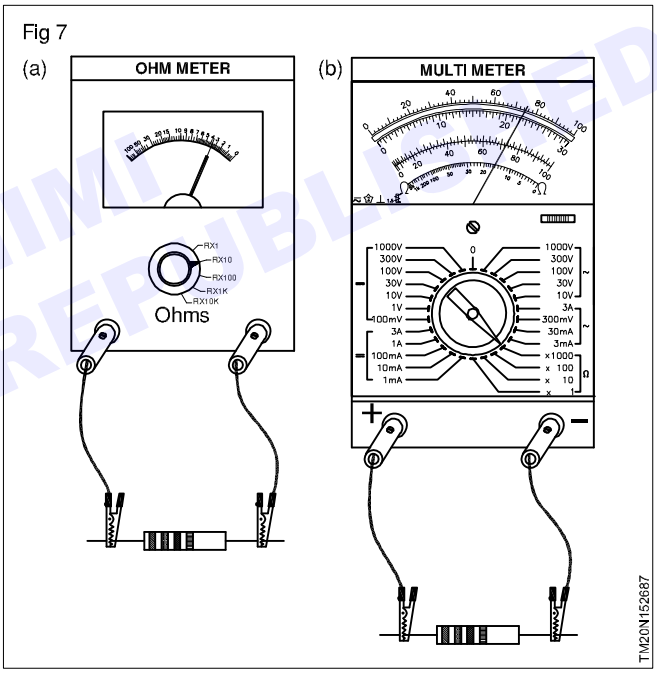
Applications

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 prods of an ohmmeter as shown in Fig 7A, 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 7B.

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.



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.

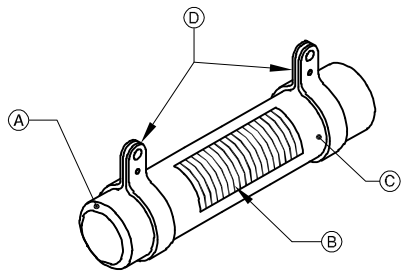
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This limitation in carbon resistors can be overcome by using wires of resistive materials like Nichrome, Manganin etc., instead of carbon. Resistors made using wires of resistive materials are known as *wire-wound* resistors. These resistors can withstand 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 8 . 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 8



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. (Refer reference book for details.)

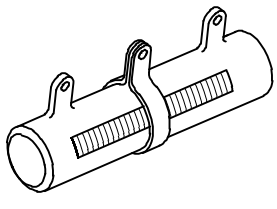
Resistor values: Wire-wound resistors are available from a fraction of an ohm to 100's of Kilo ohms, with a power ratings of 1 watt to several 100s of watts. The higher the power rating, the thicker the resistive wire used, and bigger will be the physical size of the wire-wound resistor.

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.

Special types of fixed value wire wound resistors

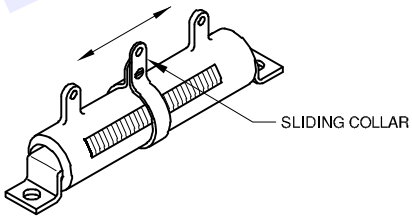
In applications where more than one fixed value wire-wound resistor is required to be used, a tapped wire wound resistor with more than one value, made in a single unit as in Fig 9 can be used.

Fig 9



Tapped resistors, whose tapings can be adjusted by adjusting the position of the sliding collar are also available as shown in Fig 10. This gives the flexibility of varying the resistance value between the tapings.

Fig 10



Comparison of fixed value carbon and wire-wound resistors

Characteristics	Carbon resistors	Wire-wound resistors
Size	Small	Comparatively large
Values available	From 1 ohm to several 10's of megohms	Fraction of an ohm to several 10's kilo ohms
Tolerance	Generally 5% to 20%	As low as 1% available
Wattage	Generally up to 2 watts	As high as 100 watts
Suitability in circuit	Suitable for High frequency circuits	Unsuitable for high frequency circuits (Suitable up to 200 KHz)
Noise generated	Less noisy	Very noisy operation
Voltage	Low voltage rating	Wide voltage rating

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Other types of resistors

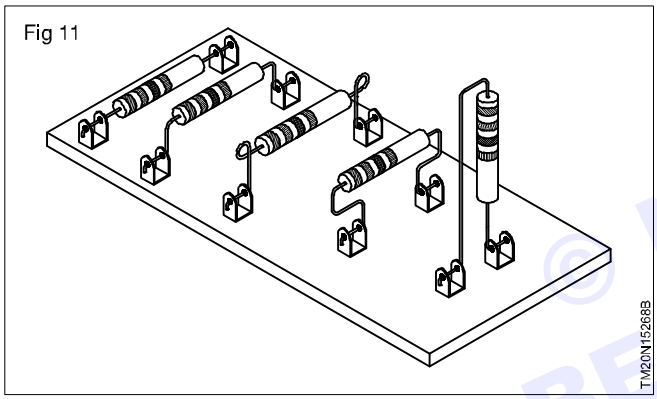
Brief constructional details of some types of resistors is given in Chart 2 at the end of this lesson. For further details on these types of resistors, refer reference books listed at the end of this book.

Resistors lead bending

The most delicate portion of a resistor is the joint between the leads and the resistor body. The leads give electrical connection to a resistor with the external circuit. While connecting a resistor in a circuit, the leads may come across vibration, shock, rough handling etc. In spite of these, the leads must maintain perfect electrical contact with the resistor. If the lead joint is loose with the body, it may lead to intermittent electrical contact resulting in the malfunctioning of the circuit.

Resistors are the most common components in any electric and electronic circuits. The circuits may be wired on, lug boards or on printed circuit boards. When resistors are to be soldered on boards, it becomes necessary to bend the leads of the resistors to different shapes as shown in Fig 11.

Fig 11



While bending the resistor leads, the following two vital points should always be kept in mind. Otherwise, the strain on the lead may make the resistor's body-to-lead connection weak.

1 Never bend the component as shown in Fig 12b. Bend the lead as shown in Fig 12a.

2 Bend the lead at least 2mm away from the resistor as shown in Fig 12c.

Types of resistor leads

Resistors are available with different types of lead attachment as shown in Fig 13. This makes it easy for the user to mount the resistors in different ways on lug boards, PCBs and other types of circuit boards.

Fig 12

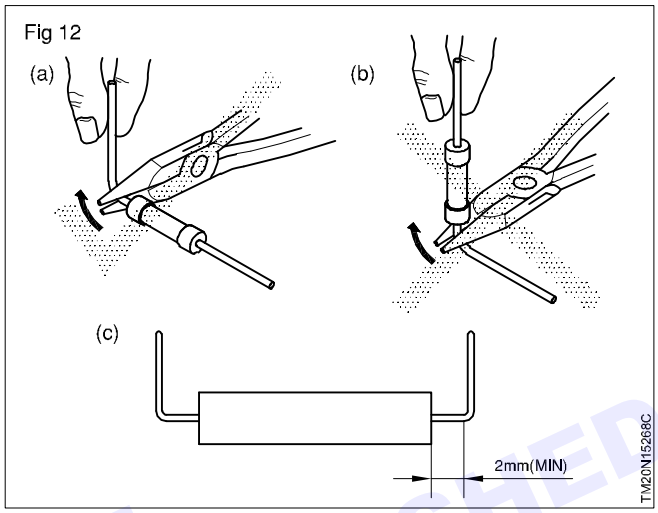
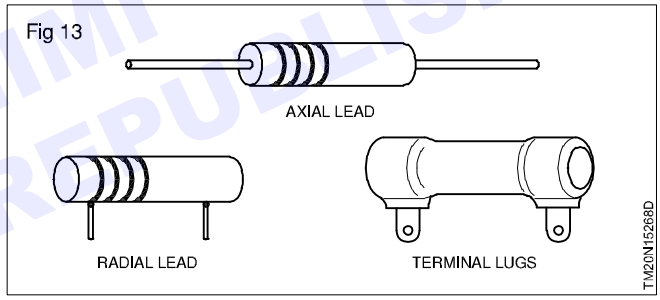


Fig 13

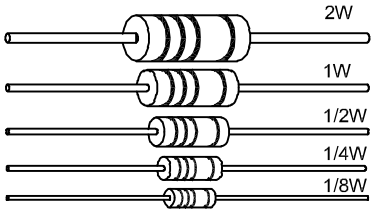


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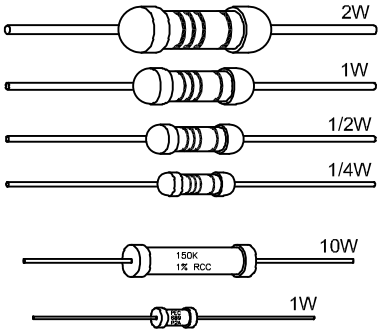
FIXED VALUE RESISTORS

CARBON TYPES

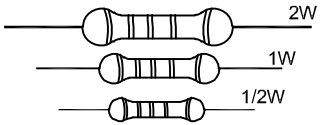
CARBON COMPOSITION



METAL FILM

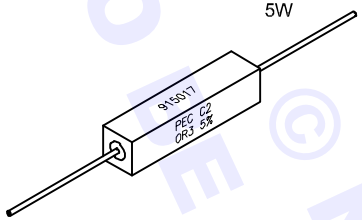


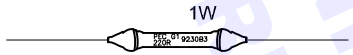
METAL OXIDE



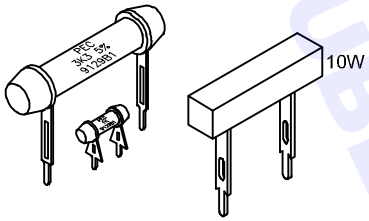
CERAMIC TYPES



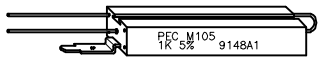




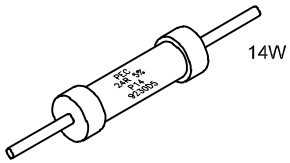
RADIAL LEADS



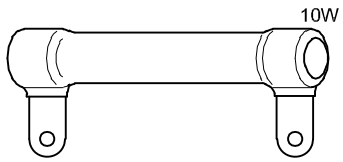
VERTICAL MOUNT

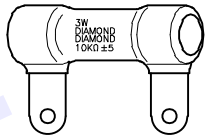


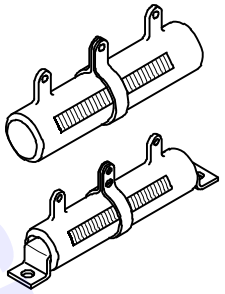
WIRE WOUND TYPES



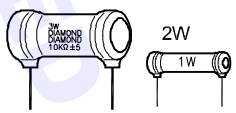
RADIAL LEADS



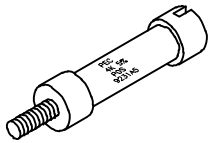




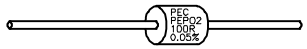
RADIAL LEADS



SPECIAL TYPES



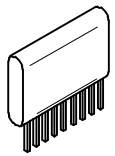
PRECISON RESISTOR



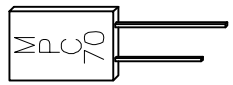
METAL FILM RESISTOR



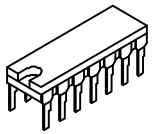
NETWORK RESISTOR



LOW OHM METAL FILM RESISTOR



INTEGRATED RESISTOR (DIL)



TM20N1526T1

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CONSTRUCTIONAL DETAILS OF FIXED VALUE RESISTORS

CARBON COMPOSITION RESISTORS

A mixture of finely powdered carbon or graphite with filler and binder is made into rods or extruded into desired shapes. Leads made of tinned copper is attached to the body by soldering or embedding. A protective layer of phenolic or bakelite is moulded over the body. Available from few ohms to megaohms in 1/8 to 2 watts. Tolerance generally 5% and above.

WIRE-WOUND RESISTORS

Resistive wires such as Nichrome, Mangamin, Eureka, etc., are wound on porcelain former. Resistance depends on type of wire, dia and number of turns. Wire ends are attached to metallic terminals. Entire construction is coated with shellac, ceramic paste or vitreous enamel. Available from fraction of an ohm to few kilo ohms and upto 100 watts. Superior to carbon composition resistors but are bulky.

INTEGRATED RESISTORS

DIFFUSED RESISTORS

A suitable quantity of impure material gets diffused into a monolithic IC substrate. The value of resistance depends on the impurity and the cross-section of the doped region. The maximum resistance values attainable are 100 ohms to 10 kilo ohms with tolerance of ±2%.

THIN FILM RESISTORS

These are formed by vacuum deposition or sputtering of Nichrome, tantalum or cermet (Cr-Sio) on points in the circuit on the surface of the substrate of an Integrated circuit. Typical resistor values lie in the range from 100Ω to 10 kΩ with ±2% tolerance.

PRINTED RESISTORS

A resistive paint or ink made of finely powdered graphite or other resistive agents suspended in a suitable binder such as shellac is applied on the surface of the Printed circuit board(PCB) at required places. The value of resistance depends upon the length, width and thickness of the paint applied. The resistance value can be adjusted by pruning the edges and the top of the deposit. Drying of paint is done by air and sometimes by baking. After completion, the printed resistors are protected by a coat of lacquer.

FILM RESISTORS

CARBON-FILM RESISTORS

A film of carbon is deposited on a ceramic, glass cylinder/rod. The value of the resistor depends on the thickness and length of the film. Leads are attached and the assembly is moulded in phenolic housing or coated with an insulating varnish and a plastic sleeve slipped over it for protection. Externally the carbon-film resistor resembles the carbon composition resistor, and is marked with the same colour code. This type of resistor has greater stability of resistance with in temperature and humidity. These are often made in small square shape with leads to fit on a PCB.

METAL-FILM RESISTORS

A film of metal or metal alloy deposited on an insulating substrate such as ceramic, glass etc. Construction details similar to carbon-film resistors. These are superior to carbon-film resistors. Availability-same as carbon-film resistors.

METAL-OXIDE FILM RESISTOR

A film of metal oxide, typically tin oxide, deposited over an insulating substrate such as ceramic, glass etc. Construction details similar to carbon-film resistors Metal-oxide resistors of 10,000 megohms with accuracy as fine as 0.5% available. This type of resistor is of great importance in ultra high-resistance applications

CERMET FILM RESISTORS

A mixture of metal and ceramic is deposited/coated as a thin film, generally in the shape of a spiral over an insulating substrate, usually an alumina core. Available in resistance values from 10 ohms to 1 megaohms with 1% tolerance. Highly stable even at very high temperatures.

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PN Junction diodes

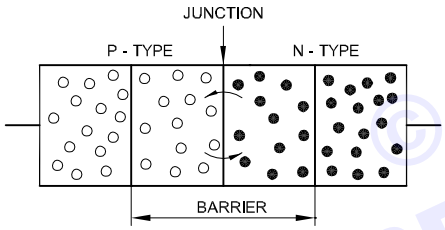
Objectives: At the end of this lesson you shall be able to

- **explain how a semiconductor diode lets the current flow in one direction**
- **describe the forward and reverse biasing of PN junction diode**
- **explain the VI characteristic of the diode.**
- **state the applications of a diode.**
- **state the important specifications of the diode**
- **state the different industry standards for diode numbering scheme**
- **state the method of finding equivalents of a diode with the help of data book**
- **state the classifications of the diode and diode packaging**
- **state the method of testing a diode**
- **state the method of identifying the polarity of the diode.**

PN junction: A diode is made by combining P and N materials. The surface at which these materials meet is the PN junction.

Diffusion occurs when P and N materials are joined together. (Fig 1) some electrons in the N material, near the junction, are attracted to the holes in the P material, thus leaving holes in the N material. The diffusion of electrical charges produces a potential difference in a small area near the junction (Fig 2). As a result, the material will conduct in one direction but not in the opposite direction. For this reason, the area in which this emf exists is called a barrier.

Fig 1



The internal barrier potential (V_b): Although it is an internal contact potential that cannot be measured directly, the effect can be overcome by 0.3V for a **Ge** junction or 0.7 V for **Si**. The barrier voltage is more for **Si** because its lower atomic number allows more stability in the covalent bonds as already stated.

The PN junction, with the depletion zone magnified, shows the iron that has +ve and -ve charges produce the internal contact potential V_b at the barrier. (Fig 2)

A PN device is knows as a diode. The diode and its symbol are shown in Fig 3. This type of construction permits the current to flow in one direction but not in the opposite direction.

Fig 3

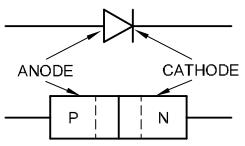
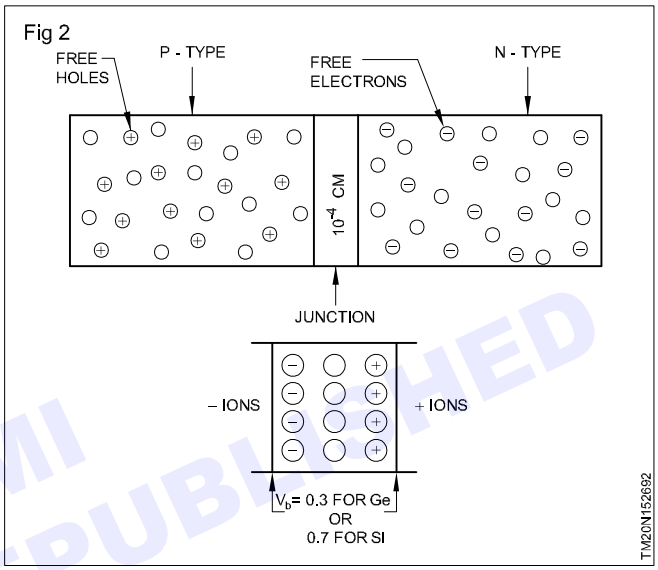


Fig 2



Biasing the PN junction

Forward Bias: A forward-biased PN junction is shown in Fig 4 The positive terminal is connected to the P-side and the negative terminal of the DC supply is connected to the N-side of the junction.

A current will flow through the diode as shown in the Fig 4. The positive terminal for the battery attracts electrons from P material, leaving an excess of holes. Because electrons are drifting away from the junction, the excess holes tend to accumulate near the junction. At the same instant, electrons from the negative terminal of the batter are attracted to the less negative N material of the diode. This action overcomes the barrier at the junction and allows the electrons to move into the excess holes of the P material, the result is a continuous flow of electrons in one direction. The voltage required to move the charge carries in forward bias conduction called the barrier voltage.

Reverse Bias: If the polarities of the DC supply are as shown in Fig 5, the PN junction is said to be reverse-biased. That is, the P side is connected to the negative and the N-side is connected to the positive terminals of the supply. Fig 5 shows the battery connection reversed (reverse bias). At the same instant, a shift in electrons in the P material causes the positive holes to appear further away from the junction near the end for the diode, which is connected to the negative terminal of the battery.

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Fig 4

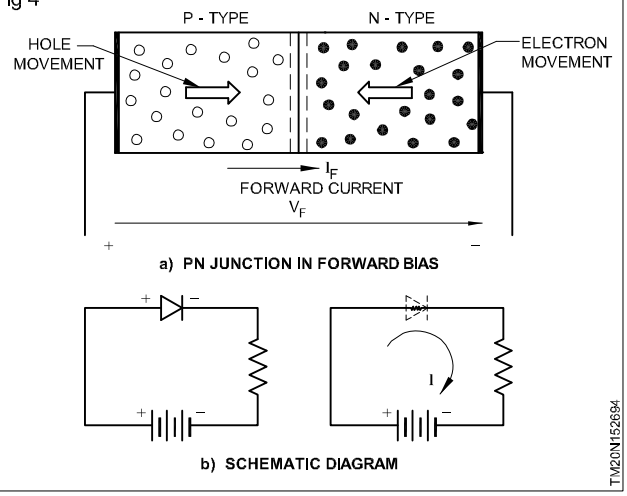
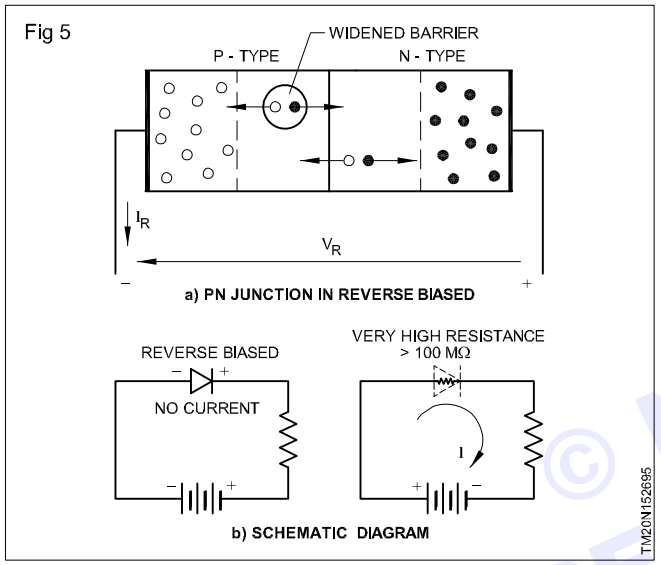


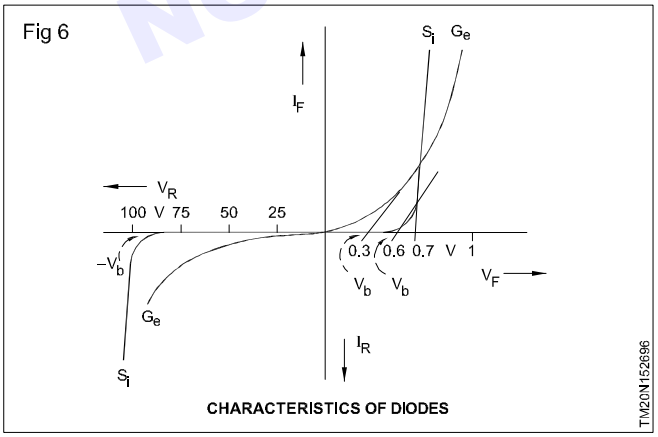
Fig 5



This action produces a wider barrier at the PN junction through which the electrons cannot flow. (A very small current leakage may however occur).

V-I characteristic of PN junction: The static current voltage characteristic is shown in Fig 6.

Fig 6



The current in the forward direction increase rapidly upon reaching the forward voltage V_b which is known as the barrier potential or the junction potential. the barrier potential for germanium is 0.3 V and for silicon it is 0.7 V.

The behaviour of the PN junction is limited by the maximum forward current, as too much of current may destroy a diode due to the excess heat generation.

The current in the reverse direction of the junction is very small. Upon reaching —V_b in the reverse direction, the reverse current suddenly increases. —V_b in the reverse direction where the current starts increasing is called the knee potential or breakdown voltage. Normally the diode should not be operated in this region. The knee voltage depends on the type of diode which varies from 3V to 20 kV or more.

Application of diodes : Semi conductor 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 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 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 doped semi-conductor material. This could be Silicon or Germanium or Selenium. 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 0.3V, whereas in Si diodes the cut-in voltage is around 0.7V.

Maximum safe reverse voltage: Denoted as V_R or Vr that can be applied across the diode. This is 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 mal functioning or getting damaged.

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Manufacturer's code of diodes: The diodes are printed with a type number. 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.

To bring standardization for the diodes and other components manufactured by different manufacturers, the manufactures 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. Similarly, prefix 2N is used with components with two junctions and so on.

b **The PRO-ELECTION type code:** The Association International pro-electron in Europe maintains a register of Pro-electron type 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. Refer to diode data book for further details and examples.

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 specification.

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 if

C = npn hf

D = npn if

Some components will have a type number which does not match with any of the above said international standards. Then, these type numbers are particular to the individual manufactures. 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.

Instructor may list a few manufacturers house codes relevant to your region by referring to any popular diode data manual. Give one data manual each to a batch of 4 trainees. Write a few diode type codes on the black/white board and ask the batches to find the specifications.)

Diode equivalent: 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, and if 1N4007 is not available in stock, then instead of 1N4007, BY 127 can be used as it is the equivalent for 1N4007.

Some data books give these lists of equivalents.

Classification of Diodes

1 Based on their current carrying capacity/power handling capacity, diodes can be classified as

- **low power diodes:** can handle power of the order of several milliwatts only
- **medium power diodes:** can handle power of the order of several watts only
- **high power diodes:** can handle power of the order of several 100's of watts.

2 Based on their principal application, diodes can be classified as,

- **Signal diodes:** low power diodes used in communication circuits such as radio receivers etc. for signal detection and mixing
- **Switching diodes:** low power diodes used in switching circuits such as digital electronics etc. for fast switching ON/OFF of circuits
- **Rectifier diodes:** medium to high power used in power supplier for electronic circuits for converting AC to DC voltage.

3 Based on the manufacturing techniques used, diodes can be classified as,

- **point contact diodes:** a metal needle connected with pressure on to a small germanium (Ge) or silicon (Si)
- **Junction diodes:** made by alloying or growing or diffusing P and N materials on a semiconductor substrate.

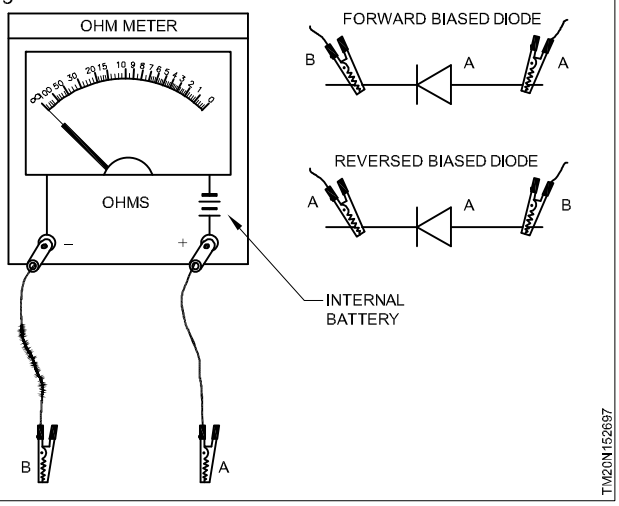
Types of diode packaging: The type of packaging given to diodes is mainly based on the current carrying capacity of the diode. Low power diodes have either glass or plastic packaging. Medium power diodes have either plastic or metal can packaging. High power diodes will invariably have either metal can or ceramic packaging. High power diodes are generally of stud-mounting type.

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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 condition 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 7. In Fig 7 the lead A is positive, lead B negative.

Fig 7



If the polarity of the meter leads are not known at first, the polarity of the meter leads can determined using a voltmeter across the ohm meter terminals.

If the positive lead of the ohmmeter, lead A in the Fig 7 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.

Polarity marking on the diodes: The cathode end of a diode is usually marked by a circular band or by a dot or by plus (+) sign. In some diodes the symbol of the diode, which itself indicates the polarities, is printed on the body of the diode.

AC-to-DC conversion using diode - Half wave rectifier

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

- **state the need for converting AC to DC**
- **state the meaning of the term rectification**
- **describe the working of a half-wave rectifier**
- **state the output of a half-wave rectifier in terms of rms value of input AC, peak value of input AC.**
- **state the meaning of pulsating DC**
- **state the ripple frequency in a half-wave rectifier**
- **state the meaning and importance of PIV**
- **state the value of PIV in a half-wave rectifier.**

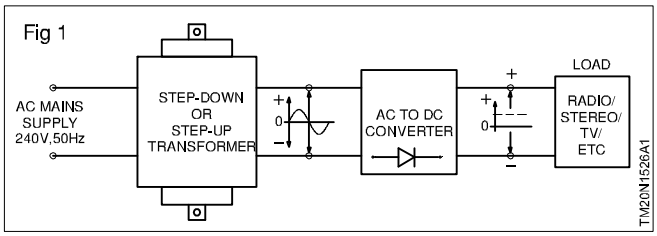
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Rectification

Almost all electronic circuits need DC voltage for their working. This DC voltage can be obtained by dry cells and batteries. Use of a dry cell is practicable only in portable electronic circuits such as transistor radio, tape recorders etc. But in circuits requiring large voltages and currents, like high power audio amplifiers, television sets etc. batteries will not only be very expensive but also be voluminous.

An alternative method of obtaining DC voltage is by converting the AC mains supply of 240V, 50Hz into DC voltage. This technique is not only convenient but also takes very small space compared to battery packs. This *process of converting AC to DC is known as rectification.* Fig 1 shows the principle of converting AC to DC of required voltage level.

Fig 1

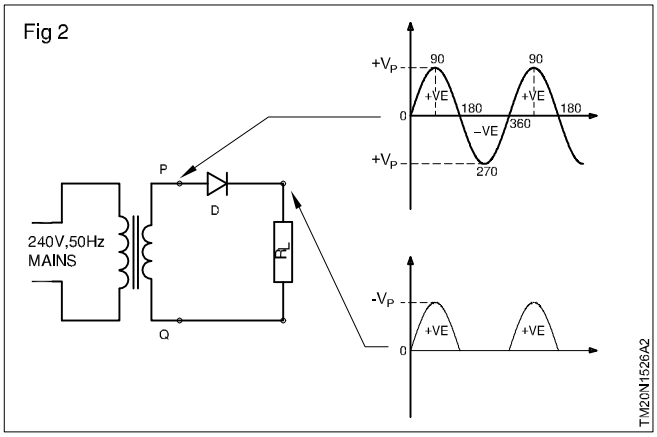


The transformer will step-down or step-up the mains AC to the required level. The stepped-up or stepped-down AC from the output of the transformer is then converted to DC using diodes making use of their unique unidirectional property.

Halfwave rectifier

The simplest form of AC to DC converter is by using one diode. such an AC to DC converter is known as *half-wave rectifier* as shown in Fig 2.

Fig 2



At the secondary of the transformer, across terminals P & Q, when seen on a CRO, the electric signal is a sinusoidal wave with its peak value of V_P and a frequency determined by the rate at which the alternations (+ve to –ve) are taking place. In Fig 2, the frequency is 50Hz as this voltage is taken from 50Hz AC mains supply.

If the voltage across P and Q is measured using an AC voltmeter, the voltmeter shows the rms (root mean square) value, V_{rms} of the sinusoidal wave which will be less than the peak value. The relationship between V_{Peak} and V_{rms} is given by,

$V_{rms} = 0.707\ V_{peak}$ .....[1]

conversely,

$$V_{peak} = \frac{V_{rms}}{0.707} = \sqrt{2}\ V_{rms}$$

When this sinusoidal signal is applied across the diode D as shown in Fig 2, the diode conducts (behaves as a closed switch) only during the +ve half cycle of the input sinusoidal voltage and does not conduct (behaves as a open switch) during the -ve half of the input sinusoidal voltage. This process repeats again and again thus producing a pulsating +ve wave-form at the output across the load, R_L as shown in Fig 2.

The operation of a half-wave rectifier circuit can be summarised with the help of Fig 3 as follows:

1 During the positive half cycle of AC input, the diode is forward biased as the anode of diode is positive as shown in Fig 3a.

2 Hence current flows from anode to cathode, through load R_L to secondary of transformer as shown in Fig 3b. The IR_L drop across load resistor R_L is the DC voltage V_{dc} with the polarity as shown in Fig 3b.

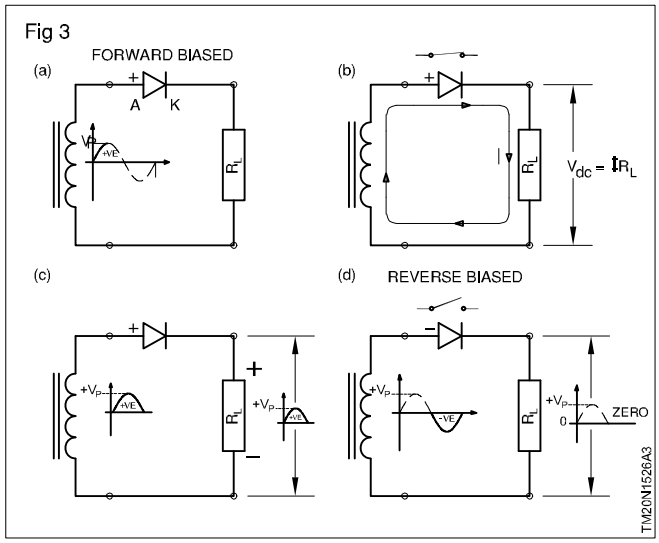
3 When the +ve half cycle of the input sinusoidal is completed, the voltage across the R_L will be a positive half sinewave as shown in Fig 3c. The peak of rectified voltage is also equal to the peak of the input AC voltage.

4 During the negative half cycle of the input AC, the diode is reverse biased as the anode of diode is negative as shown in Fig 3d.

5 Hence, the diode behaves as an open switch and no current flows through the load and hence there is no voltage output across load R_L as shown in Fig 3d.

6 After completing the –ve half cycle, when the input signal goes positive again, the whole operation repeats starting from step 1.

Fig 3



As can be seen from Fig 2, the output of the half-wave rectifier is always a +ve voltage (DC) although it is pulsating. In other words, the output is either positive (during +ve half cycle of the AC input) or zero (during -ve half cycle of AC input) but never negative. Hence, the output of a rectifier is a pulsating +ve DC voltage.

The circuit at Fig 2 is known as a *half-wave rectifier* as the rectification is done by the circuit only during one half cycle of the input AC signal.

Calculating output DC level in half-wave rectifiers

Two important points to note for calculating the output DC level of a halfwave rectifier are;

– the output of a halfwave (HW) rectifier across the load resistor is a pulsating DC whose peak voltage is equal to the peak value of the +ve half cycle of the AC input as shown in Fig 4. This can be checked using an oscilloscope.

  The small forward voltage drop of the diode (0.7 for Si) when forward biased is ignored for simplicity in understanding.

– the pulsating signal level is zero when the input AC is in the –ve half cycle as shown in Fig 4.

Hence, When a DC voltmeter is connected across the load resistor R_L, the meter reads the average DC value of the pulsating signal. Ignoring the diode drop, the average DC value of the pulsating output in a half wave rectifier is given by,

$V_{average}$ or $V_{dc} = 0.318\ V_P$ .....[2]

Example: If the total secondary voltage of the transformer (V_S) in Fig 2 is 24 V_{rms} (measured by AC meter), the output V_{dc} will be,

From ...1, $V_{peak} = \frac{V_{rms}}{0.707}$

From ...2, $V_{dc} = (0.318)\ V_{peak} = \frac{V_{rms}}{0.707} = 0.45\ V_{S(rms)}$

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Therefore, for a half-wave rectifier the level of output DC is given by,

$$V_{dc} = 0.45\ V_{S(rms)} \quad .....[3]$$

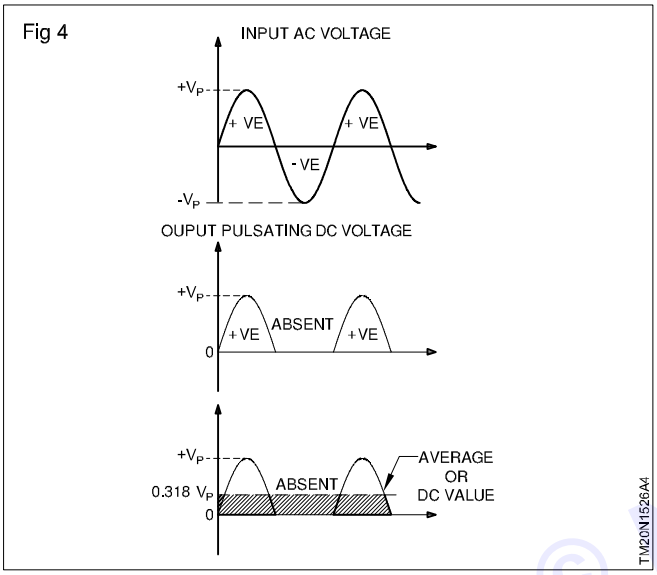
Where $V_{S(rms)}$ is the input *rms* AC voltage.

In the example considered above, the output DC voltage at Fig 2 will be,

$$V_{dc} = 0.45 \times V_{S(rms)} = 0.45 \times 24 = 10.8 \text{ volts.}$$

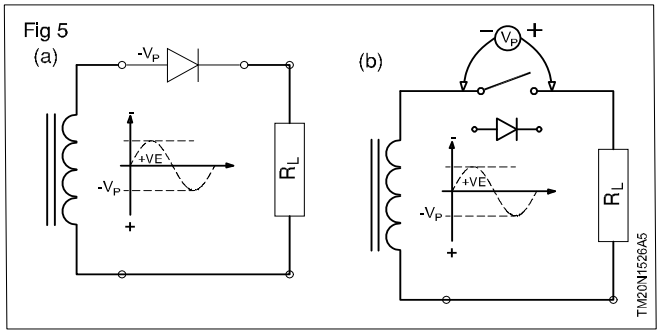
Ripple frequency: From Fig 4 it is evident that the frequency of the rectified pulsating DC is same as the frequency of the input AC signal. This is true for all half-wave rectifiers.

Fig 4



Peak inverse voltage: Fig 5a shows the half-wave rectifier at the instant the secondary voltage is at its maximum negative peak.

Fig 5



In this condition, since the diode is reverse biased, it behaves as an open switch as shown in Fig 5b. Since the diode is reverse biased, there is no voltage across the load R_L. Therefore, From Kirchhoff's voltage law, all the secondary voltage appears across the diode as shown in Fig 5b. This is the maximum reverse voltage that appears across the diode in the reverse biased condition. This voltage is called the peak reverse voltage or more commonly as the **peak inverse voltage (PIV).** Therefore, in a half-wave rectifier the peak inverse voltage across the diode is equal to the -ve peak value of the secondary voltage $V_{S(peak)}$. Since, the -ve peak voltage and +ve peak voltage in a sinusoidal wave is same in magnitude, the peak inverse voltage (PIV) across the diode in a halfwave rectifier can be taken as a $V_{S(peak)}$.

In the example considered earlier, the PIV across the diode will be,

$$V_{s(peak)} = \frac{V_{s(rms)}}{0.707} = \frac{24}{0.707} = 33.9 \text{ volts.}$$

To avoid break down of the diode used, the PIV appearing across the diode of the designed HW rectifier must be less than the PIV rating of the diode. For instance, in the above example to avoid break down of the diode, the PIV rating of the diode should be greater than 34 volts.

Full wave rectifiers

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

- **state the limitations of half-wave rectifiers**
- **describe the working of a two-diode fullwave rectifier**
- **state the output DC level in a two-diode fullwave rectifier**
- **state the ripple frequency in a fullwave rectifier**
- **state the value of PIV across diodes in a two-diode fullwave rectifier**
- **state the current rating of the diode in a two-diode fullwave rectifier**
- **list the disadvantages of two-diode full wave rectifiers**
- **state the working of a bridge rectifier**
- **state the output level, ripple frequency and PIV in a bridge rectifier**
- **compare half-wave, fullwave and bridge rectifiers.**

Two-diode fullwave rectifier

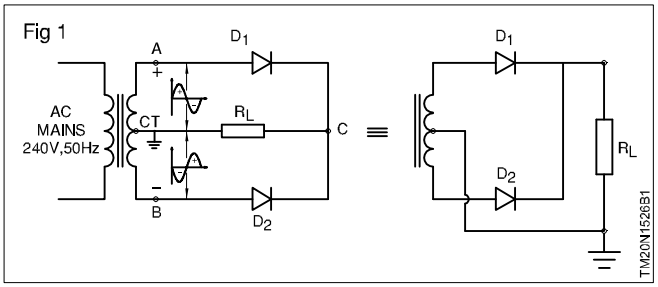
In a half-wave rectifier there is no rectification action during the -ve half cycle of the input AC voltage. Because of this the output DC level is low (0.318 $V_{S(peak)}$). This limitation of a half-wave rectifier can be overcome by using two diodes and a centre-tap-transformer as shown in Fig 1.

In Fig 1, each diode and the common load resistor R_L form two independent half-wave rectifiers. Because of the centre-tapped secondary winding, each diode receives only half of the total secondary voltage.

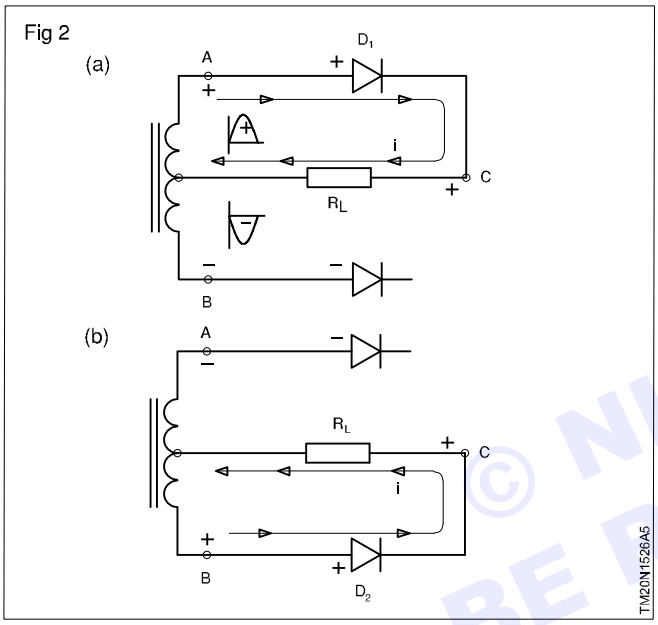
The opposite ends of the transformer secondary windings always have opposite polarities with respect to the centre tap. As shown in Fig 1, when end A of the secondary winding is positive, the bottom end B will be negative.

For the polarity shown in Fig 2a, the anode of D_1 is positive and, hence, forward biased. Whereas, the anode of D_2 is negative, and, hence, does not conduct. Current flows from the transformer (end A)➔ D_1➔ R_L ➔back to the transformer centre-tap. This direction makes point C across the load R_L as the +ve terminal of the output DC voltage.

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During the next half cycle, end B of transformer is +ve and A is –ve as shown in Fig 2b. Hence the anode of D_2 is +ve and this diode conducts whereas D_1 does not. Current flows from the transformer(end B) ➔ D_2 ➔ R_L ➔back to the transformer centre-tap. This direction of current again makes point C across the load R_L as the +ve terminal of the output DC voltage.



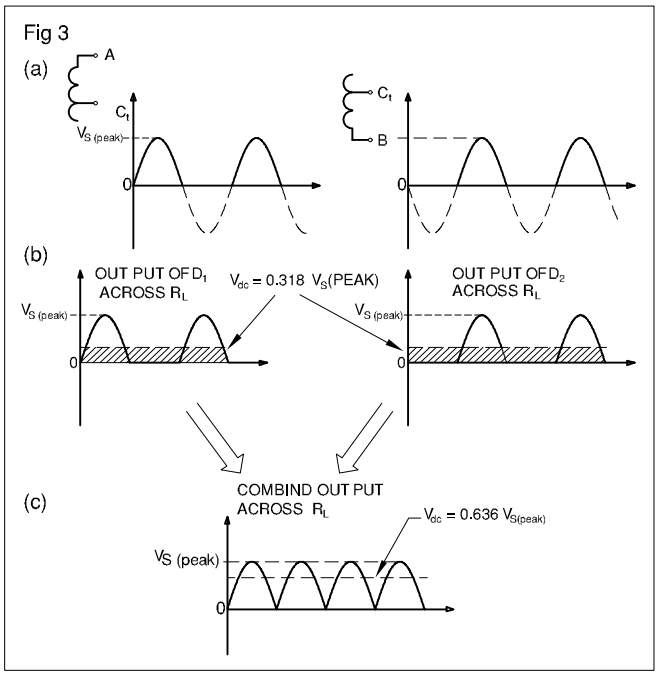
It is important to note the following two points;

– At any instant of time either D_1 or D_2 conducts but never both.

– While any of the two diodes is conducting, the rectified current i, flows through R_L in the same direction as shown in Fig 2a and Fig 2b. So the DC output voltage is positive at the common cathodes of the diodes D_1,D_2.

Fig 3 shows the input and output wave-forms of a fullwave rectifier. As can be seen from Fig 3, the rectifier works both in the positive and negative half cycles of the AC input to produce a DC output across the load resistor R_L. Although only one diode conducts at a time, the outputs are combined in R_L. Hence, fullwave rectifier provides double the DC current to the load compared to that of a half-wave rectifier.

Since both the half cycles of the input AC signal are rectified by the circuit at Fig 1, this circuit is known as a *fullwave rectifier.* Since this fullwave rectifier uses two diodes this circuit is also known as *two diode fullwave rectifier.*



Output DC level in a two-diode full wave rectifier

Since a full wave rectifier is nothing but a combination of two half-wave rectifiers, the average or DC value of a fullwave rectifier is naturally twice the output of a half-wave rectifier driven by the same secondary voltage.

From Fig 3 it is evident that the average or DC value of a fullwave rectified output is

$$V_{dc} = 0.318\ V_{S(peak)} + 0.318\ V_{S(peak)}$$

$$V_{dc} = 0.636\ V_{S(peak)}$$

where, $V_{S(peak)}$ is the equal peak voltage between the centre-tap and any one end A or B of the transformer secondary.

In terms of $V_{S(rms)}$, V_{dc} of a fullwave rectifier is given by,

$$V_{S(rms)} = 0.707\ V_{S(peak)}$$

Therefore, $$V_{dc} = 0.636 \cdot \frac{V_{s(rms)}}{0.707}$$

$$= 0.9\ V_{S(rms)}$$

Example: Suppose the secondary voltage of the transformer is 24-0-$24_{V(rms)}$, the DC output voltage of a full wave rectifier using this transformer will be,

For a two diode fullwave rectifier

$$V_{dc} = 0.9\ V_{S(rms)}$$

Therefore, in the given example,

V_{dc} = 0.9 x $V_{S(rms)}$ = 0.9 x 24 = 21.6 volts.

Ripple frequency in a full wave rectifier: From Fig 3c it can be seen that two cycles of output occur for each input cycle of AC voltage. This is because, the full wave rectifier has inverted the negative half-cycle of the input voltage. As

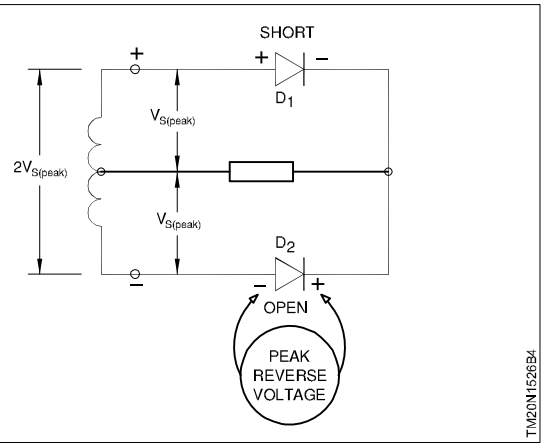
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a result, the output of a full wave rectifier has a frequency double the input AC frequency. If mains AC is used as input to a fullwave rectifier, since mains frequency is 50 Hz, the output frequency of the pulsating DC will be 100 Hz.

This increased ripple frequency has certain advantages when the pulsating DC is smoothed. This will be dealt with in further lessons.

Peak inverse voltage: Fig 4 shows the fullwave rectifier at the instant the secondary voltage reaches its maximum positive value.

Fig 4



Applying Kirchhoff's law around the outside loop, we get,

$2V_{s(peak)}$ –Reverse voltage (PIV) across D_2

+ Forward voltage across D_1 = 0

Neglecting the small forward voltage across D_1 we have,

$2V_{s(peak)}$ – PIV across D_2 + 0 = 0

or PIV across D_2 = $2V_{s(peak)}$

From the above it can be seen that each diode in a fullwave rectifier must have a PIV rating greater than the peak value of the full secondary voltage. ($2V_{s(peak)}$)

In the example considered earlier, the PIV of diodes should be greater than 34V.

Current rating of diodes in a fullwave rectifier

If the load, R_L connected in the fullwave rectifier is, say 10ý, the DC current through it will be,

$$I_{dc} = \frac{V_{dc}}{10\Omega}.$$

In the example considered above, V_{dc} = 21.6 volts.

Therefore,

$$I_{dc} = \frac{21.6}{10} = 2.16 \text{ amps.}$$

It is interesting to note this current Idc is shared by the two diodes D_1 and D_2. This is because each diode conducts only for one half cycle. Therefore, the DC current through each diode is half the total DC load current I_{dc}. Hence, the maximum current through each diode with 10W load will be 2.16/2 = 1.08 amps. From this it follows that the current rating ($I_{f(max)}$) of each diode need only be half the maximum/ rated load current.

In a halfwave rectifier (lesson 1.2.09), since there is only one diode, the current rating of the diode used should be the maximum current through the load unlike in the case of a fullwave rectifier in which the current rating of the diodes used is only half the maximum current through the load.

Example: In a two diode fullwave rectifier, with a load current requirement of 1.8 amps, what should be the current ratings of the diodes used?

Since it is a two diode fullwave rectifier, the current rating of each diode should be ³1/2 the total load current.

Therefore, $I_{f(max)}$ of diodes should be ³1.8 amps/2 = 0.9 amps.

It is fine if a diode of 1 amp current rating is used for this rectifier circuit.

Disadvantages of TWO DIODE fullwave rectifier

The full wave rectifier using two diodes and centre tap transformer has the following disadvantages;

– A centre-tapped transformer that produces equal voltages on each half of the secondary winding is difficult to manufacture and, hence, expensive.

– Centre-tapped transformers are generally bulkier than ordinary transformers, and, hence, occupy larger space.

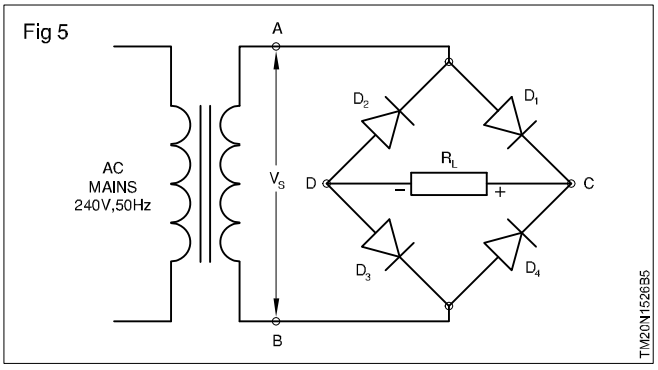
– In a two diode full wave rectifier, only half of the secondary voltage is made use of at a time although it works in both +ve and –ve half cycles.

The bridge rectifier

The disadvantages of a full wave rectifier using two diodes and centre-tap transformer can be overcome by a modified fullwave rectifier as shown in Fig 5. In Fig 5, since the diodes are connected in the form of a bridge, this rectifier circuit is commonly known as a *Bridge rectifier.*

As can be seen in Fig 5, the bridge rectifier does not need a centre-tapped transformer. Also, all the secondary voltage is used for rectification at any given time.

Fig 5



The operation of a bridge rectifier can be summarized in the following steps;

– When end A of the transformer secondary is +ve, as shown in Fig 6a, diodes D_1 and D_3 are forward biased whereas, D_2 and D_4 are reverse biased, and, hence, D_2 and D_4 do not come in the circuit.

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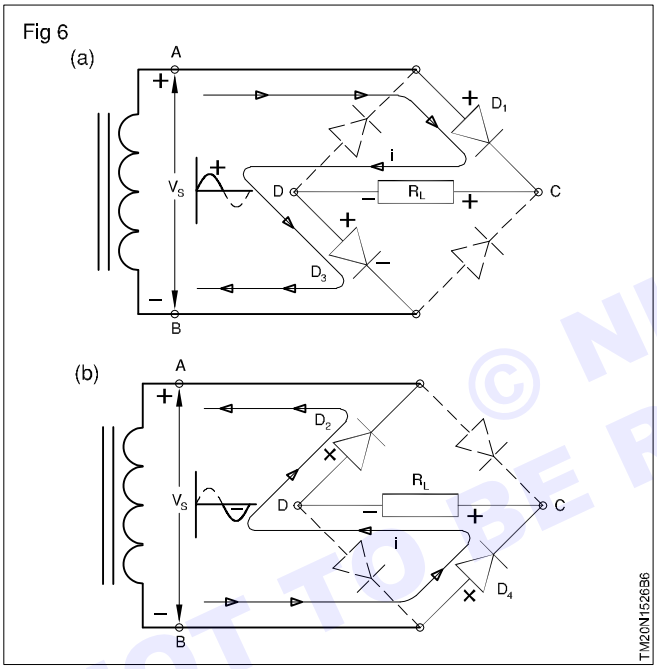
– Current flows from the transformer(end A)➔ D_1 ➔R_L ➔ D_3 ➔back to the transformer(end B). From the direction of the current flow point C is the positive terminal of the DC output across R_L.

– During the other half cycle of the input (–ve half cycle), end B of the transformer becomes +ve as shown in Fig 6b. Diodes D_4 and D_2 are forward biased, whereas D_1 and D_3 are reverse biased.

– Current flows from the transformer(end B)➔ D_4 ➔ R_L ➔ D_2 ➔back to the transformer(end A). From the direction of the current flow, point C is again the +ve terminal of the DC output across R_L.

Note that, current I is in the same direction through R_L during both +ve and –ve half cycles of the input AC. The result is, a +ve rectified DC voltage appears at the end of R_L connected to the cathodes of D_1 and D_4.

Fig 6



Output DC level in a bridge rectifier

Fig 7 shows the input AC and the output pulsating DC wave-form of a bridge rectifier.

This wave-form is similar to that of the full wave rectifier using a centre-tap transformer. Hence, the average DC value of the output is,

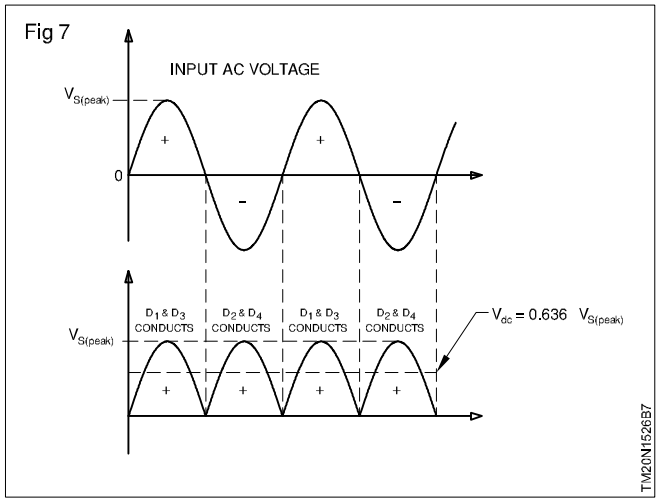
$$V_{dc} = 0.636\ V_{S(peak)}$$

or $$V_{dc} = 0.9\ V_{S(rms)}$$

where, $V_{S(rms)}$ is the full secondary AC rms voltage.

In a two-diode fullwave rectifier $V_{S(rms)}$ refers to only half of the total secondary voltage whereas in a bridge rectifier $V_{S(rms)}$ refers to full secondary voltage.

Fig 7



Example: In Fig 6, if the transformer secondary voltage $V_{S(rms)}$ is 24 volts, the rectified DC voltage V_{dc} across the load R_L will be,

From equation ....2, V_{dc} for a bridge rectifier is given by,

$$V_{dc} = 0.9\ V_{S(rms)}$$

In the given example, $V_{S(rms)}$ = 24 volts

Therefore, V_{dc} = 0.9 x 24 = 21.6 volts

Using the same transformer, a two-diode fullwave rectifier would have given only 10.8 volts which is half of that of a bridge rectifier output. –

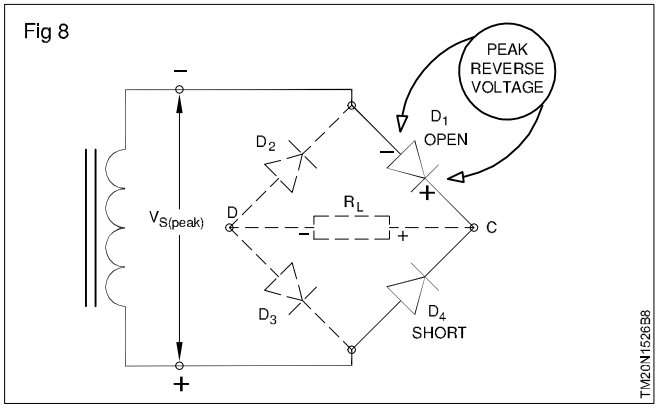
Ripple frequency - Bridge rectifier

The pulsating DC output of a bridge is similar to the two diode fullwave. Hence, as in a two diode fullwave rectifier, the output ripple frequency of the bridge rectifier is also twice the input AC frequency.

Peak inverse voltage - Bridge rectifier

Fig 8 shows a bridge rectifier at the instant the secondary voltage has reached its maximum value.

Fig 8



Diode D4 is ideally short (as it is conducting) and D_1 is ideally open. Summing the voltages around the outside loop and applying Kirchhoff's law,

$$V_{S(peak)} - \text{PIV across } D_1 + 0 = 0$$

or $$\text{PIV across } D_1 = V_{S(peak)}$$

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Therefore, the peak inverse voltage across D_4 is equal to the peak secondary voltage $V_{S(peak)}$.

In a similar way, the peak inverse voltage across each diode will be equal to the peak secondary voltage $V_{S(peak)}$ of the transformer secondary. Hence the PIV ratings of the diodes used should be greater than $V_{S(peak)}$.

Example: In Fig 8, if the transformer secondary voltage $V_{S(rms)}$ is 24 volts, find the minimum PIV of diodes used.

In a bridge rectifier PIV across the diodes is same and is equal to $V_{S(peak)}$.

Therefore, in the given example,

$$PIV = V_{S(peak)} = \frac{V_{S(rms)}}{0.707} = \frac{24}{0.707} = 34 \text{ volts.}$$

Current rating of diodes in bridge rectifiers

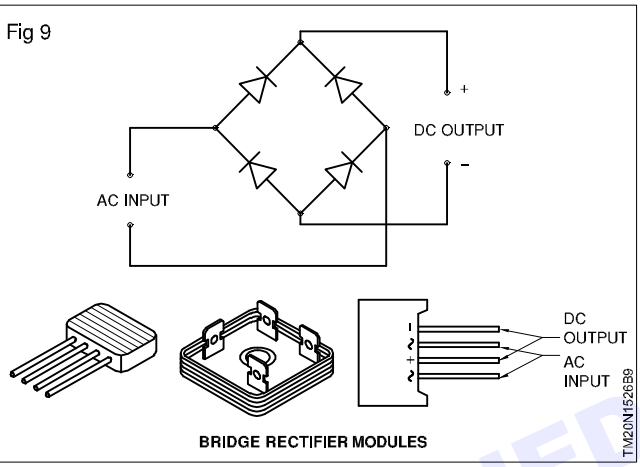
As in the case of a two diode fullwave rectifier even in a bridge rectifier shown in Fig 6, diode pairs D_1, D_3 and D_2, D_4 carry half the total load current I. This is because each diode pair is conducting only during one half of the AC input cycle.

The only disadvantage of bridge rectifiers, if it is treated as a disadvantage, is that, this circuit uses four diodes for fullwave rectification instead of two as in two-diode fullwave rectifier. But this disadvantage is compensated by the simple transformer requirement of the bridge rectifier and higher DC output level. Hence, bridge rectifiers are the most popular AC to DC rectifiers for most applications.

Encapsulated bridge rectifier modules

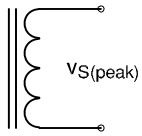
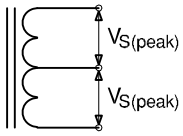
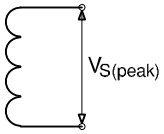
From the comparative table above it is evident that even though bridge rectifiers need four diodes, it has several advantages over the other two types of rectifiers. Hence, bridge rectifier power supplies are very often used for most applications. Because of its popularity, manufacturers are packing bridge rectifiers as a module for easy use in application. For instance, the B 40 bridge rectifier module is a commercially available bridge rectifier assembly as shown in Fig 9.

Fig 9



The bridge rectifier module shown in Fig 9 consists of four hermetically sealed diodes, interconnected and encapsulated in plastic to provide a single rugged package. It has two input pins for feeding the AC voltage from the transformer secondary and two output pins across which the rectified DC voltage is available.

A comparison of **half-wave, fullwave** and **bridge rectifier** is given below in a tabular form;

	Half wave	Full wave	Bridge
• Number of diodes required	1	2	4
• Transformers Peak output voltage			
• DC output voltage in terms of $V_{S(peak)}$	$0.318\,V_{S(Peak)}$	$0.636\,V_{S(Peak)}$	$0.636\,V_{S(Peak)}$
• DC output voltage in terms of $V_{S(rms)}$	$0.45\,V_{S(rms)}$	$0.9\,V_{S\,(rms)}$	$0.9\,V_{S(rms)}$
• Diode current rating	$I_{L(max)}$	$0.5\,I_{L(max)}$	$0.5\,I_{L(max)}$
• Peak inverse voltage	$V_{S(peak)}$	$2V_{S(peak)}$	$V_{S(peak)}$
• Ripple frequency	f_{input}	$2f_{input}$	$2f_{input}$

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Zener diodes - designing regulators

Objectives : At the end of this lesson you shall be able to
- **state the need for minimum current through the zener**
- **state the worst case conditions to be considered while designing a zener regulator**
- **calculate the value and wattage of a series resistor**
- **calculate the required wattage of a zener for a given application.**

Designing a simple zener regulator

The voltage across a zener tends to increase or decrease, it results in increase or decrease in the current I_Z, through the zener. This variation in I_Z results in the voltage across the series resistor R_S to increase or decrease, thus keeping the voltage across the zener, and, hence, the voltage across the output/load constant.

From this it is clear that, to make a voltage regulator circuit using zener, a resistor and a zener diode are required. The value of the resistor should be chosen so as to meet the following conditions;

– Under full load condition (i.e., I_L=max), at least the minimum reverse current should flow through the zener such that the zener remains to be in the zener breakdown condition.

The voltage drop across R_S should be such that,

$V_Z + V_{RS} = V_{IN}$

where, V_Z is the zener voltage and also the required output voltage V_{OUT} of the regulator.

For the zener to hold the output voltage constant, the zener must remain in the breakdown region under all conditions.

– Under no load condition, the series resistor R_S must restrict the current through the zener, such that, the power dissipation across the zener is within the specified limit of the device.

The voltage drop across R_S should be such that,

$V_Z + V_{RS} = V_{IN}$

The design steps for a simple zener regulator circuit is given below through an example:

Example: A zener regulator circuit is needed to supply a constant output voltage of 12V DC ± 0.1V. The load current may vary (depending on load resistance) from 0 to 100mA. The unregulated input to the regulator is 34V DC (maximum).

Design steps:

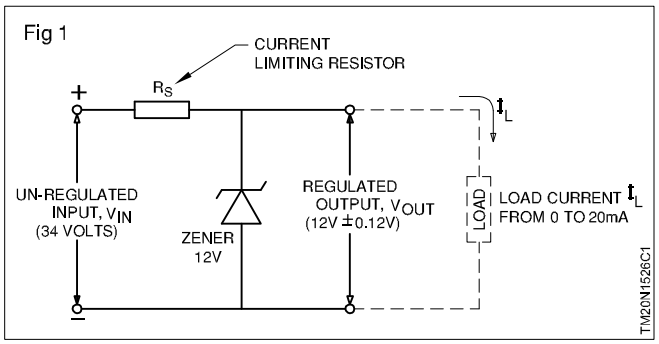
1 Draw a schematic of regulator as shown in Fig 1.

2 Choose a zener of V_Z = 12 volts as the output voltage required is 12 Volts. Choose the zener with a tolerance of ≥10%, so that the output will be 12 V DC ± 0.12 V.

3 From the specifications of the zener, find I_Z. *Say the I_Z of the chosen zener is = 20mA.*

4 Calculate the current through the zener in the worst conditions as explained below;

Fig 1



One of the worst conditions is, when the input voltage V_{IN} is minimum and, the load current is maximum. For this condition, choose the minimum I_Z that should flow through the zener to keep it in reverse-ON condition.

In the example considered, I_Z = 20mA.

Since, $I_T = I_Z + I_{L(max)}$

For the given example,

I_T = 20mA + 100 mA = 120 mA.

The other worst condition is, when maximum current flows through the zener as the load current is zero or minimum and the source voltage is maximum. In the example considered, minimum I_L = 0 mA.

When I_L = 0 mA, current through the zener will be maximum and is,

120 mA – 0 mA = 120 mA.

5 Calculate the zener wattage.

The zener wattage is determined from the maximum I_Z

$W_Z = V_Z \times I_Z = 12 \times 0.12 = 1.44$ Watts

where, V_Z is the zener voltage and I_Z is the maximum current through zener.

6 Calculate the required value of R_S

$V_{IN} - V_{OUT} = I_T R_S$

or, $I_T R_S = V_{IN} - V_{OUT}$

$= 34V - 12V = 22V$

Since, I_T = 120mA

$$R_S = \frac{22V}{R_s} = \frac{22V}{180\,\Omega} = 183W$$

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Therefore, R_S = 183W

Since 183 is not a standard resistance value, choose the nearest lower value of RS which is 180W upon choosing 180W in place of 183W, the changed value of I_T will be,

$$I_T = \frac{22}{120 \times 10^{-3}} = 122mA$$

The increased I_T of 122mA instead of 120 results in an excess of 2mA through the zener. Therefore add an extra wattage of 12V x 0.002 = 24mw to the already calculated zener wattage of 1.44 watts. Therefore the new wattage of zener should be 1.4 watts + 0.024 W = 1.464 » 1.5 W.

7 Calculating the wattage of R_S

Maximum current through R_S in the worst condition will be 122mA.

Therefore, $W = I_T^2 R_S = (0.122)^2 .180$

$= 2.69 \text{ » } 2.7$ watts

From the above calculations, On No-load,

$I_Z + I_L = I_T = 122mA$

Since $I_L = 0$, $I_Z = I_T = 122mA$

On Full-load (100mA)

$I_T = I_Z + I_L$

$I_T = 122mA$

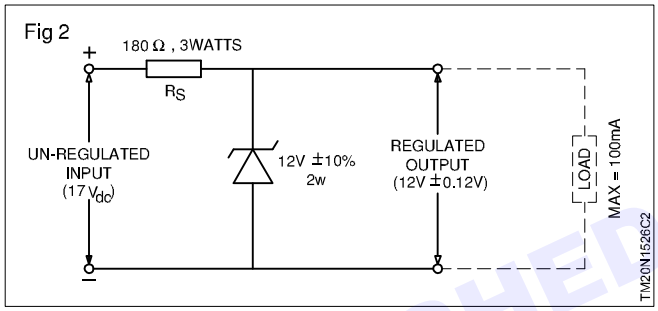
Therefore, $I_Z = I_T - I_L$

$= 122mA - 100mA = 22mA$

I_Z of 22mA is sufficient to keep the zener in reverse ON condition even during full load.

In steps 6 and 7, a good design practice is to overrate the wattage of the resistor and zener, so that the components do not get overheated and fail prematurely. Hence, the resistor should be rated at 3 watts or more and the zener at 2W. The designed simple zener regulator with component values and ratings as shown in Fig 2.

Fig 2



Integrated circuit voltage regulators

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

- **state the meaning of integrated circuits**
- **state the two main types of IC voltage regulators with examples**
- **design voltage regulators for the required output**
- **explain a fixed voltage regulator to a variable output regulator.**

Introduction

Electronic circuits invariably consist of a number of discrete components connected to each other in a specific way. For instance, the series regulator circuit discussed in earlier lessons, consisted of transistors, zener diodes, resistors and so on, connected in a defined way for it to function as a regulator. If all these components instead of building on a board, if they are built on a single wafer of a semiconductor crystal, then, the physical size of the circuit becomes very small. Although small, this will do the same job as that of the circuit wired using discrete components. Such miniaturised electronic circuits produced within and upon a single crystal, usually silicon, are known as **integrated circuits** or **IC**s. Integrated circuits (ICs) can consist of thousands of active components like transistor, diodes and passive components like resistors and capacitors in some specific order such that they function in a defined way, say as voltage regulators or amplifiers or oscillators and so on.

Classification of integrated circuits

Integrated circuits may be classified in several ways. However the most popular classifications is as follows:

1 Based on its type of circuitry

a Analog ICs - Example: amplifier ICs, voltage regulator ICs etc.

b Digital ICs - Example: Digital gates, flip-flops, adders etc.

2 Based on the number of transistors built into IC

a Small scale integration (SSI) - consists of 1 to 10 transistors.

b Medium scale integration (MSI) - consists of 10 to 100 transistors.

c Large scale integration (LSI) - 100 to 1000 transistors.

d Very large scale integration (VLSI) - 1000 and above.

3 Based on the type of transistors used

a Bipolar - carries both electron and hole current.

b Metal oxide semiconductor (MOS) - electron or hole current.

c Complementary metal oxide semiconductor (CMOS) - electron or hole current.

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The terms MOS and CMOS are another type of transistors which will be discussed in further lessons. Further details on different classifications of ICs will be discussed at appropriate lessons.

Integrated circuit (IC) voltage regulators

The series voltage regulators discussed in earlier lessons are available in the form of integrated circuits (ICs). They are known as *voltage regulator ICs*.

There are two types of voltage regulator ICs. They are,

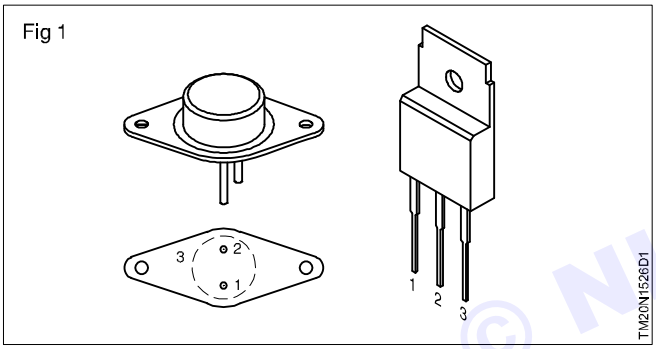
1 Fixed output voltage regulator ICs

2 Adjustable output voltage regulator ICs.

Fixed output voltage regulator ICs

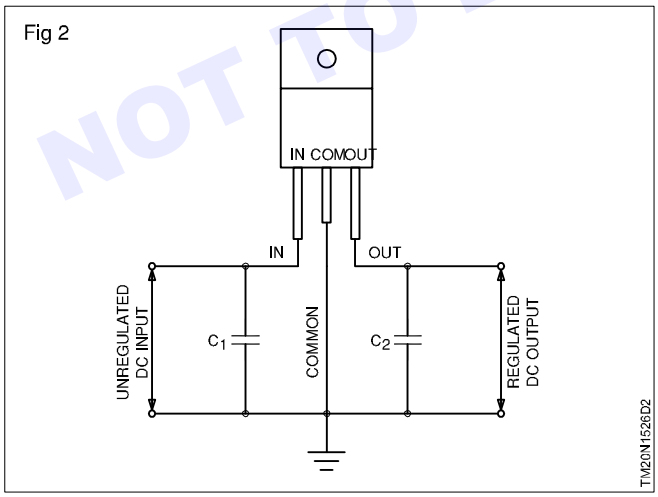
The latest generation of fixed output voltage regulator ICs have only three pins as shown in Fig 1. They are designed to provide either positive or negative regulated DC output voltage.

Fig 1



These ICs consists of all those components and even more in the small packages shown in Fig 1. These ICs, when used as voltage regulators, do not need extra components other than two small value capacitors as shown in Fig 2.

Fig 2



The reason behind using capacitor C_1 is, when the voltage regulator IC is more than a few inches from the filter capacitors of the unregulated power supply, the lead inductance may produce oscillations within the IC. Capacitor C_1 prevents setting up of such oscillations. Typical value of bypass capacitor C_1 range from 0.220µF to 1µF. It is important to note that C_1 should be connected as close to the IC as possible.

The capacitor C_2 is used to improve the transient response of the regulated output voltage. C_2 bypasses these transients produced during the ON/OFF time. Typical values of C_2 range from 0.1µF to 10 µF.

Fixed voltage three terminal regulators are available from different IC manufacturers for different output voltages (such as 5V, 9V, 12V, 24V) with maximum load current rating ranging from 100mA to more than three amps.

The most popular three terminal IC regulators are,

1 LMXXX-X series

Example: LM320-5, LM320-24 etc.

2 78XX and 79XX series

Example: 7805, 7812, 7912 etc.

A list of popular three terminal regulators is given in Pocket Table Book, Table No.30.

Specifications of three terminal IC regulators

For simplicity in understanding, let us consider the specification of a three terminal IC **µA7812**. The table given below lists the specifications of µA7812.

Parameter	Min.	Typ.	Max.	Units
Output voltage	11.5	12	12.5	V
Output regulation		4	120	mV
Short-circuit output current		350		mA
Drop out voltage		2.0		V
Ripple rejection	55	71		dB
Peak output current		2.2		A

– **Output voltage**

This specification indicates the regulated DC output voltage that can be obtained from the IC. As can be seen from the sample specification table given above, the manufacturer specifies minimum, typical and maximum output voltages. While using this IC take the typical value as this value corresponds to the output voltage at IC under normal input and load conditions.

– **Output regulation**

This indicates the amount by which the output voltage may vary at rated maximum load condition. For example, in **µA7812** IC, the output voltage may vary by 4 mV from its rated 12 V DC when the rated typical load current is 2.2A.

– **Short circuit output current**

This indicates the shorted current I_{SC} (recall lesson 11.04) if the output gets shorted. In µA 7812 the output current is limited to 350mA when the output terminals are shorted.

– **Drop out voltage**

For instance, in µA7812 in which the output voltage is +12 V, the input unregulated DC voltage to the regulator must be higher than the output voltage. The specification

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drop out voltage indicates, the minimum positive difference between the input and output voltages for the IC to operate as a regulator. For example, in, µA7812 the unregulated input voltage should be atleast 2 volts more than the regulated DC output of 12V. This means for µA7812 the input must be atleast 14V.

The difference between the voltage across the input and output of the IC should also not to be very high as this causes unwanted dissipation. As a thumb rule, the input voltage to the regulator shall be restricted to a maximum of twice the output voltage of the regulator. For example, for µA7812, the unregulated input voltage should be more than 14V, but less than 24V.

– **Ripple rejection**

This indicates the ratio of ripple rejection between the output to input, expressed in decibels.

– **Peak output current**

This indicates the highest output or load current that can be drawn. Above this rated maximum current the safety of the IC is not guaranteed.

Identification of output voltage and rated maximum load current from IC type number

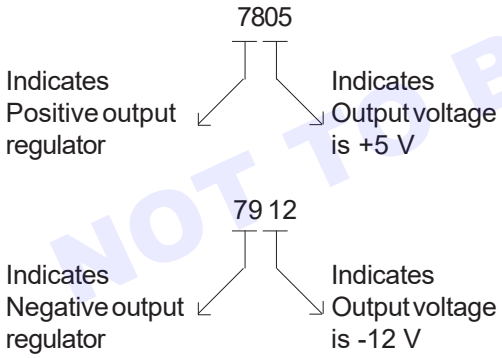
– 78XX and 79XX series are **3 Terminal voltage regulators.**

– All 78XX series are **positive output voltage regulators.**

– All 79XX series are **negative output voltage regulators.**

The term XX indicates the rated output regulated voltage.

Example:



It is important to note that, different manufacturers of 78XX/ 79XX series such as Fair Child (µA/µpc), Motorola, Signetics (SS) adopt slightly different coding schemes to indicate the rated maximum current of the three pin regulated ICs. One such scheme is given below.

78LXX - L indicates rated maximum load current as 100mA.
78MXX- M indicates rated maximum load current as 500mA
78XX - Absence of an alphabet between 78 and XX indicates that the rated maximum load current is 1A.
78SXX - S indicates rated maximum load current is 2 amps.

Example

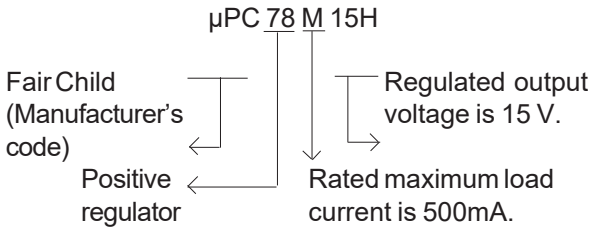


Table book, Table No.23, 24 for 78XX and 79XX series of fixed voltage, 3 terminal voltage regulators.

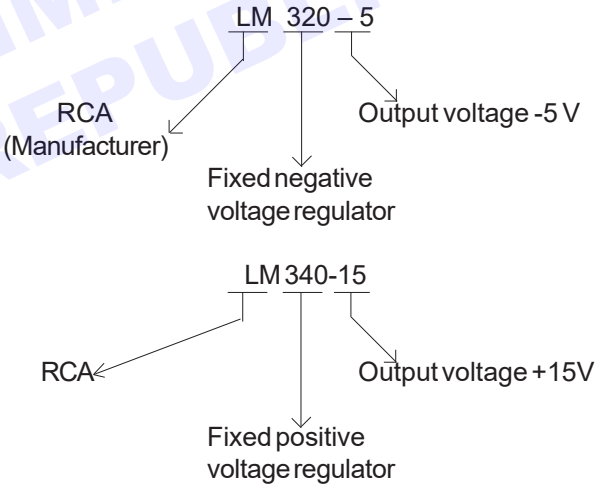
LM 3XX series of 3 terminal voltage regulators

In LM series of three terminal regulators, to find the specifications, it is suggested to refer to its data manual. However, the following tips will help in identifying whether the IC is a fixed positive or fixed negative regulator.

LM320-X and LM320-XX → Fixed -ve voltage regulators.

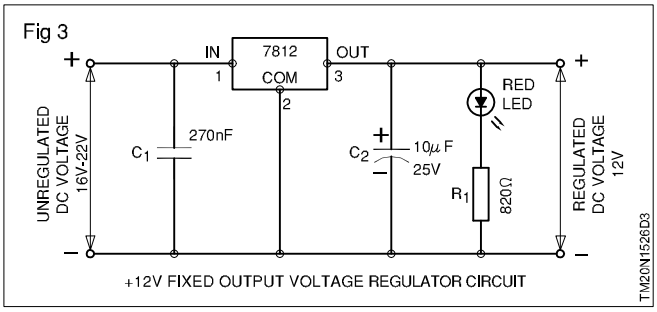
LM340-X or LM340-XX → Fixed +ve voltage regulators.

Examples:



Practical 78XX and 79XX voltage regulator circuits

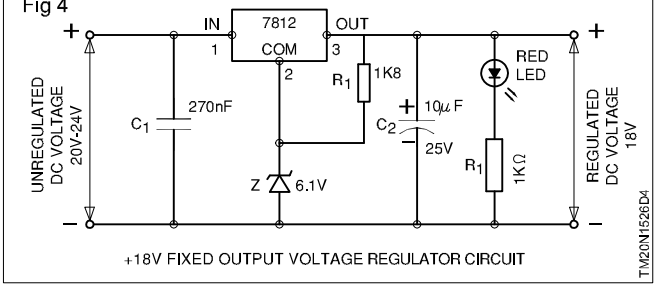
Fig 3 shows the circuit connections of a 12 V, 1 A regulated power supply using 7812.



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The output voltage of a 3-terminal regulator IC is with reference to the IC's *common terminal (COM)*. When the COM terminal is grounded, the output voltage of the regulator will be the specified output voltage of the IC as shown in Fig 3. But the output voltage of the IC can be increased above the specified value by raising the voltage at the COM terminal as shown in Fig 4. Because of 6.1V zener, the output voltage will be 6.1V + 12V = 18.1V or approximately 18V as shown in Fig 4.

Fig 4

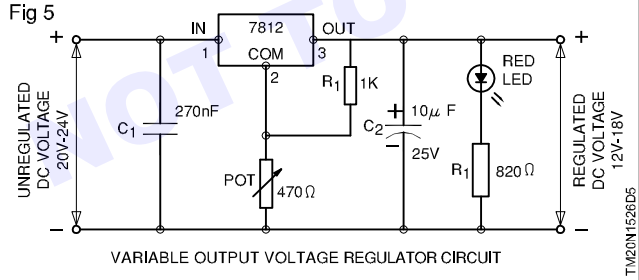


+18V FIXED OUTPUT VOLTAGE REGULATOR CIRCUIT

When the COM terminal of the IC is grounded as shown in Fig 3, the quiescent current flowing from the COM terminal to ground in 78 series is around 8 μA. This current decreases as the load current increases. When a zener is connected at COM terminal as shown in Fig 4, to ensure that the zener is always in the reverse ON condition, resistor R_1 is used. If R_1 = 1.8K, I_Z will be 7mA which is sufficient to keep the zener ON always.

Fig 5 shows a variable output voltage regulator using a fixed voltage regulator. The variable reference voltage at COM terminal is obtained using a POT to loading. Therefore, the bias voltage is determined by the sum of the quiescent current I_Q and the bias current set by R_1. In Fig 5, when the resistance of the POT is set to 0, COM is grounded and hence output will be 12V. As the set value of pot increases the output voltage also increases.

Fig 5



VARIABLE OUTPUT VOLTAGE REGULATOR CIRCUIT

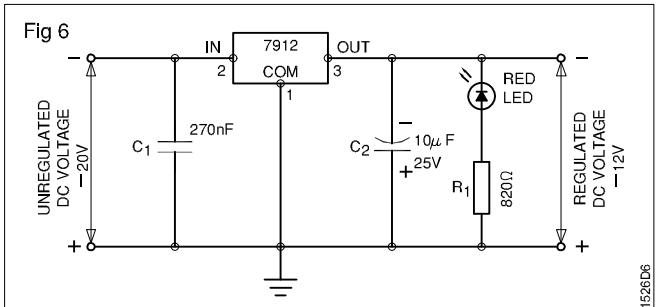
Fig 6 shows a negative voltage regulator using 7912. The working of this circuit is similar to that of Fig 7 except that it is a negative voltage regulator and hence the voltage at pin no.3 of the IC will be -12volts.

Fig 7 shows a +15 volts regulator using LM340. This circuit connection is very much similar to that of the 78XX series regulator.

Multiple voltage using three-terminal fixed voltage regulator

Fig 8 shows how a three-terminal IC can be used to obtain multiple voltages. Such economical and elegant circuits are very useful for electronic circuits and for service technicians.

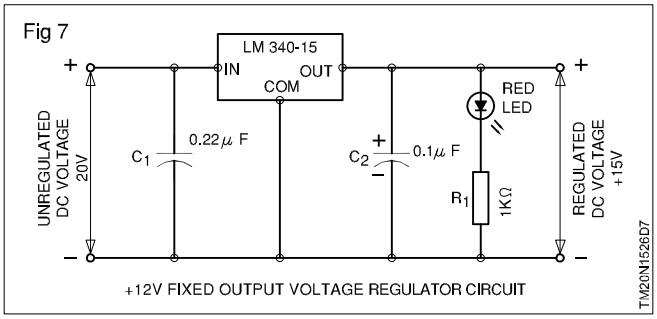
Fig 6



−12V FIXED OUTPUT VOLTAGE REGULATOR CIRCUIT

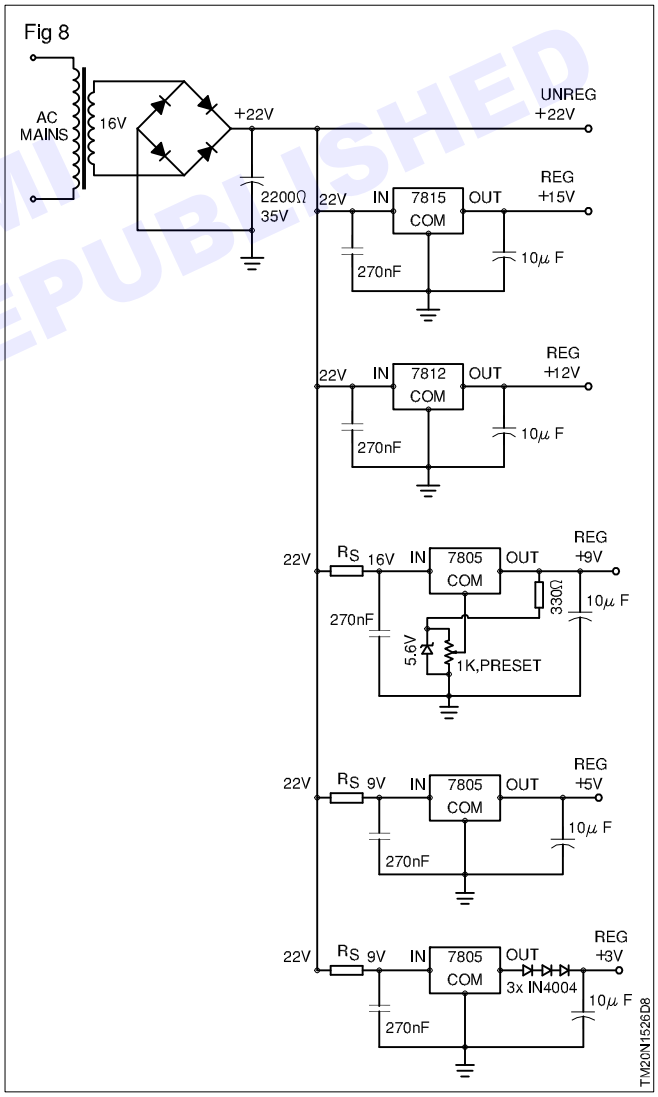
NOTE: PIN NUMBERS ARE DIFFERENT FROM 7812

Fig 7



+12V FIXED OUTPUT VOLTAGE REGULATOR CIRCUIT

Fig 8



Recall, than the value input unregulated DC to a regulator should always be less than twice the output of the regulator. As shown in the third regulator (7805) of Fig 8,

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when it is necessary to operate with a large input voltage, a series resistance R_S can be added in series to drop required voltage.

The scheme shown in Fig 8 is one of the several schemes that can be adopted to get multiple voltage output.

Since the quiescent current through the pot is very low (around 8μA) and it decreases with load resistor R_1 is used to compensate the changes in the quiescent current due

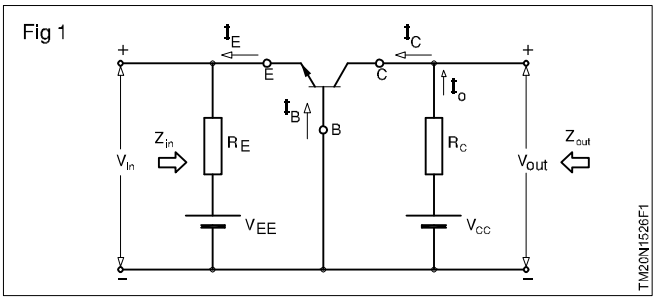
Common base amplifier

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

- **calculate the voltage gain, current gain, input impedance and output impedance of a common base amplifier**
- **list the typical applications of common base amplifiers.**

Fig 1 shows the typical circuit schematic of a **common base amplifier** (CB-amplifier).

Fig 1



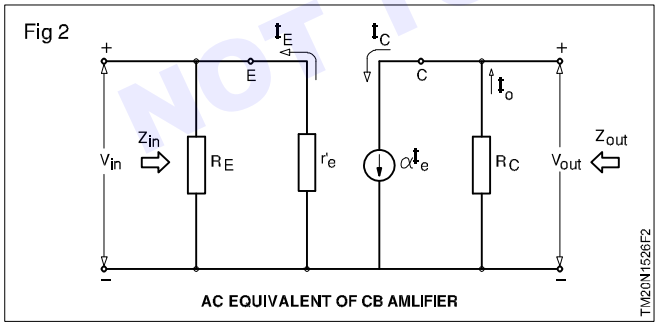
Common base amplifiers have a current gain of less than 1. Recall, the emitter current and the collector current of a transistor are almost equal. In a common base amplifier since the input current is I_E and the output current is I_C, the current gain, symbolically represented as α (alpha), is given by,

$$\text{Current gain } (\alpha) = \frac{\text{Output current}}{\text{Input current}} = \frac{I_C}{I_E}.$$

Since $I_E > I_C$, α will always be less than 1.

Fig 2 shows the ac equivalent of a common base amplifier, shown in Fig 1.

Fig 2



From Fig 2, the input impedance Z_{in} of CB amplifier is given by,

$$Z_{in} = R_E \parallel r'_e \qquad \text{.....\{1\}.}$$

Since R_E is generally much greater than r'_e, eqn..1 can be simplified as,

$$Z_{in} = r'_e$$

The equation for Z_{in} indicates that, the input impedance of a CB amplifier is very low and almost equal to the ac resistance r'_e of the emitter diode (recall r'_e will be generally 25Ω).

Referring to the AC equivalent network of the CB amplifier, the output impedance Z_{out} of CB amplifier is given by,

$$Z_{out} = R_C \qquad \text{.....\{2\}.}$$

Equation 2 indicates that the output impedance of a CB amplifier is relatively high, of the order of kilo ohms (because you can fix the value of R_C as you wish !).

From Fig 2, the output voltage V_{out} is

$$V_{out} = I_o R_C = I_c.R_C$$

Since $\alpha = \frac{I_C}{I_E}$, $I_C = \alpha.I_E$

Therefore, $V_{out} = I_C R_C = \alpha.I_E.R_C$ .....{3}.

Since, $I_E = \frac{V_{in}}{r'e}$ equation 3 can be written as,

$$V_{out} = \alpha\left(\frac{V_{in}}{r'e}\right) R_C$$

The voltage gain A_V of CB amplifier is given by,

$$A_V = \frac{V_{out}}{V_{in}} = \alpha \frac{V_{in}}{r'_e} R_C \frac{1}{V_{in}} = \alpha \frac{R_C}{r'_e} \qquad \text{.....\{4\}}$$

Since r'_e is very small compared to R_C, the voltage gain A_V of the CB amplifier is quite high.

The power gain A_p of the CB amplifier is given by,

$$A_P = A_i.A_V$$

Power gain A_P will be medium because although A_i is less than or equal to 1, A_V of the CB amplifier is quite high.

Input/output phase relationship

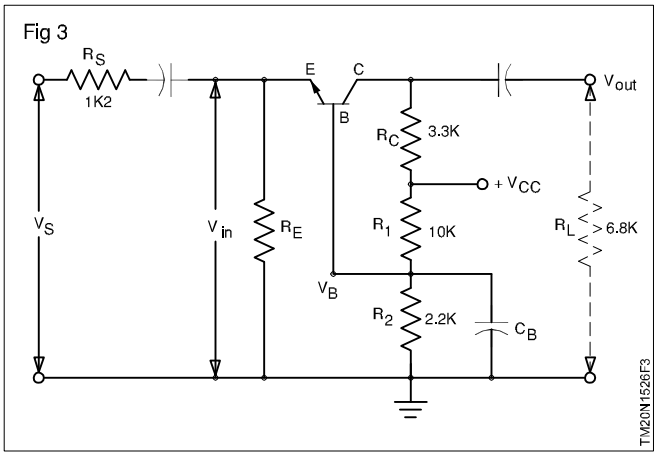
The input and output of a common base amplifier are in phase with each other. This can be found experimentally.

Fig 3 shows a CB amplifier with voltage divider bias.

In Fig 3, the base of the transistor is at ac ground due to the bypass capacitor C_B. The input signal drives the emitter and the output is taken from the collector. The biasing resistors R_1, R_2 will have negligible effect on the input impedance. Therefore, the input impedance of the CB amplifier is approximately equal to r'_e itself.

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Fig 3



The voltage at the base (at T_1) is given by,

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

$$= \frac{2.2K}{10\,K + 2.2K} . 12V$$

$$= 2.16 \text{ volts.}$$

The emitter current I_E is given by,

$$I_E = \frac{V_B - V_{BE}}{R_E}$$

$$= \frac{2.16 - 0.7}{1.2\,K\ \Omega}$$

$$= 1.22 \text{ mA}$$

Therefore, r'_e is given by,

$$r'_e = \frac{25mV}{I_E}$$

$$= \frac{25mV}{1.22\,mA}$$

$$= 20.5\ \Omega$$

Input impedance Z_{in} is given by,

$Z_{in} \approx r'_e = 20.5\ \Omega.$

The voltage gain A_V is given by,

$$A_V = \frac{R_C}{r'_e}$$

$$= \frac{3.3K}{20.5}$$

$$= 160.97 \approx 161\ \Omega$$

The output impedance Z_{out} is given by,

$Z_{out} \approx R_C = 3.3K\ \Omega$

The input V_{in} to the amplifier is given by (note that C_B bypass R_2 for AC signal),

$$V_{in} = \frac{r'_e}{R_S + r'_e} V_S$$

$$= \frac{20.5\ \Omega}{1K\Omega + 20.5\Omega} 500mV$$

$$= 10 \text{ mV.}$$

Therefore, the unloaded output voltage V_{out} is given by,

$$V_{out\ (No\ load)} = A_V . V_{in}$$

$$= 161 \times 10 \text{ mV}$$

$$= 1610 \text{ mV}$$

$$= 1.61 \text{ volts.}$$

The output voltage of the amplifier with load R_L is given by,

$$V_{out\ (Load} = \frac{R_L}{R_C + R_L} x V_{out\ (No\ load)}$$

$$= \frac{6.8K}{3.3K + 6.8K} x 1.61V$$

$$= 1.08V$$

Class Room Assignment: ***Calculate the output voltage of the CB amplifier (as done in step above) if load resistor R_L was,***

i $R_L = 3.3K$

ii $R_L = 10K$ *and,*

iii $R_L = 100K$

Pocket Table Book, table No.22 gives a summary of the important parameters of common base transistor amplifiers.

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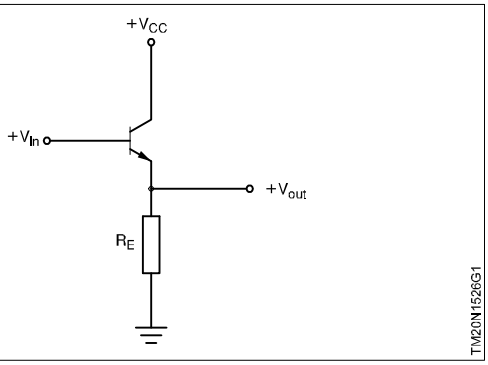
Emitter follower

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

- **state the need for impedance matching**
- **state the popular application of an emitter follower amplifier configuration**
- **calculate the voltage gain, current gain, input impedance and output impedance of a transistor amplifier using circuit component values.**

Fig 1 shows another important transistor amplifier configuration. In this configuration, unlike in a common emitter amplifier where the output is taken from the collector, the output is taken from the emitter terminal of the transistor as shown in Fig 1.

Fig 1



Emitter follower can be used, to match a high impedance source to a low impedance output load. Hence, the emitter follower configuration is frequently used as an impedance matching circuit than as an amplifier.

Need for impedance matching

When a high impedance source is connected to a low impedance load, then most of the ac signal of the source gets dropped across the internal impedance of the source itself resulting in a very small portion of the signal appearing across the required load as shown in Fig 2a. One way to overcome this problem, i.e. to have almost all the signal from the source to be developed across the load, is to use an impedance matching device or a circuit between the high impedance source and the low impedance load as shown in Fig 2b.

The circuit used for impedance matching in Fig 2b, is an emitter follower transistor amplifier. This is because, the emitter follower has a very high input impedance and a very low output impedance. This can be compared to that of a matching transformer where a load is matched to the source impedance for maximum power transfer.

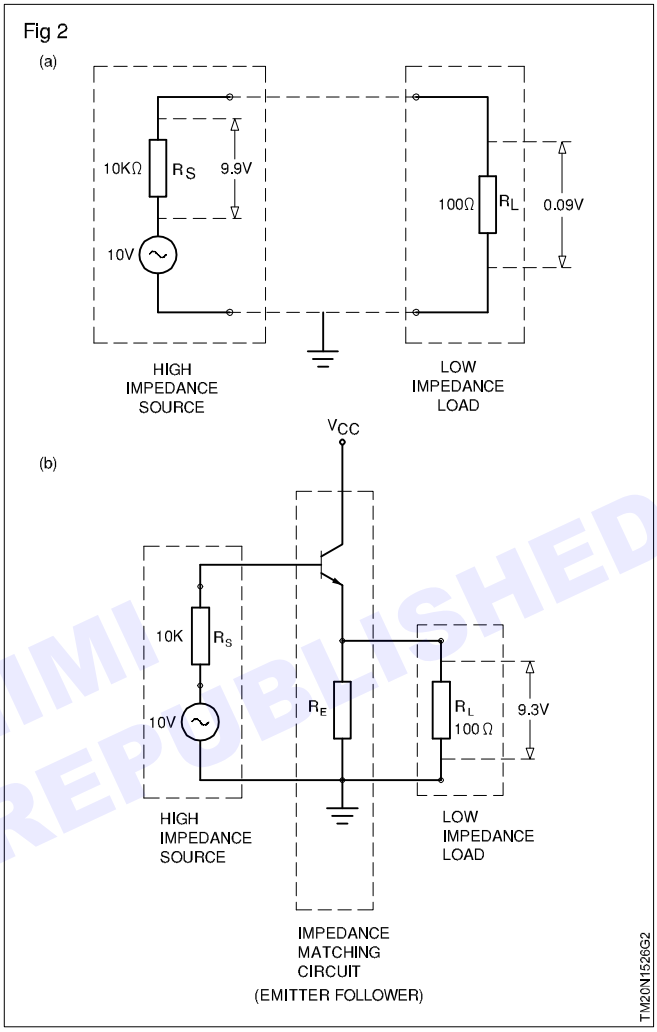
An emitter follower circuit is also called a *common collector amplifier* because, the collector behaves as the common terminal for ac signal between the input and the output.

Voltage gain of an emitter follower

As can be seen in Fig 3, the DC output voltage of the emitter follower is $V_{out} = V_{in} - V_{BE}$

Since, V_{BE} is almost a constant value (0.7 for silicon, 0.3 for germanium) the emitter voltage follows the base voltage. It is because the emitter voltage follows the base voltage, this circuit is called ***emitter follower.***

Fig 2



In Fig 3, if V_{in} is 3V, then V_{out} = 2.3V. If V_{in} is made 4\| then V_{out} increases to 3.3V. This means that changes in V_{out} is in phase wide changes in V_{in}. Therefore in an emitter follower the input and output signals are in phase as shown in Fig 3b. (recall, in a CE amplifier the input and output are 180° out of phase.)

Fig 3c shows the ac equivalent circuit of the emitter-follower shown in Fig 3a. The AC output voltage V_{out} is given by,

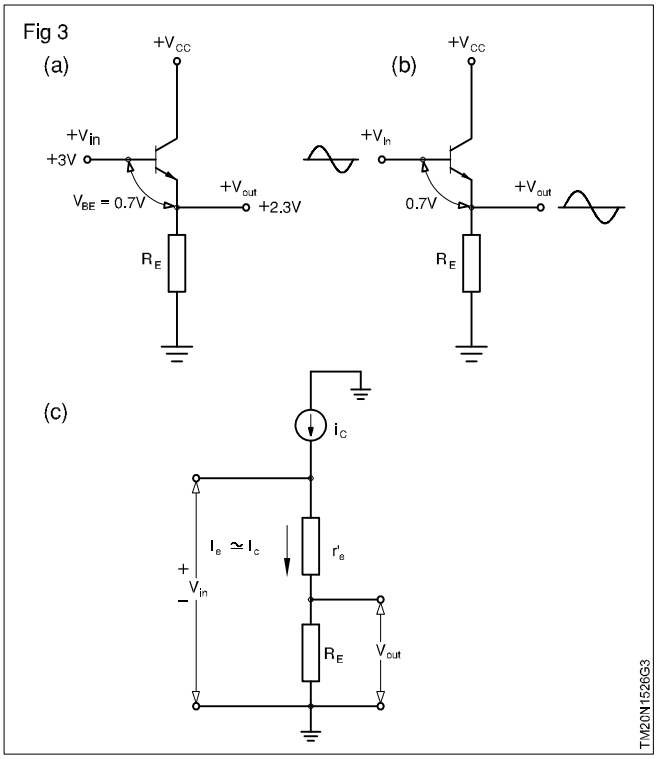
$$V_{out} = i_e R_E$$

Since the AC input voltage V_{in} is given by, $V_{in} = i_e (R_E + r'_e)$ the voltage gain A_V of the emitter follower is,

$$A_V = \frac{V_{out}}{V_{in}} = \frac{i_e R_E}{i_e (R_E + r'_e)} = \frac{R_E}{R_E + r'_e} \quad \text{.....\{1\}}$$

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Fig 3



In equation {1}, since the denominator will always be higher than the numerator, the value of voltage gain A_V will always be less than 1.

But since the value of r'_e is very small compared to R_E, the value of A_V approaches unity. We can therefore say that the voltage gain of the emitter follower is unity.

In Fig 3a, if $R_E = 4.7K\Omega$ and $r'_e = 25\Omega$ then,

$$A_V = \frac{R_E}{R_E + r'_e} = \frac{4700}{4700 + 25} = 0.995 \approx 1.$$

Input impedance of emitter follower

The input impedance of the emitter follower shown in Fig 3 is given by,

$$Z_{in} = \beta(R_E + r'_e) \quad \text{..... \{2\}}$$

Since r'_e will be generally very small compared to R_E, equation ...{2} can be simplified as,

$$Z_{in} = \beta R_E$$

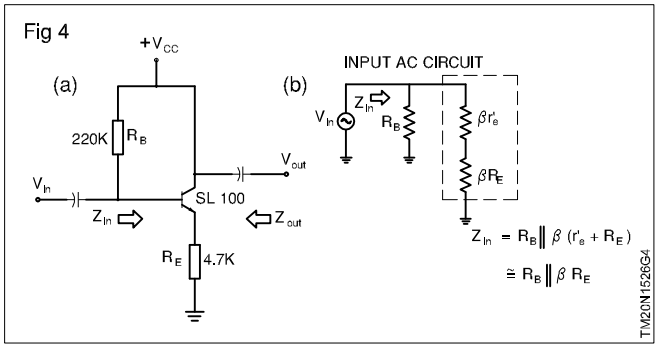
Fig 4a shows a practical emitter follower circuit using fixed biasing. The total input impedance including the biasing resistor R_B in parallel with the input impedance can be found as follows;

Writing the AC equivalent of the input of the emitter follower shown in Fig 4b, the input impedance Z_{in} is given by,

$$Z_{in} = R_B \| \beta(r'_e + R_E) \quad \text{.....\{3\}}$$

If r'_e is neglected, then, $Z_{in} = R_B \| \beta R_E$

Fig 4



Equation 3 indicates that the input impedance of a typical emitter follower is decided by the DC biasing resistance R_B. Hence, while designing an emitter follower to match a high source impedance, the values of R_B should be suitably chosen.

Example: In the emitter follower at Fig 4, if β of transistor is 100, $R_B = 220$ k and $R_E = 4.7$k the input impedance will be,

$$Z_{in} = R_{in} = R_B \| \beta R_E$$

$$= 220\ K \| \beta R_E$$

$$= 220\ K \| (100 \times 4.7K)$$

$$= 149.85\ K\Omega \approx 150\ K\Omega$$

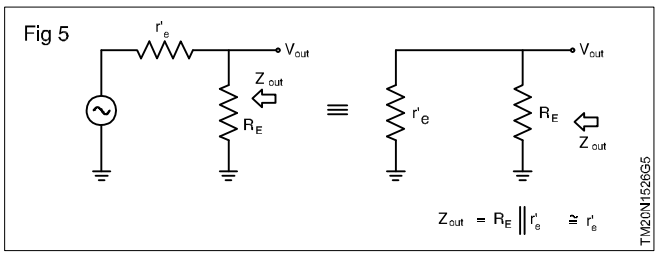
Output impedance of emitter follower

Fig 5 shows an AC equivalent or AC model of the output section of an emitter follower shown in Fig 4a.

Analysing Fig 5, the output impedance Z_{out} is given by,

$$Z_{out} = R_E \| r'_e \quad \text{.....\{4\}}$$

Fig 5



Since R_E is usually a large resistance compared to r'_e, R_E in equation (4) can be neglected. Therefore, the output impedance of an emitter follower is approximately,

$$Z_{out} = r'_e$$

Example 1: Find the output impedance of the emitter follower shown in Fig 4 assuming $r'_e = 33\Omega$,

$$Z_{out} = r'_e \| R_E \approx r'_e = 33\Omega.$$

Current gain in emitter follower Although the voltage gain A_V of emitter follower is approximately unity, the current gain of an emitter follower is high and is given by the equation;

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$$A_I = \frac{\beta R_B}{(R_B + \beta R_E)} \qquad \text{.....\{5\}}$$

Example 2: In the emitter follower shown in Fig 4, if β of the transistor is 100, then the current gain of the emitter follower is given by,

$$A_I = \frac{\beta R_B}{(R_B + \beta R_E)}$$

$$= \frac{(100)\,(220K)}{(220K) + (100)\,(4.7K)} = 31.88.$$

The current gain of the emitter follower can also be found as follows;

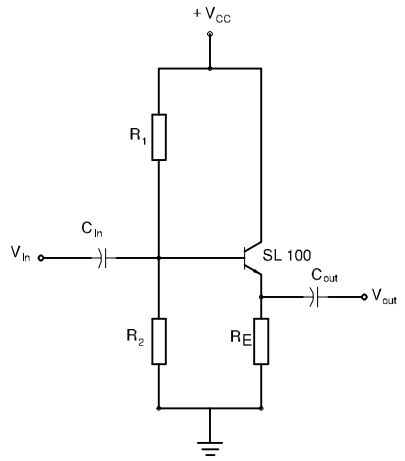
$$A_I = A_V \frac{Z_{in}}{R_E} = (0.995)\,\frac{150K}{4.7K} = 31.72.$$

Fixed bias was used in the emitter follower shown in Fig 4. Any other DC biasing could also be employed such as voltage divider bias as shown in Fig 6.

When voltage divider bias is used in an emitter follower, the equations for finding A_V, Z_{in}, Z_{out} and A_I remain the same, except for, that the fixed biased resistor R_B replaced by $R_1 \parallel R_2$.

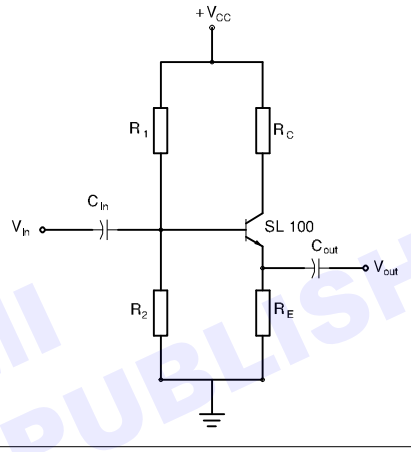
Fig 7 which includes a collector resistor R_C also provides the input-output characteristics of an emitter follower. The input impedance Z_I and the output impedance Z_o are not effected by R_C since it is not reflected into the base or emitter equivalent network of the circuit. The only use of R_C will be to fix the quiescent collector current or Q point of the transistor.

Fig 6



EMITTER-FOLLWER WITH VOLTAGE DIVIDER BIAS

Fig 7



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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.

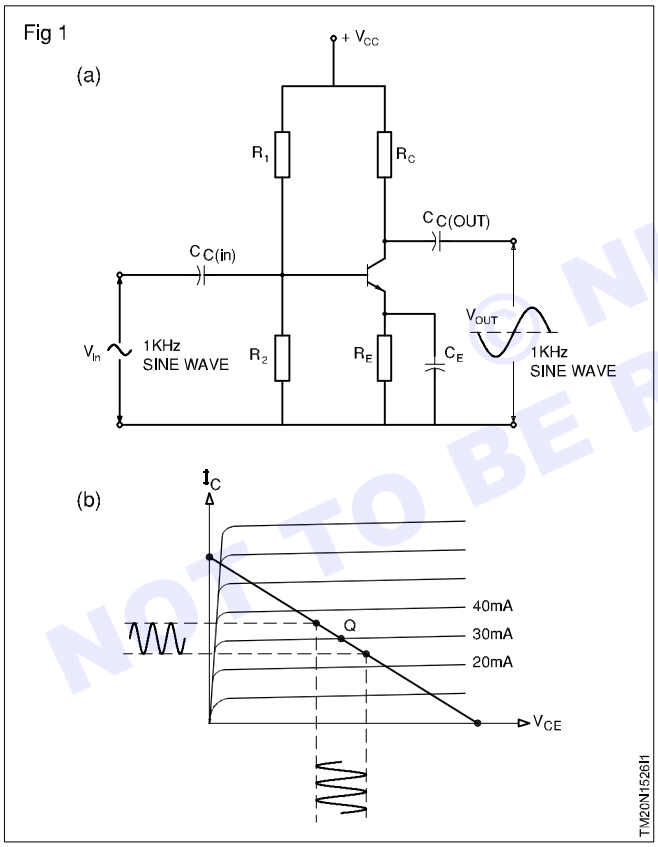
As shown in Fig 1a, if the input is a 1 KHz sine wave, the output will be an enlarged 1 KHz sine wave. The small sine wave given at the base of the transistor produces variations in the base current. Hence, the collector current is an amplified sine wave of the same frequency. The sinusoidal collector 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 within 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.

Fig 1



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.

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,

$$\text{Voltage gain, } A_V = \frac{V_{out}}{V_{in}}$$

Note: 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,

$$\text{Voltage gain, } A_V = \frac{7.2\ V_{(p-p)}}{80\text{m}\ V_{(p-p)}} = 90$$

A voltage gain of 90 means that, in this amplifier, a base voltage of 1 mV produces an output voltage of 9 mV.

NOTE: *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.

$$Z_{in} = \frac{v_{in}}{i_{in}}$$

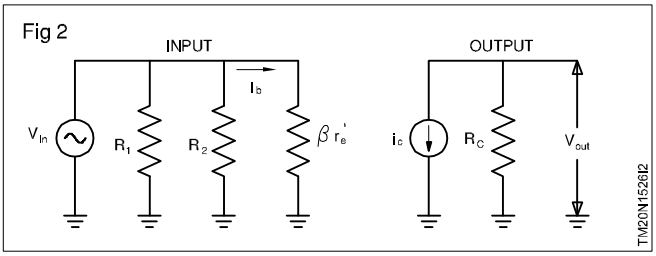
where, V_{in} and i_{in} are rms or peak or peak-to-peak values.

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,

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Fig 2



$$Z_{in} \approx R_1 \| R_2 \| \beta r'_e \quad \text{.....[1]}$$

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,

$$br'_e = 100(25\ W) = 2.5\ KW$$

$$Z_{in} = R_1 \| R_2 \| b\, r'_e$$

$$= 18\ KW \| 8.2\ KW \| 2.5\ KW$$

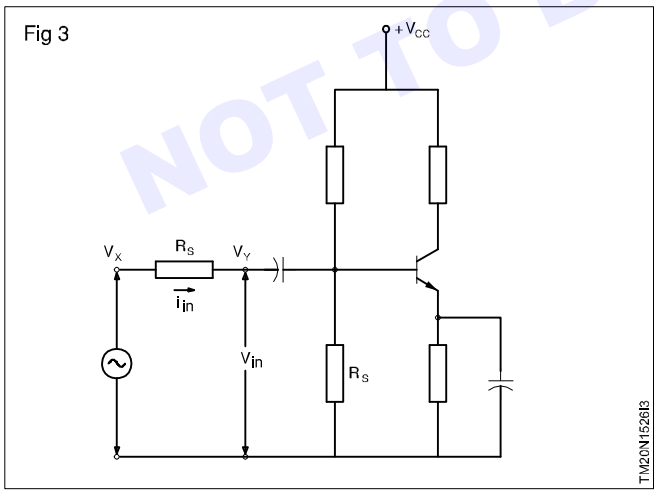
$$= 1.73\ KW.$$

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.

Fig 3



The voltage drop across the resistor R_s is measured, and Ohm's law is used to determine i_{in}.

$$i_{in} = \frac{V_x - V_y}{R_s}$$

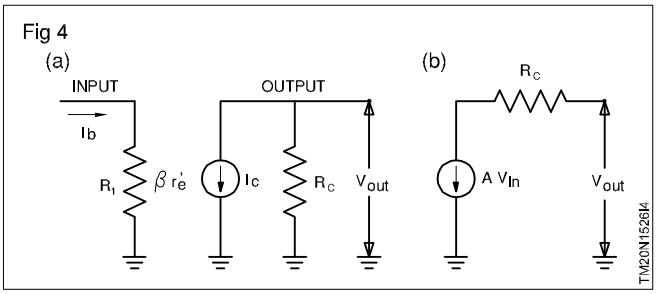
The value of V_{in} can be measured directly, as shown in Fig 3.

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 1, consider the AC equivalent of the output as shown in Fig 4a.

Fig 4



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 Thevenin'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,

$$Z_{out} \approx R_C$$

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;

1 Measure the unloaded output voltage V_{out} of the CE amplifier.

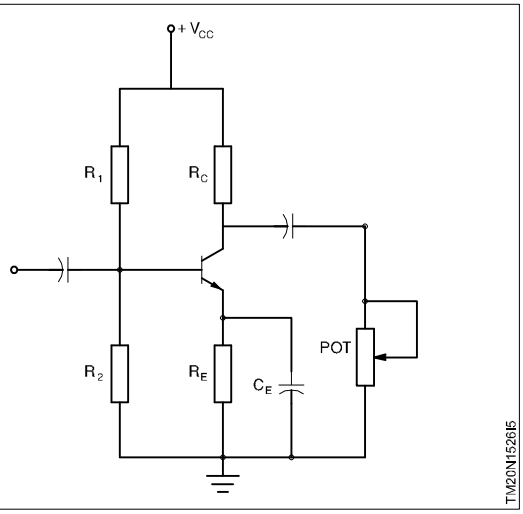
2 Place a variable resistor across the load terminals, as shown in Fig 5.

3 Adjust the variable resistor until the voltage drop across it is one-half of the unloaded output voltage V_{out}.

4 Remove the variable resistor and measure its value. This value is equal to Z_{out}.

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Fig 5



Note that 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.

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,

$$P_{out} = - v_{in}.i_b$$

Note: 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;

$$P_{out} = \frac{V_{out}^{\ 2}}{Z_{out}} \quad \text{and} \quad P_{in} = \frac{V_{in}^{\ 2}}{Z_{in}}.$$

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.

$$\text{Power gain in dB} = 10 \log \frac{P_{out}}{P_{in}}.$$

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.

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Practical way of finding input-output phase relationships

The phase relationship between input-output can be found in two ways as given below.

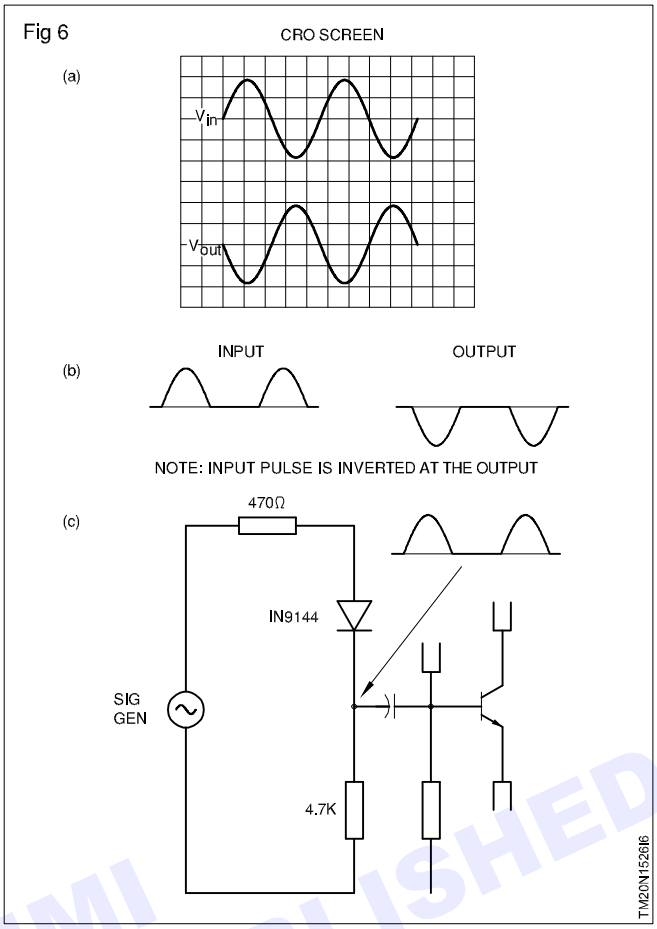
Method 1: Using a dual trace CRO, connect one of the CRO inputs to the input of the amplifier and the other CRO input to the output of the amplifier. Make the oscilloscope to trigger on the input signal. The waveforms shown on the CRO show the phase relationship between input and output as shown in Fig 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.

The pocket table book table No.22 gives a summary of the important parameters of a common-emitter amplifier with voltage divider bias.

Fig 6



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Digital IC families and their operational characteristics

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

- **explain the basic terms related to digital IC gates**
- **recognize the different types of packages of IC(s) used in the digital IC**
- **list different levels of integration used in fabrication of digital IC**
- **differentiate logic families and their characteristics**
- **explain safety precaution to be adopted while handling CMOS IC(s)**
- **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 equipment

– 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. 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 atc., 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 any one 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 implementation 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 permissible tolerances. Some of the important terminologies associated with digital ICs are given below;

Terminology of digital IC'S

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

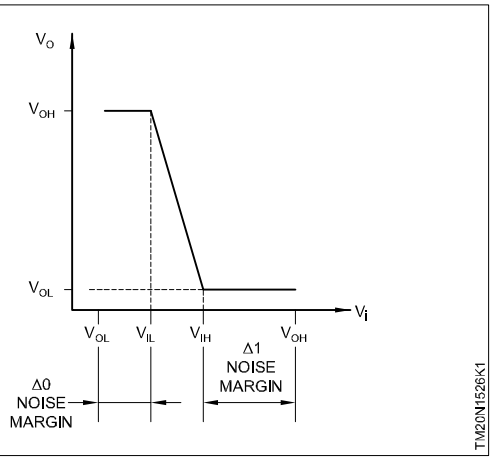
Current Mode Logic (CML) and Emitter Coupled Logic. This has ultra-fast switching speed and low logic swing.

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.

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Fig 1



VOH - The minimum voltage which will be available at a gate output when the output is supposed to be at logic '1'.

VIH - The minimum gate input voltage which will unambiguously be accepted by the gate as logic '1'.

VOL - The maximum voltage which will appear at a gate output when the output is supposed to be at logic '0'.

VIL - The maximum gate input voltage which will unambiguously be accepted by the gate as logic '0'.

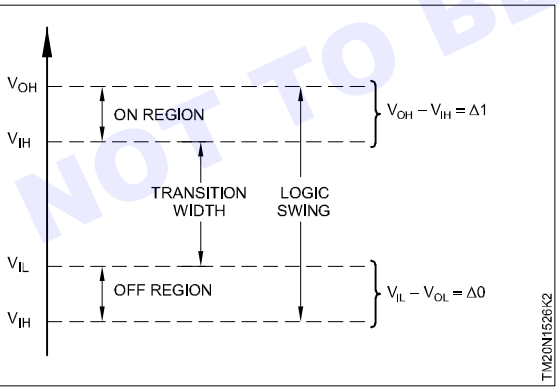
Logic swing: The difference between the two output voltages (VOH - VOL) is known as the logic swing of the circuit. That is, logic swing = VOH - VOL

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 (VIL - VOL) is low level noise margin (D0) D0 = VIL - VOL

High level noise margin

The difference (VOH - VIH) is high level noise margin (D1) D1 = VOH - VIH

Transition width:

From Fig 2, transition width = VIH - VIL

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 transition 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 circuit'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

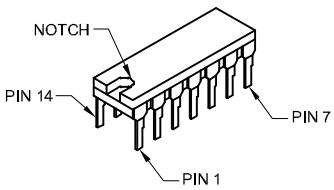
The ICs come in a wide variety of package types. The factors which determine the type of package are

- 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

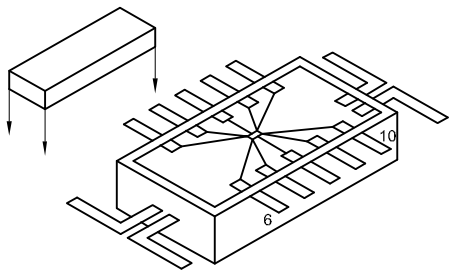


Ceramic flat package

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.

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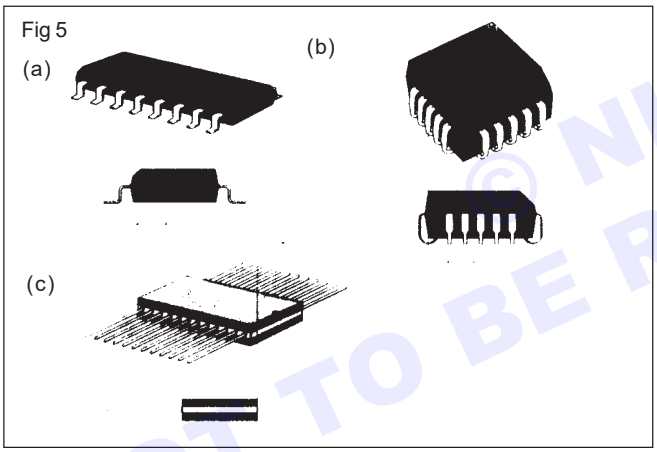
Fig 4



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.

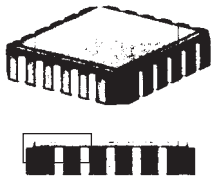
Fig 5



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.

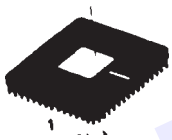
Fig 6



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



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Sl.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, register 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.

T.T.L Logic family

The word T.T.L is expanded as Transistor-Transistor Logic. In this family ICs are built with transistors. Most standard T.T.L ICs require a power supply voltage between +4.75V and +5.25V to operate properly. The IC(s) of standard T.T.L 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 T.T.L logic family consists of several sub families as shown in logic family tree. The difference between the various T.T.L 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 74500 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:

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Table

Comparison of CMOS and TTL logic families

	CMOS		TTL				
Technology	Silicon Gate	Metal-Gate	Std.	Low-Power Schottky	Schottky	Advanced 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 kHZ	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)
VNH	1.4	0.4	0.7	0.7	0.7
VNL	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 pack

Manufacturer code

Code	Manufacturer
AM	Advanced micro device
CD	GE/RCA
DM	National semiconductor
F	Fair child
GD	Gold star
H	Harris
HD	Hitachi
IM	Intersil
KS	Samsung
LR	Sharp
M	SGS
MC	Motorola
MM	Monolithic memories
MN	Panasonic
N	Signetics
P	Intel
SN	Texas instruments
SP	SPI
US	Sprague
TC	Toshiba

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Working principle, specifications and testing of SCR

Objectives: At the end of this lesson you shall be able to
- **explain the role of SCR in the field of industrial electronics**
- **explain the construction and working principle of SCR**
- **explain VI characteristics of SCRs**
- **list the specifications of SCRs**
- **explain the method of checking SCRs using JIG.**

Introduction to Industrial electronics

Industrial electronics is concerned primarily with electronics as applied to industries such as industrial equipments, controls and processes. An important application of electronics in industries is in controlling of machinery.

In communication electronics, domestic & entertainment electronics, generally, the electronic devices operate with currents in the order of microampers to milliampers. For industrial applications, most frequently, devices are required to handle currents in the range of ampers to several thousands of ampers. This, therefore calls for high power electronic devices. One such high power electronic device frequently used in industrial electronic application is the SCR. SCRs can be used to run, dc motors from an ac power source, control power tool speed, also to control motor speeds of small appliances like, mixers and food blenders, illumination control, temperature control and so on.

Silicon Controlled Rectifier (SCR)

Before Silicon controlled rectifiers were invented (1956), a glass tube device called Thyratron was used for high power applications. Silicon Controlled Rectifier (SCR) is the first device of the thyristor family. The term thyristor is coined from the expression Thyratron-transistor. SCR is a semiconductor device. SCR does the function of controlled rectification. Unlike a rectifier diode, SCR has an additional terminal called the gate which controls the rectification (gated silicon rectifier).

The basic principle application of SCRs is to control the amount of power delivered to a load (motor, lamp, etc.,).

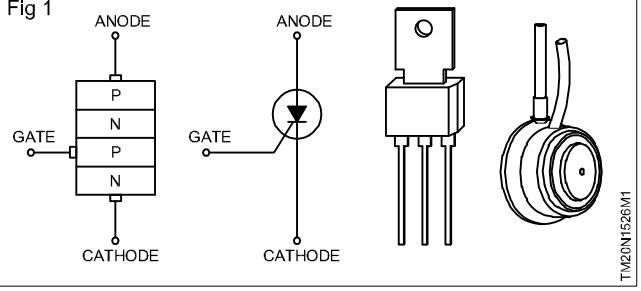
A rectifier diode will have one PN junction. SCRs on the other hand will have two PN junctions (P-N-P-N layers). Fig 1 shows the electrical symbol, basic construction and a typical SCR packages.

Basic operation of SCR

When a gate current is applied to the gate terminal, forward current conduction commences in the SCR (latched into conduction). When the gate current is removed, the forward current through the SCR **does not cut-off**. This means, once the SCR is latched into conduction, the gate loses control over the conduction. The current through the SCR can be turned off only by reducing the current through it(load current) below a critical value called the **Holding current**.

Fig 2 shows how an SCR can be gated into conduction or turned off.

Fig 1



In Fig 2a, with switched S1 open the SCR is in OFF state and no current is flowing through the load.

In Fig 2b, when S1 is closed, a small gate current (around 1/1000 or less compared to load current) turns-ON (fires) the SCR. A heavy load current starts flowing through the SCR and load R_L.

In Fig 2c, when S_1 is opened, gate current becomes zero. This will have no effect on the current through the SCR and the heavy load current continues to flow through the SCR.

In Fig 2d, if a shorting wire is placed across the anode and the cathode terminals, the current though the SCR gets by-passed and all the current starts flowing through the shorted wire instead through the SCR. This means the current through the SCR is reduced below the rated holding current (minimum current required through SCR to keep it latched). This turns-OFF the SCR. Even when the shorting wire is removed the SCR remains to be in OFF state.

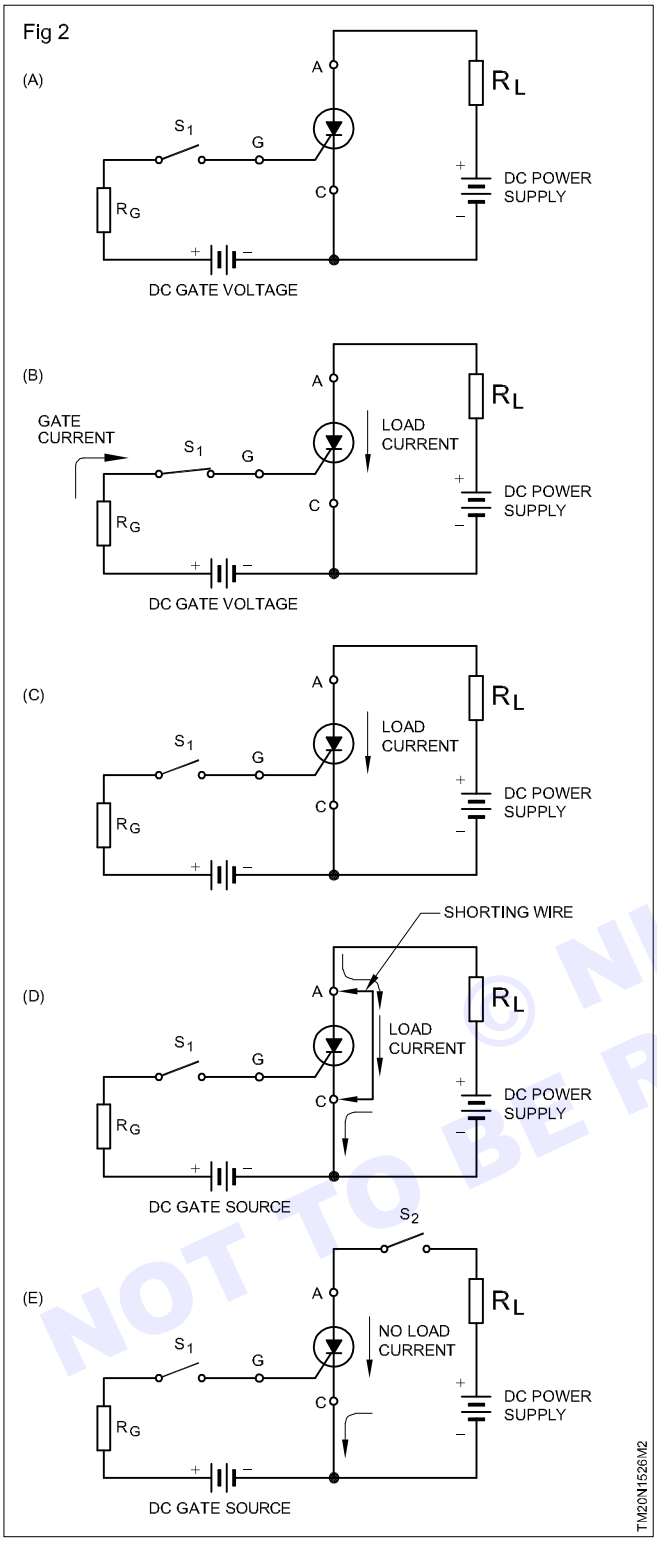
Fig 2e shows an alternative method of turning-OFF the SCR. In this instead of shorting the anode and cathode terminals of the SCR, the load current is cut-off by opening the Switch S_2. This reduced current through the SCR below the holding current and thus turns- OFF the SCR. Once the SCR is turned_OFF, the SCR does not turn-ON even if the switch S_2 is closed. To make the SCR fire again, with the switch S_2 closed, the gate current should be made to flow by closing the switch S_1.

Since the SCR does not conduct in the reverse direction, the anode of the SCR should always be positive with respect to cathode for conduction.

Important features of SCR,

– A very small gate current will control the switching of a large load current.

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Example: In 2N1597 SCR, a gate current of about 10mA will switch a load current of 1.6A (1:160).

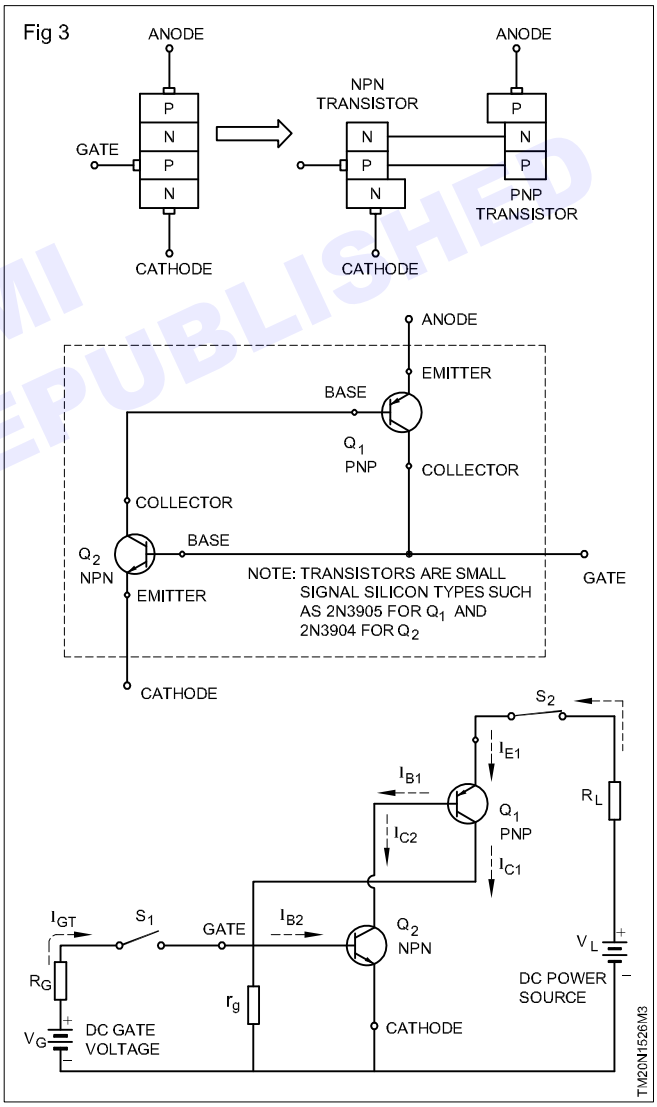
– A gate current pulse of short duration (typically 1 to 2μS) is sufficient to turn on the forward load current of SCR.

Understanding SCR as two interconnected transistors

For a clear understanding of how a SCR works, the four layer PNPN construction of SCR can be visualized as two independent transistors interconnected as shown in Fig 3a and 3b.

In Fig 3c, in the initial state with S_1 open, both Q_1 and Q_2 are in cutoff and hence there is no current through the load RL.

When S_1 is closed, the gate supply VG causes a small base current(IB2) to flow from the base of Q_2. This small base current turns on Q_2 and fairly a large collector current IC2 flows. At the same time, the emitter-base junction of Q_1 is forward biased and turns on Q_1. Since Q_1 collector current flows through the base of Q_2, this causes IC2 to increase. This increase in the base and collector currents of Q_1 and Q_2 becomes regenerative and thus takes Q_1 and Q_2 to saturation. At this time even if the base externally applied gate trigger pulse is removed, since the collector current of each transistor supplies the required base current to each other transistor, both the transistors remain to be in saturation. In this condition, the SCR acts almost like a short circuit/closed switch with a resistance as small as 0.1 ohms or less.



To bring the SCR to OFF state, since the externally applied gate has no further control of the SCR, the only way to turn-off is to reduce the collector currents of Q_1 and Q_2 to such a level that they will not sustain the regenerative action. This can be done by breaking the load current by

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switching off S_2 or by placing a short across the anode and cathode of the SCR as discussed earlier. By shorting or by opening S_2, the current through the SCR (collector currents of the interconnect transistors) is reduced below the rated holding current.

Holding current is that minimum value of current required to sustain the regenerative action in the interconnected transistors in the absence of the gate trigger.

The resistor Rg connected across the base and emitter of Q_2 is to provide immunity from false gate triggering signals such as noise spikes etc. Recall that such a connection at the input circuit of a transistor reduces the input(gate) impedance of the transistor.

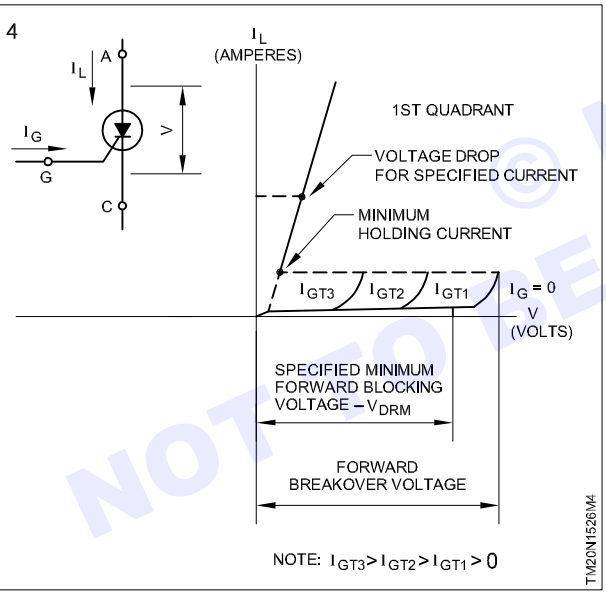
Typical VI Characteristics of SCR

SCR operation in first quadrant with DC supply

Typical Voltage-Current (VI) characteristics of a SCR is illustrated in Fig 4.

Considering that the SCR is operated with DC supply and the device is always forward biased (+ve to anode and -ve to cathode). The VI characteristics of a typical SCR will be as shown in Fig 4. This is called as the first quadrant operation of the SCR.

Fig 4



When SCR is used with AC supply, then the VI characteristics in the third quadrant will also be discussed.

Abnormal Operation of SCR

With Gate current IG=0,

– With a moderate Anode Cathode voltage, only a very small leakage current (can be neglected) flows through the SCR.

– If the anode cathode voltage is increased beyond a maximum forward blocking voltage (Fig 4), the SCR will break into forward condition and large current starts flowing through the SCR. This destroys the SCR breaking down the central pn junction. Therefore, the anode cathode voltage of SCR should always be less than the forward breaking voltage.

Break over voltage: It is that anode-cathode voltage at which the PN junctions of the SCR breaks down thus forcing the SCR into conduction.

Normal operation of SCR

With small gate trigger currents IG_1 or IG_2 or IG_3..... (Fig 4),

– With a small gate trigger current say IG_1, the SCR need a lower anode cathode voltage to fire the SCR on and a large current flows through the SCR. The amount of current through the SCR is limited only by the external load connected.

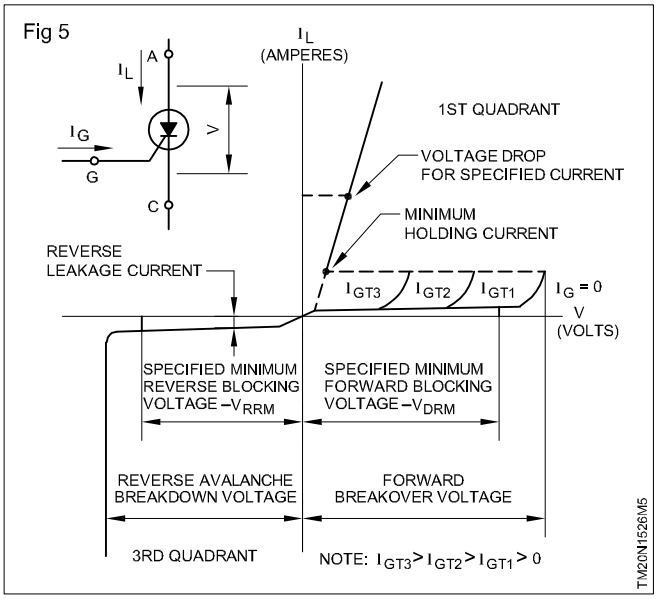
– With a slightly larger gate trigger current IG_2 ($IG_2 > IG_1$), the SCR gets fired even at a lesser anode cathode voltage.

Thus, a lower anode-cathode voltage is required to set the SCR into conduction with higher values of gate trigger current and vice-versa.

– Once the SCR is fired, it remains in conduction as long as the SCR current/load current is not allowed to drop below the "holding current value". As and when the SCR is required to stop conduction, the load current should be brought below the holding current value either by switching-off the load circuit (load current becomes zero) or by reversing the applied voltage polarity to the anode-cathode or by other suitable means.

Fig 5 illustrated the VI characteristics of SCR in first and third quadrant. The third quadrant operation basically illustrated the operation of the SCR when in reversed biased condition. The operation of the SCR in First and Third quadrant occurs when the SCR is operated using AC supply.

Fig 5



SCR operation in third quadrant with DC supply

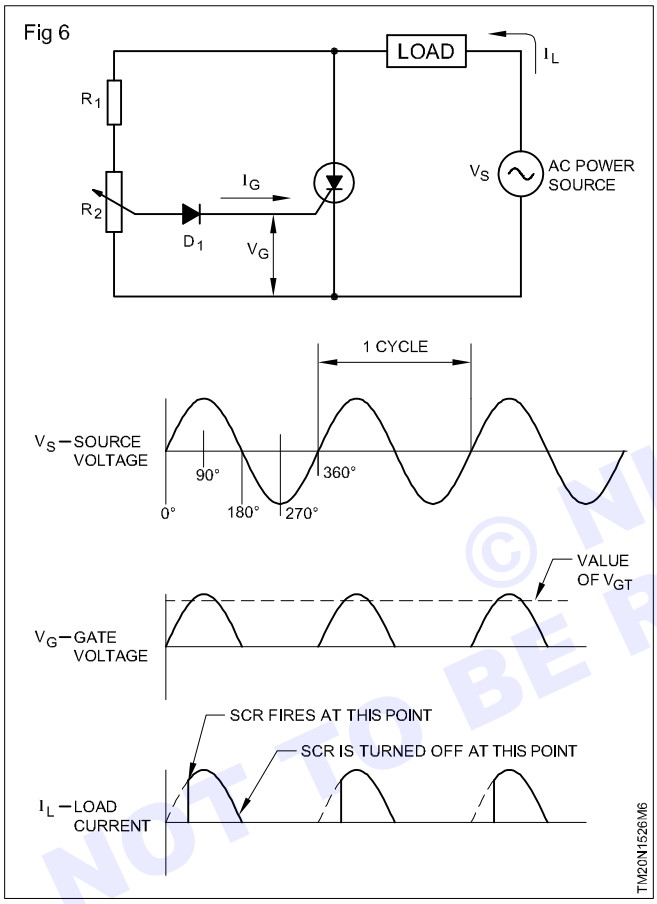
When the anode-cathode of SCR is reverse biased a small reverse leakage current flows through the SCR. When the

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reverse bias voltage is increase slowly from zero to a higher value, beyond a particular voltage called the "Maximum Reverse blocking voltage", the PN junctions of the SCR will break down and thus SCR becomes a short and enters into conduction. This results in a large current through the SCR/load as shown in Fig 5 in the third quadrant. SCR should never be applied with a reverse voltage as high as this Maximum Reverse blocking voltage.

SCR operation with AC supply

Operation of SCR with AC circuit is similar to SCR operation in the first and the third quadrant as discussed in above paragraphs. Fig 6 illustrates working of SCR in AC control circuits.



The SCR gate circuit consists of resistor R_1, potentiometer R_2 and silicon diode D_1. Resistors R_1 and R_2 act as a variable voltage divider. By adjusting the value of R2 the gate current IG can be suitably modified. Diode D_1 prevents negative voltage being applied to the gate when the ac supply is in the negative half cycle.

[X] During the +ve half cycle of the AC power source, as the positive half cycle voltage increases, the gate current Ig increases. When Ig reaches the trigger level, SCR fires and allows current I_L to flow through the load. From this point onwards the SCR impedance is low and current I_L continues to flow throughout the +ve half cycle even though the gate current reduces below the trigger value (recall: once SCR is fired it continues to conduct even if the gate trigger is decreased or removed).

[Y] At the end of the +ve half cycle of AC power source, the +ve voltage drops to zero and SCR ceases to conduct (recall: one method of turning off SCR is to reduce the current through the SCR to below the holding current. This can be done by either opening the load circuit or reducing the supply to zero). Thus the SCR remains in off state throughout the negative half cycle.

Cycle [X] and [Y] repeats and current through the load flows in pulses as shown in Fig 6d.

Fig 6b,6c shows the voltage wave forms of source and gate voltage.

If the value of R_2 is varied, the point at which SCR triggers also varies changing the firing point shown in fig 6d. In the circuit shown in Fig 6a, the firing of SCR can

If the value of R_2 is varied, the point at which SCR triggers also varies changing the firing point shown in fig 6d. In the circuit shown in Fig 6a, the firing of SCR can be adjusted anywhere between almost 180 degrees(maximum) to 90 degrees(minimum).

This simple AC control circuit shown in Fig 6 using SCR can be used to control the current through the load during the +ve half cycle of AC. During the -ve half cycle the SCR remains turned off. Thus, SCR can be used as an excellent switching device in AC control circuits.

The circuit at Fig 6 is useful only in limited applications such as temperature control of soldering iron etc., More practical AC control circuits are discussed in further lessons.

SCR Specifications

For maximum performance, reliability and safety, each SCR should be operated within the ratings specified by the manufacturer. When you are designing a new circuit or replacing an SCR of an existing circuit, it is very essential to check the data of the SCR before using.

A typical SCR data sheet list many specifications. A few of these specifications considered as most important from the point of view of a technician are listed below;

V_{DRM}: This is referred to as the anode-cathode forward Break down voltage with no input gate current. Beyond this value, the SCR will break down into forward conduction. For typical SCRs, V_{DRM} ranges from about 30 Volts to 800 Volts.

V_{RRM}: This is referred to as the maximum anode-cathode reverse breakdown voltage. Beyond this value the SCR will break into reverse conduction. For typical SCRs, V_{RRM} also ranges from about 30 Volts to 800 Volts.

V_{GT}: This is the minimum positive gate voltage required to turn on the SCR. At temperature of 25°C typical values of V_{GT} is 0.7 to 0.8 volts. For higher temperatures of about 100 to 125°C, V_{GT} drops to approximately 0.2 volts.

I_{GT}: This is the minimum forward gate current required to turn on the SCR. Typically, low power SCRs require an I_{GT} of about 100 to 300 µA for turn-on. Medium and high power SCR needs about 5 to 150 mA for turn-on.

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I_H: This is the minimum load current required to be maintained in the SCR to keep the SCR in on-state. Typical values of I_H ranges from about 6 mA for low power SCRs to 80 mA for high power SCRs.

I_T: This is the maximum allowable anode current that the SCR can withstand. This is defined by manufacturers in terms of rms forward current(I_{rms}) or average forward current (I_{avg}) for 180° of conduction. Typical values of I_{rms} for low and medium power SCRs range from about 1 to 30 Amperes.

V_{TM}: It is the maximum on state anode-cathode voltage drop across the SCR when it is conducting. Some manufacturers refer to this specification as V_F or V_{FM}. For most SCRs , V_{TM} is of the order of 1.6V.

t_{gt}: It is the time required for a specified gate current to turn on the SCR. Typical values lie in the range of 1 to 2 µSec.

t_q: It is the time required for a specified SCR to turn-off when the load circuit is made open. Typical values lie in the range of 15 to 35 µSec.

In addition to the above specifications, there are a few more specifications of SCR, some are of general nature to be considered while designing circuits using SCR and some are specific to certain SCR types. For further details on SCR specifications refer reference books listed at the end of this book or refer specification sheets of SCR supplied by the manufacturers.

Specifications of a few SCRs

2N 5060

V_{DRM}	
V_{RRM}	30V
V_{TM}	
V_{GT}	1.2V
I_{GT}	0.35A t_{gt}
I_H	t_q
I_T	0.8A
Package type:	TO 92

MCR 218-5

V_{DRM}	300V
V_{RRM}	
V_{TM}	1.5(typ) to 1.8V(max)
V_{GT}	0.2V(min) - 2.5V(max)
I_{GT}	10mA(typ) to 25mA(max)
I_H	16mA(typ_ to 30mA(max)
$I_{T(rms)}$	8 Amps.
t_{gt}	
t_q	
Package type :	TO 220

Quick check of SCRs: Quick check on SCRs can be carried out using a ohmmeter/multimeter. Since SCRs are made of PNPN junction, resistance between junctions can be measured to conclude good working condition of the SCR. A good SCR shows following resistances between its terminal leads;

Check - 1

Between Anode - Cathode - Infinite resistance

[Irrespective of polarity]

Between Gate - Cathode

i Forward biased - Very low resistance (30 to 500 ohms)

ii Reverse biased - High resistance

Between Gate - Anode - Infinite resistance

[Irrespective of polarity]

Check - 2

– Set multimeter to low resistance range.

– Connect positive lead of multimeter to the anode and the negative lead to the cathode. Meter should show infinite resistance.

– Now, for moment, short anode and gate of SCR by a piece of wire. The meter should show low resistance and will continue to show low resistance even after the short between anode and gate is been removed.

It is difficult to check leaky SCRs using only a ohmmeter/multimeter.

Checking SCRs using a SCR checking JIG

A simple "SCR checking jig" is shown in Fig 7. In Fig 7, the SCR shown in dotted lines is the SCR to be checked. This could be any SCR that you want to check.

In Fig 7, the stepped down to 12 AC is rectified by diode D_1 and filtered by capacitor C_1 when switch S_2 is at position A. The rectified and filtered DC is applied to the anode of SCR through lamp L_1 via a limiting resistor R_4. Resistor R_2, R_3 in series with a push button switch S_3 form a potential divider across dc. Voltage across R_3 is applied to the gate of SCR.This voltage is sufficient to turn on the SCR. Another push button Switch S_4 is connected directly across the Anode and Cathode of the SCR to be checked.

When a good SCR is placed in the test jig(in place of the SCR shown dotted) the circuit should function as given below;

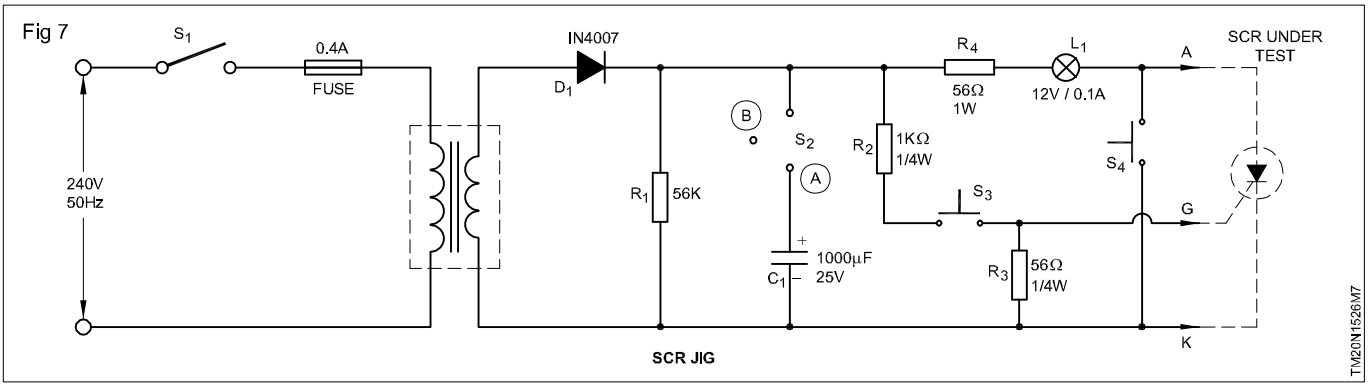
1 When mains supply is on, and S_2 is at DC position, the lamp will start glowing as soon as the switch S_3 is pressed. Even on releasing S_3, the lamp should keep on glowing. Under this condition, if switch S_4 is pressed once and released the SCR stops conducting and hence the lamp stops glowing.

2 If switch S_2 is put to AC position, lamp should glow only as long as switch S_3 is pressed.

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Instructor to discuss reasons for 1 & 2 above as an interactive discussion. Instructor should also discuss the outcome of above steps when a open or a shorted SCR is checked.

Fig 7



SCR applications

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

- **list a few application of SCRs**
- **list the two ways of controlling the speed of DC motors**
- **explain how the speed of DC shunt motor can be controlled by armature control method**
- **explain the principle of speed control in AC motors**
- **explain the method of speed control in Universal motor using SCR.**

SCR Applications

The list of applications of SCRs is endless. However, a small list of popular applications of SCR is given below;

– DC Motor control

– AC Motor control

– Regulated DC Power supplies

– Over voltage protection

– AC power control

– Time delay circuits

– Soft start circuits

– Pulse, Logic and Digital circuits

and so...on...

Speed control of DC Motors

DC motors consists of field winding and armature winding. The speed of DC motors can be varied by,

1 controlling the field current

or 2 controlling the armature voltage

The first method is used for controlling the motor speed above the rated speed of the motor.

The second method is used for controlling the motor speed below the rated speed of the motor.

Speed control of DC shunt motor by controlling the armature voltage

This is the most popular method of controlling the speed of DC shunt motors. Fig 1 illustrates the speed control of a DC shunt motor with separate field excitation.

The DC supply to the field winding is given from a full wave bridge rectifier. The DC supply to the armature is given using a 'symmetrical half controlled bridge rectifier'. By controlling the SCRs 1 and 2 the DC voltage to the armature can be varied thus varying the motor speed.

The principle of operation of the circuit at Fig 1a can be understood by examining the current and voltage waveforms shown in Fig 1b.

SCR-1 and 2 are fired in half cycles. During the positive half cycle, SCR-1 and D1 will conduct. The SCR firing angle is set to a. Hence the reduced applied armature voltage is shown shaded. This applied voltage to the armature can be varied by changing the firing angle using a suitable phase control circuit thus controlling the motor speed.

A similar operation will take place during the negative half cycle as shown in Fig 1b when SCR-2 and D2 conduct.

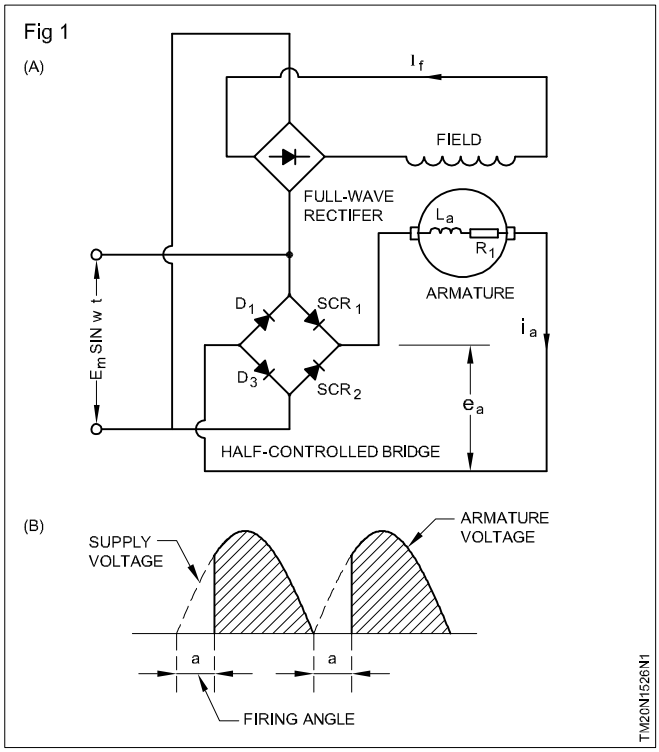
Fig 2a shows another simple circuit for speed control of DC motors. The speed control is based on controlled full wave rectified supply to the armature through an SCR. This control circuit is applicable only to shunt or separately excited motors. The voltage and current wave-forms are given in Fig 2b.

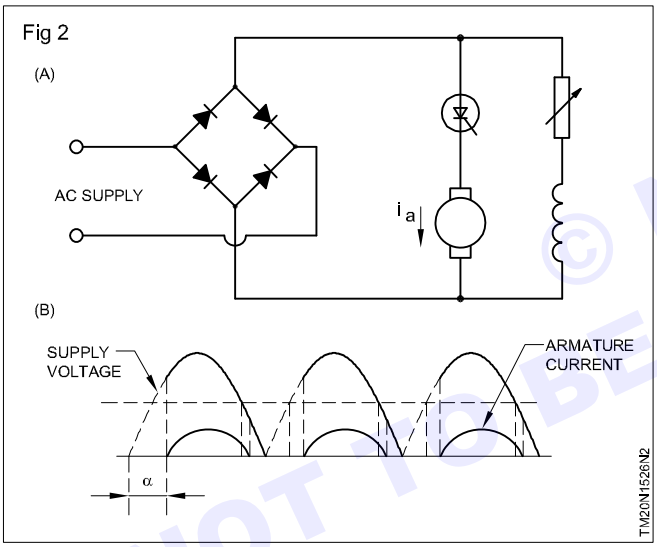
Please note that DC series motor cannot be controlled by this circuit. For reasons refer reference books listed at the end of this book.

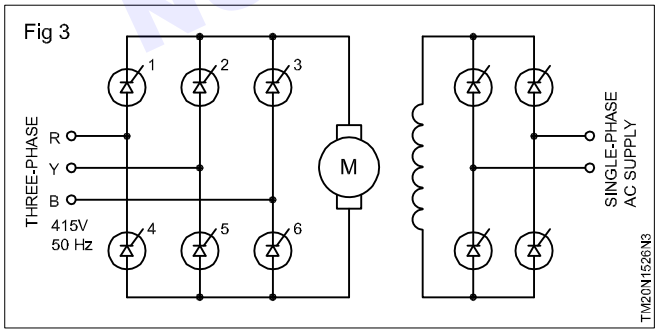
Fig 3 shows a speed controller by armature control method for a separately excited 415 volts DC motor.

Other DC motor speed control circuits are discussed in further lessons after learning a few more components that go along with SCR in motor speed control.

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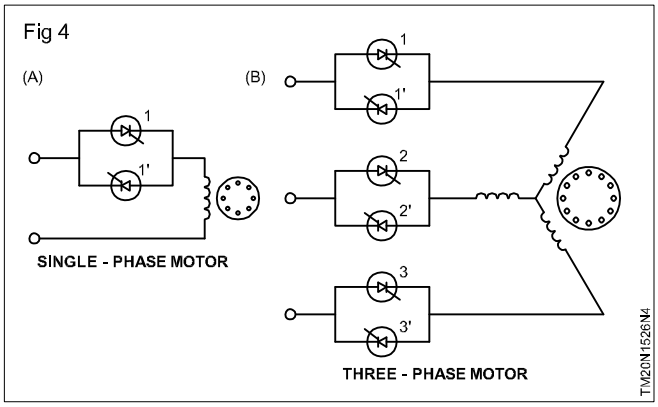
Speed control of AC Motors

Phase control can be very conveniently used for speed control of AC motors also. This is achieved by applying a variable voltage to the motor whose speed is to be controlled. As the speed of the synchronous motors does not change when the input voltage is varied, this method is useful only for commutator or induction motors.

For AC motors, full-wave phase-control circuits are required. Fig 4 shows a schematic arrangement of for speed control of single phase and three phase induction motors.

In Fig 4 above, by varying the firing angle of the SCRs, the RMS input voltage to the motor can be changed thus changing the speed of the motor.

For further details, refer reference books listed at the end of this book.



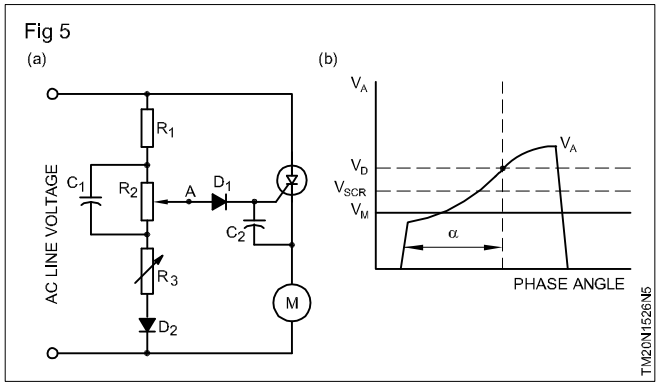
Speed control of Universal motors using SCR

Majority of domestic appliances like electric drilling machine, grinder, mixer etc., incorporates universal electric motors. Any of the half-wave or full-wave controls discussed earlier can be used to control speed of universal motors.

Universal motors have some unique characteristics which allow their speed to be controlled very easily and efficiently with a feedback circuit shown in Fig 5.

The circuit at Fig 5a, provides phase controlled half-wave power to the motor; that is, on the negative half cycle, the SCR blocks current flow in the negative direction causing the motor to be driven by a pulsating direct current whose amplitude is dependent in the phase control of the SCR.

The operation of the circuit shown in Fig 5 is as follows;



– Assuming that the motor is running, the voltage at point A in the circuit must be larger than the forward drop of diode D_1, the gate to cathode drop of the SCR, and the emf generated by the residual mmf in the motor, to get sufficient forward flow to trigger the SCR.

– The wave form at point A (V_A) for one positive half cycle is shown in Fig 5b along with V_{SCR}, V_D and motor generated emf V_M. The phase angle a at which the SCR would trigger is shown by the vertical dotted line.

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– For any reason if the motor speed increases, then V_M will increase, the trigger would move upwards and to the right along the curve so that the SCR would trigger later in the half-cycle thus providing less power to the motor, causing it to slow down. Similarly, if the motor speed decreases, the trigger point will move to the left and down the curve, causing the SCR to trigger earlier in the half cycle providing more power to the motor thereby speeding it up.

– Resistors R_1,R_2,R_3 along with diode D_1 and C_1 forms a ramp generator. Capacitor C1 is charged by the voltage divider R_1, R_2 and R_3 during the positive half cycle. Diode D_2 prevents negative current flow during the negative half cycle, therefore C1 discharges through R_2 and R_3 during negative half cycle. Varying the value of R_2 varies the trigger angle alpha.

A practical version of the circuit for controlling the speed of universal motors is shown in Fig 6.

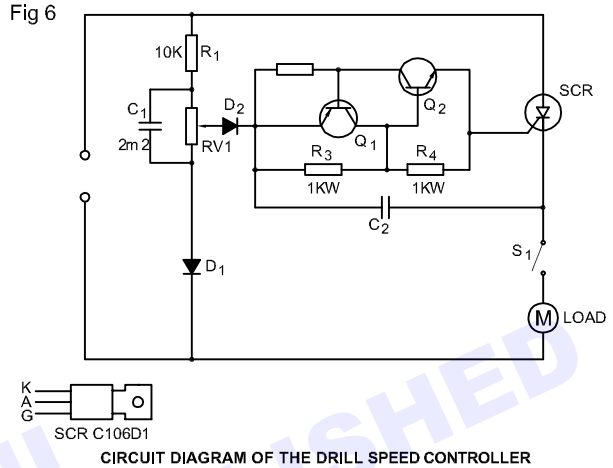
As can be seen the circuit at Fig 6 is quite similar to that at Fig 5 but for the addition of two transistors and a few resistors.

In Fig 6, the action of Q_1-Q_2 is to provide adequate gate current to trigger the SCR in to conduction.

Q_1-Q_2 and their associated resistors acts as a voltage sensitive switch. In each half cycle, C_2 is able to charge via R_{V1}. As soon as voltage across C_2 rises to suitable value, Q_1 and Q_2 both switch-on and partially discharge C_2 into the gate of the SCR, thus delivering a pulse of high current to the SCR gate, independent of any current-drive limitations of R_{V1}. The Q_1-Q_2 and C_2 network thus enables virtually any SCR to be used in the circuit almost irrespective of its sensitivity characteristics.

The universal motor speed control circuit shown in Fig 6 enables the motor speed to be smoothly varied from zero to 75% of maximum via a single control. It also incorporates built-in feed-back compensation to maintain the motor speed virtually constant at any given speed setting, regardless of load changes as discussed earlier.

Fig 6



CIRCUIT DIAGRAM OF THE DRILL SPEED CONTROLLER

Field Effect Transistors

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

- **explain the difference between bi-polar transistors and Field effect transistors**
- **state the basic construction and symbol used**
- **explain the theory of operation of FETs**
- **list specifications of a typical FET**
- **explain the method of quick testing FETs**
- **list applications**
- **explain a typical FET AC voltage amplifiers.**

Field Effect Transistors (FET)

The main difference between a Bi-polar transistor and a field effect transistor is that,

Bi-polar transistor is a current controlled device

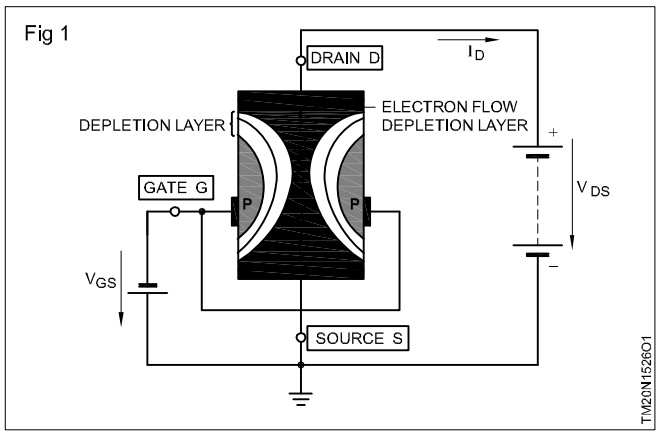
In simple terms, this means that the main current in a bi-polar transistor (collector current) is controlled by the base current.

Filed effect transistor is a voltage controlled device

This means that the voltage at the gate (similar to base of a bi-polar transistor) controlled the main current.

In addition to the above, in a bi-polar transistor (NPN or PNP), the main current always flows through N-doped and P-doped semiconductor materials. Whereas, in a Field effect transistor the main current flows either only through the N-doped semiconductor or only through the P-doped semiconductor as shown in Fig 1.

Fig 1



If the main current flow is only through the N-doped material, then such a FET is referred as a N-channel or N-type FET. The current through the N-doped material in the N-type FET is only by electrons.

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If the main current flow is only through the P-doped material, then such a FET is referred as a P-channel or P-type FET. The current through the P-doped material in the P-type FET is only by Holes.

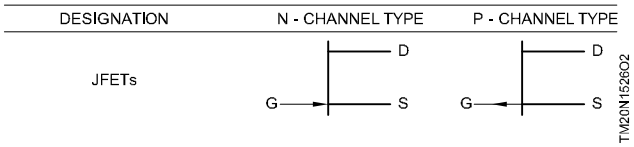
Unlike in bipolar transistors in which the main current is both by electrons and holes, in contrast in FETs depending on the type (P or N type) the main current in either by electrons or by holes and never both. For this reason FETs are also known as Unipolar transistors or Unipolar device.

There are a wide variety of FETs. In this lesson one of the fundamental types called as Junction Field Effect Transistor (JFET) is discussed. Other types of FETs are discussed in further lessons.

Junction Field Effect Transistor (JFET)

It is a three terminal device and looks similar to a bi-polar transistor. The standard circuit symbols of N-channel and P-channel type FETs are shown in Fig 2.

Fig 2



The internal diagram of a N-channel FET is shown in Fig 3.

Construction

As shown in Fig 3a, a n-Channel JFET has a narrow bar of n-type. To this, two p-type junctions are diffused on opposite sides of its middle part Fig 3a. These diffused junctions form two P-N diodes or gates. The n-type semiconductor area between these junctions/gates is called channel. The diffused P regions on opposite sides of the channel are internally connected and a single lead is brought out which is called gate lead or terminal. Direct electrical connections are made at the two ends of the bar. One of which is called source terminal, S and the other drain terminal, D.

A p-channel FET will be very similar to the n-channel FET in construction except that it uses P-type bar and two N type junctions as shown in Fig 3b.

FET notation listed below are essential and worth memorizing,

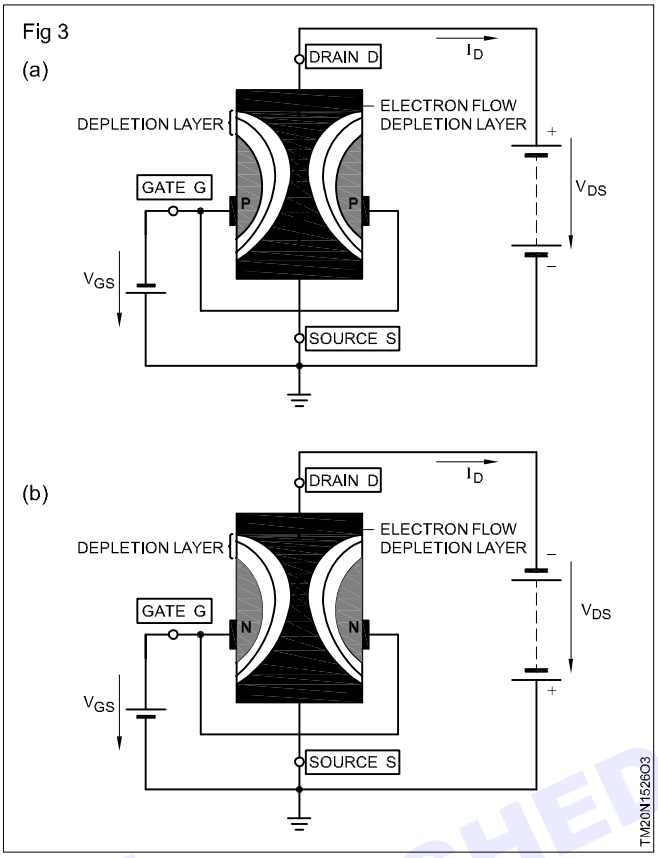
1 **Source terminal:** It is the terminal through which majority carriers enter the bar (N or P bar depending upon the type of FET).

2 **Drain terminal:** It is the terminal through which majority carriers come out of the bar.

3 **Gate terminal:** These are two internally connected heavily doped regions which form two P-N junctions.

4 **Channel:** It is the space between the two gates through which majority carriers pass from source to drain when FET is working(on).

Fig 3



Working of FET

Similar to Bipolar transistors, the working point of adjustment and stabilization are also required for FETs.

Biasing a JFET

– Gates are always reverse biased. Therefore the gate current I_G is practically zero.

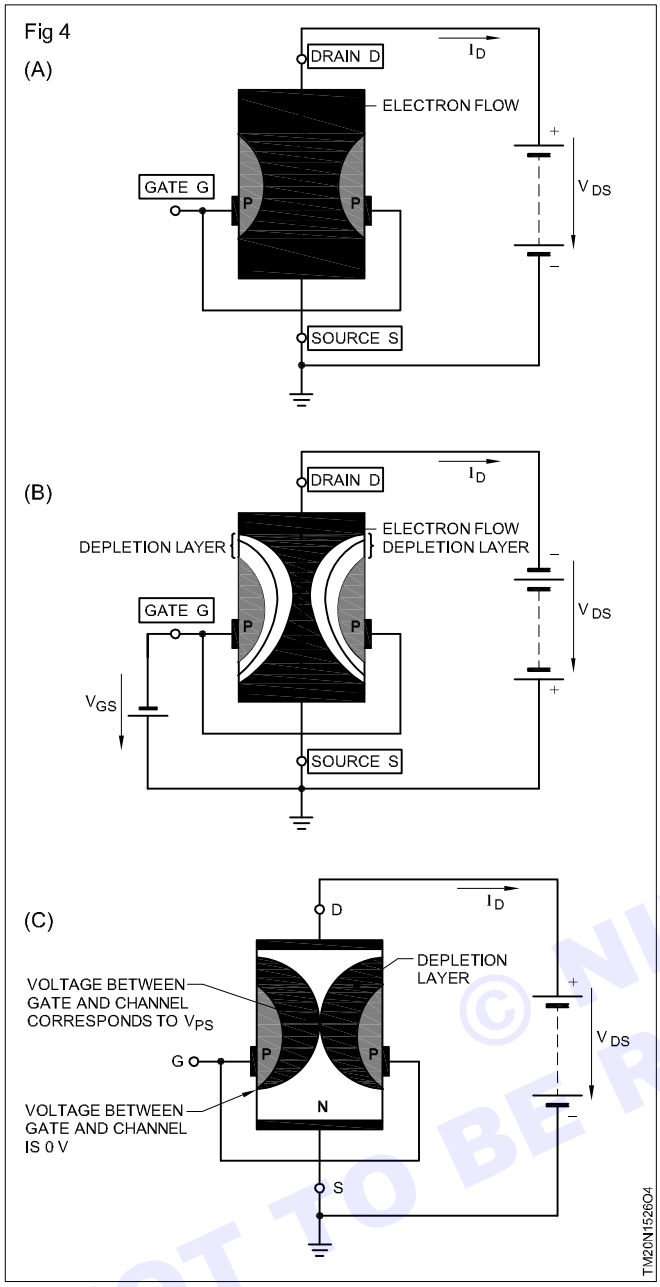
– The source terminal is always connected to that end of the supply which provides the necessary charge carriers. For instance, in an N-channel JFET source terminal S is connected to the negative of the DC power supply. And, the positive of the DC power supply is connected to the drain terminal of the JFET.

whereas in a P channel JFET, Source is connected to the positive end of the power supply and the drain is connected to the negative end of the power supply for the drain to get the holes from the P-channel where the holes are the charge carriers.

Let us now consider an N channel JFET, the drain is made positive with respect to source by voltage V_{DD} as shown in Fig 4a. When gate to source voltage V_{GS} is zero, there is no control voltage and maximum electron current flows from source(S) - through the channel - to the drain(D). This electron current from source to drain is referred to as Drain current, I_D.

When gate is reverse biased with a negative voltage (V_{GS} negative) as shown in Fig 4b, the static field established at the gate causes depletion region to occur in the channel as shown in Fig 4b.

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This depletion region decreases the width of the channel causing the drain current to decrease.

If V_{GS} is made more and more negative, the channel width decreases further resulting in further decrease in drain current. When the negative gate voltage is sufficiently high, the two depletion layers meet and block the channel cutting off the flow of drain current as shown in Fig 4c. This voltage at which this effect occurs is referred to as the Pinch off voltage, V_P.

Thus, by varying the reverse bias voltage between gate and source($-V_{GS}$), the drain current can be varied between maximum current (with $-V_{GS}=0$) and zero current (with $-V_{GS}$=pinch off voltage). So, JFET can be referred as a voltage controlled devices.

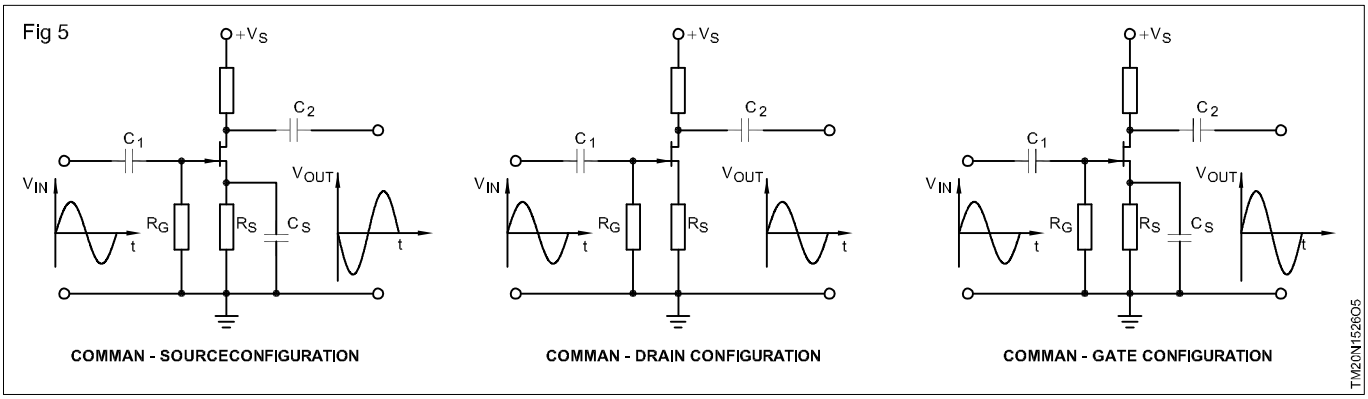
P channel JFET operates in the same way as explained above except that bias voltages are reversed and the majority carrier of channel are holes.

Important specifications of typical JFETs

	BF245B	BFW10
Polarity of the device (N-type/P-type) Nj	Nj	
Maximum drain-source voltage, V_{DS}	30 V	30 V
Maximum gate-source voltage, V_{GS}	30 V	30 V
Maximum drain current, I_D	25 mA	20 mA
Maximum forward gate current, I_G	10 mA	10 mA
Pinch-off Voltage (at I_D=0), V_P		8 V
Maximum power dissipation, P_{max}	300 mW	300mW
Package type	TO92	TO72

The term Nj in the specification indicates that it is a N-type junction FET.

As discussed earlier FETs also need a proper biasing arrangement for it to work. Like transistors, FETs can also be connected in different configuration. Fig 5 gives a summary and comparison of basic FET configurations.



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Typical applications of JFET: One very important characteristic of JFET is its very high input impedance of the order of 10^9 ohms. This characteristic of FET has made it very popular at the input stage of a majority of electronic circuits.

As discrete components FETS are chiefly used in,

– DC voltage amplifiers

– AC voltage amplifiers (input stage amplifiers in HF and LF ranges)

– Constant current sources

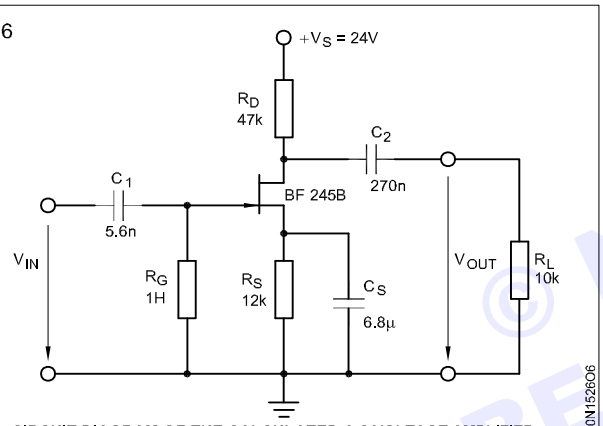
– Integrated circuits of both analog and especially in Digital technology.

A few applications of JFETs are illustrated below;

1 Fixed gain AC voltage amplifier

In the circuit at Fig 6, the amplification is determined by the design. it can be varied within certain limits of the drain resistance and the source resistance are made variable. Pots can be connected in series for this purpose.

Fig 6



CIRCUIT DIAGRAM OF THE CALCULATED A.C VOLTAGE AMPLIFIER

2 Electronic D.C voltmeter using JFET

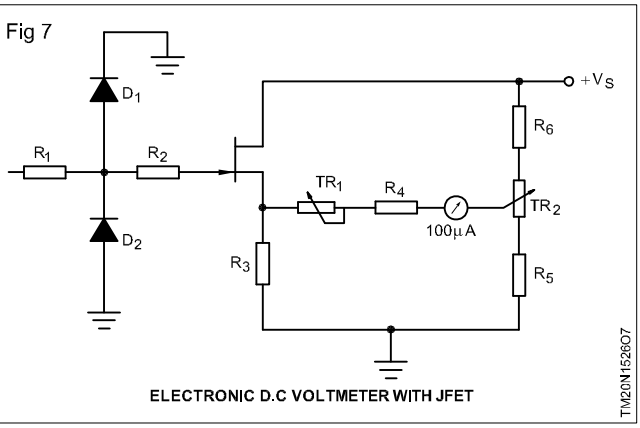
By virtue of their very high input resistance, field-effect transistors can also be used satisfactorily as DC. voltage amplifiers in electronic voltmeters. This is shown as an example in Fig 7.

In Fig 7, the JFET is operated with a common drain. With its source resistance, the JFET forms one branch of a bridge circuit. The 100-µA measuring mechanism is connected in the bridge diagonal. Zeroing is carried out using trimmer Tr2, with the input short-circuited by setting the bridge current to zero.

Full-scale deflection of the 100-µA instrument takes place at an input voltage of 100mV. Balancing to full scale deflection is carried out using trimmer Tr1. Diodes D1 and D2 act as overload protection. They become conducting when a voltage in excess of 0.7V occurs after input resistance R1. The gate bias is generated by a resistor R3.

If a DC voltage measuring signal is delivered via input resistor R1 to the gate of the JFET, its drain current increases. Its channel resistance R_{DS} is thus reduced and the bridge ceases to be in equilibrium. A current flows through the instrument, whose deflection is proportional to the input measuring voltage.

Fig 7



ELECTRONIC D.C VOLTMETER WITH JFET

The electronic voltmeter described above can be extended into a multi-range instrument by connecting a multi-stage voltage-divider in front of it as shown in Fig 8.

The above design of the voltage divider produces measuring ranges with full-scale deflections for U_{in}= 100mV to U_{in}=50V. These measuring ranges can be selected using switch S2. By opening switch S1, an additional resistance of 90 MO is inserted between the input socket and the voltage divider. This increases all the measuring ranges by a factor of 10.

When switch S1 is closed, the electronic voltmeter thus has six measuring ranges with full-scale deflections of 100mV, 250mV, 500mV, 1V, 5V and 50V. The input resistance is in this case 10 MO. When switch S1 is open, six measuring ranges are obtained, with full-scale deflections of 1V, 2.5V, 5V, 10V, 50V and 500V. The input resistance is then 100MO.

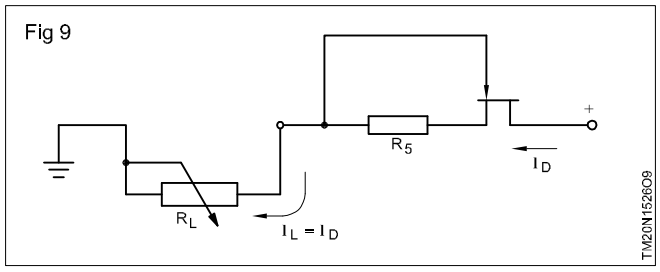
3 Constant current source

Constant-current sources are circuits with a very high internal resistance, which supply almost constant currents over a wide voltage range. Constant-current sources can be very easily constructed using field-effect transistors. Use is made of the high output resistance r_{DS} of FETs when operated in the pinch-off region. The drain-source voltage U_{DS} has only a very small influence on the magnitude of the drain current. Fig 9 shows a constant-current source with a JFET.

When using constant-current sources with JFETs, it is absolutely essential to ensure that the limiting values U_{DSmax}, I_{Dmax} and P_{tot} cannot be exceeded.

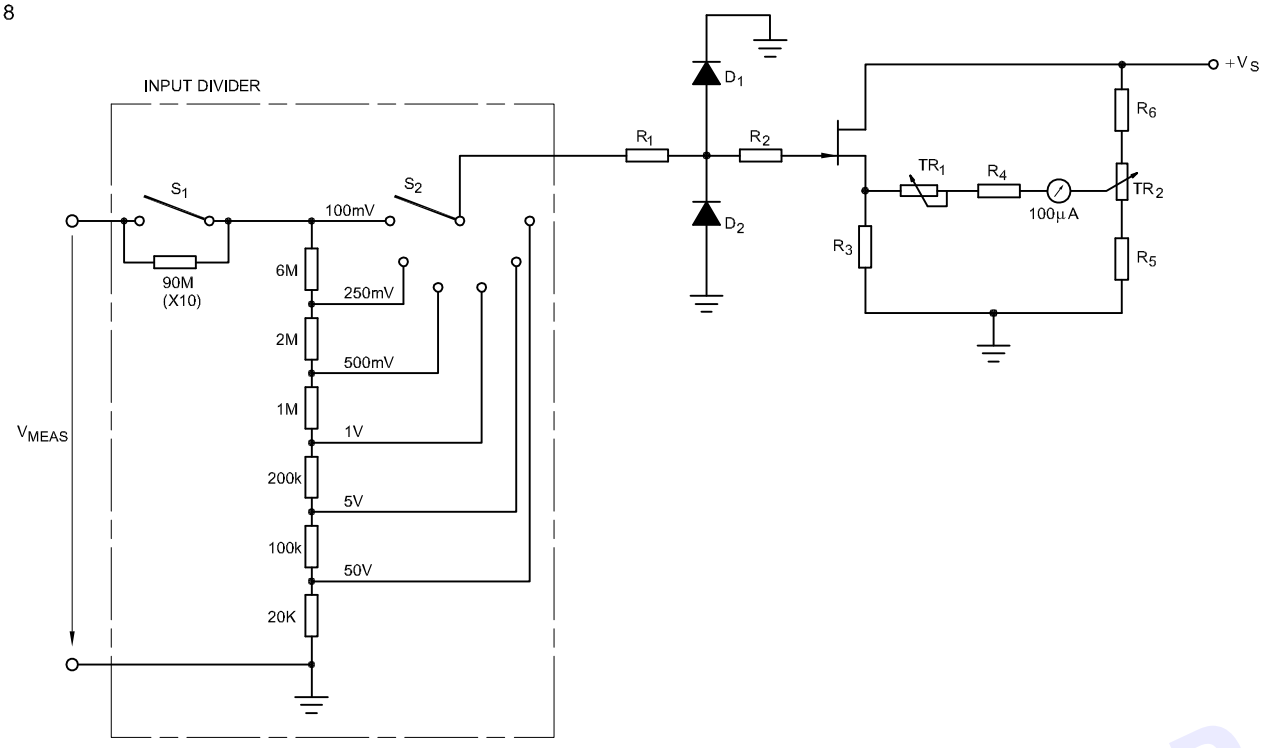
Constant-current sources with FETs have the great advantage that additional auxiliary voltages are not essential and that they can be treated as two-terminal networks. They can therefore be inserted in a circuit like any normal resistor.

Fig 9



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Fig 8



ELECTRONIC VOLTMETER USING FET

Unijunction transistor (UJT) and its applications

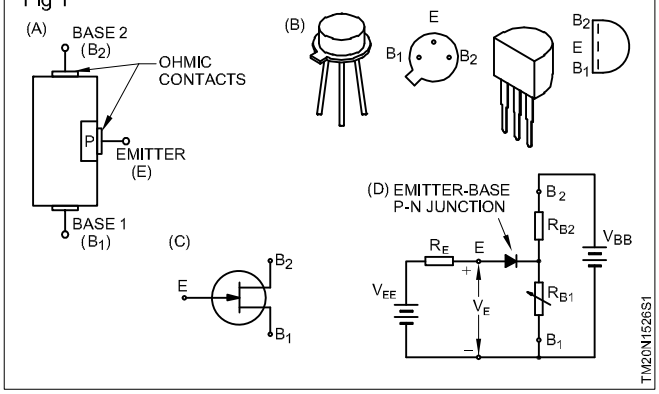
Objectives: At the end of this lesson you shall be able to

- **explain the construction and working principle of UJT**
- **state how to make a quick test of UJT**
- **list the important specification of UJT**
- **list and explain the application of UJTs**

Unijunction transistor(UJT) is a three terminal semiconductor device as shown in Fig 1a. In its appearance it looks like a transistor as shown in Fig 1b. As shown in Fig 1a, it consists of two layers(a P-layer and a N-layer) and therefore it has only one junction(hence its name, uni-junction).

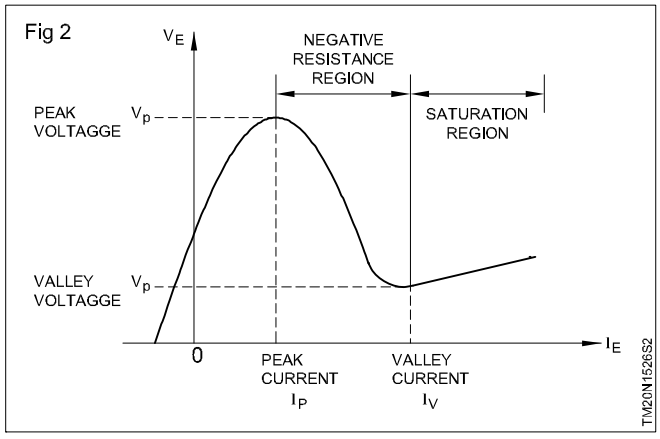
The symbol of UJT and its electrical equivalent circuit is shown in Fig 1c and 1d.

Fig 1



UJT is a special semiconductor device because it exhibits negative resistance characteristics as shown in Fig 2. The details of the characteristics are discussed in subsequent paragraphs.

Fig 2



Construction of UJT

From its construction a UJT can be described as a double based diode. UJT is fabricated on a N-type silicon bar with ohmic contact for the two base terminals as shown in Fig 1a. The P-type emitter is heavily doped and is on one side of the N-type bar. An ordinary ohmic, non-rectifying contact is made at the two ends of the N-type bar. These contacts are called Base-1 and Base-2. When packaged UJT looks like a small signal Bipolar junction transistor with power ratings less than 1 Watt. For example, the 2N 2646 and 2N 2647 UJT's are available in the modified TO-18 case style as shown in Fig 1b.

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Equivalent circuit of UJT

The electrical equivalent circuit of UJT is shown in fig 1d. The resistance between the B_1 and B_2 terminals is called the inter-base resistance R_{BB}. The N-type silicon bar serves as a resistance divided into two parts R_{B1} and R_{B2} by the PN junction. The total of the internal R_{B1} and R_{B2} is the interface resistance R_{BB}. Value of R_{BB} is typically in the range of 4 to 10 Kohms. Also r_{B1} usually a little greater than r_{B2} because the emitter is a little closer to B_2.

The interface resistance R_{BB} is measured with the emitter open.

$R_{BB} = R_{B1} + R_{B2}$ at I_E=0.

Operation of UJT

The DC supply polarities for a UJT to function is shown in Fig 3. As can be seen from fig 3, B_2 is connected to +ve and B_1 to ground. As a result current (conventional) flows from B_2 to B_1. This conduction results in a voltage gradient along the N-type silicon bar. Therefore, there is a voltage in the region of the emitter junction(V_E) which is positive with respect to ground. The magnitude of this voltage is given by the simple voltage divider action between R_{B1} and R_{B2}.

$$V_E \text{ or } (V_{RB!}) = \frac{R_{B1}}{R_{B1}+R_{B2}} V_{BB} = \eta V_{BB} \quad \text{....[1]}$$

The Greek letter η (eta) is called the intrinsic stand-off ration. This is an important data of any UJT and is invariably mentioned in all UJT data sheets. From the above equation, intrinsic stand-off ration η (eta) is given by,

$$\eta = \frac{R_{B1}}{R_{B1}+R_{B2}} \quad \text{....[2]}$$

Typical values of h Vary form about 0.5 to 0.8 for most UJT's.

The value of h is important because, knowing h and the applied voltage across the base terminals V_{BB}, voltage across R_{B1} can be calculated using equation [1].

For example, if η = 0.65 and V_{BB} = 12 Volts,

then, $V_{RB1} = \eta_{VBB}$ = 0.65 x 12 V = 7.8 volts.

Voltage V_{RB1} represents the reverse bias voltage at diode D.In order for an emitter current I_E to flow, the emitter voltage V_{EB1} should be above V_{RB1} by about 0.7volts(internal barrier potential for a silicon diode). This emitter voltage V_{EB1} that will cause the diode to be forward biased and conduct emitter current is usually designated as V_P.

The value of V_P can be calculated using the formula,

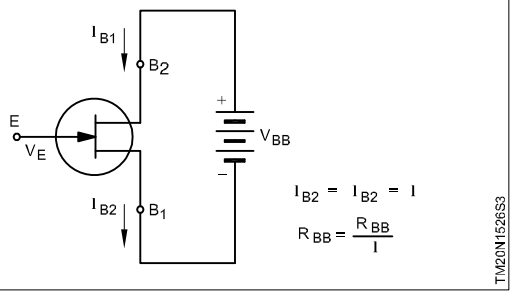
$V_P = \eta V_{BB}$ + 0.7 volts

In the example considered above, V_P = 7.8 V + 0.7V = 8.5 Volts.

When V_P is raised to 8.5 volts, diode D conducts. This means I_E flows through the R_E, diode D, R_{B1} to ground. This sudden rush of current through the highly doped N-type R_{B1} reduces the resistance of R_{B1}(remember R_{B1} is not a fixed value resistor, it is the resistance of the N-type semiconductor). Because of the reduced R_{B1} (from a few thousand ohms to a value as low as 40 to 50 ohms) results in a small voltage drop across R_{B1}. Hence emitter voltage V_{EB1} drastically decreases to around 1 volt (from 8.5V before the diode conduction to around 1V when the diode starts conducting). This drop in the value of V_{EB1} as shown in Fig 3. This point is sometimes referred to as the on-state condition.

Since an increase in the emitter current results in decrease in emitter voltage(V_{EB1}), this region of the UJT characteristics is referred to as the negative resistance region.

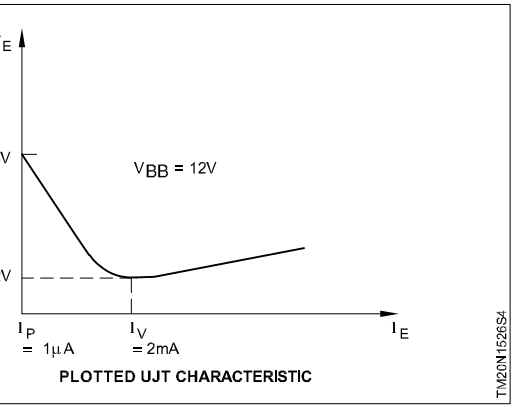
Fig 3



After a certain point referred to as the 'valley point', any further increase in the emitter biasing voltage V_{EE}/emitter current I_E will start increasing and the voltage drop across the emitter and base-1. This region is called as the UJTs saturation region. This will occur when the rate of hole injection is so great as to build up a positive space charge in the region (for further details refer reference books listed). It should be noted that after the valley point, the emitter current should not be increase beyond the rated maximum forward emitter current value (typically around 50mA) beyond which the diode D may break down.

A comparison of the UJT theoretical characteristics (as in Fig 2) and actual characteristics which can be plotted is shown in Fig 4.

Fig 4



Some of the important terms associated with UJT characteristics are given below;

Peak Point Current(I_P) - minimum amount of emitter current to place the UJT in negative resistance region.

Valley Current (I_V) - maximum allowable emitter current within the negative resistance region.

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Valley voltage (V_V) - minimum voltage that can maintain the UJT in its negative resistance region.

Quick test of UJT using OHM meter

From the construction of a UJT it can be seen that, Emitter and Base-1 with Base-2 open, behaves as a PN diode. Therefore, when tested using a ohm meter this should show low resistance when forward biased and high resistance when reverse biased.

Similarly, Emitter and Base-2 with Base-1 open behaves as a PN diode and hence the same forward and reverse bias test using a ohm meter can be carried out to confirm its good condition.

To carry out a quick test of a given UJT, check forward and reverse bias conditions of the two diodes of UJT as given in above two paragraphs.

Typical UJT Specifications

UJT specification as can be seen in any data manual is given below. 2N 2646 UJT is taken only as a sample for understanding the specifications. Specifications for other UJT will almost be in the same format. However, the manufacturers data sheets given more details than what is listed below;

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

Addition of binary numbers

	Sum	Carry
0 + 0 = 0	0	
1 + 0 = 1	1	
0 + 1 = 1	1	
1 + 1 = 0	0	1 (one plus one is equal to zero with carry one)

Ex: 1

```
  1 0
+ 1 1
-------
  1 0 1
-------
```

Ex: 2

```
1 +1+1 =  1
        + 1
        ---
         10
          1
        ---
         11
```

(one plus one plus one is equal to one with carry one)

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.

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	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: $(15)_8 \tilde{} (13)_{10}$

Octal Decimal

	0		
8	1	1	⟶ MSB
8	13	5	⟶ LSB

$\therefore (13)_{10} = (15)_8$

Octal to Decimal conversion

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	
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 $= (65)_8$

$(11010000100)_2 = (\ )$

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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

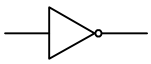
3 ASCII code - American, Standard code for Information interchange

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

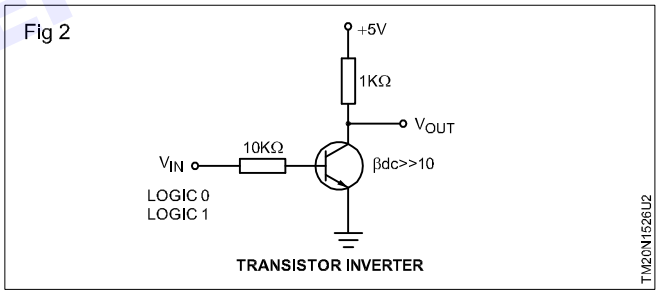


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Transistor inverter

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.

Fig 2



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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.

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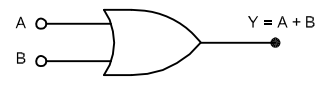
OR and NOR gate circuits

Objectives: At the end of this lesson you shall be able to
- **explain OR gate using diode and its truth table**
- **explain T.T.L OR gate IC 7432**
- **explain NOR gate and its truth table.**

OR GATE

The output of an OR 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 1 shows the schematic Symbol of an OR Gate :

Fig 1



The boolean expression for OR gate is Y=A+B.

The equation is to be read as Y equals A OR 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
1	0	1
0	1	1
1	1	1

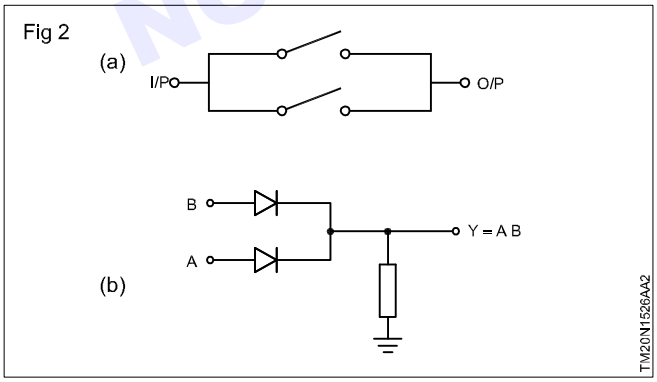
Electrical equivalent circuit

The Fig 2a 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 2b 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 2



Assume logic 0 = 0V (low)

logic 1 = +5V (high)

Since this is a 2 input OR gate, there are only four possible cases,

Case 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.

Case 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.

Case 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.

Case 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 T.T.L OR gate IC having 4 OR gates inside it. For pin diagram refer Appendix 'D'.

Simple application of OR gate

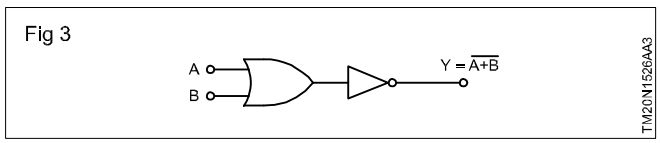
Intrusion detection

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.

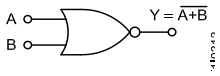
NOR Gate

In the Fig 3 the output y of the circuit equals the complement of A OR B, because the circuit is an OR gate followed by a NOT gate. To obtain high output [Logic-1], both the inputs should be tied to low input [Logic-0]. For the rest of the other three possibilities, output will be zero, the combination of this OR and NOT gate is called as NOR gate.

Fig 3



Symbol



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We can define a NOR gate as follows:

The output of a NOR gate is 0, even if one of the inputs is in logic-1. Only when both the inputs are in logic-0, the output is in logic-1.

Truth table

A	B	A+B
0	0	1
0	1	0
1	0	0
1	1	0

IC7402 is a T.T.L NOR gate IC. It contains 4 NOR gates. For pin details, refer data book.

AND and NAND gate circuits

Objectives : At the end of this lesson you shall be able to
- **explain AND gate using diodes and its truth table**
- **explain NAND gate and its truth table**
- **explain AND gate application**
- **explain logic pulser using NAND gates.**

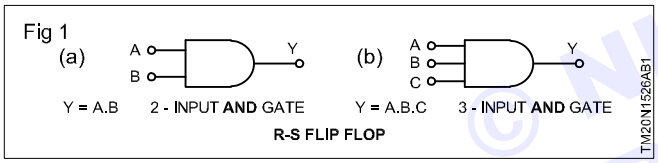
AND gates

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.

AND gate symbols for 2 input and 3 input gates are shown in Fig 1a and 1b.

Truth table

Fig 1



Two input AND gate

A	B	Y=AB
0	0	0
0	1	0
1	0	0
1	1	1

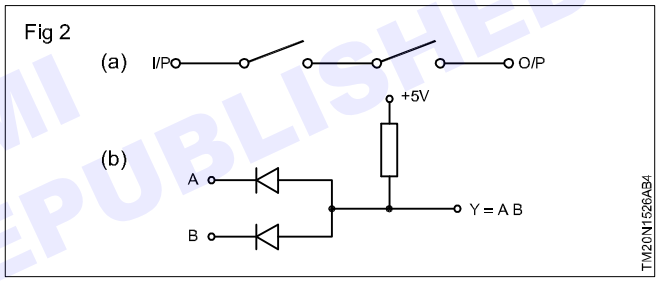
Three input AND GATE

A	B	C	Y=ABC
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

Electrical equivalent circuit of an AND gate

The output is available only when both the switches are closed. IC7408 is a T.T.L quad AND gate IC. (Refer data book for pin diagram). The electrical equivalent of AND gate and NAND gate using diodes are shown in Fig 2a and 2b.

Fig 2



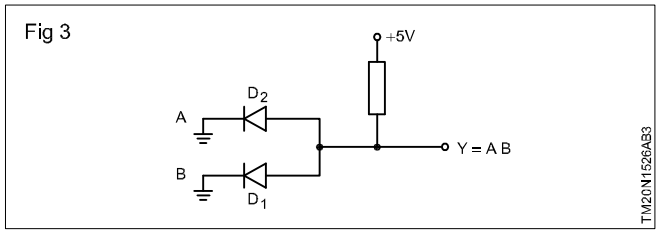
Two input AND gate using diode

I Condition

A=0, B=0, Y=0 as shown in Fig 3.

During the above condition I/P A and B are connected to ground to make logic low inputs. During this condition, both the diodes conduct, and pulls the O/P Y to logic-0.

Fig 3



II Condition

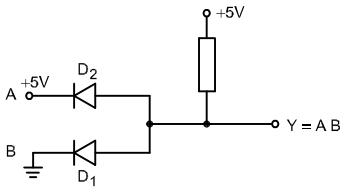
A=0, B=1, Y=0 as shown in Fig 4.

In the II condition shown in the figure above, diode D_1 is connected 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

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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

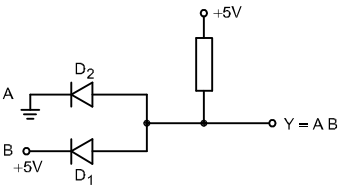


III Condition

A=1, B=0, Y=0 as shown in Fig 5.

The III condition is similar to the II condition. D_2 is forward biased. D_1 is reverse biased. Hence output Y is pulled to logic-0.

Fig 5

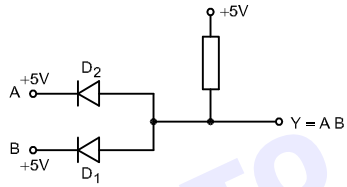


IV Condition

A=1, B=1, Y=1 as shown in 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 logic-1 condition.

Fig 6



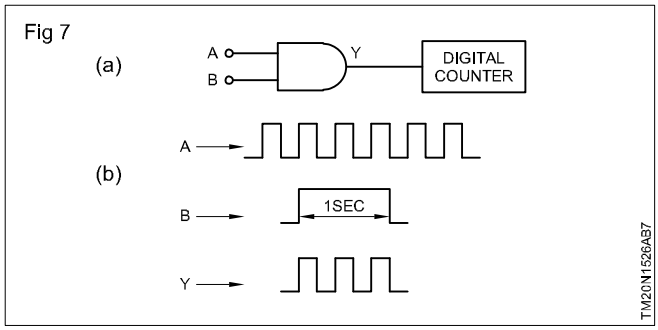
AND gate as an Enable/Inhibit device

A common application of the AND gate is to enable (i.e to allow) the passage of a signal (pulse waveform) from one point to another at certain times and to inhibit (prevent) the passage at other times.

In Fig 7a AND gate controls the passage of a signal (waveform A) to a digital counter. The purpose of this circuit is to measure the frequency of waveform 'A'. The enable pulse has a width of precisely 1 second. When the enable pulse applied at B is high, waveform A passes through the gate to the counter, and when the enabled pulse is low, the signal is prevented (inhibited) from passing through. Refer Fig 7b for the waveforms of the above process.

During the 1 second interval of the enabled pulse, a certain number of pulses in waveform A pass through the AND gate to the counter. The number of pulses counted by the counter is equal to the frequency of the waveform 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.

Fig 7

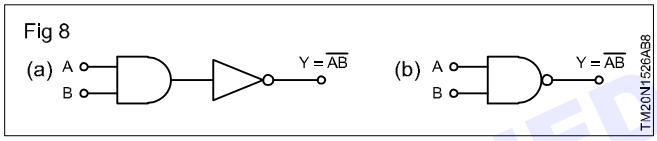


NAND gate

An AND gate followed by a NOT gate forms the NAND gate as shown in Fig 8a. In this gate to get a low output (logic=0), all the inputs must be in high state and to get high output state, any one of the inputs or both inputs must be in low state.

Fig 8b is the standard symbol for a NAND gate. The inverter triangle has been deleted and the bubble is moved to the AND-gate output.

Fig 8



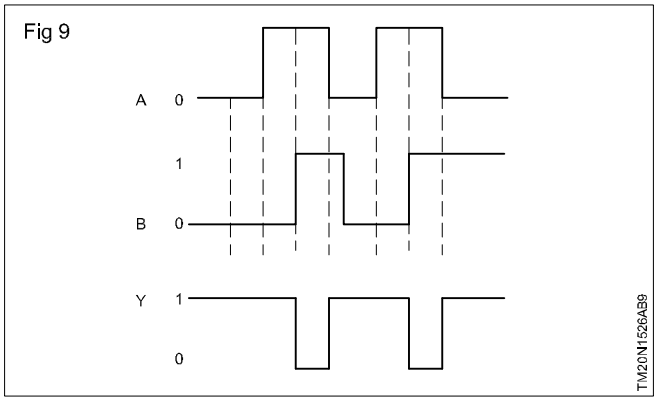
Truth table for NAND gate

A	B	Y=AB
0	0	1
0	1	1
1	0	1
1	1	0

Pulsed operation

Output waveform Y is low only for the time intervals when both inputs A and B are high as shown in the timing diagram Fig 9.

Fig 9

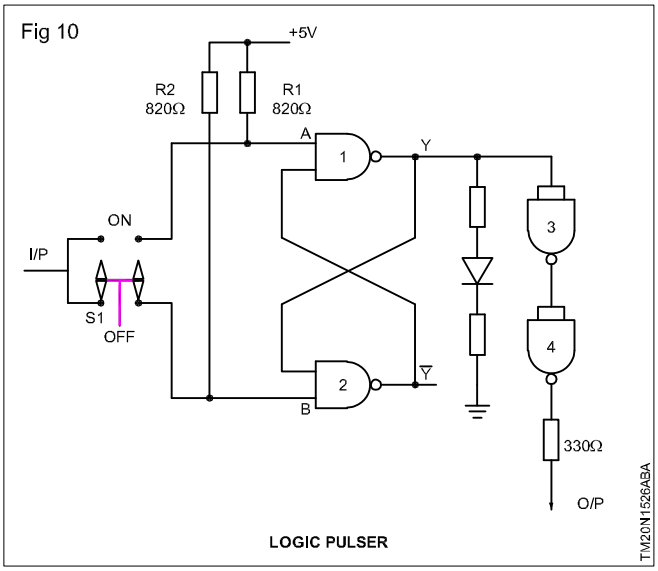


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Logic pulser

The Fig 10 shows the circuit diagram of logic pulser, the circuit essentially consists of NAND gates connected debouncer circuit and its output is Double inverted. The LED indicates, pulses ON or OFF status.

Fig 10



LOGIC PULSER

When switch S1 is not pressed, (OFF position) B input of NAND gate No.2 is grounded, hence its output $\overline{Y}$ is forced to go logic HIGH. This HIGH output is feedback to NAND gate 1, A input of NAND gate 1 is also held HIGH through R_1 resistor (820W) and thus the output of NAND gate-1 'Y' is at low. This logic low output keeps LED in OFF condition and this logic low is again double inverted at the logic pulser tip through NAND gate 3 and 4 to get logic low level at pulser tip.

When S1 is pressed to ON, A input of NAND gate is forced to go logic-low. Hence the output of this NAND gate is forced to go logic-HIGH. Therefore the 'Y' output is at logic-1, so LED glows and a logic-HIGH appears at probe tip. Also note that with HIGH at Y output, the inputs of NAND gate 2 are also at logic-HIGH and the output of NAND gate-2 is forced to go low. As long as switch S1 is at ON position the probe tip is HIGH. When it is released it springs back to OFF position, and the output returns to a logic-LOW condition.

OR and EX-NOR gate circuits

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

- **explain the basic exclusive OR gate and its truth table**
- **explain 4 input Ex-OR gate circuit**
- **explain terms even parity and odd parity**
- **explain basic exclusive NOR gate and its truth table.**

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EX-OR agate

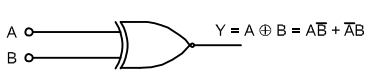
Exclusive-OR gate

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.

An OR gate recognizes words with one or more 1's. The Exclusive-OR gate is different; it recognizes only words that have an add number of 1's.

Standard symbols for Exclusive-OR (XOR for short) gate as shown in Fig 1.

Fig 1



Truth Table

A	B	Y=A + B
0	0	0
0	1	1
1	0	1
1	1	0

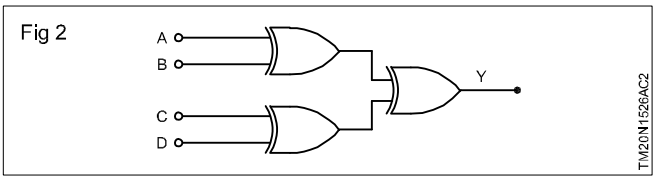
The EX-OR gate has only two inputs unlike the other gates, it never has more than two inputs.

Using 2-input EX-OR gates as building blocks, an EX-OR gate with more than two inputs can be built.

Four input EX-OR gate

Y = A+B+C+D

Fig 2



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.

Parity

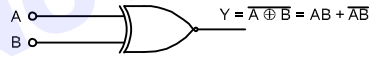
Number of 1's in a binary word. Even parity means an n-bit input has even number of 1s. For instance, 110011 has even parity because it contain four 1s. Odd parity means an n-bit input has an odd no. of 1s. For example, 110001 has odd parity because it contains three 1s.

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

Fig 3



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Inputs		Output
A	B	Y=AB + $\overline{A}\ \overline{B}$
0	0	1
0	1	0
1	0	0
1	1	1

The standard symbols for the EX-NOR (XNOR) gate are shown in Fig 3. 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.

In an exclusive-NOR gate operation, "Output Y is LOW' if input A is LOW and input B is HIGH or if A is HIGH and B is LOW, Y is HIGH if A and B are both HIGH or both LOW.

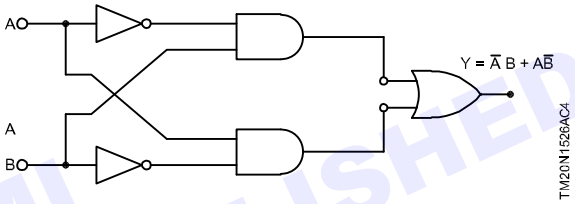
EX-OR gate as a two-bit adder

An examination of the truth table for XOR gate will show you that its output is the binary sum of the two input bits. In the case where the inputs are both 1's, the output is the sum 0, but without the carry of 1.

Exclusive-OR gate using discrete gates

Fig 4 shows the construction of EX-OR gate using discrete gates. The upper AND gate gives the output AB (since inverted A input given to AND gate) and the lower AND gate gives the output AB (Inverted B input given to AND gate). Both outputs of AND gates after O ring results A + B.

Fig 4



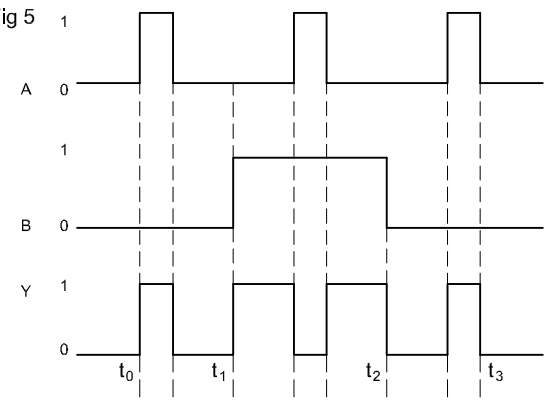
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From the waveforms shown in Fig 5 it is observed that the Ex-OR gate output will go HIGH only when its inputs are at different levels.

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.

Fig 5



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Oscillators using Integrated circuits - Timers

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

- **list the features that make 555 a popular integrated circuit**
- **name the functional blocks of a 555 IC**
- **describe the principle of operation of a 555 IC**
- **list the different types of packaging of 555**
- **list the two basic modes of operation of 555**
- **explain the schematic of an astable multi-vibrator using 555**
- **find the ON-time and OFF-time of a given astable multi-vibrator using 555**
- **explain the term PRF**
- **list a few applications of astable using 555**
- **describe the working of 555 as a VCO.**

Timer

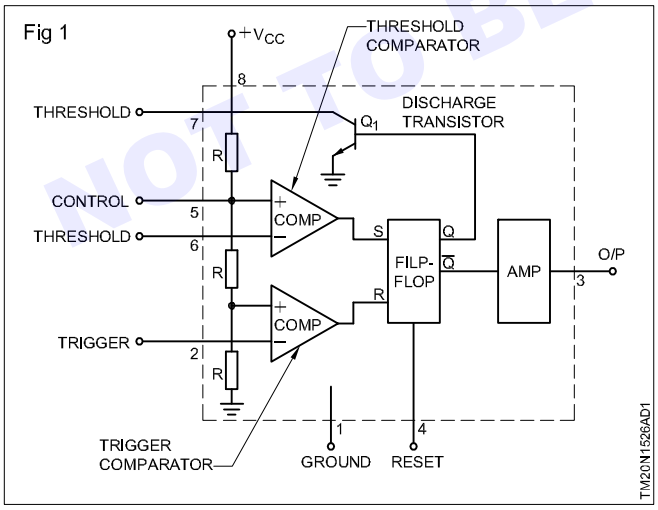
Applications such as square wave, ramp, pulse generators, and one-shot multi-vibrators etc. require a circuit essentially capable of producing timing intervals. Due to the circuit components count and the delicacy in using transistors, integrated circuits(ICs) are preferred to transistors. One such most suitable and popular IC for producing timing intervals is the 555. This IC is popularly known as **555 timer**. Similar to operational amplifiers, 555 IC is reliable, easy to use in a variety of applications, and at low cost. The 555 IC can operate from a wide range of supply voltages of + 5 V to +18 V. This makes 555 compatible with standard digital circuits whose voltage levels (0-state = 0V, 1-state = 5 V) are known as TTL (transistor-transistor logic) levels.

The 555 timer

The functional blocks in 555 timer is shown in Fig 1.

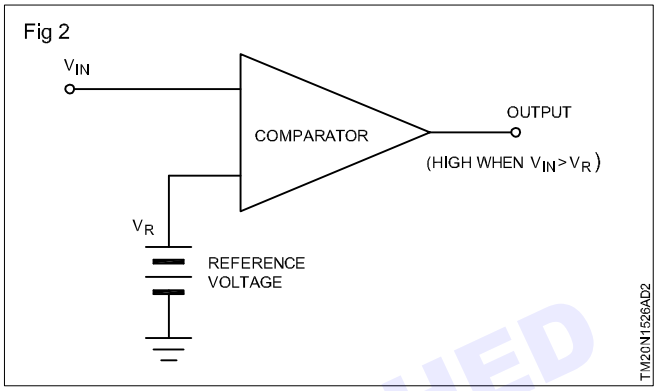
As can be seen from Fig 1, the 555 IC contains two comparators, one transistor, three equal value resistors, a flip-flop, and an output stage.

Fig 1



A *comparator* is a circuit having two inputs and a single output. It compares the signal voltage given at one input with a reference voltage on the other input as shown in Fig 2. Comparators are essentially made using Op-Amps.

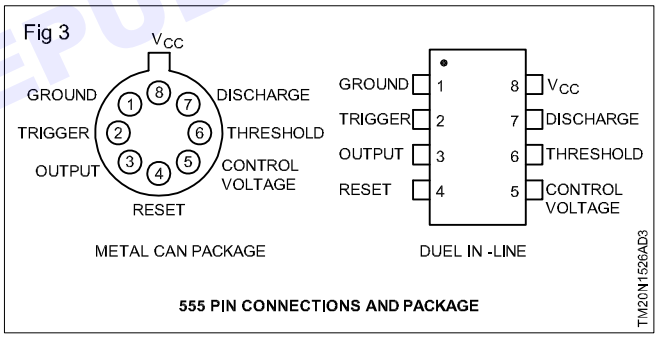
Fig 2



Types of 555 timer IC packages

The 555 timer IC is available in two package styles metal can (TO) and DIP as shown in Fig 3.

Fig 3



Source and Sink current capacity

The internal circuitry of 555 requires about 0.7mA per supply volt (7 mA for V_{CC} = +10V) to set up internal bias currents. Maximum power a 555 IC can dissipate is around 600 mW.

The maximum current that can be drawn from the output terminal (pin No.3) of 555(called source current) or the maximum current that can be forced through the output terminal(called sink current) is around 40 mA.

Modes of operation

The 555 IC timer has two modes of operation:

– as an astable (free-running) multi-vibrator

– as a mono-stable (one-shot) multi-vibrator.

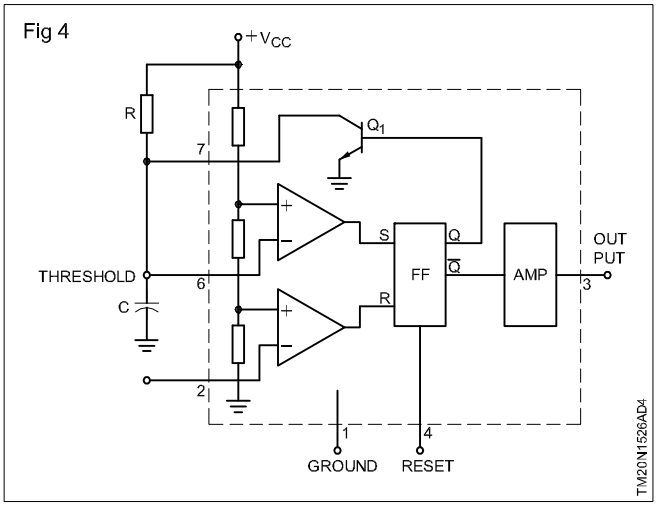
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Principle of 555 operation

Referring to the block diagram of IC 555 in Fig 1, at the input there are two comparators connected to an internal resistive voltage divider. Both comparators have a reference input tied to the voltage divider. The **threshold comparator** is referenced to as $2(V_{CC}/3)$, and the **trigger comparator** is referenced to as $V_{CC}/3$. Comparator outputs are connected to a **set-reset flip-flop**. If the trigger voltage input falls below $V_{CC}/3$, its associated comparator resets the flip-flop output low.

For using the 555 IC, certain external components are required to be connected as shown in Fig 4.

Fig 4



The threshold input is usually connected to an external RC timing circuit. If the capacitor charge (threshold input) exceeds the $2/3\,V_{CC}$ reference on the threshold comparator, the comparator is triggered and the flip-flop is set. When the flip-flop is set, the discharge transistor is turned-on and the capacitor discharges.

IC 555 as an astable multi-vibrator

Fig 5 shows 555 connected for astable operation.

- The reset input is connected to V_{CC}. If it were connected to ground, 555 will get disabled.
- C_f provides noise filtering for the control voltage input.
- When the discharge transistor is off, capacitor C is charging through R_A and R_B. Thus the circuit time constant is given by,

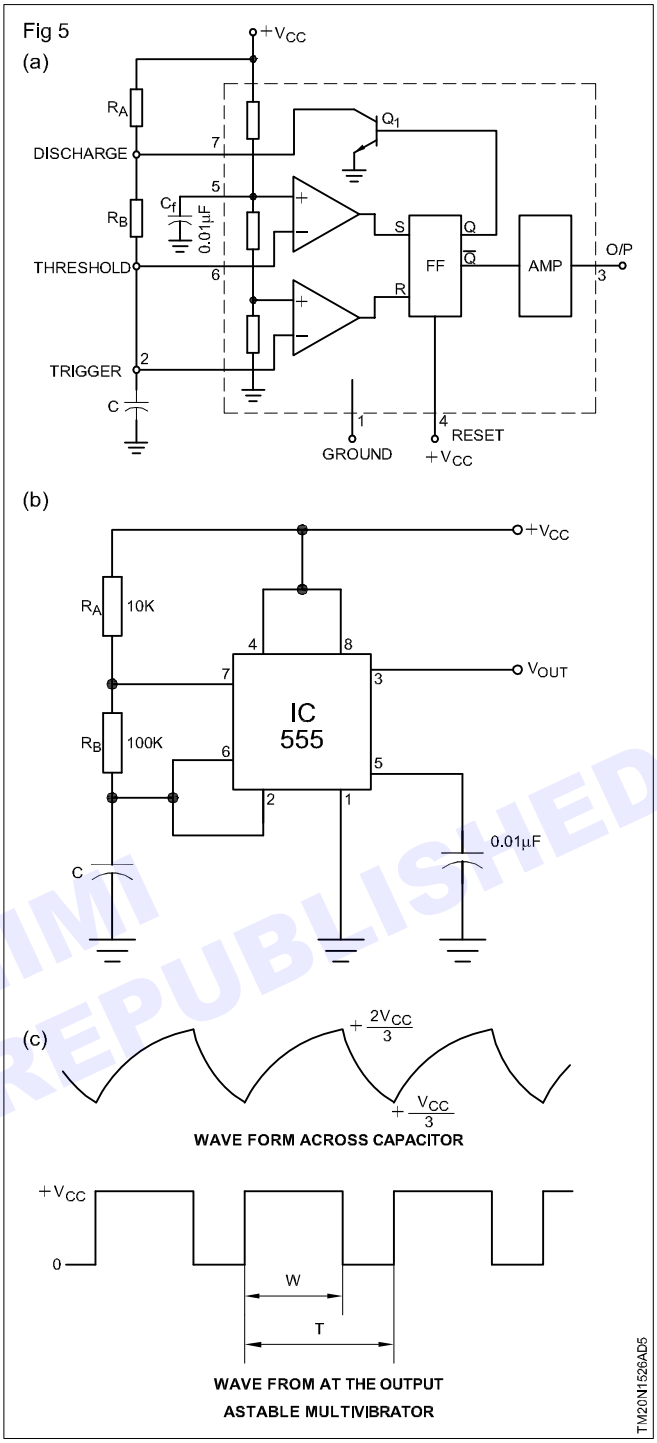
  $t = (R_A + R_B)C$

- As capacitor C charges, the threshold input voltage will soon reach $2V_{CC}/3$. At this point the flip-flop changes states, causing the discharge transistor Q_1 to turn on. Transistor Q_1 saturates and discharges C through resistor R_B and Q_1. The discharge time constant is therefore given by,

  $t = R_B C$

- Since the threshold and trigger inputs are tied together, as C discharges, at some point it falls to a value below $V_{CC}/3$ and activates the trigger comparator. This resets the RS flip-flop, turning off Q_1 and allowing C to start charging again. So, 555 operates as an astable multi-vibrator by causing C to continuously charge and discharge between $V_{CC}/3$ and $2V_{CC}/3$. Wave-forms at the capacitor (trigger input) and at the output 555 are shown in Fig 5c.

Fig 5



It is important to note that, because the charging path for C is through $R_A + R_B$ and the discharge path is through only R_B, the output is not symmetrical. In other words, the ON-time and the OFF-time of the output pulses are not equal. The ratio of the ON-time of the pulse to the OFF-time of the pulse is known as **duty cycle**. The duty cycle of 555 astable circuit range from near 50% to near 100%. The duty cycle can be calculated as follows:

$$\text{Duty cycle}(D) = \frac{R_A + R_B}{R_A + 2R_B} \times 100\%$$

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From the above equation,

– if R_B is made much greater than R_A, the duty cycle will approach 50 %.

– for higher duty cycle, R_A should be made greater than R_B.

Pulse Repetition Frequency (PRF)

The term frequency is generally used with repetitive wave-forms which are symmetrical such as sine wave form. For repetitive wave-forms which are non-symmetrical such as the output of an astable multi-vibrator, instead of the term frequency the term **Pulse Repetition Frequency(PRF)** is used. PRF can be calculated as follows:

If t_{ON} is the ON-time of the pulse

and, if t_{OFF} is the OFF-time of the pulse,

then, Time period, $T = t_{ON} + t_{OFF}$

Hence, $PRF = \frac{1}{T}$

Application of astable multi-vibrators

Application of astable multi-vibrators are almost innumerable: some general applications are listed below;

– ***In electronic pianos*** **:** Different frequencies are generated by astable with different RC values.

– ***Signal injectors*** **:** Used as a testing instrument by service technicians.

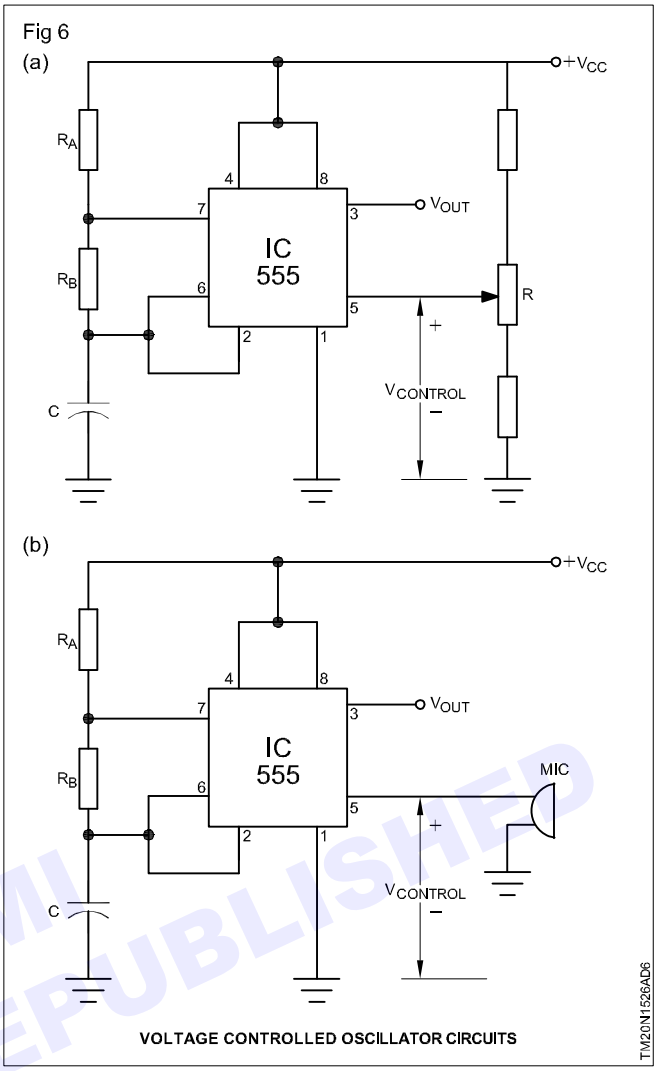
– ***Flashing light*** **:** If lamps or LEDs are connected at the output of the astable, the lamp/LED flashes at the rate set by the values of RC.

– ***As Voltage Controlled Oscillator(VCO)*****:** The oscillator frequency is controlled by the input control voltage. A VCO circuit is shown in Fig 6.

IC 555 Timer as VCO

A Voltage-Controlled Oscillator (VCO) changes its output frequency in relation to the input voltage at the control input of the threshold comparator (pin No.5). The voltage at pin 5 is normally $2V_{CC}/3$ owing to the internal resistive voltage divider. However, by connecting an external component or voltage source as shown in Fig 6a, the voltage at pin 5 can be changed. If the voltage on pin 5 is raised, the capacitor must charge to a higher value, which decreases the output frequency. With pin5 elevated in voltage, a greater time is required for C to discharge to $V_{CC}/3$ as well.

Fig 6



VOLTAGE CONTROLLED OSCILLATOR CIRCUITS

Voltage controlled oscillator circuit can be used in digital circuits where, data are converted to tones for recording or transmission on telephone lines. Such a circuit may produce a tone of 2400 Hz when a low is applied to pin 5 and a tone of 1200 Hz when a high is applied. Fig 6b shows a typical VCO whose output frequency is in relationship to the voice input amplitude.

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Introduction to digital computer

Objectives: At the end of this lesson you shall be able to
- **explain the block diagram of a digital computer/micro computer**
- **explain the different buses in microprocessor**
- **state the history of microprocessor evolution.**

Digital computer

A digital computer is a multipurpose, programmable machine that accepts binary data as input, processes data according to given instructions and give results as output. A set of instructions written for the computer to perform a task (say to add two numbers) is called a program. A group of such programs is called software.

Digital computer recognizes and operates in binary digits (0 and 1). These are known as bits. A bit is the abbreviated form of the term binary digit. These digits are represented in terms of electrical voltages. Generally, 0 represents low level and 1 represents high level.

Digital computer is programmable machine. This means that, it can be instructed to perform required tasks within its capability. Digital computers are designed to understand and execute binary instructions.

A computer is a multipurpose machine, that can be used to perform sophisticated tasks to do this, it consists of logic circuits. The manufacturer of the computer provides the user with a list of the instructions the computer will understand (Instruction set). For example, an instruction for adding two numbers may look like a group of eight binary digits, such as 1 0 0 0 0 0 0 1.

Program languages

A computer must be programmed so that it knows what to do. A program, referred to as software (or firmware) consists of a series of instructions. The instructions are followed by data for the computer to 'fetch-and-execute'.

Programs can be written in machine code, i.e. the 0s and 1s as mentioned in earlier paragraphs. But it is a tedious, time-consuming process, prone to error. Program 'languages' have therefore been developed to make the job easier.

Low-level and assembly languages

These are close to the binary system. Programs are written in mnemonics. For example, that the mnemonic for return is RET. It would also give the binary code for this operation. To enable the computer to understand the instruction RET i.e. to convert the mnemonic code into machine code, a special program called an assembler is available in the computer.

High-level languages

They are more like every day English and are easier to understand and work with. This is because they use terms such as LOAD, ADD, PRINT, STOP. However, they are converted into several machine code instructions. Programs called compiler or interpreter does the translation into machine code. BASIC (Beginner's All-purpose Symbolic Instruction Code) is a popular high-level language. COBOL is designed for business use, while FOR-TRAN is suitable for scientific and mathematical work.

Flowcharts: binary multiplication

All programs, whether high or low level must give absolutely clear instructions to the computer. Writing a program is easier if a flowchart is drawn up initially to show the different steps required for the task.

Suppose the task is the binary multiplication of 6 and 5 i.e. 110 and 101. First consider how it is done by long-multiplication. The method is the same for decimal multiplication, i.e. the multiplicand (6) is multiplied separately by each digit of the multiplier (5) in turn and the partial products properly shifted with respect to one another before they are added.

The operation is simpler in binary because we have to deal with just two digits (1 and 0) and so at each stage there are only two possible answers ie. 110 x 1 = 110 or 110 x 0 = 0. It is performed as follows

multiplicand	110	= 6
multiplier	101	= 5
partial product	110	<- (110 x l.s.b of 101, i.e. 110 x 1)
partial product	000	<- (110 x 2nd bit of 101, i.e. 110 x 0)
partial product	110	<- (110 x m.s.b. of 101, i.e. 110 x 1)
final product	11110	= 30 (sum of partial products)

The process is one of 'shift-and-add' in which the partial products are either zero or a shifted version of the multiplicand. When a digital computer is used for multiplication, it is more convenient to add each partial product as it 'accumulates' rather than adding them all at the end. The result is the same but the sequence is

	101
partial product	110
partial product	000
partial sum	0110
partial product	110
final product	11110

In practice, one shift register (X) is needed for the multiplicand another (Y) for the multiplier and a third, the accumulator, stores the partial products and sums and contains the final product when the multiplication is complete. This event is detected by a binary counter which records the number of 'shift-and-add' cycles to enable the whole operation to be stopped when finished.

Flowchart

A flowchart for binary multiplication is given in Fig 1. The 'shift-and-add' cycle is repeated (as shown by the 'loop') until every bit in the multiplier has multiplied the multiplicand. Note that 'terminal' symbols (start, stop) are oval, 'operation' ones are rectangular, while those involving a 'decision' are diamond-shaped.

Details on programing and flowcharts is discussed in further lessons.

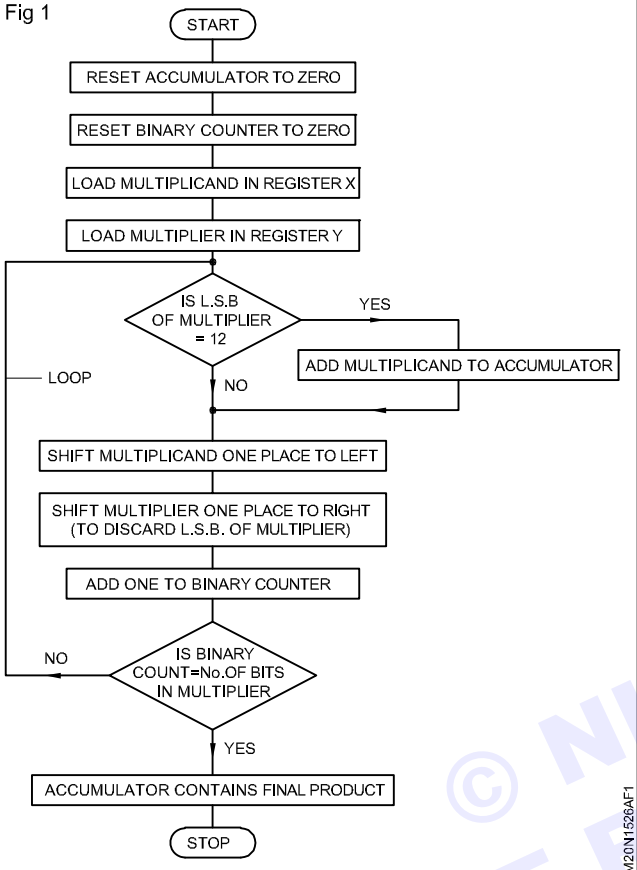
Memory of digital computers

Memory of a digital computer considered like the page of a notebook with space for a storing fixed number of binary digits on each line. In computers, these pages are generally made of semiconductor material or some form of magnetic material. Typically, each line has space for eight binary bits. In reality, a line is an 8-bit register that can store eight binary bits (refer chapter on digital electronics) several of these registers arranged in a sequence is referred to as semiconductor memory. These registers are always grouped together in powers of two. For example, a group of 1024 (2^{10}) 8-bit registers on a semiconductor chip is known

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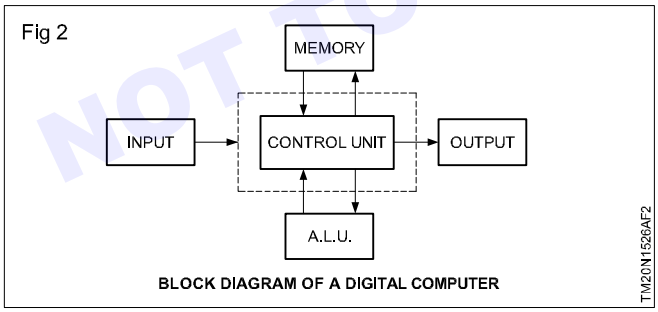
as 1K byte of memory. (1K is the closest approximation in thousands). Actually a computer user writes the necessary instructions and data in memory, asks the computer to perform the given task and find an answer. These instructions are loaded into the memory through the input device (keyboard) of the computer.

Fig 1



As shown in Fig 2, a digital computer will have 5 main blocks or units.

Fig 2



Input unit

Through this unit, data and program is fed to the computer. Examples of input units are keyboard, mouse....

Output unit

A computer after carrying out necessary computation of the fed data sends the result through output unit. Typical output devices are video monitor, printer.

Memory

Memory unit consists of devices called RAM, ROM and disks etc., which store data and programs.

CPU (Control Processing Unit)

This is the heart of any computer. CPU is made of two sub units namely Control unit and ALU (Arithmetic & Logic unit). Control unit fetches the instructions of a program from the memory and performs arithmetic or logical operation depending on the instruction. It then sends the result to the output device or to the memory.

The CPU of small digital computers such as the popular desktop computers or the personal computers or microcomputers use one single integrated chip to perform the function of CPU. This chip is known as a microprocessor.

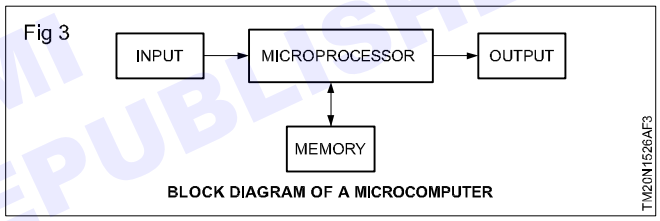
Microcomputer

Fig 3 shows the basic blocks of a microcomputer. Note that in Fig 2, the CPU shown in Fig 1 is replaced by a microprocessor.

Microprocessor

A microprocessor performs the function of CPU of a digital computer. A microprocessor generally in the form of a single chip may also have a small amount of semiconductor memory unit into it. This microprocessor once interfaced with memory, input and output devices, become a microcomputer. These are referred as microcomputers because it uses a microprocessor as its CPU.

Fig 3



Buses

Various blocks of a microcomputer as shown in Fig 2 are interconnected through what are called buses. A bus is common group of wires that interconnect components in a computer. These group of wires carry electrical signals. There are three types of electrical information that travel between the various units of computer. They are the address of memory, data and control signals. The size of a bus means the number of wires of the bus. The size of a bus is referred as 8-bit, 16-bit, 32 bit and so on. 8-bit bus means 8 wires will parallel electrical signals. Since, it is a digital signal that passes through this bus, the electrical signal will have digital information.

The three main types of buses in a microcomputer are

1 Data bus

2 Address bus

3 Control bus

Data bus

Data bus is used to transmit data between parts of the computer. An 8-bit data bus carries an 8-bits of data at any given time. The data bus is known as a bi-directional bus because it carries data in both directions between any two or more parts. For example, data bus gives and takes data from and to memory.

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Address bus

Address bus carry binary information about the location or addresses from where or at which data/instructions need be fed or data to be stored. A microprocessor with 16 lines (16-bit) address bus can address 2^{16} locations of the memory in which the data/program is stored or to be stored. Address bus is a unidirectional bus.

Control bus

Control bus carries such information instruction the memory or a device to accept or give (read or write) data. In essence, the control bus synchronizes all the activities of the micro computer. For example, it sends control signals to an input device to put the data on the data bus and simultaneous sends signal to memory to accept and store the data available on the data bus in the memory.

Microprocessors - The intel family

Microprocessors are available from many manufacturers. Microprocessors from Intel Corporation which are widely used are listed in the order of their appearance in market with time.

Microprocessor no.	Data bus	Address bus	Memory capacity
4004	4-bit	12-bit	4-KB
8008	8-bit		
8080	8-bit	16-bit	64-KB
8085	8-bit	16-bit	64-KB
8086	16-bit	20-bit	1-MB
8088	8-bit	20-bit	1-MB
80186	16-bit	20-bit	1-MB
80286	16-bit	24-bit	16-MB
80386	32-bit	32-bit	4-GB
80486	32-bit	32-bit	4-GB
80586 (Pentium)	64-bit	32-bit	4-GB

Using these microprocessors as the CPU several generations of microcomputers have evolved. Some of these are tabulated below;

Computer type	Micro processor used	Data bus width	Floppy disk drive (FDD)	Hard disk drive (HDD)
PC	8088	8-bit	1 or 2	NIL
PC-XT	8088	8-bit	-do-	1 or 2
PC-AT-286	80286	16-bit	-do-	-do-
PC-AT-386	80386	32-bit	-do-	-do-
PC-AT-486	80486	32-bit	-do-	-do-
PC-AT-586 (Pentium)	80586	64-bit	-do-	-do-

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Microprocessor Intel 8085 and its internal block diagram

Objectives: At the end of this lesson you shall be able to
- **state the internal architecture of Intel 8085**
- **explain the about machine language program, assembly language program**
- **state the programming process, algorithm, coding into MLP and ALP.**

Basic architecture of a microprocessor

A microprocessor is a programmable logic device. The internal logic design of the microprocessor is called its 'architecture'. This architecture determines how and what various operations are performed by the microprocessor.

All microprocessors are designed with the following three elements in addition to those discussed earlier;

– registers to store intermediate data

– flip-flops to indicate status of a operation (flags)

– timing elements - clocks and counters

How does the microcomputer work?

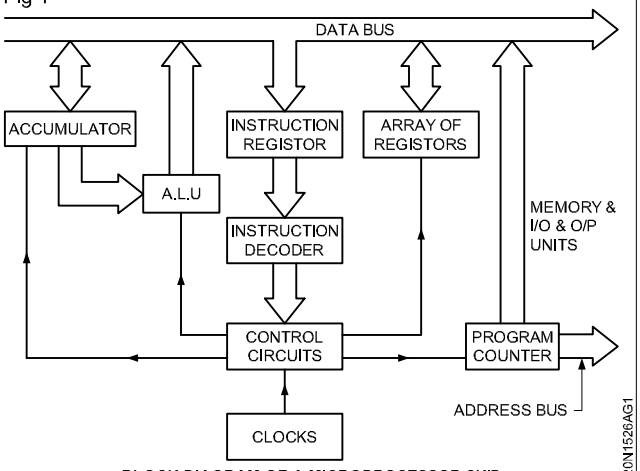
Assume that a program and data are already entered in the R/W memory. The program includes binary instructions to add given data and to display the answer. When the micro-computer is given a command to execute the program, it reads and executes one instruction at a time and finally sends the result to the display.

This process of program execution can best be described by comparing it to the process of assembling a circuit. The instructions for assembling the circuit are given in a sheet of paper in sequential steps. One reads the first instruction, then picks up the necessary components of the circuit and performs the task. Thus the sequence is read, interpret and perform. The microprocessor also performs in a similar way. The instructions are stored sequentially in the memory. The microprocessor fetches the first instruction from its memory sheet, decodes it and executes that instruction. The sequence of fetch, decode and execute is continued until the microprocessor comes across the instruction, Stop. During the entire process, the microprocessor uses its buses to fetch the binary instructions and data from the memory. It uses registers to store data temporarily. It performs the computing function in the ALU section. Finally, it sends out the result in binary, using the same bus lines, to the output display such as a monitor.

A simplified block diagram of a typical microprocessor chip is shown in Fig 1. This can be used to understand the outline of how a microprocessor works.

In the block diagram at Fig 1 for easy understanding, mP is programmed with necessary instructions and data to add two numbers. The program counter whose function is to keep track of the memory address from where the instructions/data is to be fetched is reading zero. Also all registers contain 0's and the clock has stopped.

Fig 1



BLOCK DIAGRAM OF A MICROPROCESSOR CHIP

Action: The program counter is connected by the address bus to the memory (ROM or PROM in which the instructions are stored). The binary output (count) from the counter is the address input to the memory and is initially all 02 (e.g. 0000 0000 for an mP with an eight-bit address bus). The instruction in this first address is thus 'read' out of the memory into the via the mP via the data bus.

The read instruction is held by the instruction register (until another is received). This instruction is decoded by the instruction decoder into a signal that goes to the control circuits. By opening and closing logic gates the control circuit routes the data that enable the mP to perform the operation required by the first instruction. Suppose it is LOAD.

If the clock is now started and advances the program counter by one count, the program advances by one step (line) and the data stored at the second address (e.g 0000 0001) is 'read' out of the memory and loaded ('copied' is more exact) via the data bus into the accumulator. (The data will have been entered previously by the programmer and transferred into a RAM).

To obtain addition of the data (number) in the accumulator and the data (number) stored at another address in the RAM, the program must give the necessary instructions on succeeding clock pulses to enable the first data to be shifted from the accumulator to one of the internal registers in the mP and for the second data to be copied into the accumulator.

If the ADD instruction is then given, the instruction decoder arranges for the ALU to perform the addition (i.e act as a full-adder) and to store the result in the accumulator for subsequent transfer to the output unit.

Having discussed in brief a microcomputer and a microprocessor work, let us discuss a more detailed working of a mP choosing a specific mP chip. The mP chosen for this discussion is the INTEL 8085, 8 bit microprocessor. 8085 mP is chosen for the reason that, it is fairly simple to understand its architecture and have a few hands on practice of programming. Several companies produce 8085 trainee kits using which practice can be had in the laboratory lessons.

Microprocessor Intel 8085

Intel 8085 is a 8-bit microprocessor. It is available as a 40-pin DIP as shown in Fig 2a. Its data bus width is 8 and address bus width is 16. It has multiplexed address/data lines for the lower-order address as shown in Fig 2b. It has a CPU, flags and few registers as shown in Fig 3 and as listed below;

1 8-bit registers: A,B,C,D,E,H and L

2 16-bit registers: PC (Program counter)

SP (Stock pointer)

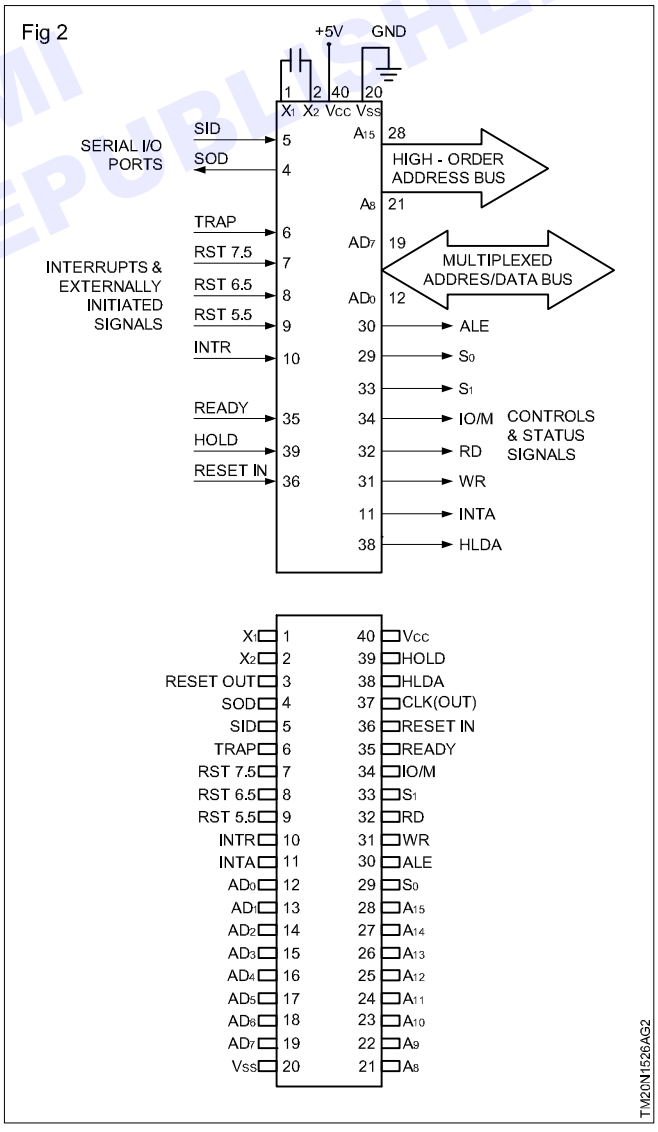
3 Flags: S,Z,AC,CY,P

Internal architecture of Intel 8085

Buses

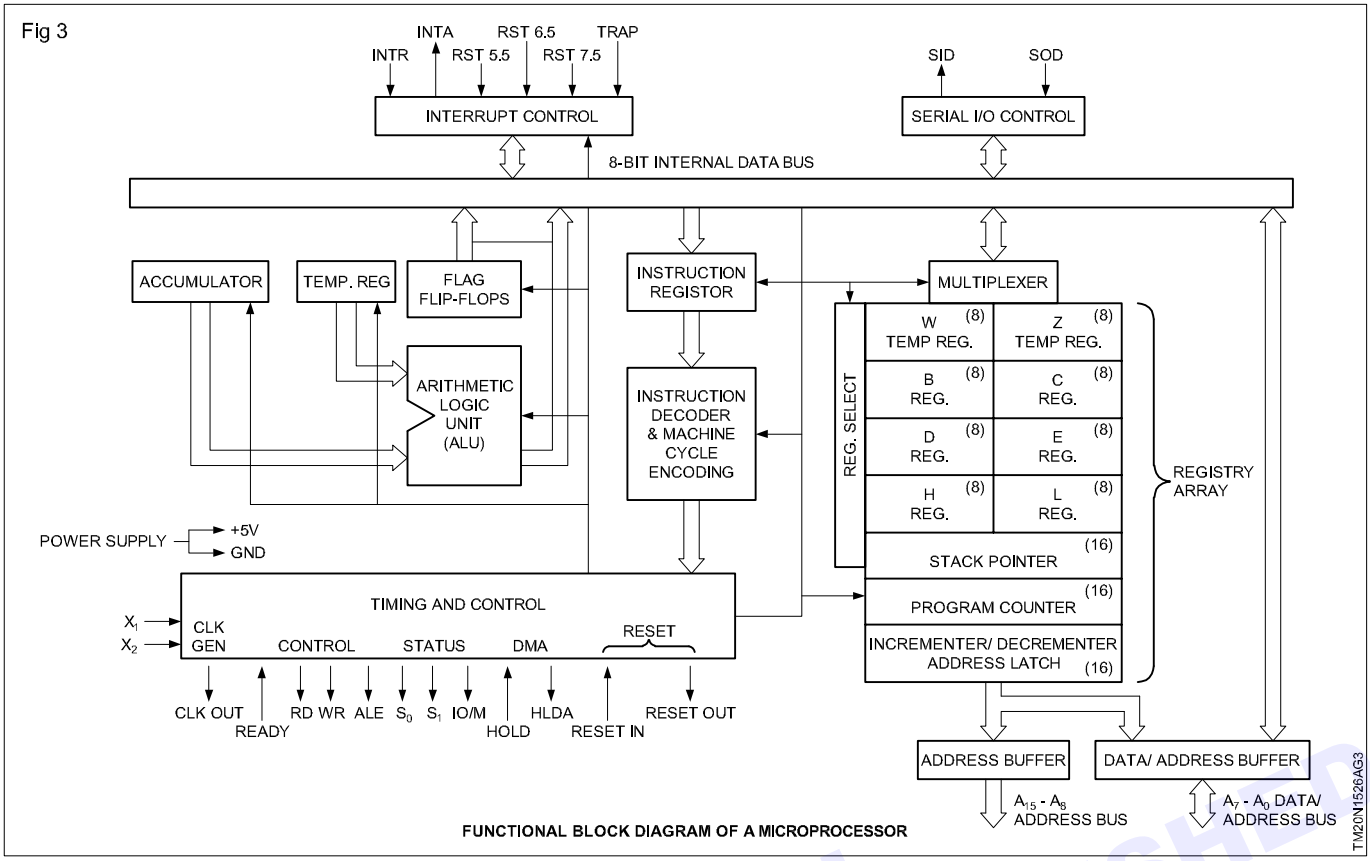
8-bit internal data bus is to carry instructions and data between the CPU registers.

Fig 2



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Fig 3



FUNCTIONAL BLOCK DIAGRAM OF A MICROPROCESSOR

External buses are Address bus, Address/Data bus, Control bus. These buses are used to connect to peripheral chips like memory, input/output etc.

a Address bus is designated as A15-A8. This bus is exclusively used to carry upper 8-bits of the address.

b Address/Data bus is designated as AD7-AD0. The same bus is used to carry either lower 8-bits of address or data.

c Control bus is used to carry control signals such as , WR, ALE etc.

Registers

Intel 8085 contains seven 8-bit registers namely A-reg (also called Accumulator) which is a special register and general purpose registers B,C,D,E,H and L.

It contains two 16-bit registers namely PC (Program Counter) and SP (Stack Pointer). Program counter always holds the address as the next instruction to be executed. Stack pointer also holds the address of a memory location of stack.

Incremented - decremented latch is used to add 1 or subtract 1 from the content of SP or PC.

ALU and Flags

The ALU (Arithmetic and Logic Unit) is used to carryout arithmetic and logical operations. As shown in Fig , the contents of A-reg and temporary register are inputs to the ALU. Depending upon the instruction executed, ALU performs arithmetic or logic operation on the contents of A-reg and temporary register. For instance, during the execution of ADD C instruction, the content of C-register is copied in the temporary register during one clock cycle and the contents of A and temperature register are added during the another clock cycle period. The result is stored back in the A-register.

There are five flip flops (flags) which will be set or reset whenever ALU performs arithmetic or logical operation. Flags are affected as follows:

1 Sign (S) — 1: If the MSB of the result is 1.
0: If the MSB of the result is 0.

2 Zero (Z) — 1: If the value of the result is 0.
0: If the value of the result is not equal to 0.

3 Carry(CY) — 1: If there is a overflow from MSB during addition or if there is a borrow during subtraction.
0: Otherwise

4 Parity(P) — 1: If the result has even no. of 1s.
0: If the result has odd no. of 1s.

5 Auxiliary carry(AC) — 1: If there is a overflow out of lower nibble during addition.
0: If there is no overflow out of lower nibble during addition.

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Address buffer and address-data buffer: The contents of the stack pointer (SP) and program counter (PC) can be loaded into the address buffer (higher byte) and address-data buffer (lower byte). The output of these buffers then drives the external address bus (A15-A8) and address-data bus (AD7-AD0). Memory and I/O chips are connected to these buses. In this way, the CPU can send the address of desired data to the memory or I/O chips.

Instruction register and decoder/encoder: During fetch cycle, the opcode of an instruction is stored in instruction register. This opcode then drives the instruction decoder and machine cycle encoder. The output of machine cycle encoder is fed to timing and control unit.

Timing and control

This section includes an oscillator and a controller-sequencer. The oscillator generates the two phase clock signals (CLK and $\overline{CLK}$) that synchronise all the registers and peripherals. The controller sequencer produces the control signals needed for internal and external control.

Interrupt control

There are 5-interrupt inputs lines such as TRAP, RST5.5, RST6.5, RST7.5 and INTR and one interrupt acknowledge output line $\overline{INTA}$.

Sometimes it is necessary to interrupt the execution of the main program to answer a request from an I/O device. For instance an I/O device may send an interrupt signal to the interrupt control unit to indicate that data is ready for input. The processor temporarily stops what it is doing, inputs the data, then returns to what it was doing.

Serial I/O control

Some I/O device work with serial data rather than parallel. In such case, the serial data stream from an input device must be converted into 8-bit parallel data before the computer can use it. Likewise, the 8-bit data out of a computer must be converted into serial form before a serial output device can use it.

SID input is used for serial input and SOD output is used for serial output.

Program: A program is a sequence of instructions that operate a certain data to perform a particular task.

Machine Language Program (MLP)

A program written using 0s and 1s is known as Machine language program.

Since any microprocessor can understood only instructions written using sequences of 0s and 1s, programs should be in machine language. But writing machine language programs is a very cumbersome, error-prove and machine dependent.

Assembly language program (ALP)

A program written using symbolic names such as ADD, SUB, ANA, ORA, DCR, INR etc and define the data using decimal, hexadecimal or binary notation is called assembly language program. Compared to MLP debugging the error is easy in ALP.

Since any microprocessor can understood only MLP, programs written using ALP needs to be translated into MLP. Such a translator that translates an ALP into MLP is known as an assembler.

Even assembly language programming is cumbersome if programs of reasonably large size are to be written. In such cases, it is advisable to write programs using languages like Fortran, Cobol, C, Pascal etc known as High Level Language (HLL).

Programming process

Once the problem is stated, develop an algorithm for it. An algorithm is a precise statement of the procedure required for solving the problem. The language used for writing an algorithm must be such that the intension of the programmer can be clearly expressed. Hence English like language is used to write algorithm.

The algorithm is then coded into a suitable programming language say machine or assembly language of the 8085.

To understand about algorithm and programming let us take a simple problem and try to solve.

Problem

Add 2 single byte numbers stored at memory location 4230H and 4231H and store the result at memory location 4232H.

Algorithm

1 Load the address of the first byte in register pair HL.

2 Load A reg with content of memory location pointed by the pair.

3 Increment the content of register pair HL (now HL points to the second byte of the data).

4 Add the content of memory location pointed by HL to A reg.

5 Increment the content of register pair HL.

6 Store the result i.e the content of A register in memory location pointed by register pair HL.

7 Halt.

The above algorithm can be coded into a Assembly language program as follows:

LXI H,4230H	Load 4230H into HL pair
MOV A, M	Move the content of memory pointed by HL into A reg.
INX H	Increment the content of HL pair by 1
ADD M	Content of A is added with the content of memory location pointed by HL pair and place the result in A reg.
INX H	Increment the content register pair HL by 1.
MOV M,A	Move the content of A into memory pointed by HL pair.
HLT	Halt

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The complete coding sheet which contains both assembly language and machine language program is shown below.

By referring to data book, you can find the opcode for each instruction.

Problem

Add 2 single byte numbers stored at memory location 4230H and 4231H and store the result at memory location 4232H.

Assume

1 Data 1 at memory location 4230H is 37H.

2 Data 2 at memory location 4231H is 5CH.

3 Result at memory location 4232H is 37H + 5CH = 93H.

4 Starting memory location of RAM is 4200H.

Address	Object code			Label	Menomonics	Operand	Comment
4200	21	30	42		LXI	H, 4230H	(H) (L) <- 4230H
4203	7E				MOV	A, M	(A) <- ((H) (L))
4204	23				INX	H	(H) (L) <- (H) (L) + 1
4205	86				ADD	M	(A) <- (A) + ((H) (L))
4206	23				INX	H	(H) (L) <- (H) (L) + 1
4207	77				MOV	M, A	(H) (L) <- (A)
4208	76				HLT		Halt

Intel 8085 instruction set - Introduction

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

- **state the data structures used in Intel 8085**
- **list the type of address used in Intel 8085**
- **list the instruction types**
- **state about addressing modes used in Intel 8085**
- **list the instruction sets of Intel 8085.**

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Data

In Intel 8085, data bus width is 8. It means that at a time only 8-bits can be transferred or manipulated.

a Possible 8-bit unsigned datas are as follows:

	D7	D6	D5	D4	D3	D2	D1	D0
Minimum	0	0	0	0	0	0	0	0
Maximum	1	1	1	1	1	1	1	1

i.e 00H to FFH

b Taking MSB as a sign bit

i.e

i For +ve numbers, MSB=0

ii For -ve numbers, MSB=1 and it will be in 2's complement.

Positive numbers

Minimum = 0000 0000 = 00H = 0_{10}

Maximum = 0111 1111 = 7FH = 127_{10}

i.e. 00H to 7FH

Negative numbers (in 2's complement)

Minimum = 1111 1111 = FFH = -1_{10}

Maximum = 1000 0000 - 80H = -128_{10}

i.e 80H to FFH

Address

In Intel 8085, address bus width is 16. Therefore address range is as follows:

	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	
Starting address	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	= 0000H
Last address	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	= FFFFH

i.e Address range is from 0000H to FFFFH

Total no. of memory locations $= 2^{16}$

$= 64K$

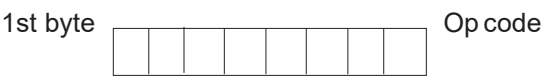
$= 65536$

Out of 64K memory locations, some portion will be used to address ROM and some portion will be used to address RAM. Actual address range for ROM and RAM chips depends upon the way in which it is interfaced/ interconnected.

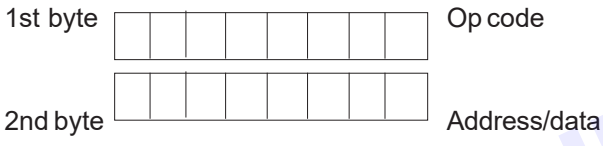
Instructions

Instructions are of 3-types namely,

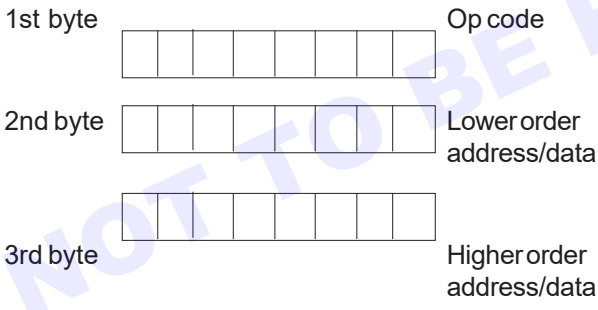
1 Single byte instruction



2 Two byte instruction



3 Three byte instruction



Addressing modes: Addressing modes means the mode or method in which the location of the data is addressed. In Intel 8085, the following addressing modes are used.

1 Immediate addressing mode

In this mode, the instruction itself will contain the data.

(e.g) MVI A, 37H

The data 37H is moved to register A.

2 Register addressing mode

In this mode, the instruction points to a register where the data is available.

(e.g) MOV A, C

The data available in C-register is moved to A-register

3 Direct addressing mode

In this mode, the instruction contains the address of the memory location where the data has to be moved.

(e.g) LDA 2090H

In this instruction, 2090H is the address of the memory location. The data stored at memory location 2090H is moved to A-register.

4 Register indirect addressing mode

In this mode, the instruction contains a register pair whose content is the address of a memory location where a byte of data is moved.

(e.g) LDAX B

In this instruction, B indicates the register pair BC, the content of memory location whose address is the content of BC-pair is moved to A-register.

Instruction sets

Intel 8085 instruction set contains 72-instructions. They are grouped as follows.

1 Data transfer group

2 Arithmetic group

3 Logic group

4 Branching group

5 Stack, I/O and machine control group

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Data transfer group instructions

Objectives : At the end of this lesson you shall be able to
- **state the data transfer group instruction**
- **state the meaning/function of the instruction.**

8085 mp has six 8-bit general purpose registers. They are identified as B, C, D, E, H and L. They can be combined as register pairs BC, DE and HL to perform 16-bit operation.

These registers are programmable meaning that a programmer can use them to load or transfer data from the registers by using instructions. Conceptually registers can be viewed as memory location built inside the microprocessor.

Accumulator A is an eight bit special register used to store 8 bit data. While performing arithmetic or logical operation one of the datas must be available in this register and the result is also stored in the same register. The accumulator is also identified as register A.

Sl.No.	Instruction	Meaning	Example
1	MOV r_1, r_2	$(r_1) <- (r_2)$ The content of r_2 is moved to r_1 where r_1, r_2 can be any of the following registers A, B, C, D, E, H, L	MOV B, C (B) <- (C)
2	MOV r, M	(r) <- ((H)(L)) The content of memory location whose address is in HL register pair is moved to register r	MOV B, M (B) <- ((H)(L))
3	MOV M,r	((H)(L)) <- (r) The content of register r is moved to memory whose address is in register pair HL.	MOV M,C ((H)(L)) <- (C)
4	MVI r, data	(r) <- (Byte 2) The content of byte 2 of the instruction is moved to register r.	MVI D, 79H (D) <- 79H
5	MVI M, data	((H)(L)) <- (Byte 2) The content of byte 2 of the instruction is moved to memory whose address is in register pair HL.	MVI M, 9CH ((H)(L)) <- 9CH
6	LXI r_p, data	(r_h) <- (Byte 3) (r_l) <- (Byte 2) Byte 3 of the instruction is moved to high-order register (r_h) and byte 2 low-order register (r_h) of the register pair r_p. Register pairs (r_p) are BC, DE, HL and SP.	LXI H, 4230H (L) <- 30H (H) <- 42H
7	LDA address	(A) <- ((Byte 3) (Byte 2)) The content of the memory location whose address is specified in byte 3 and byte 2 of the instruction is moved to register A.	LDA 4250H (A) <- (4250H)
8	STA address	((Byte) (Byte)) <- A The content of register A is moved to memory location whose address is specified by byte 3 and byte 2 of the instruction.	STA 4290H (4290H) <- (A)
9	LHLD address	(L) <- ((Byte 3) (Byte 2)) (H) <- ((Byte 3) (Byte 2) + 1) The content of memory location whose address is specified in byte 3 and byte 2 of the instruction is moved to register L. The content of the memory location at the succeeding address is moved to register H.	LHLD 4250H (L) <- (4250H) (H) <- (4251H)
10	SHLD address	((Byte 3) (Byte 2)) <- (L) ((Byte 3) (Byte 2) + 1) <- (H) The content of register L is moved to the memory location whose address is specified in byte 3 and byte 2. The content of register H is moved to the succeeding memory location.	SHLD 4260H (4260H) <- (L) (4261H) <- (H)
11	LDAX r_p r_p = BC, DE	(A) <- $((r_p))$ The content of the memory location whose address is in register pair r_p is moved to register A.	LDAX B (A) <- ((B)(C))
12	STAX r_p r_p = BC, DE	$((r_p))$ <- (A) The content of register A is moved to the memory location whose address in register pair r_p.	STAX D ((D)(E)) <- (A)
13	XCHG	(H) <-> (D) (L) <-> (E) The contents of registers H and L are exchanged with the contents of registers D and E.	

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Arithmetic group instructions

Objectives: At the end of this lesson you shall be able to
- **state the arithmetic group instructions**
- **state the meaning/function of each instruction.**

Arithmetic group instructions

Almost all the instructions in this group affect the conditional flags (S, Z, AC, CY, P) unless or otherwise mentioned other way.

Whenever arithmetic or logical operation is performed, one of the datas must be available in A register and affect the flags. These flags are arranged in a 8-bit pattern called F-register or flag register as follows

F-register/Flag register

S	Z	X	AC	X	P	X	CY
7	6	5	4	3	2	1	0

Bit 0 : CY -> Carry flag

Bit 2 : P -> Parity flag

Bit 4 : AC -> Auxiliary carry flag

Bit 6 : Z -> Zero flag

Bit 7 : S -> Sign flag

Bits 1, 3, 5 : X -> don't cares.

Sl.No.	Instruction	Meaning	Example
1	ADD r [r = A,B,C,D,E,H,L]	(A) <- (A) + (r) The content of register r is added to the content of register A and the result is placed in A register.	ADD C (A) <- (A) + (C)
2	ADD M	(A) <- (A) + ((H)(L)) The content of register A is added to the content of memory location whose address is in register pair HL and the result is placed in A register.	LXI H, 4250H ADD M
3	ADI data	(A) <- (A) + (Byte 2) The content of A register is added to the byte 2 of the instruction and the result is placed in A register	ADI 37H (A) <- (A) + 37H
4	ADC r	(A) <- (A) + (r) + (CY) The content of A register is added to the content of register r and the carry bit. The result is placed in a register.	ADC E (A) <- (A) + (E) + (CY)
5	ADC M	(A) <- (A) + ((H)(L)) + (CY) The content of A register is added to the content of memory location whose address is in register pair HL HL and the carry flag CY. The result is placed in A register.	
6	ACI data	(A) <- (A) + (Byte 2) + (CY) The content of A register is added to the content of	ACI 39H (A) <- (A) - 39H
7	SUB r	(A) <- (A) - (r) The content of register r is subtracted from the content of A register and the result is placed in A register. Note: During subtraction if (r) > (A), CY flag is set. i.e. If there is a borrow, CY flag is set to 1.	SUB B (A) <- (A) - (B)
8	SUB M	(A) <- (A) - ((H) (L)) The content of memory location whose address is in register pair HL is subtracted from the content of A register and the result is placed in A register.	
9	SUI data	(A) <- (A) - (Byte 2) The content of byte 2 of the instruction is subtracted from A register and the result is placed in A register.	SUI 57H (A) <- (A) - 57H

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10	SBB r	(A) <- (A) - (r) - (CY) The content of register r and the content of CY flag are both subtracted from A register and the result is placed in A register.	SBB D (A) <- (A) - (D) - (CY)
11	SBB M	(A) <- (A) - ((H) (L)) - (CY) The content of memory location whose address is in register pair HL and the content of CY flag are both subtracted from A register and the result is placed in A register.	
12	SBI data	(A) <- (A) - (Byte 2) - (CY) The content of byte 2 of the instruction and the content of CY flag are both subtracted from the A register and the result is placed in A register.	SBI 19H (A) <- (A) - (Byte 2) - (CY)
13	INR r	(r) <- (r) + 1 The content of register r is incremented by one. Note: All flags except CY are affected.	INR E (E) <- (E) + 1
14	INR M	((H) (L)) <- ((H) (L)) + 1 The content of memory location whose address is in register pair HL is incremented by one. Note: All flags except CY are affected.	
15	DCR	(r) <- (r) - 1 The content of register r is decremented by one. Note: All flags except CY are affected.	DCR C (C) <- (C) - 1
16	DCR M	((H) (L)) <- ((H) (L)) - 1 The content of memory location whose address is in register pair HL is decremented by one. Note: All flags except CY are affected.	
17	INX r_p	(r_p) <- (r_p) + 1 The content of register pair rp is incremented by one Note: None of the flags is affected.	INX H (H) (L) <- (H) (L) + 1
18	DCX r_p	(r_p) <- (r_p) - 1 The content of register pair r_p is decremented by one Note: None of the flags is affected.	DCX B (B) (C) <- (B) (C) - 1
19	DAD r_p	(H) (L) <- (H) (L) + (r_p) The content of register pair HL is added to the content of register pair r_p and the result is placed in register pair HL. Note: Only CY flag is affected.	DAD D (H) (L) <- (H) (L) + (D)(E
20	DAA	The 8-bit number in the A register is adjusted to form two 4 bit BCD digits (only after performing addition operation) by the following process: 1 If the value lower 4 bits (Nibble) of the A register is greater than 9 or if AC is in set condition, 6 is added to A register. 2 If the value of higher nibble is greater than 9 or if CY flag is in set condition, 6 is added to the higher nibble of the A register.	

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Logical group instructions

Objectives: At the end of this lesson you shall be able to
- **state the meaning/function of each instruction in this group.**

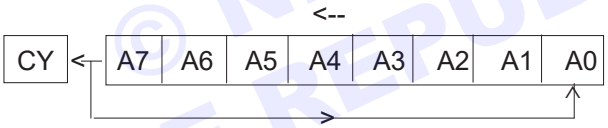
Logical group instructions

Almost all the instructions in this group affect the flags unless or otherwise mentioned other way.

Logical operations are performed on the corresponding bit i.e. bit 0 with bit 0, bit 1 with bit 1 etc.

Sl.No.	Instruction	Meaning	Example
1	ANA r	(A) <- (A) ^ (r) The content of register A is logically ANDed with the content of register r and the result is placed in A register. Note: CY flag is cleared and AC is set.	ANA B (A) <- (A) ^ (B)
2	ANA M	(A) <- (A) ^ ((H)(L)) The content of register A is logically ANDed with the content of memory location whose address in register pair HL and the result is placed in A register. Note: CY flag is cleared and AC is set.	
3	ANI data	(A) <- (A) ^ (Byte 2) The content of A register is logically ANDed with the content of byte 2 of the instruction and the result is placed in A register. Note: CY flag is cleared and AC is set.	ANI 37H (A) <- (A) ^ 37H
4	XRA r	(A) <- (A) V (r) The content of A register is exclusive-ORed with the content of register r and the result is placed in A register. Note: CY and AC are cleared.	XRA A (A) <- (A) " (A)
5	XRA M	(A) <- (A) V ((H)(L)) The content of A register is exclusive-ORed with the content of memory location whose address is in register pair HL and the result is placed in A register. Note: CY and AC are cleared.	
6	XRI data	(A) <- (A) V (Byte 2) The content of A register is exclusive-ORed with the content of byte 2 of the instruction and the result is placed in A register. Note: CY and AC are cleared.	XRI 9AH (A) <- (A) " 9AH
7	ORA r	(A) <- (A) Ú (r) The content of A register is inclusive ORed with the content of register r and the result is placed in A register. Note: CY and AC are cleared.	ORA C (A) <- (A) Ú (C)
8	ORA M	(A) <- (A) Ú ((H)(L)) The content of A register is inclusive ORed with the content of memory location whose address is in register pair HL and the result is placed in A register. Note: CY and AC are cleared.	

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9	ORI data	(A) <- (A) Ú (byte 2) The content of A register is inclusive ORed with the content of byte 2 of the instruction and the result is placed in A register. Note: CY and AC are cleared.	ORI 3AH (A) <- (A) Ú 3AH
10	CMP r	(A) - (r) The content of register r is subtracted from A register but the A register remains unchanged. Only the condition flags are set as a result of the subtraction. * Z flag is set to 1 if (A) = (r) * CY flag is set to 1 if (A) < (r)	
11	CMP M	(A) - ((H)(L)) The content of memory location whose address is in register pair HL is subtracted from A register but A register remains unchanged. Only the condition flags are set as a result of the subtraction. * Z flag is set to 1 if (A) = ((H)(L)) * CY flag is set to 1 if (A) < ((H)(L))	
12	CPI data	(A) - (byte 2) The content of the second byte of the instruction is subtracted from A register but A register remains unchanged. Only the condition flags are set as a result of the subtraction. * Z flag is set to 1 if (A) = (byte 2) * CY flag is set to 1 if (A) < (byte 2)	
13	RLC	Rotate left  (Au+1) <- (Au); (A0) <- (A7) (CY) <- (A7) The content of A register is rotated left by 1bit position. A0 and CY flag are both set to the value shifted out of the MSB i.e. A7 * Only CY flag is affected	

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POCKET TABLE

Table 1

Standard commercial carbon composition resistor values

Resistance in Ohms ± 10%							
1.0	10	100	1K	10K	100K	1M	10M
1.1	11	110	1.1K	11K	110K	1.1M	11M
1.2	12	120	1.2K	12K	120K	1.2M	12M
1.3	13	130	1.3K	13K	130K	1.3M	13M
1.5	15	150	1.5K	15K	150K	1.5M	15M
1.6	16	160	1.6K	16K	160K	1.5M	16M
1.8	18	180	1.8K	18K	180K	1.8M	18M
2.0	20	200	2K	20K	200K	2.0M	20M
2.2	22	220	2.2K	22K	220K	2.2M	22M
2.4	24	240	2.4K	24K	240K	2.4M	
2.7	27	270	2.7K	27K	270K	2.7M	
3.0	30	300	3K	30K	300K	3.0M	
3.3	33	330	3.3K	33K	330K	3.3M	
3.6	36	360	3.6K	36K	360K	3.6M	
3.9	39	390	3.9K	39K	390K	3.9M	
4.3	43	430	4.3K	43K	430K	4.3M	
4.7	47	470	4.7K	47K	470K	4.7M	
5.1	51	510	5.1K	51K	510K	5.1M	
5.6	56	560	5.6K	56K	560K	5.6M	
6.2	62	620	6.2K	62K	620K	6.2M	
6.8	68	680	6.8K	68K	680K	6.8M	
7.5	75	750	7.5K	75K	750K	7.5M	
8.2	82	820	8.2K	82K	820K	8.2M	
9.1	91	910	9.1K	91K	910K	9.1K	

Table 2

Coding scheme for three colour band resistors

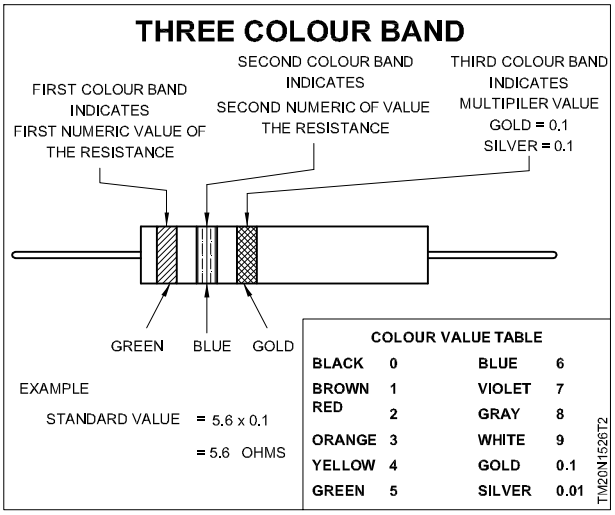


Table 3

Coding scheme for four colour band resistors

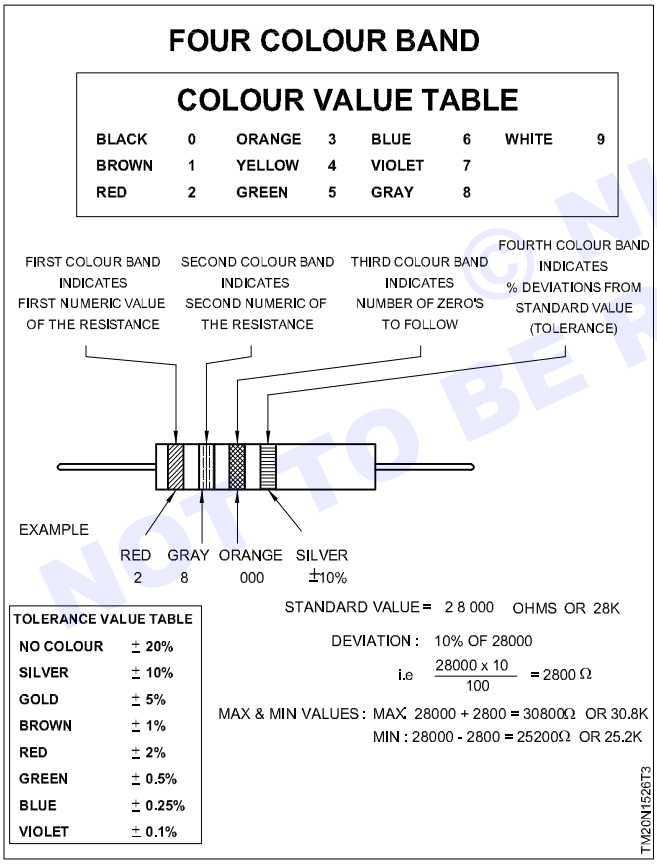


Table 4

Coding scheme for five colour band resistors

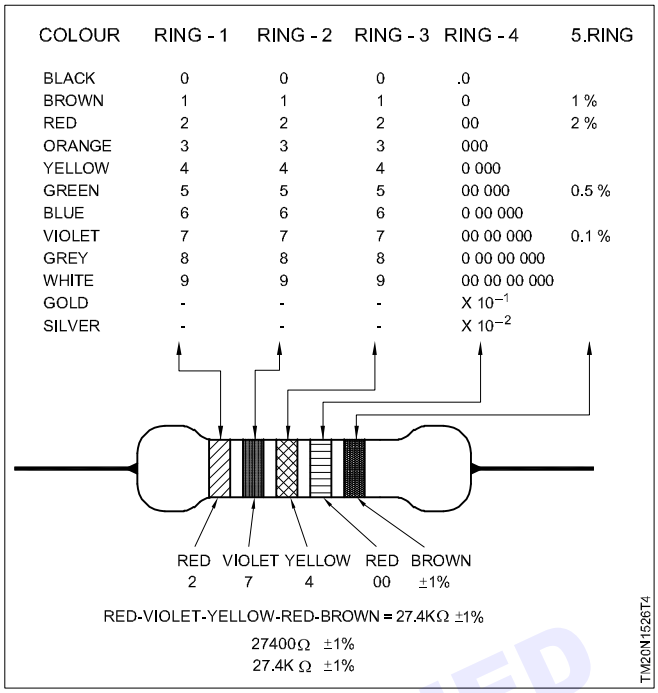


Table 5

Typographical/Numerical coding of resistor values

Printed code format	Meaning	Examples of Printed code	Corresponding Resistance values
xE	x ohms	1E	1 ohms
x	x ohms	100	100 ohms
xohms	x ohms	56 ohms	56 ohms
xKy	x.y K ohms	4K7	4.7K ohms
x.K	x K ohms	56K	56K ohms
xMy	x.y M ohms	6M8	6.8 M ohms
xM	xM ohms	10M	10M ohms

ಸೂದೃಢತೆ : ಕ ಪ್ರದಶ್ನ ಕ ಶ್ರೇಷ್ಠ ಮತ್ತ ಪ್ರದರ್ಶ ತ್ವದಶ್ಚಕ್ಷಪ್ರಕ್ಷಪ್ರ ಧ್ಯಶ್ಚಪ್ರತ್ತ.

Table 6

Setting OHM Meter range for resistance Measurement

Pots maxmimum resistance value	Set meter range to
Less than 100 ohms	X 1 Ω
Between 100 to 1000 ohms	X 10 Ω
Between 1K to 10K ohms	X 100 Ω
More than 10 K ohms	X 1000 Ω

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Table 7

Resistivity of substances at Room Temperature (20°C)

Substances	Resistivity in W· m
Metal-Conductors	
Silver	1.47×10^{-8}
Copper	1.72×10^{-8}
Gold	2.45×10^{-8}
Aluminimum	2.63×10^{-8}
Tungsten	5.51×10^{-8}
Nickel	7.8×10^{-8}
Alloy-conductors	
Manganin	44×10^{-8}
Constantan	49×10^{-8}
Nichrome	100×10^{-8}
Pure Semiconductors	
Carbon	3.5×10^{-5}
Germanium	0.60
Silicon	2300
Insulators	
Wood	$10^{8} - 10^{11}$
Paper	10^{10}
Nylon	8×10^{12}
Lucite	10^{13}
Glass	$10^{10} - 10^{14}$
Rubber	$10^{13} - 10^{14}$
Amber	5×10^{14}
Mica	$10^{11} - 10^{15}$
Sulfur	10^{15}
Teflon	10^{15}
Porcelain	10^{16}
Polystrene	10^{16}
Quartz (fused)	75×10^{16}

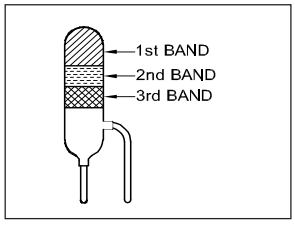
Table 8

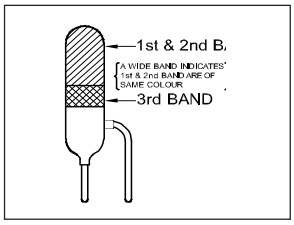
Dielectric constant K of commonly used insulators
(Average values at room temperature)

Material	K
Vacuum (and air)	1
Glass	5
Mica	5
Rubber	3
Neoprene	7
Bakelite (plastic)	6
Polyethylene	2
Vinylite	3
Teflon	2
Paper	3
Polyesters	4
Polystyrene	2.5
Ceramics-Procelain	7
Titanium dioxide	14-110
Strontium titanate	7500

Table 9

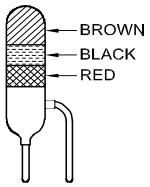
Coding scheme for capacitors with 2 or 3 bands





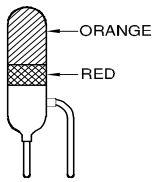
Note: Capacitance values formed using colour code is always in PF (Picofarads)

Example



1st Band	2nd Band	3rd Band
Brown	Black	Red
1	0	10^2

Capacitance = 1000 pf = 1 kpf

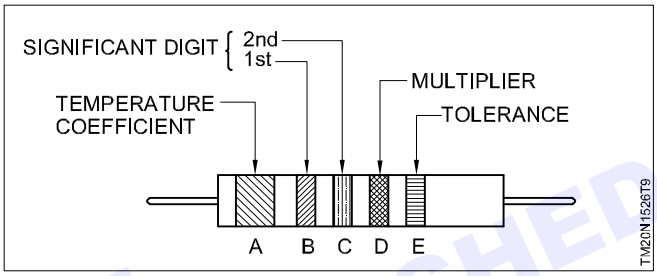


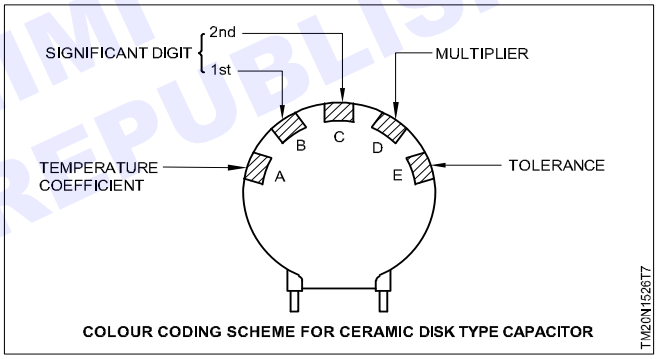
1st Band	2nd Band	3rd Band
Orange	Orange	Red
3	3	10^2

Capacitance = 3300 pf = 3K3 pf

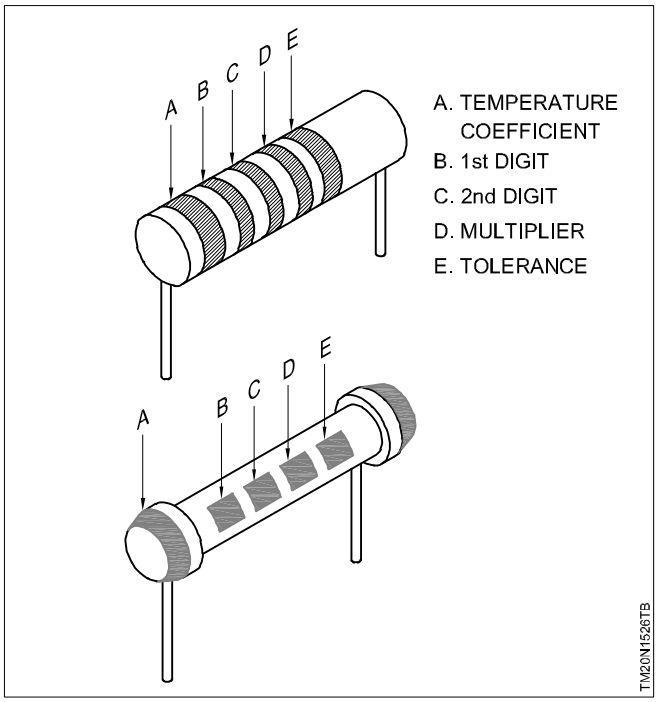
Table 10

Coding scheme for ceramic capacitors





COLOUR CODING SCHEME FOR CERAMIC DISK TYPE CAPACITOR



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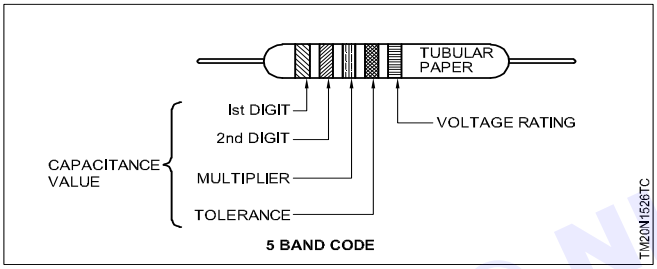
Table 11

Colour	Temperature Coefficient	First Digit	Second Digit	Multiplier	Tolerance	
					More than 10pf (%)	Less than 10 pf (pf)
	(A)	(B)	(C)	(D)	(E)	
Black	0	0	0	1.0	±20	±2
Brown	-30	1	1	10	±1	---
Red	-80	2	2	100	±2	---
Orange	-150	33	3	1000	±3	---
Yellow	-220	4	4	10,000	±4	---
Green	-330	5	5	----	±5	±0.5
Blue	-470	6	6	----	±6	---
Violet	-750	7	7	----	±7	---
Gray	+30	8	8	0.01	±8	±0.25
White	+120 to -750	9	9	0.1	±10	±1
Gold	--	--	--	0.7	±5	--
Silver	--	--	--	0.01	±10	--

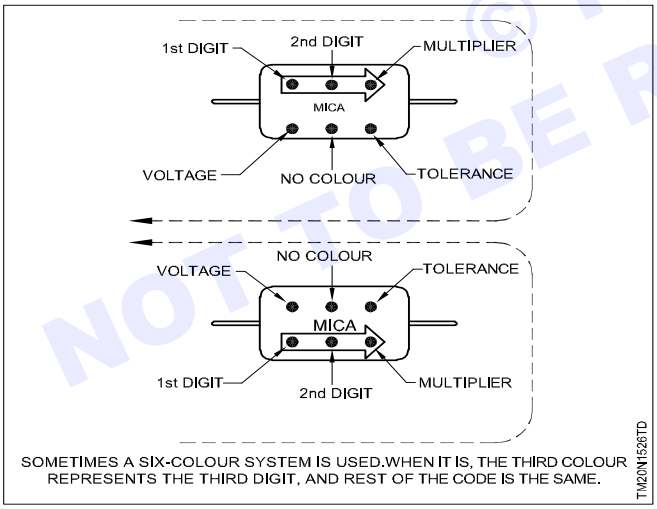
NOTE: Capacitance values formed using colour code is always in PF or Picafarads

Table 12

Coding scheme for moulded, tubular paper and mica capacitors



5 BAND CODE



SOMETIMES A SIX-COLOUR SYSTEM IS USED.WHEN IT IS, THE THIRD COLOUR REPRESENTS THE THIRD DIGIT, AND REST OF THE CODE IS THE SAME.

Table 13

Colour	First Digit	Second Digit	Multiplier	Tole-rance	Voltage Rating (Volts)
Black	0	0	1	±20	100
Brown	1	1	10	±1	200
Red	2	2	100	±2	300
Orange	3	3	1000	±3	400
Yellow	4	4	10,000	±4	500
Green	5	5	1,00,000	±5	600
Blue	6	6	1,000,000	±6	700
Violet	7	7	10,000,000	±7	800
Gray	8	8	100,000,000	±8	900
White	9	9	1,000,000,000	±9	1000
Gold	--	--	0.1	±5	2000
Silver	--	--	0.01	±10	--

Table 14 - Typographic codes for capacitors

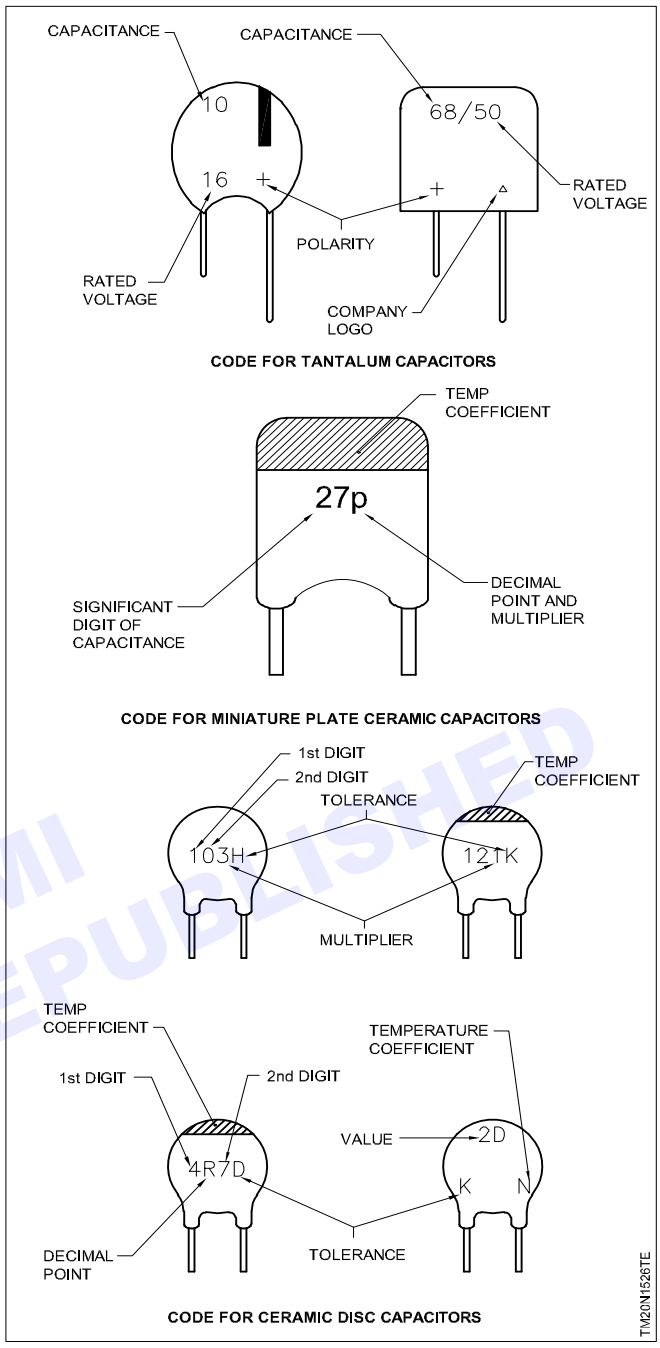


Table 15 - Code table for capacitors

Code	Multiplier
0	None
1	x 10
2	x 100
3	x 1000
4	x 10000

Code	<10 pt	>10 pt
B	0.1 pF	---
C	0.25 pF	---
D	0.5 pF	---
E	---	25%
F	1 pF	1%
G	---	2%
H	---	2.5%
J	---	5%
K	---	10%
M	---	20%
P	---	-0+100%
S	---	-20+50%
W	---	-0+200%
X	---	-20+40%
Z	---	-20+80%

NOTE : Refer Table 22/1

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Table 16

Proelectron type code for diodes

Semiconductor material (First letter)	Main function (Second letter)
A Germanium	A Signal diode
B Silicon	B Varactor diode
C Gallium arsenid	E Tunnel diode
D Indium antimonide	G Oscillator diode
R Materials for photo conductors and hall generators	H Magnetic field diode
	K Hall generator
	M Hall generator
	P Photo diode
	Q Luminescence diode
	T Controllable power rectifier
	X Multiplier
	Y Rectifier/power diode
	Z Z-diode and reference diode

Examples for identifying types of semiconductor diodes

Type Number	Semiconductor material and nature of semiconductor diode
AA143	Germanium - Signal diode
AEY 30A	Germanium - Tunnel diode for **industrial/professional applications**
AHY 10	Germanium - Magnetic field diode for **industrial/professional applications**
BA 157	Silicon - Signal diode
BAT 43	Silicon - Schottky-diode
BY 103	Silicon - Rectifier diode
BB 121A	Silicon - Varactor diode
BZX 84/C9V1	Silicon - Z-diode
BPW 50	Silicon - Photo diode
CQY 65	GaAs - LED

Table 17

Diode Equivalents

Diode type-number	Possible equivalent type-number(s)
OA79	1N34,1N54,1N60
OA85	1N478
OA90	1N87A
DR25	OA10
DR300	BA148
BY125	1N4003.....1N4007
BY126	1N4005.....1N4007
BY127	1N4006.....1N4007
1N36	AA113, 1N34, 1N60
1N38	AA117, AA118
1N914	1N4148...49,1N4151
1N915	1N4148...49, 1N4151
1N4001,1N4002	BY126...127, BY133...135, 1N5614..22
1N4004	BY126...127, BY133...134, 1N5616
1N4007	BY127, BY133, BY227, 1N5622
1N4148	BAW62, BAX95, 1N4446

Table 18

Key Information On Rectifiers With Capacitor-input Filter

	Half-wave	Fullwave	Bridge
Number of diodes	1	2	4
DC output voltage	1.41 $V_{s(rms)}$	1.41 $V_{s(rms)}$	1.41 $V_{s(rms)}$
Diode current rating	I_L	0.5 I_L	0.5 I_L
Peak inverse voltage	2 $V_{s(peak)}$	2V*$_{s(peak)}$	$V_{s(peak)}$
Ripple frequency	f_{in}	$2f_{in}$	$2f_{in}$

* $V_{s(peak)}$ is the voltage across the secondary and the centre-tap.

Note : In the case of low-voltage rectifiers, as an improvement to the data given in the table above,

- subtract 0.7 V from the DC output voltage of the half-wave and fullwave rectifiers
- subtract 1.2 to 1.4 V from the DC load voltage of the bridge rectifiers.

Table 19

Diodes: quick reference data

Type Number	Material	Rated peak inverse voltage	Max. average forward current mA	Max. forward voltage drop @ I_f	Max. forward surge current Amps	Max. reverse current at V_R mA	Max. junction temperature °C	Application
		V_R	I_f	V_f	I_S	I_{Vr}		
OA79	G	30	35	0.3		2.8	60	SIG
OA85	G	90	50	0.25		4.5	75	SIG
DR25	G	25	250	1		200	90	Rec
DR150	S	1500	250				150	High V, Low I
DR300	S	300	300				125	Scan rectifier
DS5	S	5	30				125	Stabiliser
DS10	G	10	20	0.15		500	75	Bias
SD50	S	50	200				125	Gen . Pur.
BY125	S	100	1A		40		150	Rec
BY126	S	450	1A	1.5	40	10	150	Rec
BY127	S	800	1A	1.5	40	10	150	Rec
CD5		5	150	1.2		0.1		Gen. Pur.
CD12		12	200	1.2		1.0		Gen. Pur.
CD21		20	150	1.2		1.0		Gen. Pur.
CD22		50	150	1.2		1.0		Gen. Pur.
CD23		100	150	1.2		1.0		Gen. Pur.
CD27		50	200	1.2		1.0		Gen. Pur.
1N36	G	35	4	1				SIG
1N38	G	100	60	1	0.5	500	25	SIG
1N914	S	100	75	1	-	5.0	150	SW
1N915	S	50	75	1		25n	100	SW
1N4001	S	50	1000	1.5	30	10	175	Rec
1N4002	S	100	1000	1.5	30	10	175	Rec
1N4004	S	400	1000	1.5	30	10	175	Rec

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Table 20

Zener diodes: Quick reference data

Type Number	Nominal Zener voltage (V_Z)	Zener current (I_Z)	Max power (P_Z)	% tolerance	Zener resistance in zener mode R_Z	Package
BZX61-	9.1	20mA		±5%	8	
BZ147	7.5	–	250mw	±5%,±10%	<40W	
BZ148	8.2V		250mw	±5%,±10%	<40W	
CZ6	6.8	5mA	200mw	±5%,±10%		TO106
CZ9	9.1	5mA	200mw	--do-		TO106
CAZ3.0	3.0	20mA	400mw	±5%(Caza)	24	DO-7
CAZ5.1	5.1	20mA	400mw	±5%(Caza)	14	DO-7
CAZ6.2	6.2	20mA	400mw	±5%(Caza)	3	DO-7
CAZ9.1	9.1	10mA	400mw	±5%(Caza)	6	DO-7
CAZ12	12	10mA	400mw	±5%(Caza)	10	DO-7
CAZ15	15	5mA	400mw	±5%(Caza)	14	DO-7
ESZ9.1	9.1		200mw	±5%	12	TO106
ESZ12	12		200mw		12	TO106
EZ9-1D10	9.1	28mA		±10%	7	
OAZ230	12	20mA		±5%	28	
SZ12	12		330mw		12	TO18
ZC012	12v	1mA		±5%	45	
ZD5012	12v	200m		±10%	2.5	
ZSD120CF	12V	50mA		±20%	2.5	
1N709A	6.2V	24mA		±10%	4	
1N716B	12	12mA		±20%	10	
1N716	12	12mA		±10%	10	
1N759	12	20mA		±10%	30	
1N936	9	7.5mA		±5%	20	
1ZC12T10	12	15mA		±10%	10	
1Z.9-1	9.1	10mA		±10%	30	
1Z12	12	10mA		±10%	30	

Table 21

Pro Electron type code for transistors

First letter Semi conductor material used	Second letter Frequency of application and power rating
A - Germanium B - Silicon C - Gallium arsenid D - Indium antimonide	C - AF, LP, Transistor D - AF, HP, Transistor F - RF, LP, Transistor L - RF, HP, Transistor S - SW, LP, Transistor T - SW, HP, Transistor U - SW, HP, Transistor

1 Transistors in Pro-Electron system are registered either under, two letter/three numeral code (e.g. BC 148) for consumer devices

or

2 Three letter/two numeral code (e.g ACY17, BCW54) for industrial devices.

Examples

1 A C 128

A — Germanium

C — Audio frequency low power transistor

2 B D 140

B — Silicon

D — AF, high power, transistor

Table 22

Summary of important parameters of CE, CC and CB amplifiers

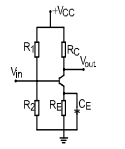
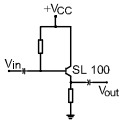
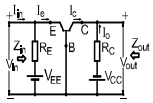
	Common emitter amplifier	Emitter follower	Common Base amplifier
			
Input impedance Z_{in}	$(R_{in}=R_1 \| R_2) \approx R_1 \| R_2 \| \beta r'_e$	$\simeq R_B \| \beta R_E$ (High)	$\simeq r'_e$
Output impedance Z_{out}	$\simeq R_C$ (Medium)	$\simeq r'_e$ (Very low)	$\simeq R_C$ (Medium)
Voltage gain A_V	$\cong -\frac{R_C}{r'_e}$ (High)	$\simeq 1$ (low)	$\frac{R_C}{r'_e}$ (High)
Current gain A_i	$=\frac{\beta R_{in}}{R_{in}+\beta r'_e}$ High (when $(R_{in}=R_1 \| R_2)$	$=\frac{\beta R_B}{R_B+\beta R_E}$ (Medium)	$\simeq -1$ (Low)

Table 23

Fixed voltage 3-terminal IC regulators

Type	Short description	Figure
L7805 C(CT)	+5V, 1.5A	3
L7806 C(CT)	+6V, 1.5A	3
L7807	+7V, 1.5A, 5%	1
L7808 C(CT)	+8V, 1.5A	3
L7809(C)T	+9V,1.5A	3
L7810CV, ACV	+10V, 1.5A, 5%	1
L7812 C(CT)	+12V, 1.5A	3
L7815 C(CT)	+15V, 1.5A	3
L7818 C(CT)	+18V, 1.5A	3
L7820 CV	+20V, 1.5A	1
L7824 C(CT)	+24V, 1.5A	3
L7875 (C)T	+7.5V, 1.5A	3
L7905 CT	-5V, 1.5A	4
L7908CT	-8C, 1.5A	4
L7912 CT	-12V, 1.5A	4
L7915CT	-15V, 1.5A	4
L7918CT	-18V, 1.5A	4
L7920CT	-20V, 1.5A	4
L7924CT	-24V,1.5A	4
L7952 CT	-5,2V, 1.5A	4
LM7805 CK	+5V,1A	3
LM7806 CT,CU	+6V,1A	1
LM7808 CT,CU	+8V, 1A	1
LM7812 CK	+12V, 1A	3
LM7815 CT,CU	+15V,1A	1
LM7818 CT,CU	+18V,1A	1
LM7824 CT,CU	+24V, 1A	1
LM7905 CT,CU	-5V, 1A	2
LM7912 CT,CU	-12V, 1A	2
LM7915 CT,CU	-12V, 1A	2

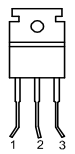
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Table 24

Type	Short description	Figure
MC78 T05(A)CK	+5V,3A,4%(A=2%),0..+125	3
MC78 T06(A)CK	+6V,3A,4%(A=2%),0..+125	3
MC78 T08(A)CK	+8V,3A,4%(A=2%),0..+125	3
MC78 T12(A)CK	+12V,3A,4%(A=2%),0..+125	3
MC78 T12(A)CT	+12V,3A,4%(A=2%),0..+125	1
MC78 T15(A)CK	+15V,3A,4%(A=2%),0..+125	3
MC78 T15(A)CT	+15V,3A,4%(A=2%),0..+125	1
MC78 T18(A)CK	+18V,3A,4%(A=2%),0..+125	3
MC78 T18(A)CT	+18V,3A,4%(A=2%),0..+125	1
MC78 T24(A)CK	+24V,3A,4%(A=2%),0..+125	3
MC78 T24(A)CT	+24V,3A,4%(A=2%),0..+125	1
MC7805(A)CK	+5V,1.5A	3
MC7805(A) CT	+5V,1.5A, 4%(A=2%),0..+125	1
MC7806(A)CK	+6V,1.5A	1
MC7806(A)CT	+6V,1.5A,4%(A=2%),0..+125	1
LM 330T - 5.0	+5V, 0.15A	TO220
LM390K	+5V, 1A	TO3
LM 323K	+5V, 3A	TO3

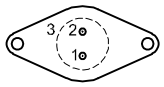
Note: Suffix CV = 5% ACC; ACV = 2%ACC

Fig 1 & 2



Pins 1 2 3
Fig 1 ---> IN GND OUT
Fig 2 ---> GND IN OUT

Fig 3 & 4



Pins 1 2 3
Fig 3 ---> OUT IN GND
Fig 4 ---> OUT GND IN

Table 25

Adjustable voltage regulators

Type		Pack-age	Output min (V)	Output max (V)	Out -put $I_{max.(A)}$	Input voltage V_{in} -V_{out} mod(V)	Drop voltage typical
LM 317L	+	TO-92	+1.2	+37	0.1	40	2.5
LM 337L	-	TO-92	-1.2	-37	0.1	40	2.5
LM317H	+	TO-39	+1.2	+37	0.5	40	2
LM337H	-	TO-39	-1.2	-37	0.5	40	2
LM317T	+	TO-220	+1.2	+37	1.5	40	2.5
LM337T	-	TO-220	-1.2	-37	1.5	40	2.5
LM350K	+	TO-3	+1.2	+32	3	35	2.5
LM333T	-	TO-220	-1.2	-32	3	35	2.5
LM338K	+	TO-220	+1.2	+32	5	35	2.5
LM396K	+	TO-3	+1.2	+15	10	20	2.1
mA78GU1C	+	TO-220	+5	+30	1	40	2.5
mA79GU1C	-	TO-220	-2.5	-30	1	-40	2
LAS15U	+	TO-3	+4	+30	1.5	40	2.4
LAS18U	-	TO-3	-2.6	-30	1.5	-40	2.1
LM376N	+	DIP-8	+5	+37	0.03	40	3
NE550N	+	DIP-14	+2	+40	0.15	40	3
mA723PC	+	DIP-14	-12	+37	0.15	40	3
LAS1000	+	TO-5	+3	+38	0.15	40	2
LAS1100	+	TO-5	+3	+48	0.15	50	2
MC1466L	-	DIP-4	0	+1000	-	-	2
LAS3700	+	TO-5	0	+1000	-	-	-

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Study of commonly used transducers

Objectives : At the end of this lesson you shall be able to
- **describe the working of various transducers**
- **measure various physical quantities using transducers.**

Linear variable differential transformer

LVDT is a sensor which is used to measure linear displacement of an object accurately. It can measure linear displacement in the range of 0.3mm to 300mm. LVDT works on the principle of Faradays law of electromagnetic induction. “Faraday"s law of electromagnetic induction states that "when a current carrying conductor is moved inside a magnetic field, an EMF will be induced. The induced EMF will be directly proportional to the rate of cutting flux." “LVDT works on the principal of transformer. It also consists of primary winding and secondary winding like a transformer. In fact, LVDT has one primary winding at the Centre, two secondary windings on either side . The iron bar is placed at the Centre inside the primary winding initially in such a way that it can move freely inside the coils. The object whose linear displacement to be measured, is connected to the iron bar with the help of the plunger. When the object displaces, the iron bar will move inside the coils. Due to this, there will be some secondary voltage. This secondary voltage depends upon the movement of iron bar. For example, if the object moves in forward direction, then secondary voltage VS1 will be greater than secondary voltage VS2 if the object moves in reverse direction, then the secondary voltage VS2 will be greater than the secondary voltage VS 1. The output voltage of L VDT will be differential voltage of two secondary windings. In practice the output voltage Vs will vary according to the displacement of the object. “L VDTs are in wide use in various applications. These range from use in machine tools, to robotics and digital positioning systems. LVDTs often form part of systems which measure force, pressure and acceleration.

Fig 1

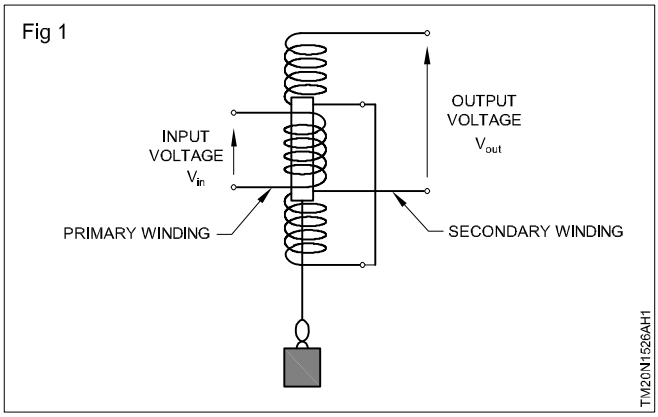


Fig 2

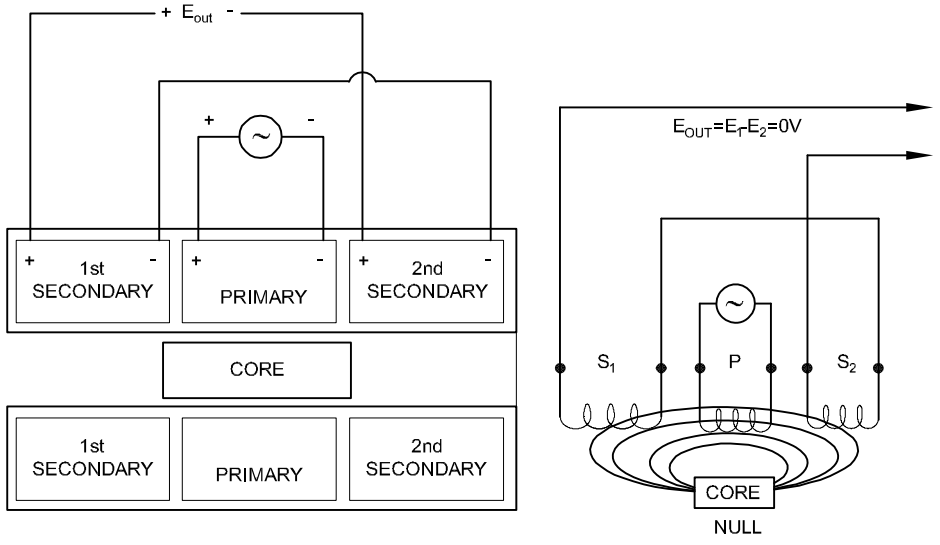
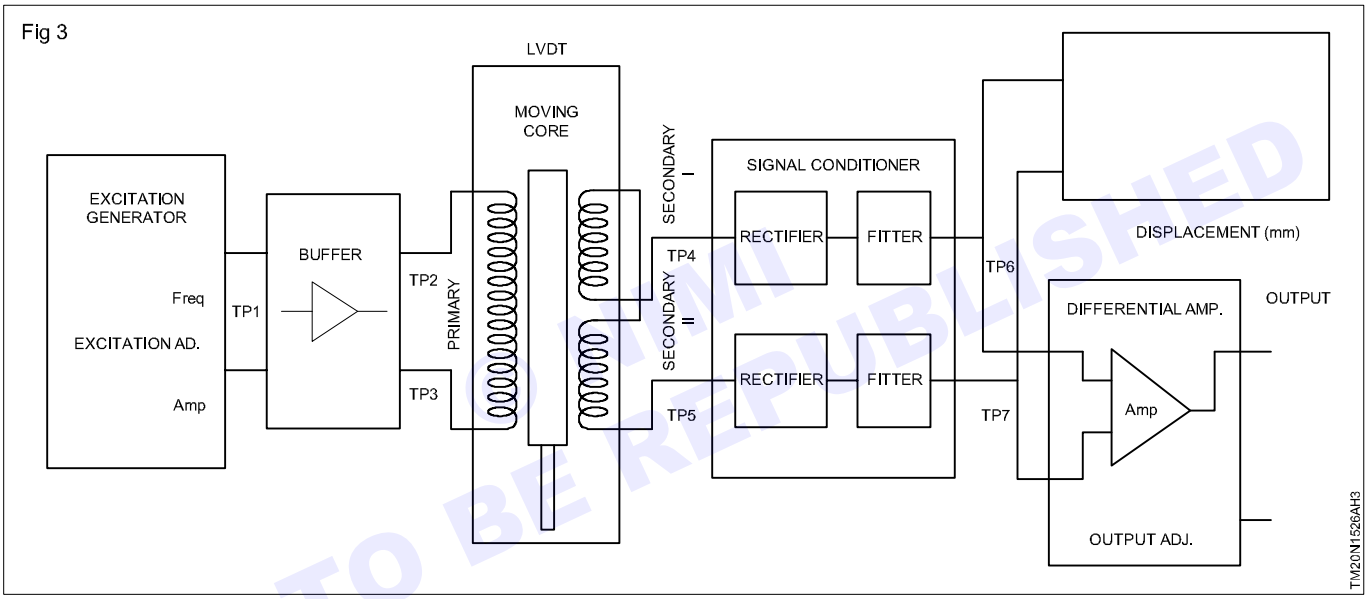


Fig 3



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Strain gauge

It is a transducer which is used to measure linear displacement within an object when it is compressed or stretched. Strain gauge measures strain of an object by measuring change in length of the object. Strain is generally described as ratio of change in length to the original length. It is also called as mechanical strain or tensile strain.

Mechanical strain = change in length / original length

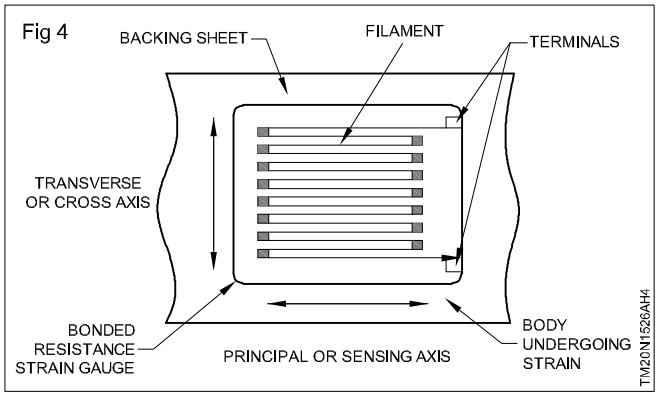
$$R = \frac{pL}{A}$$

p = resistivity
L = length
A = cross sectional area

Since length of an object is directly proportional to the internal resistance of that object, the mechanical strain can be modified into electrical strain. Generally resistance of an object is given by the formula Hence electrical strain can be given as the ratio of change in resistance to the original resistance.

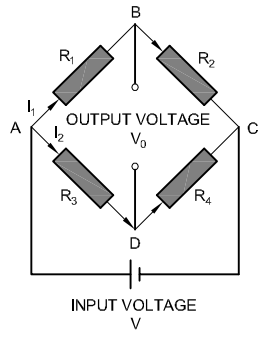
Electrical strain = change in resistance / original resistance

Fig 4



Strain gauge consists of an epoxy resin sheet in which a continuous thin metal strip is fixed on it. The metal strip is made up of copper nickel alloy or nickel chromium alloy, since it has high resistivity and mechanical strength. Usually, the strain gauge will be fixed or attached on an object whose strain is to be measured. When load is applied on the object, the length of the object will change. Due to this, the length of strain gauge will also change. This results in change in internal resistance of strain gauge. Thus, strain gauge provides change in resistance as output with respect to the load applied. The change in internal resistance of the strain gauge can be converted into electrical signal using a wheat stone bridge. The Wheatstone bridge is generally used to measure change in resistance and convert it into electrical signal. Wheatstone bridge consists of 4 resistors and they are connected to each other. The values of the resistors are adjusted in such a way that the output voltage will be constant. This condition is called as balanced condition of the bridge.

Fig 5



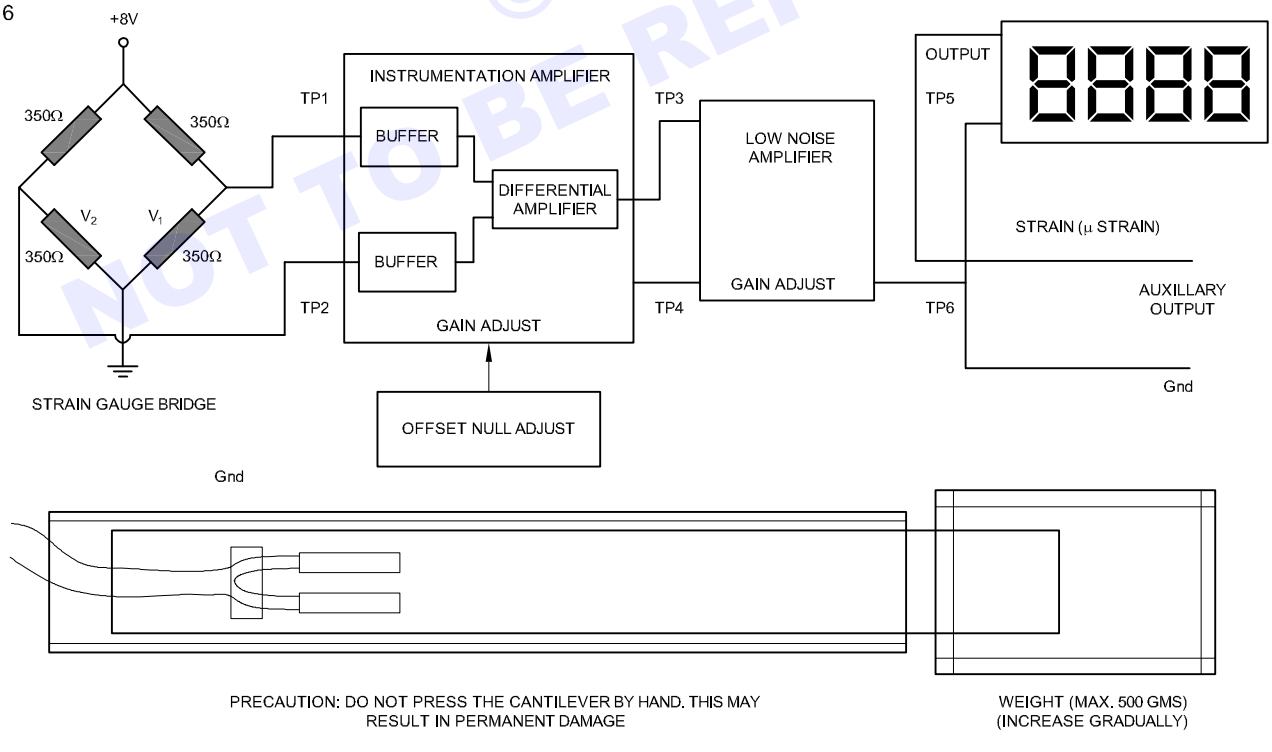
During the measurement of strain, one of the resistors of Wheatstone bridge will be replaced by strain gauge. If the load is applied, the internal resistance of strain gauge will change. This causes the output voltage to change. Hence the strain of an object will be directly proportional to the output voltage of the bridge. Thus, strain gauge and Wheatstone bridge are integrated to measure the strain of an object. They are used in civil engineering to monitor strain in road and rail bridges, walls of tall buildings, or embedded in roads to record use or wear. In mechanical engineering they are used extensively to measure strain in metal test specimens or, for example, in prototype turbines, cylinders, aircraft or other machinery

Thermocouple

Thermocouple is used to measure temperature of high range

- It works on the principle of seeback effect seeback effect states that "if any two dissimilar materials are connected to form two junctions and if these two junctions are exposed to different temperatures then EMF will be induced at these junctions
- Here the thermocouple has two metals metal X and metal y, which are connected to form two junctions J1 and J2
- These two junctions are exposed to different temperatures t1 and t2
- Due to this, EMF1 and EMF 2 will be induced at the junction J1 and J2 respectively

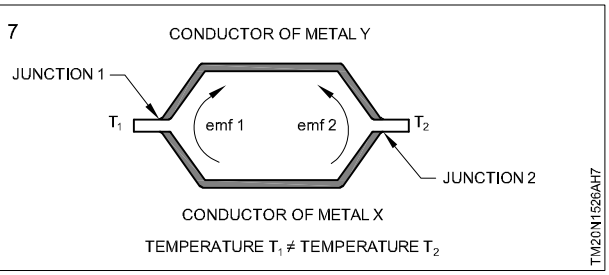
Fig 6



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- If these two junctions are kept at same temperature then there will be no EMF
- In practice, one of the junctions will be kept at fixed temperature and the other junction will be kept exposed to the varying temperature
- There are many types of thermocouple available some of them are
- J type thermocouple which can measure temperature of 1300ºC
- K type thermocouple which can measure temperature up to 800ºC

Fig 7



Temperature Measurement Trainer consists of the following modules:

i Electric Heater

ii Sensor Module - Thermocouple

iii Amplifier Module for Thermocouple

iv Display Output Module

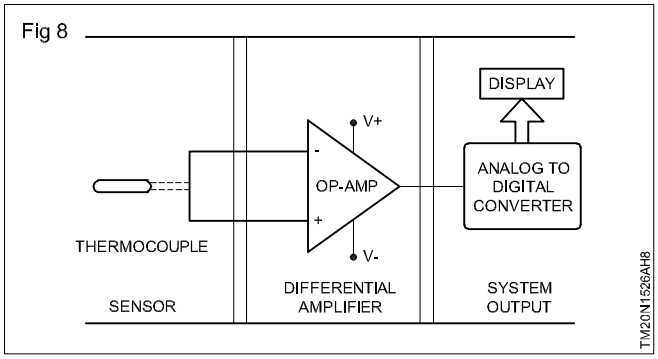
i Electric Heater: Electric Heater consists of high wattage water heater with provision made for inserting the temperature sensor and thermometer. The unit is connected to AC 220V for its operation.

ii Sensor Module: Thermocouple is connected to the amplifier circuit.

iii Amplifier Module: Sensor output voltage is amplified by an Operational Amplifier. DC Power Supply for Op-amp is DC ±5V.

iv Output Module: Output from operational amplifier is directly fed to an Analog to Digital Converter IC and output in volts corresponding to temperature is directly read on digital panel meter.

Fig 8



Over load relay: A non-directional heavily damped induction disc relay which has an adjustable inverse time/current characteristic with a definite minimum time. The relay has a high torque movement combined with low burden and low overshoot. The relay disc is so shaped that as it rotates the driving torque increases and offsets the changing restraining torque of the control spring. This feature combined with the high torque of the relay ensures good contact pressure even at currents near pick-up. Damping of the disc movement is by a removable high retentively permanent magnet. The unique method of winding the operating coil ensures that the time/current characteristics are identical on each of the seven current taps. Selection of the required current setting is by means of a plug setting bridge which as a single insulated plug. The maximum current tap is automatically connected when the plug is withdrawn from the bridge, allowing the setting to be changed under load without risk of open circuiting the current transformers. The IDMT relay has an auxiliary unit which is powered by a secondary winding on the electromagnet through a rectifier and as such a separate auxiliary supply is not required. The disc unit operates and closes its contacts, the auxiliary element connected across the secondary winding on the electromagnet operates, and one normally open contact of the auxiliary element reinforces the disc contact.

Pick Up current of relay: In all electrical relays, the moving contacts are not free to move. All the contacts remain in their respective normal position by some force applied on them continuously. This force is called controlling force of the relay. This controlling force may be gravitational force, may be spring force, and may be magnetic force. The force applied on the relay's moving parts for changing the normal position of the contacts, is called deflecting force. This deflecting force is always in opposition of controlling force and presents always in the relay. Although the deflecting force always presents in the relay directly connected to live line, but as the magnitude of this force is less than controlling force in normal condition, the relay does not operate. If the actuating current in the relay coil increases gradually, the deflecting force in electro mechanical relay is also increased. Once, the deflecting force crosses the controlling force, the moving parts of the relay initiate to move to change the position of the contacts in the relay. The current for which the relay initiates it operation is called pick up current of relay.

Current setting of relay: The minimum pick up value of the deflecting force of an electrical relay is constant. Again the deflecting force of the coil is proportional to its number of turns and current flowing through the coil. Now, if we can change the number of active turns of any coil, the required current to reach at minimum pick value of the deflecting force, in the coil also changes. That means if active turns of the relay coil is reduced, then proportionately more current is required to produce desired relay actuating force. Similarly if active turns of the relay coil are increased, then proportionately reduced current is required to produce same desired deflecting force.

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Practically same model relays may be used in different systems. As per these systems requirement the pick-up current of relay is adjusted. This is known as current setting of relay. This is achieved by providing required number of tapping in the coil. These taps are brought out to a plug bridge. The number of active turns in the coil can be changed by inserting plug in different points in the bridge

The current setting of relay is expressed in percentage ratio of relay pick up current to rated secondary current of CT.

For example, an over current relay should operate when the system current just crosses 125% of rated current. If the relay is rated with 1 A. the normal pick up current of the relay is 1 A and it should be equal to secondary rated current of current transformer connected to the relay. Then, the relay will be operated when the current of CT secondary becomes more than or equal 1.25 A.

Programmable logic controller

A PLC (Programmable Logic Controller) is an industrial computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are expected to work flawlessly for years in industrial environments that are hazardous to the very microelectronic components that give modern PLCs their excellent flexibility and precision.

Prior to PLCs, many of these control tasks were solved with contactor or relay controls. This is often referred to as hardwired control. Circuit diagrams had to be designed, electrical components specified and installed, and wiring lists created. Electricians would then wire the components necessary to perform a specific task. If an error was made the wires had to be reconnected correctly. A change in function or system expansion required extensive component changes and rewiring.

Before you start using PLC, it is convenient to know and understand its architecture as shown in figure, PLC consists of the following parts:

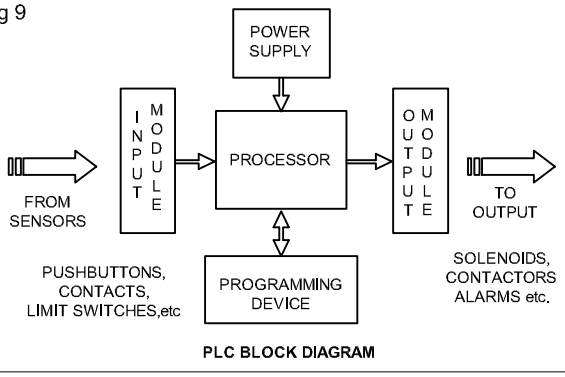
1 **Power supply:** Provides the voltage needed to run the primary PLC components.

2 **1/0 Modules:** Provides signal conversion and isolation between the internal logic-level signals inside the PLC and the field's high level signal.

3 **Processor system:** Provides intelligence to command and govern the activities of the entire PLC systems.

4 **Programming device:** Used to enter the desired program that will determine thesequence of operation.

Fig 9



PLC BLOCK DIAGRAM

The following are some advantages of PLC over other microcontrollers:

1 Cost effective for controlling complex systems.

2 Flexible and can be reapplied to control other systems.

3 Computational abilities allow more sophisticated control.

4 Trouble shooting aids making programming easier and reduce downtime.

5 Small physical size, so shorter project time.

Ladder logic programming

When SW1 is closed, the current will flow from L-1 to L-2 and energize the load.

Fig 10



Even though PLC ladder logic was modeled after the conventional relay ladder, there is no electrical continuity in PLC ladder logic. PLC ladder rungs should have logical continuity in order for the output to be energized. PLC ladder program uses familiar terms like "rungs", "normally open" and "normally closed" contacts, as illustrated in table .

In a ladder logic program, there is no physical conductor that carries the input signal through to the output. Each rung in the ladder diagram is a program statement. This program statement consists of a condition or sometimes conditions, along with some type of action.

Inputs are the conditions, and the action, or output, is the result of the conditions. As in case of physical wiring hardware devices connected in series or parallel, PLC also combines ladder program instructions in series or parallel. However, rather than working in series or parallel, the PLC combines instructions logically using logic operators like: AND, OR, and NOT. These operators are used to combine the instructions on a PLC rung to make the outcome of each rung either true or false.

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Welding and press shop

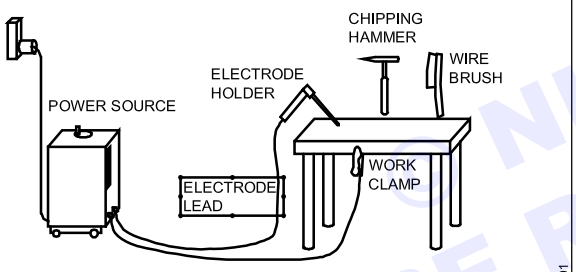
Objectives: At the end of this lesson you shall be able to
- **state the methods of welding**
- **state about press shop machine and its parts.**

Introduction

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the workpieces to form a bond between them, without melting the work pieces. It is often used in construction engineering.

Different parts of welding: (Fig 1)

Fig 1



DIFFERENT PARTS OF WELDING

Some of the best known welding methods include:

Shielded metal arc welding (SMAW) - also known as "stick welding", uses an electrode that has flux, the protectant for the puddle, around it. The electrode holder holds the electrode as it slowly melts away. Slag protects the weld puddle from atmospheric contamination.

Gas tungsten arc welding (GTAW) - also known as TIG (tungsten, inert gas), uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas such as Argon or Helium.

Gas metal arc welding (GMAW) - commonly termed MIG (metal, inert gas), uses a wire feeding gun that feeds wire at an adjustable speed and flows an argon-based shielding gas or a mix of argon and carbon dioxide (CO_2) over the weld puddle to protect it from atmospheric contamination.

Flux-cored arc welding (FCAW) - almost identical to MIG welding except it uses a special tubular wire filled with flux; it can be used with or without shielding gas, depending on the filler.

Submerged arc welding (SAW) - uses an automatically fed consumable electrode and a blanket of granular fusible flux. The molten weld and the arc zone are protected from atmospheric contamination by being "submerged" under the flux blanket.

Electro slag welding (ESW) - a highly productive, single pass welding process for thicker materials between 1 inch (25 mm) and 12 inches (300 mm) in a vertical or close to vertical position.

Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including in open air, under water, and in outer space. Welding is a hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation.

Until the end of the 19th century, the only welding process was forge welding, which blacksmiths had used for centuries to join iron and steel by heating and hammering. Arc welding and oxyfuel welding were among the first processes to develop late in the century, and electric resistance welding followed soon after. Welding technology advanced quickly during the early 20th century as World War I and World War II drove the demand for reliable and inexpensive joining methods. Following the wars, several modern welding techniques were developed, including manual methods like SMAW, now one of the most popular welding methods, as well as semi-automatic and automatic processes such as GMAW, SAW, FCAW and ESW. Developments continued with the invention of laser beam welding, electron beam welding, magnetic pulse welding (MPW), and friction stir welding in the latter half of the century. Today, the science continues to advance. Robot welding is commonplace in industrial settings, and researchers continue to develop new welding methods and gain greater understanding of weld quality.

Press shop

A forming press, commonly shortened to press, is a machine tool that changes the shape of a workpiece by the application of pressure.1 Presses can be classified according to

1 their mechanism: hydraulic, mechanical, pneumatic;

2 their function: forging presses, stamping presses, press brakes, punch press, etc.

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3 their structure, e.g. Knuckle-joint press, screw press

4 their controllability: conventional vs. servo-presses

Mechanical forging press machine - How It Works

Mechanical forging press machines are widely used for producing forging components. This article will explain the details of the different sections of a forging press machine and its working procedure.

Like drop forging hammer, mechanical forging press is also used for mass production of forging components.

Overview of mechanical press forging process

1 The billet is heated up to the recrystallization temperature and kept over the bottom half of the die.

2 The bottom half of the die is kept fixed.

3 The top die goes up and down repeatedly to shape up the billet to final product.

4 The billet is pressed (or squeezed) rather than hammered in a mechanical forging press. So the life of the die is more in case of mechanical press forging.

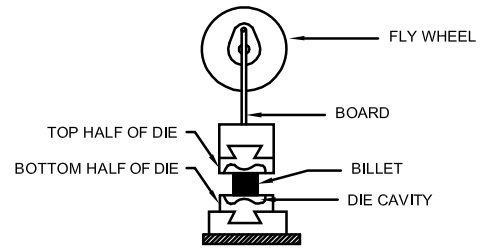
5 The production rate of mechanical forging press is greater than that for a drop forging hammer.

6 Working of Mechanical Forging Press

7 Mechanical Forging Press

Various parts of a mechanical forging press and their functions are as below: (Fig 2)

Fig 2



MECHANICAL FORGING PRESS

Flywheel: Flywheel supply power for forging. The flywheel is connected to a prime mover (either electric motor or diesel engine) either directly or through a drive (belt drive or gear drive). The fly wheel is supported by bearings. The speed of the flywheel is directly proportional to production rate of forging components.

Board: The board is connected eccentrically to the flywheel. This mechanism converts rotary motions of the flywheel into vertical linear motion of the board.

Ram: The ram is the connecting member between the board and the upper half of the die. The ram is guided by lubricated guide shafts (not shown in picture) for maintaining proper vertical motion.

Die: The forging die has two halves. The top half moves up and down with the ram, whereas the bottom half is kept fixed by the anvil. The design of the die cavity decides the final shape of the forged component.

Anvil: The anvil keeps the bottom half of the die rigidly fixed. Rigidity of the anvil is important for proper functioning of any forging press.

Blow room machine

Objectives: At the end of this lesson you shall be able to
- **state about blow room and its objects**
- **state the basic operation in blow room and modern blow room**
- **explain principle of opening and cleaning**
- **explain about opening, cleaning and mixing machine.**

Blow room

Blow room consists a number of machines used on succession to open and clean the cotton fibre. Since the tuft size of cotton becomes smaller and smaller, the required intensities of processing necessitates different machine configuration.

Objectives of blow room

1 Opening

a To open the compressed bales of fibres.

b To make the cotton tuft as small as far as possible.

2 Cleaning

To remove dirt, dust, broken seeds, broken leaves, and other foreign materials from the fibre.

3 Mixing & blending

To make good value of yarn and to decrease production cost mixing and blending is done.

4 Lap or flocks formation

To transfer opened and cleaned fibre into sheet form of definite width and length which is called lap or in modern system directly feed to the carding machine into flocks form.

Basic operations in the blow room

1 Opening

2 Cleaning

3 Mixing or blending

4 Micro dust removal

5 Uniform feed to the carding machine

6 Recycling the waste

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Blow room installations consist of a sequence of different machines to carry out the above said operations. Moreover Since the tuft size of cotton becomes

Modern blow room line

In processing the material, different types of machines are necessary, namely those suitable for opening, those for cleaning and those for blending. Different intensities of processing are also required, because the tufts continually become smaller as they pass from stage to stage.

Accordingly, while a coarsely clothed cleaning assembly is ideal after the bale opener, for example, it is inappropriate at the end of the line. Therefore, there are no universal machines, and a blow room line is a sequence of different machines arranged in series and connected by transport ducts. In its own position in the line, each machine gives optimum performance - at any other position it gives less than its optimum. Also there may be advantages in different modes of transport, feeding, processing, and cleaning and so on from one machine to another along the line. Finally, the assembly of a blow room line depends among other things on:

1 The type of raw material;

2 The characteristics of the raw material;

3 Waste content;

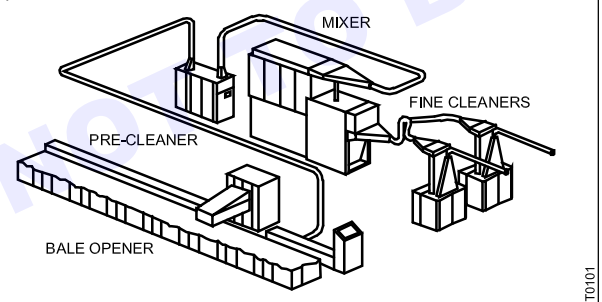
4 Dirt content;

5 Material throughput;

6 The number of different origins of the material in a given blend.

In most cases a modern blow room line consists of the following machines, (Fig 1)

Fig 1



Principle of opening and cleaning

The basic principle of opening and cleaning in the blow room line are as follows

1 The action of opposing spikes

2 The action of air currents

3 The action of beaters

The action of opposing spikes

The spikes of the evener lattice pick up the pieces of cotton and carried them to point lattice, where they are met by a series of spikes of the evener roller which move in the opposite direction and oppose any further passage. Rough combing action occurs and the spiked lattice carries a small part of the fed cotton along with it. The tearing action is taking place between the two opposing spikes.

The action of air current

Air and cotton enter the chamber of the machine together at the bottom or at the center of the beater chamber where the cotton starts to receive one of the many blows from the strikers of the beater. The cotton is thrown against the grid bars by centrifugal force. This action forces the heavier impurities through the bars into the large duct box under the grid bars.

The action of beaters

This involves the holding of the mass of fibres while the beater strikes it. The holding of fibres can be done in three ways.

1 Feeding by two rollers

2 Feeding by a feed roller and a feed plate

3 Feeding by a feed roller and pedals

Two feed roller arrangements gives the best forwarding motion, but unfortunately results in greatest clamping distance between the cylinders and the beating element. Feed roller and pedal arrangement gives secure clamping throughout the width and a small clamping distance, which is very critical for an opening machine.

In a feed roller and table arrangement, the clamping distance can be made very small. This gives intensive opening, but clamping over the whole width is poor, because the roller presses only on the highest points of the web. Thin places in the web can be dragged out of the web as a clump by the beaters.

Opening machines

Opening is the first operation it means, tearing apart the compressed and matted cotton until it is very much loosened and separated into small tufts with a gentle treatment, and a fibre loss as small as possible.

Opening is also related to cleaning as where is opening there is also cleaning

The term opening in the technological sense, means while number of fibres is remaining constant volume of the flock is increased i.e. the specific density of the material is reduced.

There are two different level of opening

1 Opening into fibre tufts (performed in blow room)

2 Opening into individual (performed in carding and rotor spinning)

Two different type of opening

1 Breaking up of larger tufts into several tufts to create new surfaces (bale breaker)

2 Opening of individual tufts to increase the volume (with weight remaining the same)

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Both ways are performed, with different intensities in different processing steps (i) in the opening, the breaking up of tufts is dominant (ii) fine cleaning the opening up of a single tuft is mainly performed.

Degree of opening

It increases when number of machine increase in process. It depends on,

1 Raw material (thickness of feed, fibre alignment and size of flock in the feed)

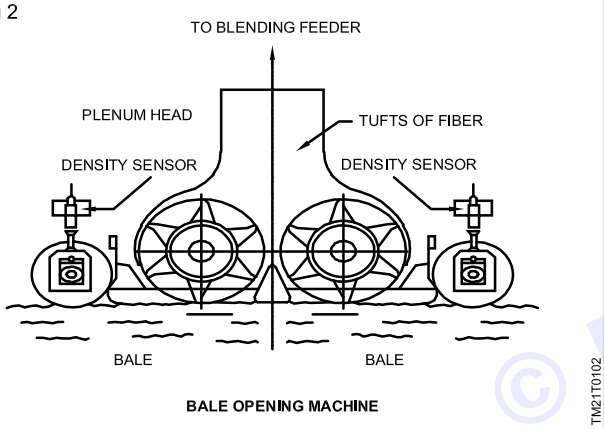
2 Machines (arrangement of the pins, teeth, needle, type of clothing, spacing between the material and opening device)

3 Speed

4 Condition (humidity, temperature).

Bale opening machine (Fig 2)

Fig 2



BALE OPENING MACHINE

Object

1 To open the tuft of cotton.

2 To mix & blend the fiber.

3 To remove a considerable amount of trash from fiber which is taken out by fan.

4 To act as a reserve box for the next machine.

Function of bale opener machine

1 Regulating motion by swing paddle.

2 Air suctioning.

3 Beating action.

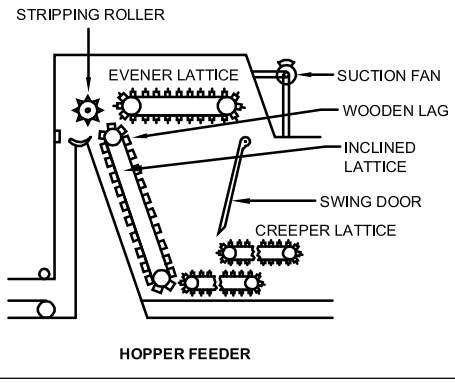
4 Spiked lattice action.

Hopper feeder (Fig 3)

In Hopper Feeder the following objects are achieved:

The material is thoroughly blended in main bin. The material is combed by the spikes of the inclined lattice. The cotton is well opened when passes in between evener roller and spiked inclined lattice. Sand, heavy trashes are extracted through grid bars and iron particles are removed from the cotton by the magnet. Fan is provided in the top of the machine and sucks the dusty air which is settled down in the cellar. Also, the principle object of the Hopper Feeder is to provide uniform feeding of cotton on lattice across the full width of the machine. The Hopper Feeder is repeated in the Blow room line

Fig 3



HOPPER FEEDER

The cotton coming from previous machine is deposited on creeper latticed Reserve bin. Creeper lattice will deliver the cotton on feed Lattice of main bin. Feed lattice will take cotton forward close to the inclined lattice. Swing door is used to maintain the constant level of cotton on feed lattice. Due to the spikes on the inclined lattice and direction of movement, lumps of cotton will be carried upwards by the inclined lattice.

Hard pressed layers of cotton are well combed by the spikes of inclined lattice. Revolving spikes of the evener roller or lattice beats and open the cotton. Due to the close space between evener lattice and inclined lattice and rotation of evener roller in a opposite direction, unopened excess lumps of cottons are thrown back into mixing bin. Stripping roller strip the cotton from inclined lattice and projects it over a grid bar system where sand, heavy trash are passed through the spacing of the grid.

From stripping roller the cotton is deposited, layer by layer in. the reserve box and is taken into next machine by lattice in the form of uniform feeding across the full width of the sketcher.

Importance of feed control in hopper feeder

The volume of cotton contained in the reserve bin determines the regularity or uniformity of the lap.

Front sheet should be set properly according to the lap weight per yard required.

Improper feeding in the hopper and improper setting of front sheet will tend to produce too heavy or low weight lap (or) non uniformity lap which causes to reject the lap.

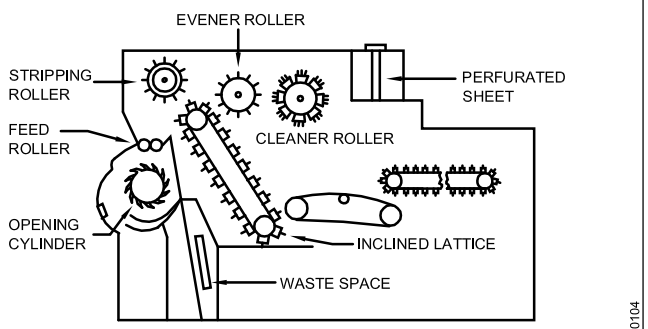
So feed control in Hopper Feeder is important in the blow room line to produce uniform lap.

Mixing Bale opener (Fig 4)

Object, passage of cotton & working procedure of Mixing bale opener is same as the hopper bale opener, but the difference. From stripping roller, the cotton flocks are thrown into trunk, which guides them into the pair of feed roller which is spring loaded.

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Fig 4



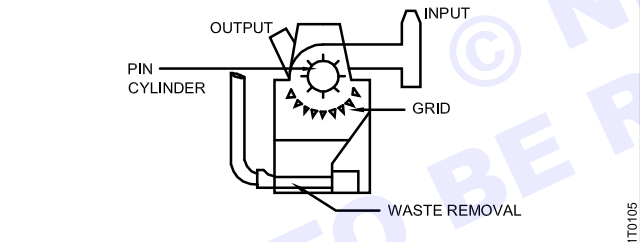
MIXING BALE OPENER

The compressed sheets of cotton which are delivered from feed roller are heavily beat by saw toothed cylinder. This beating action divides the material ' into smallest flock. Saw toothed cylinder projects the flocks over the grid, where sand and heavy trash particles are extracted.

The cotton falls into an outlet funnel are taken away pneumatically to the next machine. In addition to the cleaning through grid bar system an exhaust fan at the top of the machine will suck the dust, air and short fibres from inside of the machine through perforated sheet. This pepper trash is taken by pneumatic pipe to the cellar (dust chamber).

Mono cylinder (Fig 5)

Fig 5



MONO CYLINDER

Object: To open and clean the cotton.

Advantages: Impurities are separated without being crushed.

This proves favorable during subsequent operations. The well opened tuft of cotton from mixing bale opener enters the machine at right angles to the pin cylinder axis. The pin cylinder has 8 rows of six pins each, arranged spirally around its circumference. Due to the collision of the cotton tufts with rapidly revolving pin cylinder against grid bar, impurities from cotton is extracted and passed through the

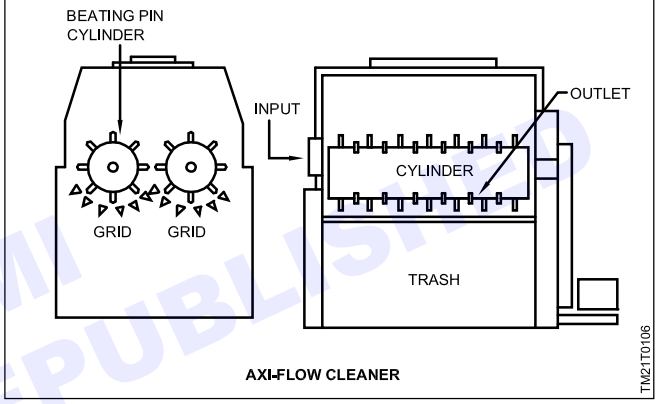
After the tufts come into the contact with the grids for the first time, they are flung into the top part of the housing. Owing to the guide plate, the tufts moves along a helical path, so that they fall on the pin of the cylinder again and retaken past the grid a second time. At the same time the tufts are turned over, so that their entire surface is brought into contact with grid, assisting the removal of dirt. The spiral path is continued by the guide plate and the tufts pass over the grid a third time, after which they leave the machine at the outlet.

The grids are arranged in two separate sections which can be adjusted individually. The grid can be adopted to handle any degree of impurities and opening in the cotton to be processed by means of the lever provided with the scales. The grid can be adjusted regarding spacing (0 to 12 mm) between the grid bar, as well as inclination (angular setting of the grid bar -0° to 30°). It is thus possible to adjust the amount of waste and its quality to the requirements and the different types of raw material,

Magnetic double elbow: This is installed in mono cylinder to remove larger or smaller solid foreign bodies of metallic and non-metallic origin. By deviating the fibre-air stream through a sharp angle, heavy particles are thrown in to the metal box by inertia. Light metallic parts are further more attracted by a permanent magnet plate.

Axi-flow cleaner (Fig 6)

Fig 6



AXI-FLOW CLEANER

Opening and cleaning of cotton is achieved by the repeated beating action of the rapidly revolving two beating cylinder on cotton against grid bar. A trash particle from the cotton is extracted through the grid bar and is collected below the grid bar.

Smaller tufts that are already sufficiently opened for a quick and thorough cleaning thus leave the Axi-flo earlier without receiving unnecessary beating. This prevents loss of good fibre, formation of neps and fibre entanglement. Fibre contained in large tufts cannot get entangled or lost through the grid. They remain in the machine till they are transformed in to small tufts and release their impurities easily.

An adjustable guide plate fixed to the inlet pipe control the angle at which the tufts approach the right beating cylinder.

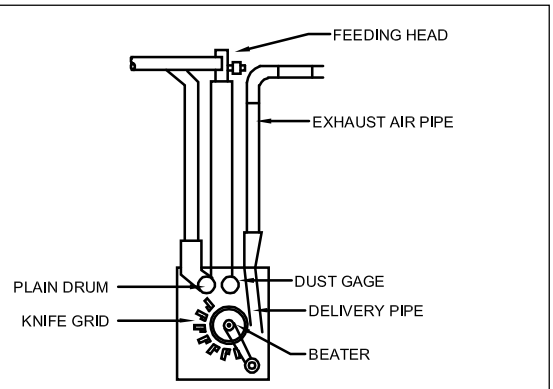
This cylinder takes the tuft downwards, guides them over the broad waste grid and throws them up against the adjustable defector plate. The defector plate directs the tuft stream within the reach of the left cylinder which then passes the material over its own grid and transfers the 1arger tufts back to the right cylinder. The position of the adjustable guide plate between the two cylinders decides how long the tufts remain under the influence of each cylinder.

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The angular position of the bar is adjustable for each set separately. Each set of grid bar can be raised or lowered to alter the distance between the grids to the end of the spike. It is thus possible to adjust the amount of waste and its quality to the requirements and the different types of raw material.

ERM cleaner (Fig 7)

Fig 7



ERM CLEANER

Type: Gripped and controlled feeding & saw toothed disc opener the fibre is blown into the laminar chute by an integrated fan. The filling of the chute is monitored by 2 photocell. The pair of spring loaded feed roller in it ensure a controlled feed of the fibre tufts. Due to the heavier beating of the rapidly revolving saw toothed disc on cotton tufts against knife grid, highest possible degree of opening and cleaning of the fibre is achieved.

By means of graduated lever, the grid bar can be adjusted regarding spacing between the knife grid bar & brought into proper position relative to opening Roller according to handle any degree of impurities and opening in the cotton to be processed. It is thus possible to adjust amount of waste and its quality to the requirements of different types of material.

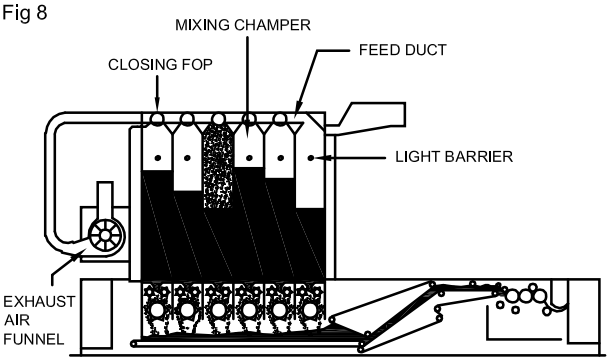
After opening and cleaning, the material is conveyed pneumatically through outlet pipe to the next machine.

Unimix (Fig 8&9)

A fan feeds the material into the miner. The individual chambers are filled one after the other. The dust fade transport air escaper through perforated plates in the chamber and is then fed to a filter. The filling of the multiplier mean starts with the last chamber. All chambers are successively filled in several stages until one chamber reaches its minimum filled height.

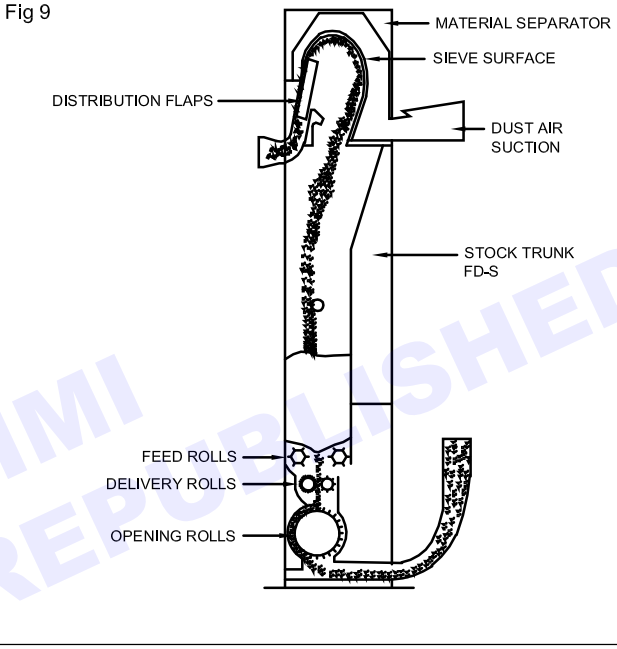
Then the delivery rolls underneath each chamber are activated and the material is fed via the opening roll onto the conveyor belt. As the chambers empty, they are again filled one after another. A loss layer of tufts from the several chambers builds up on the bleeding conveyor. At its end there are material layer from all chamber layer on top of each other. From the web in directed fed into a clearer or an open. This process of filling mining and feeding a cleaner are controlled and monitored by the integral control.

Fig 8



UNIMIX

Fig 9



In this machine, an intensive, instantaneous perfect and homogeneous blending of mini tufts (.005-.010 gram) together with simultaneous mixing by doubling over an extended period time is achieved.

Storage section: It consists the material distributing duct into which the tufts are blown. Over an adjustable separating noses, a relevant turbulence is formed which creates a thorough instantaneous blending. Six vertical filling trunks of varying heights are arranged in the direction of flow material.

Condensing funnel

This brings about a 2-3 fold mechanical condensation of six layers of material. In this way, holding capacity of 350 kg

is obtained. A conveyor belt together with conveying roller carries the material to the opening & mixing section.

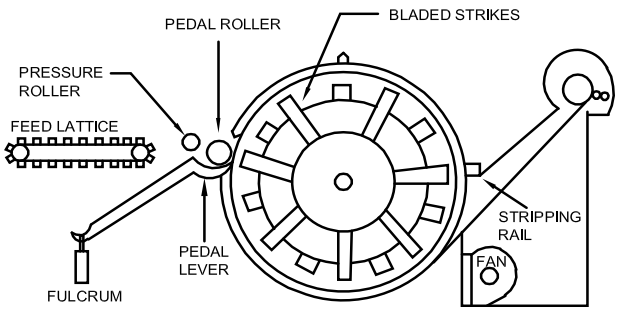
Opening & mixing section

This section directs the flow of material to the action of two pairs of pressure roller each with an opening roller. Owing to the different stretches to be traveled the Constituent comprising the mixing, which have been fed simultaneously to the trunks, arrive at the delivery and sucked-off by the subsequent machine.

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Porcupine opener (Fig 10)

Fig 10



PORCUPINE OPENER

The cotton fed by the previous opener is carried forward by the feed lattice. The sheets of cotton now pass between pedal and pedal roller. The weight of cotton fed per unit time is maintained constant by this pedal feed regulating motion.

Pedal roller feed the sheet of cotton in between pair of feed roller which is weighted to give necessary grip on the cotton. 16 circular discs are mounted on the shaft of this opener. 14 to 18 striker blades are riveted alternatively on each circular disc. Each striker is bent to a slightly different angle.

The compressed sheet of cotton delivered from the feed roller is heavily beated by the rapidly revolving striker of the porcupine beater against grid bar. Because of this beating action, the cotton is effectively opened and extracted trash particles are passed through the spacing of the grid bar.

At the end of the grid bar, stripping rail is provided; this is a metal bar which is set about 1/16 inch away from the end of the striker. This small clearance between stripping rail and striker prevents bunches of cotton being carried around by the beater. Cotton from the beater region is taken out by the air current set by the fan and is deposited on to the cages.

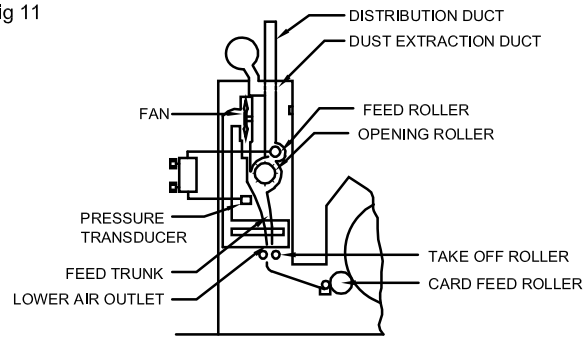
During the passage of cotton between beater section and cage, it passes over a series of suspended leaf bars where lighter impurities are removed. The compressed sheet of cotton is delivered from the cage by means of pair of delivery roller to the next process. While processing fine cotton and viscose rayon, porcupine opener is not recommended, in this case this opener is by passed by suitable by-pass arrangement provision in this opener.

Chute feed line (Fig 11)

Chute feed is a system of feeding small tufts of cotton fibres directly from blow room to a series of cards, arranged in a circuit through pneumatic pipe. A condenser in the pneumatic pipe sucks the material from blow room and delivers it to the flock feeder through pneumatic pipe by way of the filling trunk.

Photo electric cell in the filling trunk regulates the supply of material from blow room. From here, the material is fed to the kirschner beater by way of two ridged roller and two feed rollers. Krischner beater open the cotton into desired size tufts.

Fig 11



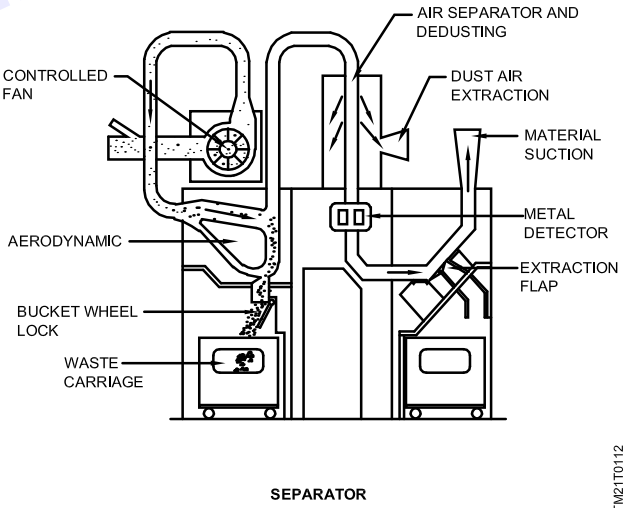
CHUTE FEED LINE

A fan blows the tufts from the kirschner beater into horizontal c closed circuit loop situated above the cards. The return trunk has the duty of returning the surplus material (after the supply to last card) to the beater that also of uniting well opened material with supply of fresh material thus delivering it directly to the horizontal duct again.

The separating head arranged in the horizontal closed circuit loop divert the part of tufts from air current into vertical feed chutes above the card inlets. Vertical feed chute ensures a uniform supply of material over the full working width of the card. Uniform separation of the tufts from the air current is achieved by adjusting the nose in the separating head. Raising the leading edge produces more separation and vice versa.

Separator (Fig 12)

Fig 12



SEPARATOR

The Multi Function Separator SP-MF - which works reliably even at production rates up to 2,000 kg/h - is positioned at the transition from Automatic Bale Opener (BO-A) to cleaning line. An integrated micro-computer control system controls all functions:

1 Suction of BLENDOMAT BO-A

2 Heavy part separation

3 Metal separation

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4 Dust removal/air separation

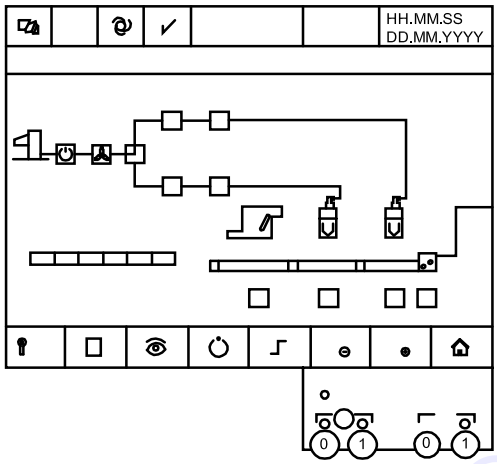
5 Waste feeding

Suction

The Automatic Bale Opener BLENDOMAT BO-A is directly sucked off. Energy costs are also considerably reduced compared to conventional solutions: They require condenser and booster fan to operate at highest output level to ensure reliable material transport even at the furthest point of a bale cutter. Single fan is sufficient to reliably generate an air flow that is always within ideal limits - independent of where the BLENDOMAT is currently working.

Control display (Fig 13)

Fig 13



The Electronic Installation Control LC-I has been specially developed for use in spinning mills. Its electronics is insensible to dusty air, humidity and high temperatures. The LC-I coordinates the functions of the individual machines and controls the material transport of the entire installation fully automatically.

Malfunctions in the installation or individual machines are graphically displayed, thus allowing quick and specific reactions.

All safety-relevant functions such as emergency stop and door safeties are hardware wired; this ensures a particularly high level of fail-safe performance. The Electronic Installation Control LC-I is optimally suited for coordinating individual machine controls. It uses modern intelligent network technology and offers maximum functional safety and reliability:

1 Simple commissioning

2 Simple operation with colour touch screen

3 High amount of information in the displays

4 Use of international standards

5 Open system

6 Tele-diagnosis via telecommunication

7 Minimum cabling

8 Same spare parts as for machine controls

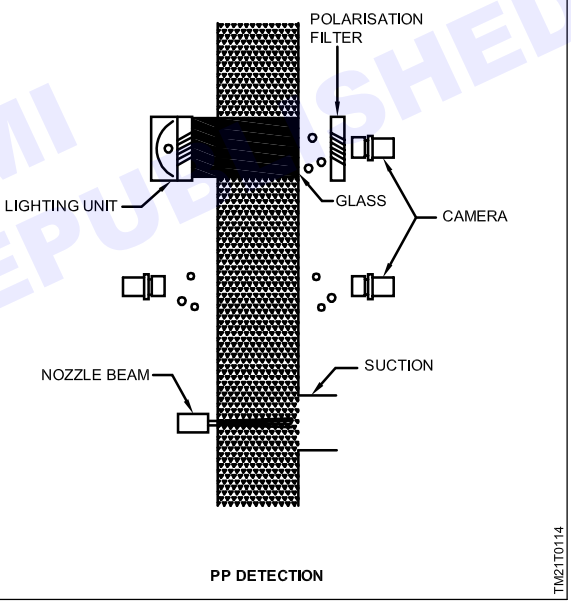
Separation of white and transparent foreign parts and fibres

In addition to natural contamination, white and transparent particles (e.g. PP or PE foil) often cause quality problems in the blow room. The further foreign parts get into the production chain, the greater the damage to value creation. Foreign parts and foreign fibers must be divided into two completely different groups: One group consists of parts that differ significantly from cotton by colour, contrast and structure and that are reliably detected by special cameras. The other group is made up of bright and transparent foreign parts that hardly differ in colour from cotton and therefore are invisible to conventional separators (e.g. polypropylene (PP) or PE foils). Not so the foreign part separators of the SECUROPROP series. To achieve maximum efficiency,

Principle of PP detection and separation (Fig 14)

PP module reliably detects transparent and semi-transparent parts due to its patented method with polarised transmitted light. This makes sense when packing residues from PP fabric are contained in the cotton.

Fig 14



Foreign part separator (Fig 15)

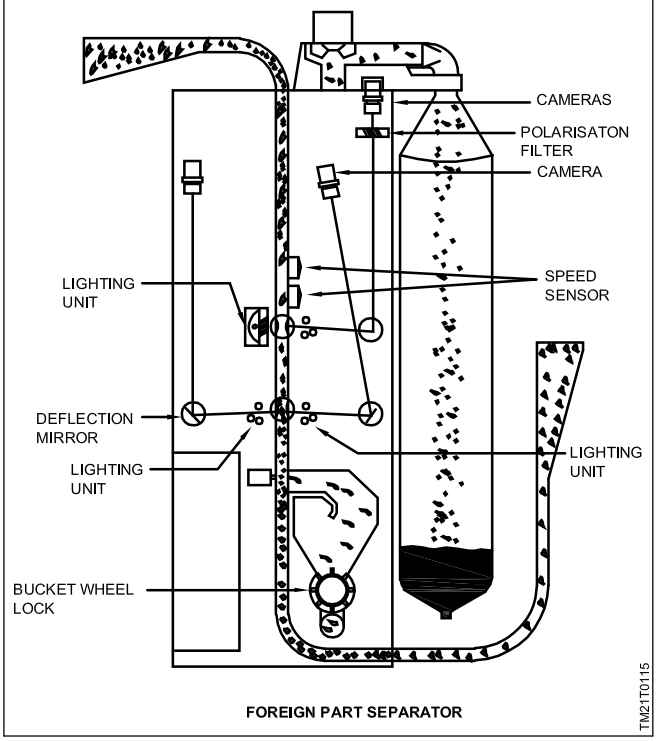
The patented process of the Securoprop Separators uses the physical properties of plastics which make them appear coloured in polarised light. Within a field of polarised light and UV light, one or two special cameras located in a rectangular fiber channel scan the tufts that fly past. The cameras detect the distorted colours or contrasts generated by the polarization in light polypropylene and transparent or semi-transparent PE foils. For reliable detection, colour effects of just a few pixels are sufficient.

Uniform feeding for uniform sliver (Fig 16)

A typical CONTIFEED application is the control of a cleaner of the CLEANOMAT system. In this case the material transport from cleaner to card is controlled by evaluating the pressure in the feed pipelines and the overall production of the card line as signal.

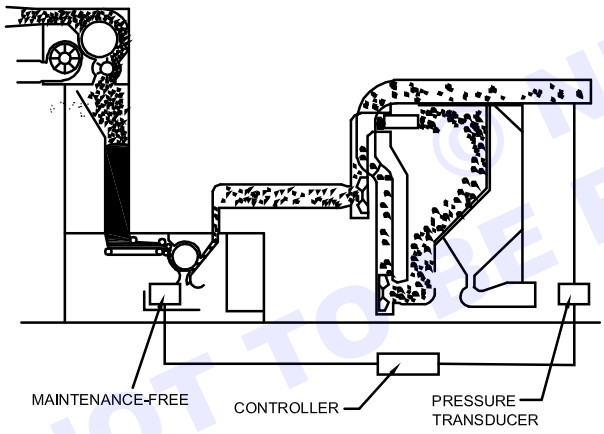
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Fig 15



FOREIGN PART SEPARATOR

Fig 16

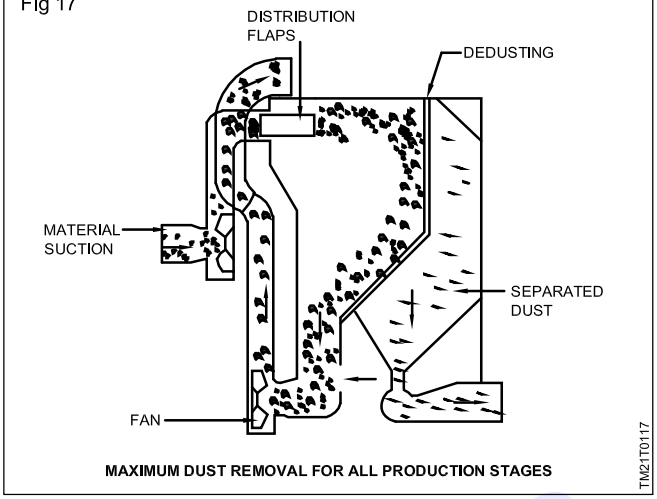


UNIFORM FEEDING FOR UNIFORM SLIVER

Based on these data, the control can provide precise, uniform feeding of the tuft feeders before the cards. Thus, the evenness of the card slivers is higher than with stop-and-go operation.

Maximum dust removal for all production stages (Fig 17)

Fig 17



MAXIMUM DUST REMOVAL FOR ALL PRODUCTION STAGES

If an integrated solution (e.g. SP-FPO) is not applied, the effective dust removal with a DUSTEX SP-DX machine offers:

1 Higher efficiency rates
2 Longer lives of clothings and spinning components
3 Improved running behaviour of the spinning machines
4 Increased economic efficiency of the overall installation
5 Clean ambient air

This is of particular advantage to downstream processing: Thoroughly deducted slivers ensure optimised running behaviour during yarn formation, e.g. in rotor spinning machines, but also significantly higher efficiency rates (less yarn breaks) in winding, knitting, warping and weaving

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Carding machine

Objectives: At the end of this lesson you shall be able to
- **state the introduction and objects of carding**
- **state the purpose of carding**
- **state the function and passage of material through carding**
- **list the different action in carding machine**
- **state about heel and toe mechanism.**

Introduction

Carding is the most important process in spinning. It contributes a lot to the yarn quality. The following process parameters and specifications are to be selected properly to produce a good quality yarn with a lower manufacturing cost cylinder wire (wire angle, height, thickness and population) flat tops specification licker-in wire specification doffer wire specification feed weight draft between feed roller and doffer cylinder grinding doffer grinding flat tops grinding cylinder, flat tops, doffer wire life Licker-in wire life Cylinder speed flat speed Licker-in speed setting between cylinder and flat tops setting between licker-in and feed plate setting between licker-in and under casing elements like, mote knife, combing segment etc. setting between cylinder and doffer setting between cylinder and back stationary flats setting between cylinder and front stationary flats setting between cylinder and cylinder under casing.

Objects of carding

1 Opening into individual fibers

2 Elimination of impurities

3 Elimination of dust

4 Disentangling neps

5 Elimination of short fibers

6 Fiber blending

7 Fiber orientation

8 Sliver formation

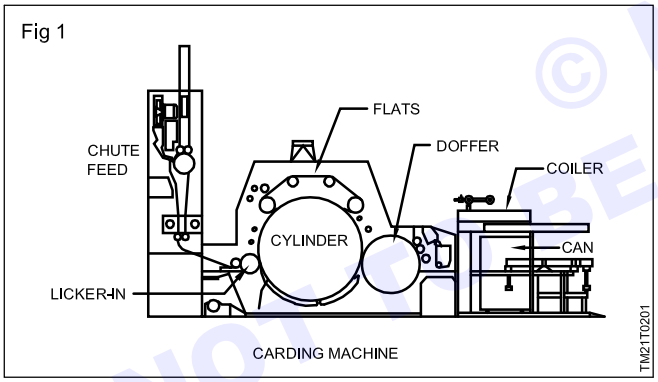
Purpose of carding

Chiefly, carding should separate the flocks into individual fibers. Additionally, carding results in cleaning, reduction of neps, aligning, blending, and elimination of some short fibers. The elimination of short fibers must, however, be viewed in proportion.

The main eliminated material is in the flat strips. Assuming flat waste at 1 to 2%, with about half in the form of short fibers there is such a minor percentage of short fiber elimination that it could hardly be measured with the current coarse staple measuring equipment. The operation of carding is performed with the aid of oppositely disposed sets of teeth or small wire hooks.

Passage of material through carding machine: (Fig 1)

Fig 1



Functions of carding

Carding fulfils a series of precise objectives, serving:

1 To open the blend fibres fully and definitively

2 To arrange (as far as their length allows) the fibres parallel with one another

3 To remove impurities

4 To blend the raw material further

5 To reduce the blend to a web of fibres and to divide it up into roving's of the required count, suitable for feeding to the spinning machines.

Carding plays a crucial role in all spinning cycles, and its role is never more central than in the woolen spinning cycle, in which it incorporates different functions, all essential in order to obtain the level of quality required of the product.

Basically, passing the material over the card undoes tangles of fibres and therefore makes it possible to remove all kinds of impurity. This is achieved thanks to the action of the spikes covering the surfaces of cylinders that rotate around parallel axes.

The equipment also fulfils another function, which is both delicate and fundamental: it has to guarantee the accuracy and evenness of the web count and subsequently of the roving count. Indeed, the definitive spinning machines that operate within the woolen spinning cycle can impart only a very low draft, which means that there is practically no possibility, at this stage, of intervening to correct the yarn count.

The carding room equipment thus performs the same operations already carried out in the preparation stage, this time more thoroughly, supplying the divider with roving's of the right count.

Action in Carding Machine:

The following 4 actions take place in a carding machine:

1 Combing action;

2 Carding action;

3 Stripping action;

4 Doffing action.

1 Combing action

Combing action takes place feed roller and taker in. Here the pin direction of the two surfaces are the same. Combing is the straightening and paralleling of fibre and the removal of short fibres and impurities by using a comb or combs which is assisted by roller and brushed.

2 Carding action

Carding action takes place between flat and cylinder.

In carding action

1 Directions of wire in two surfaces are opposite.

2 The moving direction of roller are also opposite.

3 One roller is slower and other is fast.

So carding action is known as point against point action.

3 Stripping action

Stripping action takes place between a. Taker in & Cylinder and b. Doffer & Stripper.

In stripping action

1 Wire direction will be the same.

2 Roller moving direction will be the same.

3 One roller will be faster than another.

So stripping action is known as "Point back point" action.

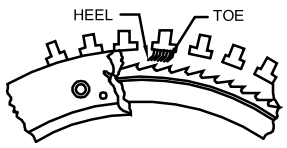
4 Doffing action

This action takes place between cylinder and doffer. In this place fibre is transferred from cylinder to doffer. Low speed doffer is called fibre from high speed cylinder and makes a condensed web for formation of sliver.

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Heel and Toe mechanism (Fig 2)

Fig 2



HEEL AND TOE MECHANISM

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The wire surface of the flat is not parallel to that of the cylinder.

Wire point setting between cylinder and flat is wider where the cotton enter and closed where the cotton leave. This arrangement is called as heel and toe arrangement. Object of heel and toe arrangement is to achieve gradual carding action at each flats.

Necessity: When the cotton is carried forward from one flat to another, the air current, centrifugal force, elasticity of fibre causes the fibre to raise from the surface of cylinder. These raised fibres would be rather severely dealt with if they were dragged into the narrow setting between cylinder and flats. This suddenness action is avoided by heel & toe arrangement.

Draw frame, lap former and comber

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

- **state the objects of draw frame and its principle**
- **explain auto leveling, drafting arrangement, servo draft, disc leveler and disc monitor**
- **explain lap former**
- **state the objectives of combing machine and automation in comber.**

Introduction

Carded Slivers are fed into the Draw-Frame and are stretched / Straightened and made in to a single sliver. Also fibre blending can be done at this stage. The cans that contain the sliver are placed along the draw-frame feeder rack, usually including eight pairs of cylinders (each pair is above the space occupied by a can),the lower cylinder is commanded positively, while the upper one rests on the lower one in order to ensure movement of the relative sliver that runs between the two.

Object of draw frame

1 To straighten the fibres in the slivers.

2 To make them lie in a manner parallel to their neighbors and to the sliver axis.

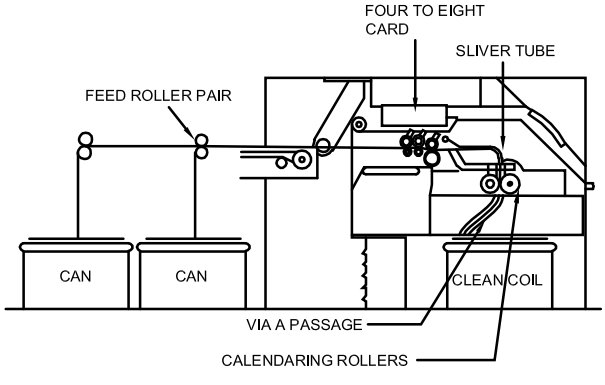
3 To improve the uniformity or evenness of the slivers.

4 To remove dust from the sliver.

5 To make perfect blending of the component.

Operating principle of draw frame (Fig 1)

Fig 1



OPERATING PRINCIPLE OF DRAW FRAME

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Four to eight card or draw frame slivers are fed to the drafting arrangement (3). A feed roller pair (2) above each can (1) feeds the material without false drafts. The slivers runs into the drafting arrangement, subjected to a draft of 4 to 8 and leave it as a web and condensed into a sliver immediately. This sliver is then guided through a tube (4) via a passage (6) of the tube gear into a can (7), in which it must be laid in clean coils with optimal utilization of the space in the can by sliver compressing with passing it through calendaring rollers (5)

Delivery arrangement

To avoid disintegration of the web, it must be collected together in a converging tube immediately after the delivery roller and guided to the sliver trumpet. The design of the trumpet is very important, as it is responsible for the proper integration of the edge fibers of the fiber strand. The bore of this sliver trumpet must be adapted precisely to the sliver volume (sliver hank). These technological parts are therefore interchangeable.

Condensing

Downstream from the trumpet, the sliver runs between two calendar rollers which are pressed towards each other. This condensing of the sliver enables more material to be fitted into the cans. Several manufacturers replace the fluted or smooth cylindrical calendar rollers with grooved or stepped rollers. Since these latter rollers do not permit the fibers to escape laterally, an even better condensing effect is achieved. In this way, the total filled weight of the can may be increased by up to 20%. Grooved or stepped rollers can be used simultaneously as measuring devices for auto leveling systems. However, this condensing action, with the greater fiber adhesion that results, must be taken into account in further processing. For example, break draft conditions are changed at the roving frame. The break draft distance might have to be increased.

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Sliver coiling

As already described for the card, two rotary movements are required for cycloidal coiling of the sliver. On the one hand, the rotatable plate must be rotated above the can, while the can itself must rotate, at a considerably slower rate, below the plate. A sliver tube is provided on the plate as a fixed part to guide the sliver from the calendar rollers into the can (Fig. 11). This tube extends from the center of the plate to its periphery. It is important for the coils that the circumferential velocity at the deposition point (sliver exit point) is somewhat higher than the delivery speed, so that blockages of the sliver in the tube are avoided.

Can changers

Modern high-performance draw frames are fitted with automatic can changers. These reduce the burden on personnel, enable more machines to be allocated to one person, reduce the necessity for the operative's attendance at the machine, and (the chief effect) also increase efficiency. They can be classified into:

1 Single-step changers (flying change);

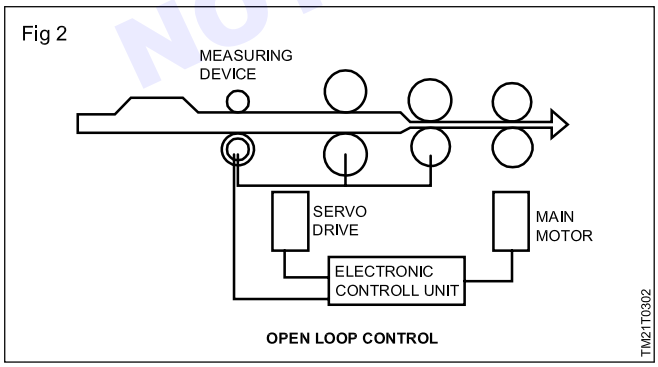
2 Multiple-step changers (interrupted change).

Auto leveling

The main task of auto leveling is to eliminate deviations in mass. The efficiency of an auto leveling device used to be defined as follows: "Those machines qualify on which the reaction time is shorter than the length of the deviation to be eliminated". This applied to the elimination of long-term deviations. In the mean time the range of application has also shifted toward short-term regulation, due to the development of servo drives operating faster and the availability of more efficient electronics. For modern auto leveling draw frames the above mentioned definition must be changed to: "Those machines qualify which allow corrections to be made as quickly as deviations appear in the incoming sliver"

Open loop control (Fig 2)

Fig 2

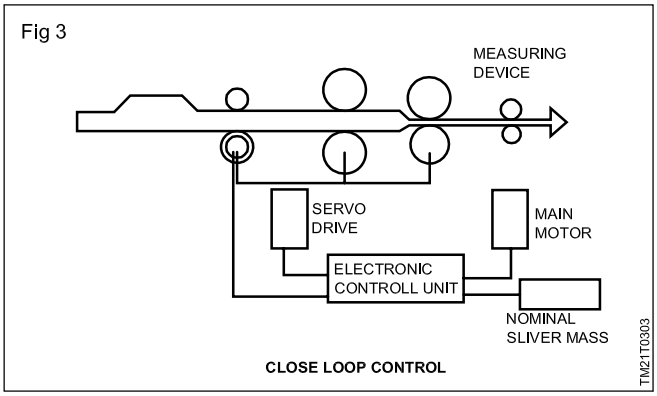


The total volume of all slivers is measured at the in-feed and adjustment is effected with the appropriate time delay in the main drafting zone, i.e. the extent of the change is retained in a storage device until the measured deviation arrives at the drafting point. Detection is usually carried out mechanically (rollers with grooves, bores or steps) or by capacitive sensors.

This system permits very precise leveling of very short lengths. A second advantage is the ability to measure far greater sliver masses due to the lower in-feed speed (corresponding to the amount of draft). Recording becomes more precise. In practice, draw frame leveling using open-loop control is now predominant.

Closed loop control (Fig 3)

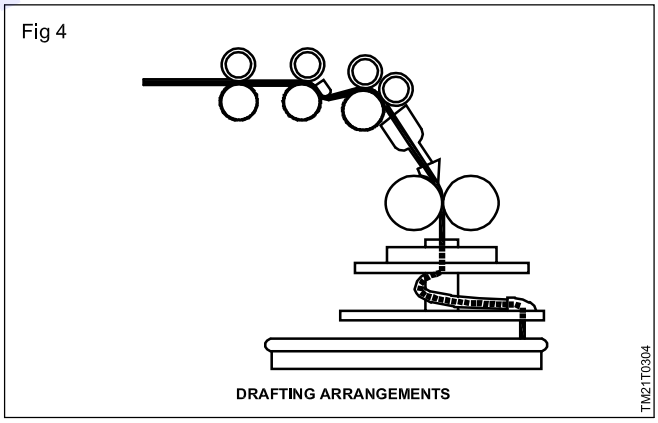
Fig 3



In this system, the evenness of the sliver delivered is measured rather than the in-feed sliver, as is the case with open loop control. In contrast to the open-loop control system, where the adjusting point is located after the measuring point, the adjusting point in the closed-loop control system is located in front of the measuring point. In this case measuring has to be performed at very high speeds and with relatively small fiber masses, making high demands on the sensing device and signal processing. Nevertheless, the adjustment is still made in the main drafting zone. Mechanical or pneumatic sensing devices are generally used.

Drafting arrangements (Fig 4)

Fig 4

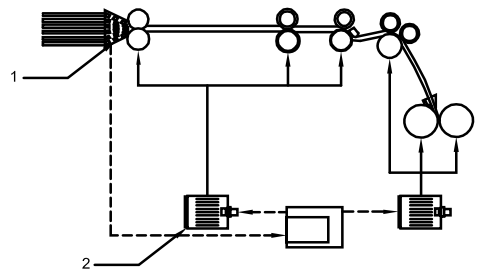


Manufacturer was able to further improve the reliable 4-over-3 drafting system with pressure bar: The 4th top roll ensures an ever more careful sliver deflection at the delivery side of the drafting system, while the adjustable pressure bar in the main draft area provides controlled guidance of even short fibers. When adjusting the drafting zone widths, the top rolls are guided in the bearing housings of the bottom rolls. This approach - in connection with high-precision mechanics - ensures 100 % axis parallelism for optimal control of the fiber flow.

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Servo draft (Fig 5&6)

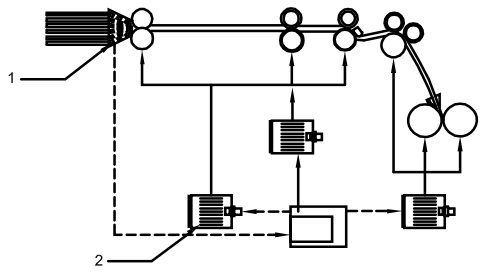
Fig 5



SERVO DRAFT

TM21T0305

Fig 6



SERVO DRAFT

TM21T0306

Servo draft provides highly dynamic compensation of deviations from the target sliver weight. To achieve this degree of short-term levelling, which cannot be realised with conventional concepts, SERVO DRAFT uses special drives, determines precise actual values, ensures fault-free signal processing and direct conversion of the levelling signal.

Disc leveler

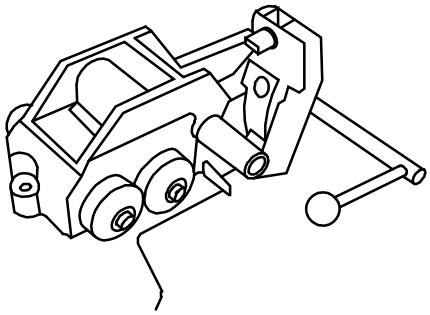
The sensor is based on friction-free, fiber-friendly measurement. It allows a very high, adjustable pressure at the measuring point, thus the deviations in material thickness must be placed on the same level as the actual mass deviations. The sensor features maximum accuracy and signal quality, without interference from external sources. Translating these signals into draft changes with SERVO DRAFT results in a perfectly levelled sliver and consistent sliver count stability.

DISC LEVELLER is equipped with a new, permanently lubricated bearing that features a more rigid design than conventional constructions; nevertheless, it allows quick and simple replacement of the groove and sensing rolls during lot change.

Disc monitor (Fig 7)

DISC MONITOR is the robust and reliable new quality sensor that doesn't miss a thing. It measures every inch of the produced sliver. In the event of irregular of faulty sliver, the DISC MONITOR sends a warning or shuts down the draw frame. When and how this is to take place can be individually configured. And because the DISC MONITOR permanently monitors the current production, the otherwise common, routine laboratory tests can be significantly reduced.

Fig 7



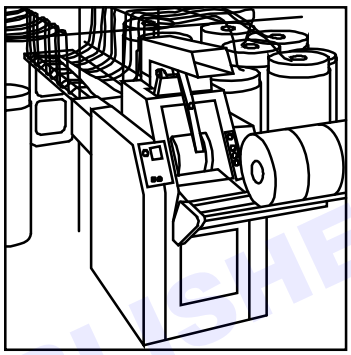
DISC MONITOR

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Lap former

Sliver lap and ribbon lap machine (Fig 8&9)

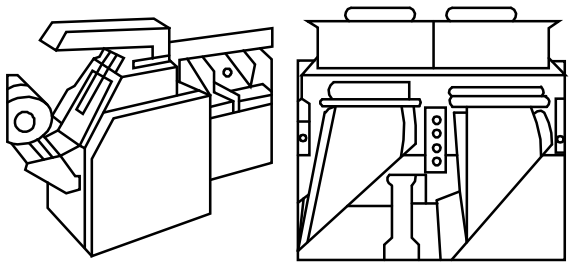
Fig 8



SLIVER LAP

TM21T0308

Fig 9



LAP MACHINE

TM21T0309

The idea of creating a comber feeding lap by a single web forming process directly in front of the comber - with a draw frame passage in front of this web former, of course - can be traced back to a development in 1948 by the former Whitin Company, called the super lap machine. Although all later machines are of different designs they all are based on this idea. That is why modern high-performance preparation systems will now be explained on the basis of the Rieter machines, starting with the first designs. As already mentioned, the web former (e.g. UNIlap) always follows a normal draw frame. On the UNIlap machine the material flow starts with the creel, consisting of two feed rails. In normal operation 12 cans are laid out under each roller-assisted feed table. Altogether, this gives a total of 24 doublings. The pre-draw frame slivers run over a guide bridge above the service alley and also over several guide rollers to the drafting system at 2. The web created by the

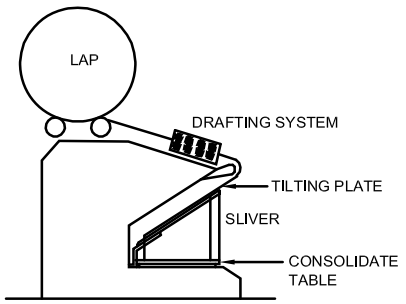
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draft of 1.3 to 2.5 passes over two deflecting plates onto the web table on which the webs are superimposed. Calender rollers draw these superimposed webs from the table to the lap winding assembly.

Ribbon lap machine parts (Fig 10)

The strong compression created between the calender rollers forms a new web, which is rolled into a lap in the lap forming assembly. Empty tubes are automatically exchanged for full laps. Transport of the laps to the combing machine is semi-automatic or fully automatic.

Fig 10



RIBBON LAP MACHINE

TM21T0310

The first part of the machine is a creel on each side feeding two drafting arrangements from max. 28 cans from the draw frame. Here also the slivers are guided over a service alley (one on each side) to the drafting arrangement.

The UNIlap machine features a 3-over-3 roller, two-zone drafting arrangement. The pneumatically weighted top rollers can be continuously adjusted from minimum to maximum per top roller. Draft distances are individually variable, as are the draft levels in each of the break and main draft zones. Upper and lower clearer aprons in combination with a suction system keep the rollers clean. The easily accessible drive for the drafting arrangement is in an enclosed housing and is fitted with appropriate change gears and oil spray lubrication.

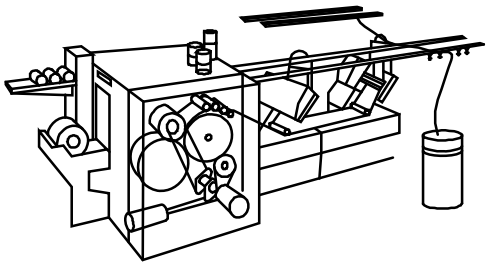
After passing the web table, the web runs through four calender rollers. The pressure generated by two membrane cylinders can be adjusted up to 16000 N. The calender rollers are followed by two winding rolls (2) and a lap tube holding device (3) with a lap weighting device; these have to cooperate to form the lap.

The required weighting pressure (up to 10,000 N), derived from a piston, is transferred via a pivoting lever to the weighting frame and thus to the lap tube. The UNIlap has an automatic lap pressure control which adapts the pressure according to the lap diameter. An increase in diameter of the lap raises the weighting frame, in the course of which the pressure increases. The size of the increase can be set by adjustment using setting screws. The machine stops when a preset lap length is reached, whereupon an automatic device replaces the full lap by an empty tube.

Super lap machine (Fig 11)

The idea of creating a comber feeding lap by a single web forming process directly in front of the comber using a draw frame passage in front of this web former, is developed in 1948 by a Company, called the super lap machine.

Fig 11



SUPER LAP MACHINE

TM21T0311

Although all later machines are of different designs they all are based on this idea. That is why modern high-performance preparation systems will now be explained on the basis of the machinery manufacturers machines, starting with the first designs.

As already mentioned, the web former (e.g. Web Former) always follows a normal draw frame. On the Web Former machine the material flow starts with the creel 1, consisting of two feed rails. In normal operation 12 cans are laid out under each roller-assisted feed table.

Altogether, finally gives a total of 24 doublings. The pre-draw frame slivers run over a guide bridge above the service alley and also over several guide rollers to the drafting system at 2.

The web created by the draft of 1.3 to 2.5 passes over two deflecting plates onto the web table on which the webs are superimposed. Calendar rollers draw these superimposed webs from the table to the lap winding assembly.

The strong compression created between the calendar rollers forms a new web, which is rolled into a lap in the lap forming assembly. Empty tubes are automatically exchanged for full laps. Transport of the laps to the combing machine is semi-automatic or fully automatic.

Objectives of combing

Following are the objectives of combing process

1 To remove naps in the carded sliver.

2 To make the fiber more parallel and straight.

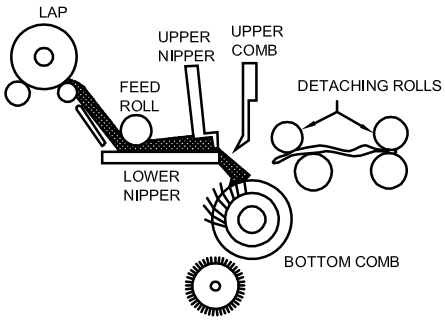
3 To produce a uniform sliver of required per unit length.

4 To remove the fiber shorter than a predetermined length.

5 To remove remaining impurities in the comber lap.

Comber (Fig 12)

Fig 12



COMBER

TM21T0312

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Combing process removes predetermined level of short fibres from the group of cotton fibres. It is well known that the cotton fibres have distribution of fibre lengths starting from long to very short fibres. The short fibres, shorter than 12 mm do not contribute to the strength of the yarn, but in turn they only increase the hairiness of the yarn and adversely affect the appearance and other good properties of the yarns and the fabrics made out of them. In the staple fibre yarn manufacturing process, only the trash particles, foreign matters and very short fibres are removed in the blow room and carding operations. In these processes, it is not possible to remove fibres which are shorter than a predetermined length, which can increase the average fibre length. In the combing operation, fibres shorter than length of fibres or certain fixed percentage of short fibres are removed. Since the shorter cotton fibres are generally coarser, removing the shorter fibres leaves behind fibres which are relatively finer. Hence, fabric made from combed cotton fibres has a very soft touch. Combing involves additional processing step and also certain amount of fibres are removed as waste. Hence, combed cotton is more expensive than conventional carded cotton.

Automation in comber

Automatic lap transport is a problem that has been awaiting a solution for several years. Material has to be transported in large quantities in an unwieldy form and with high lot weights, both within the combing preparation stage and then between the preparatory machines and the combers. Although automation in combing is not a very simple matter it is already available to different degrees. These differences allow mills to choose the degree of automation according to their requirements, since - as already stated in Technology of Short-staple Spinning - automation is not a plaything nor is it obtainable free of charge.

Investment in automation has to pay for itself. Since these installations will become increasingly important in years to come, a short description of them will be given.

Simplex, ring frame, open end spinning and auto cone

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

- **state about speed frame and its objects**
- **state the 4 segment servo drive, automation in speed frame and cone drum mechanism**
- **state about ring frame and its parts**
- **state about waste evacuation system**
- **explain about open end spinning and its principle**
- **explain about cone winding machine and its importance of winding**
- **explain about electronic yarn clearer and capacitive or optical sensors.**

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Introduction

Simplex is an intermediate process in which fibers are converted into low twist lea called roving. The sliver which is taken from draw frame is thicker so it is not suitable for manufacturing of yarn. Its purpose is to prepare input package for next process. This package is to prepare on a small compact package called bobbins. Roving machine is complicated, liable to fault, causes defect adds to the production costs and deliver the product. In this winding operation that makes us roving frame complex. There are two main basic reasons for using roving frame.

Objects / functions of speed frame

1 Attenuation of drawn sliver to form roving of required count by drafting.

2 Insert small amount of twist to give required strength of roving.

3 Wind the twisted roving on to the bobbin.

4 Build the roving in bobbin such a form which will facilitate handling, withdrawing & transfer to the next process.

Operations involved in simplex machine

1 Creeling

2 Drafting

3 Twisting

4 Winding

5 Building

6 Doffing

Creeling

To feed the sliver by the help of several rows of driver rollers to the machine.

1 Creel draft

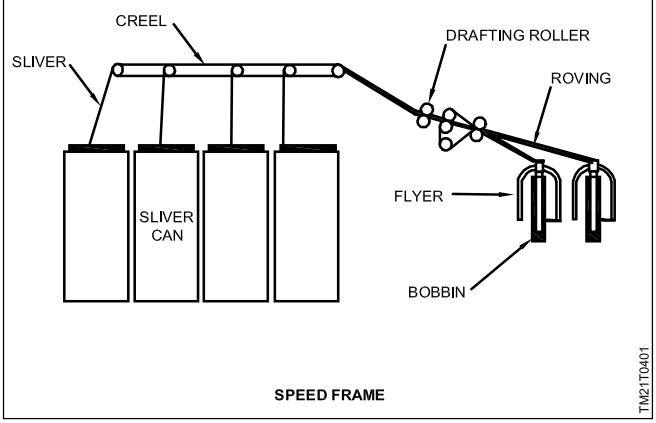
2 Creel Stop motion

3 Block creeling

Machine parts (Fig 1)

M/c description: Draw frame slivers are fed to the roving frame in large cans. The slivers are passed through separators and then over the guide rollers and tension rollers. Now the slivers are passed through the drafting rollers. There is dead weight over these drafting rollers. Here generally 6-15 draft is given. The delivered slivers are too thin to hold themselves together and so twist is needed. The drafted strands of fibres are then passed through flyers. These flyers create twist in the fibre strands by rotating and twist is usually 30-65 per meters. There are spindles in the flyers on which the twisted fibres i.e. roving are wound.

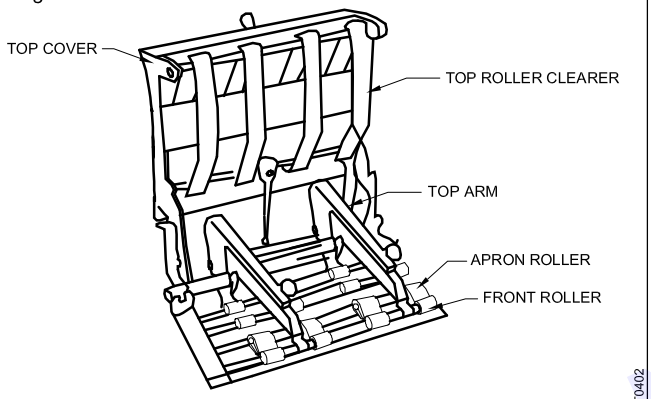
Fig 1



SPEED FRAME

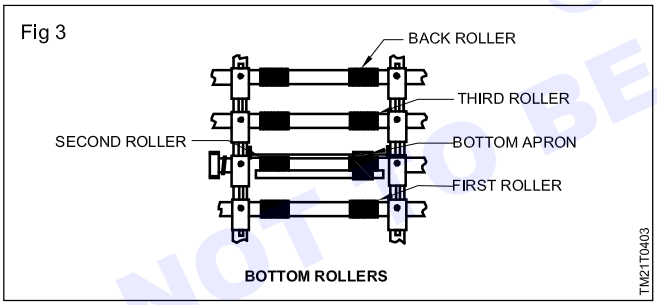
Parts of drafting system (Fig 2&3)

Fig 2



SPEED FRAME DRAFTING SYSTEM

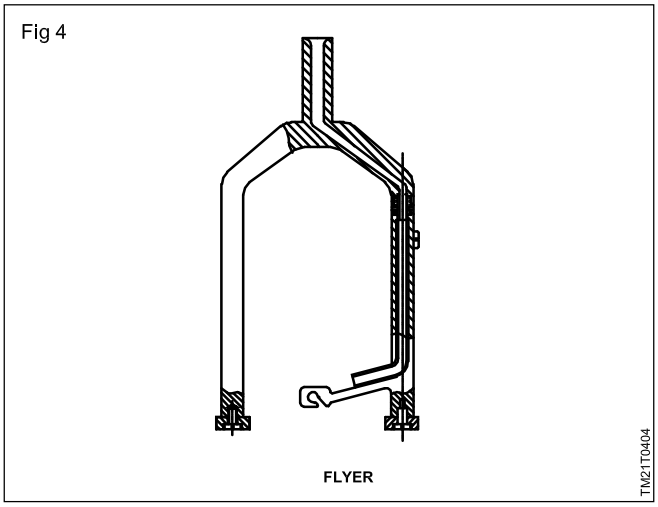
Fig 3



BOTTOM ROLLERS

Flyer (Fig 4)

Fig 4



FLYER

The flyers are made of light alloys instead of steel.

1 Reduces the spread of legs ensures controlled bobbin build.

2 Reduces power consumption

The structure and components of the flyer used in roving frame. Flyer is doing a major part that it has to lead the very sensitive strand from the flyer top to the package without introducing the false drafts. Because,

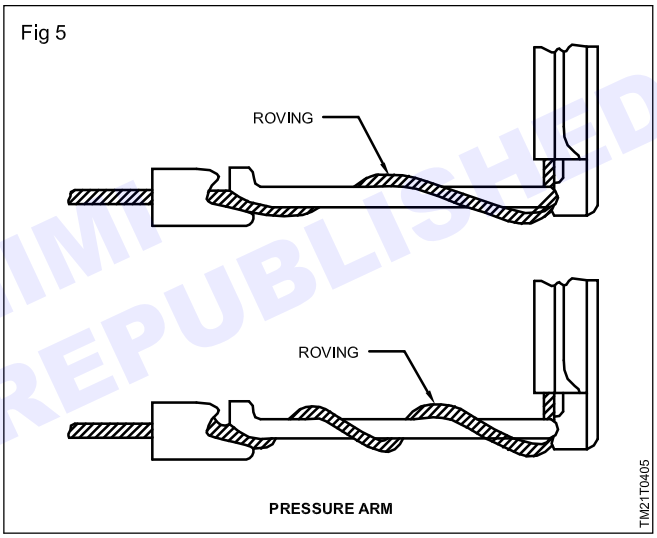
1 Fiber strand has only protective twist and is very liable to break.

2 It is passing through flyer which is rotating more than 1500 rpm, so it should be protected against air current.

To overcome this problem, one of the flyer legs is usually hollow with a deep guide groove roving is passed. If guide groove is very smooth then occurrence of false draft is reduced. However piecing of broken strands is very difficult

Pressure arm (Fig 5)

Fig 5



PRESSURE ARM

1 The pressure arm made up of steel yoke is attached to the lower end of the hollow flyer leg.

2 It guides the roving from exit of the flyer leg to the package.

3 The roving is wrapped two (A) or three (B) times around the yoke.

4 No. of turns determines the roving tension and package hardness.

5 If this is high, then a hard, compact package is obtained. If it is too high, false drafts or roving breaks may happen.

4 Segment servo drive

All the key elements in the Speed frame are driven by the Servo motors namely, Bobbin, Flyer, Drafting, and Bobbin trough with the above,

1 The Main draft and Twist control through display

2 Flyer speed throughout the bobbin build through adjustable speed curve

3 Bobbin speed with bobbin build

4 Precise winding of bobbin

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Bobbin tilting for manual doffing

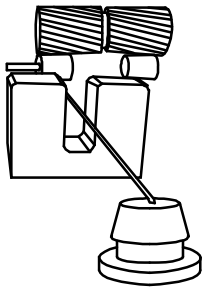
The machine is equipped with a simple individual bobbin tilting mechanism. When the trough moves down after doffing, a lifting mechanism makes individual bobbin to tilt forward. This tilting enables easy doffing of full bobbin. Thus ensures user-friendly doffing of full bobbins.

Automatic roving tension control

Roving tension is maintained at an optimal level by means of two Automatic roving tension controllers operated on CCD principle and through the individual servo motors. Automatic roving tension controller fine tunes bobbin drive and controls uniform tension throughout bobbin build which results in better stretch% values.

Roving tension sensor (Fig 6)

Fig 6



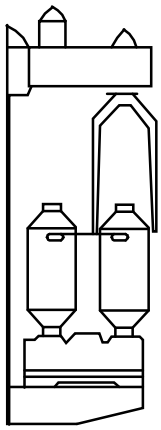
ROVING TENSION SENSOR

TM21T0406

Roving tension sensors measure and control the roving tension (constant) throughout the bobbin build. These tension sensors do not actually contact the roving while measuring the tension. The tension is measured at periodic intervals and the required change in tension is actuated by changing the bobbin speed through servomotor. Rieter F15/F35 roving frame, Zinser 668 roving frame, Marzoli FTN roving frame, Lakshmi LFS 1660 speed frame and Toyota FL100 roving frame have incorporated roving tension sensor on their machines. Figure 2 shows the roving tension sensor used in Rieter roving frame.

Bobbins doffing (Fig 7)

Fig 7



BOBBINS DOFFING

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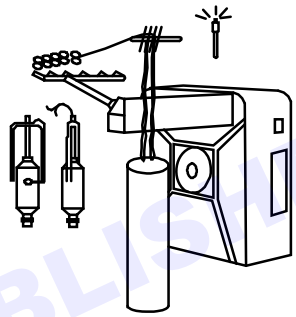
This is an important area where automation should be done. Nowadays manual doffing is costly, time consuming and ergonomically unsatisfactory operation that has a significance influence on efficiency. Development of the fully automated roving frame has resulted in a significant reduction in doffing time. Separate actuation of bobbin rail and doffer rail is the basis for the shortest doffing time compared with manual doffing.

Sliver stop motions

Monitoring at the in-feed is usually carried out by light barriers, with a light emitter at one side of the frame and a light receiver (photocell) at the other. The device is located between the last transport roller of the creel and the drafting arrangement. If a sliver breaks or runs out, the end falls from the transport roller, passes through the light barrier and stops the machine.

Roving stop motion (Fig 8)

Fig 8



ROVING STOP MOTION

TM21T0408

Monitoring at the delivery of the drafting arrangement can also be performed by light barriers. In this case, the light beam is usually directed straight past the flyer tops. In the event of a roving break, the broken roving end whirls around the flyer top or so-called "hoods" form at the flyer top. This interrupts the light beam and causes the machine to be stopped.

Cone drum mechanism

To transfer the cone drum belt

There is a dead wt. at one end of the mechanism which causes the vertical shaft to rotate. They are connected through a chain. There is a rack driving wheel connected to the vertical shaft. The rack is behind the rack driving wheel. The motion of vertical shaft causes the rack driving wheel to rotate. If rack wheel rotate in the clockwise direction, it cause the rack to move in the left side. The be of cone drum is connected with the rack through a connecting rod. The left side movement of rack causes the belt to move to the left, thus reducing bobbin speed with its increasing dia.

The rack driving wheel moves in the anticlockwise direction then rack will move to the right causes the belt to move to the right. The rotation of vertical shaft is controlled by ratchet wheel. The movement of vertical shaft may be continuous due to dead weight. But ratchet wheel controls its movement. The ratchet wheel makes a 0.5 inch movement after completing winding of one layer of roving on the

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bobbin. As vertical shaft is connected with ratchet wheel it cannot move continuously. Again the amount of shifting of belt depends upon roving thickness i.e. on roving count. The amount of shifting of belt is controlled by replacement of ratchet wheel on by substitution of change wheels. When the bobbin is fully wound the belt must be moved back to its starting point. Today it is usually done automatically.

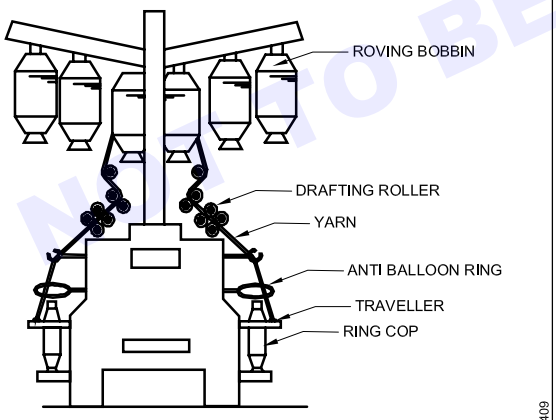
To traverse the bobbin rail

Second function of the building mechanism is to traverse the bobbin rail. If the bobbin does not traverse the roving will wind in only one position thus making the package unstable. So to wind roving on to full length of bobbin it requires traversing motion of bobbin rail. It is done by the above mechanism.

The connecting rod gets traversing motion from building mechanism. Double bevel is on the connecting rod. During the motion of the connecting rod when the left bevel comes in contact with the fixed bevel it gets motion from the fixed bevel. The fixed bevel has a definite direction of movement. If it moves in anti clockwise direction the left bevel will move in clockwise direction. Through gear train bobbin rail driving shaft will also move in clockwise direction. The rack driving wheel which is on it will also move in clockwise direction. Thus causing the rack to move in downward direction. Again when right bevel comes in contact with fixed bevel it will move in anti-clock wise direction. Through gear train the bobbin rail driving shaft will also move in anti-clock wise direction. So the rack will move in upward direction. In this way traversing of bobbin rail occurred.

Ring frame (Fig 9)

Fig 9



RING FRAME

Ring spinning was perfected as a process by the end of the 19th century. Its prominence reflects its versatility in terms of productivity, the range of yarn counts that can be spun on it and the fibre types that can be used. Ring spun yarns are also superior in terms of yarn strength and character in terms of fabric handle and comfort. The ring frame consists of a large number of spindles. One traveler and spindle co-operate with a bobbin, to twist and wind the yarn from a drafting system. The ring spinning frame transforms the roving from the roving frame into spun yarn using the operations of:

i Drafting

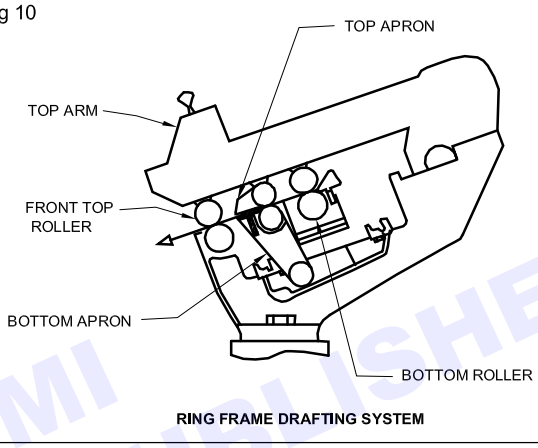
ii Twisting and

iii Winding

The ring frame is normally fed with roving from a large bobbin, and delivers yarn to a smaller one. Because of this, the roving bobbins in the creel have to be renewed less frequently than the yarn bobbins (ring tubes). When spinning a coarse count, the ring bobbins have to be doffed every few hours. This used to consume considerable amounts of labor. These days, the doffing is carried out automatically or semi automatically and this process is referred to as auto-doffing.

Parts of drafting system (Fig 10)

Fig 10



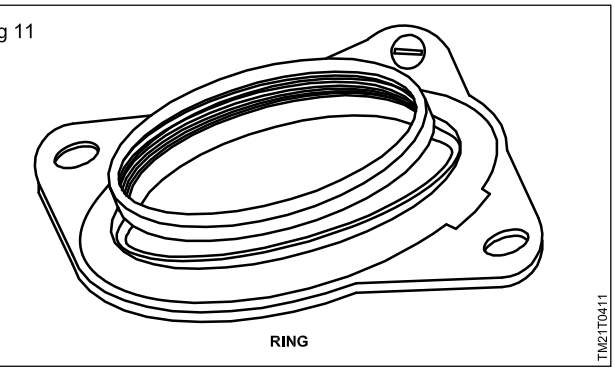
RING FRAME DRAFTING SYSTEM

Parts of ring frame machine

Ring (Fig 11)

The rings are positioned on the ring rail, which has a channel that is connected with the central automatic-dosing lubrication system. The rings usually have a diameter of 75-95 mm in the case of fine yarns.

Fig 11



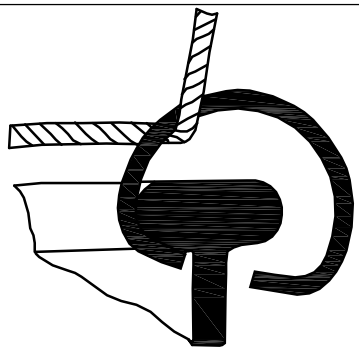
RING

Traveller (Fig 12)

The traveller allows the twisting and the correct delivery of the yarn on the bobbin. The take up speed of the yarn, which corresponds to the difference between the peripheral speed of the bobbin and the peripheral speed of the traveller, is equal to the peripheral speed of the delivery cylinders of the drafting unit.

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Fig 12

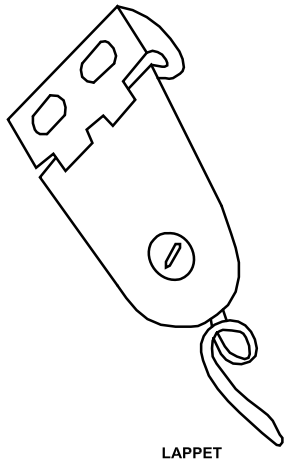


TRAVELLER

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Lappet (Fig 13)

Fig 13



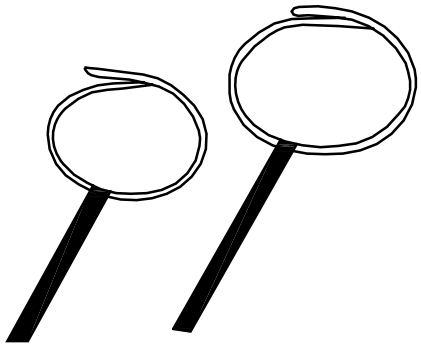
LAPPET

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Mounted directly above each spindle is a lappet designed to lead the yarn centrally over the spindle axis. The lappet consists of a thread guide made of bent wire and a pivotable support arm. The guide is adjustably mounted on the support arm to enable centering, while the arm itself is secured to a lappet rail which extends over length of the machine. This rail along with the lappets can be raised and lowered. During winding of a cop, the lappet rail performs the same sequence of movements as the lappet rail performs the same sequence of movements as the ring rail, but shorter stroke.

Balloon control ring (Fig 14)

Fig 14



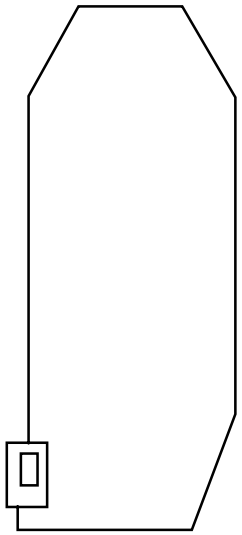
BOLLOON CONTROL RING

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The spacing between the ring and the thread guide is correspondingly long, thus giving a high balloon. A high balloon is associated with a large balloon diameter, causing space problems. The large balloon dimensions lead to relatively high air drag on the yarn in the balloon curve of the plane intersecting the spindle axis. This lead to balloon instability, there increased danger of collapse.

Separator (Fig 15)

Fig 15



SEPARATOR

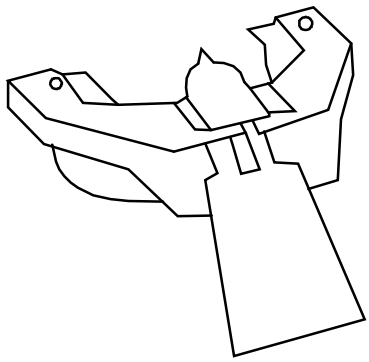
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Most ends down occur in the spinning triangle, since that is where very high forces act on a fiber bundle that is not yet fully integrated. If a break occurs, the yarn end that has now become free must be pulled to the cop and wound onto it. On its way there the thread whirls around the spindle. In the absence of a protective device the yarn would be flung into the neighboring balloon and that yarn would also be broken.

This would be repeated continuously, resulting in serial ends down. In order to prevent this, aluminum or plastic separator plates are arranged between the individual spindles

Spindle brake (Fig 16)

Fig 16



SPINDLE BRAKE

TM21T0416

Spindle brake is used to stop the spindle. Spindle brakes are made by plastic. It is located at bottom of the spindle.

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Automation in ring frame machine

Automation

Textile industry as a whole and ring frame section in particular is labour intensive. With unaffordable labor costs in the developed countries and increasing labour costs in developing countries, automation in the textile industry becomes an important aspect in terms of techno-economical point of view as well as quality point of view. Many operations in the ring spinning section needs skilled workers, which is becoming difficult proposition even in developing countries. In such a situation, maintaining the product quality becomes an issue with the semi-skilled or unskilled workers. In this background, the automation becomes a necessity in many situations.

Preparation for doff

Although it takes between 2 to 40 hrs to fill a cop, depending up on yarn count, process limitations restrict the weight of the yarn on the cop to the range 50 - 140 gram. A further disadvantage of the small package is the necessity to remove full cops at quite short span of time and replace with empty bobbins - a fairly costly operation. In order to ensure that the doff can be carried out efficiently and without causing a large number of end breaks, several preparatory steps must be performed.

1 After the full bobbins have been prepared for the doff and the ring rail has reached its uppermost position, both ring rail and the balloon control rings are lowered in order to provide better access to the cops.

2 Simultaneously, the lappets are tilted upwards, since otherwise the cops cannot be drawn off over the tops of the spindles.

3 The ring rail descends to a so-called under-winding position which is lower than the starting position it will occupy at the start of the next winding operation.

4 The under-winding position has a special function - it creates a thread reserve. During lowering of the ring rail, yarn is still delivered and forms several coils in a return winding around the finished cop. There should be 3 to 4 coils at the most, and with yarn of high breaking strength possibly only 11/2 to 2.

5 When the ring rail has reached the under-winding position, the delivery of yarn has still not been terminated; accordingly, several yarn coils accumulate here as bunch.

Waste Evacuation system (WES)

The WES consists of four modular components

1 PLC Control Module

2 Sump Module

3 Pump Module

4 Collection Site Module

The PLC controlled system is capable of continuous removal of compatible fluids from the collection sumps by use of the pump module and then sending them to a remote collection site.

1 Point of use collection sumps in 3 to 10 gallon sizes can collect waste fluid from multiple tools. Each collection sump has monitoring for fluid level, local exhaust, and leak detection.

2 Pump performance capacity allows distances to 200+ feet with up to 35 feet of head elevation making for easy adaptation into existing fabs.

3 Collection site, Safety Storage Modules can accommodate from a single 10 gallon canister to multiple 55 gallon drums.

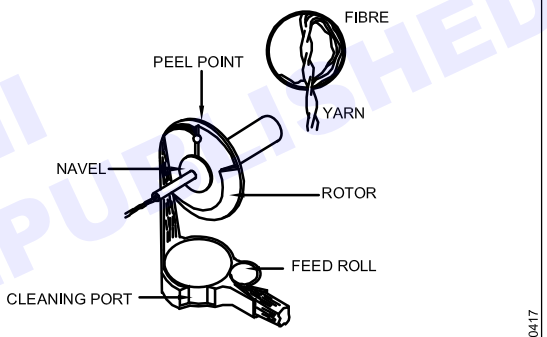
4 Level detection provide local and system wide fluid level alarms

5 Auto switching as a standard feature

Multiple collection sumps are connected to strategically placed pump modules. The air operated pump provides safe fluid handling and reliable, low maintenance operation. Collection sites can be located out of critical environmentally controlled fab areas. IDI-CYBOR Safety Storage Modules can accommodate chemicals from multiple pump modules.

Open end spinning (Fig 17)

Fig 17



OPEN END SPINNING

The twist insertion mechanism which requires one full rotation of the yarn bobbin to introduce one turn of twist into the yarn is one of the main reasons for limiting the productivity of ring spinning. Increasing the spindle speed, and thereby the bobbin speed, increases productivity but the increase in spindle speed is itself limited owing to the heat transfer and wear problems of the traveller situated on the ring. The upper limit of the traveler speed in mill conditions is 35 meters/sec. Open end spinning methods overcome these problems of ring spinning by separating twisting and winding. Open end spinning enables substantial increases in productivity and the possibility of full automation of the spinning process.

Principle of Open-End Spinning

In all other spinning processes, an uninterrupted stream of fibers proceeds continuously, but with gradual attenuation, from the feedstock to the take-up package. In open-end spinning, this flow of fibers is interrupted, the fiber strand being opened into individual fibers at a predetermined position, usually by means of an opening roller, followed by airborne fiber transport. This interruption or break in the fiber flow is physically achieved by increasing fiber speed locally to very high levels (up to 100 m/s), so that -

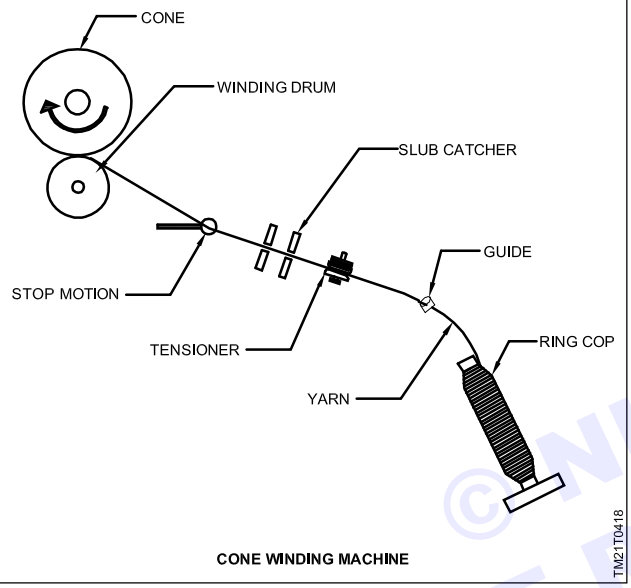
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according to the equation of continuity the number of fibers in the cross-section drops to such low values that the fibers lose contact with each other.

This enables twist to be imparted merely by rotation of the yarn end, which in turn leads to a significantly higher potential rotation speed. However, the break in fiber flow also leads directly to one of the most important and difficult tasks in open-end spinning, namely to control the configuration of the individual fibers, airborne at high speed, and the need to re-collect these fibers without losing their elongated configuration, which is essential to the formation of a new fiber strand.

Cone winding machine (Fig 18)

Fig 18



CONE WINDING MACHINE

The most of the winding operations deal with the conversion of ringframe bobbins into cones or cheeses. One ringframe bobbin (cop) typically contains around 100 grams of yarn. If the yarn count is 20 tex, then the length of yarn in the package will be around 5 km. As the warping speed in modern mills is around 1000 m/min, direct use of ringframe bobbins in warping will necessitate package change after every 5 minutes which is unacceptable. Therefore, ringframe bobbins are converted into bigger cones (mass around 2 kgs or more) or cheeses.

Importance of winding

Unevenness in traditionally spun staple yarns is a natural phenomenon usually induced by the process of manufacturing (spinning). Although with modern process controls and machines many imperfections in the spun yarns can be controlled, some still remain in the final yarns. Most common of all imperfections are thin or weak places, thick places, slubs, neps, and wild fibers, as shown schematically.

During the subsequent processes of winding, warping, and slashing, not all but some of these imperfections create obstacles to steady and smooth working. Therefore, it is important to classify, quantify, and remove those imperfections which may cause the interruption of the operation. In other words, only "objectionable" faults need to be removed for trouble-free processing of the yarns.

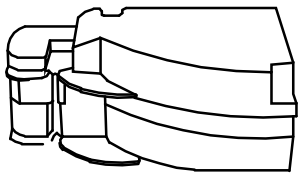
The ring-spinning operation produces a ring bobbin containing just a few grams of yarn which is unsuitable for the efficiency of further processing, such as warping, twisting, and quelling. This necessitates the preparation of a dense and uniform yarn package of sufficiently large size which can unwind in the subsequent operations without interruptions.

The packages prepared for warping are normally cross-wound containing several kilograms of yarns. This implies that a number of knots or splices are introduced within each final package. Bear in mind, each knot or splice itself is an artificially introduced imperfection; therefore, the size of this knot or splice must be precisely controlled to avoid an unacceptable fault in the final fabric.

In modern winding machines, knots and splices are tested photo electrically for size, and only acceptable knots and splices are allowed to pass on to the winding package. In modern spinning processes, such as open end, friction and air jet, the spinning process itself produces a large cross-wound package, thus eliminating the winding operation.

Electronic yarn clearer (Fig 19)

Fig 19



ELECTRONIC YARN CLEARER

USTER® QUANTUM 3 is the third generation of the best-selling online quality assurance system for winding machines. These state-of-the-art yarn clearers use Smart Clearing Technology to optimize production efficiency and reduce costs for spinners

Capacitive or optical sensors

Advanced capacitive and optical sensor options equip the USTER® QUANTUM 3 for any application and environment. The advantages of the capacitive technology are well known. And now the optical sensor of USTER® QUANTUM 3 has been redesigned and substantially enhanced. So both types offer all the benefits of yarn body analysis, smart clearing and cut forecasts.

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Electrical and electronic components of textile machines

Objectives: At the end of this lesson you shall be able to
- **describe about different electronic components**
- **describe about different electrical components.**

Introduction

An electronic circuit is composed of various types of components. Some of these components are termed as active components because they take part in the transformation of the energy while other components, which only dissipate or store energy, are called as passive elements. The vacuum tubes, rectifier, transistors are some of-the common active while the resistances, which dissipate the power and energy storing elements such as capacitances and inductances are known as passive elements. The transformers may be regarded as a matching device. The success of any electronic circuit depends not only on proper selection of the active elements but on the passive and matching elements too. The proper function, of an active device is decided by the proper values of these passive elements. Hence the selection of these elements such as resistances, inductances, capacitance, and transformers not only require the proper attention, but also decide the proper function of the active devices as well as the circuit as a whole.

PLC board (Fig 1)

Fig 1



PLC BOARD

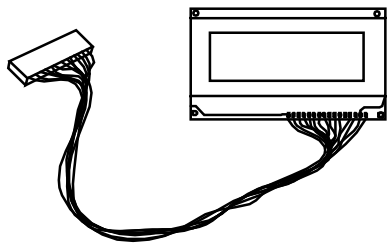
TM21T0501

A programmable logic controller, PLC or programmable controller is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many industries and machines. PLCs are designed for multiple analogue and digital inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. A PLC is an example of a "hard" real-time system since output results must be produced in response to input conditions within a limited time, otherwise unintended operation will result.

LED Display (Fig 2)

LCD (liquid crystal display) is the technology used for displays in notebook and other smaller computers. Like light-emitting diode (LED) and gas-plasma technologies, LCDs allow displays to be much thinner than cathode ray tube (CRT) technology.

Fig 2



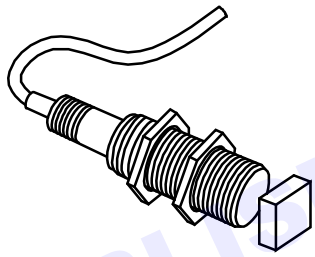
LED DISPLAY

TM21T0502

Types of sensors

Proximity Sensor (Fig 3)

Fig 3



PROXIMITY SENSOR

TM21T0503

A proximity sensor detects the presence of objects that are nearly placed without any point of contact. Since there is no contact between the sensors and sensed object and lack of mechanical parts, these sensors have long functional life and high reliability. The different types of proximity sensors are Inductive Proximity sensors, Capacitive Proximity sensors, Ultrasonic proximity sensors, photoelectric sensors, Hall-effect sensors, etc.

Working

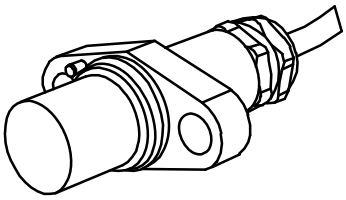
A proximity sensor emits an electromagnetic or electrostatic field or a beam of electromagnetic radiation (such as infrared), and waits for the return signal or changes in the field. The object which is being sensed is known as the proximity sensor's target.

- **Inductive Proximity sensors -** They have an oscillator as input to change the loss resistance by the proximity of an electrically conductive medium. These sensors are preferred for metal targets.
- **Capacitive Proximity sensors -** They convert the electrostatic capacitance variation flanked by the detecting electrode and the ground electrode. This occurs by approaching the nearby object with a variation in an oscillation frequency. To detect the nearby object, the oscillation frequency is transformed into a direct current voltage which is compared with a predetermined threshold value. These sensors are preferred for plastic targets.

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Speed sensor (Fig 4)

Fig 4



SPEED SENSOR

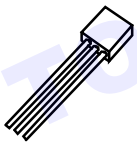
TM21T0504

A vehicle speed sensor is a type of tachometer that sends signals reading the speed of a vehicle's wheel rotation and it usually consists of a serrated ring and a pickup. These devices like you may expect are innovated for the purpose of monitoring just how fast one is driving and will help determine if the driver wants to accelerate or reduce their speed. Other than the above general purpose of determining the speed of a vehicle, there are those that are for special purposes.

Road vehicles use wheel speed sensors that are used in anti lock braking systems. Bearingless motor speed sensors are used on rail vehicles. These bearingless motor Speed sensors are rotary peed sensors that are interconnected with their regulator system. They scan a toothed wheel on the rotating motor of the gearbox and thus the lack of need of a bearing. These sensors require a considerable small air gap to operate and an outstanding advantage of the rotary speed sensors is that they are used for wheel for wheel slide protection and have integrated monitoring functions

Working of different types of Temperature Sensors along with examples (Fig 5)

Fig 5



TEMPERATURE SENSOR

TM21T0505

i **Thermocouple -** They are made of two wires (each of different homogeneous alloy or metal) which form a measuring junction by joining at one end. This measuring junction is open to the elements being measured. The other end of the wire is terminated to a measuring device where a reference junction is formed. The current flows through the circuit since the temperature of the two junctions are different. The resulted milli-voltage is measured to determine the temperature at the junction. The diagram of thermocouple is shown below.

ii Resistance Temperature Detectors (RTD) - These are types of thermal resistors that are fabricated to alter the electrical resistance with the alteration in temperature. They are very expensive than any other temperature detection devices. The diagram of Resistance Temperature Detectors is shown below.

iii Thermistors - They are another kind of thermal resistor where a large change in resistance is proportional to small change in temperature.

IR - Infrared Sensor

This device emits and/or detects infrared radiation to sense a particular phase in the environment. Generally, thermal radiation is emitted by all the objects in the infrared spectrum. The infrared sensor detects this type of radiation which is not visible to human eye.

Advantages

1 Easy for interfacing

2 Readily available in market

Disadvantages

1 Disturbed by noises in the surrounding such as radiations, ambient light etc

UV sensor

These sensors measure the intensity or power of the incident ultraviolet radiation. This form of electromagnetic radiation has wavelengths longer than x-rays but is still shorter than visible radiation. An active material known as polycrystalline diamond is being used for reliable ultraviolet sensing. UV sensors can discover the exposure of environment to ultraviolet radiation.

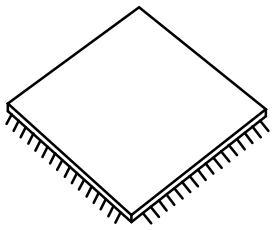
Limit switches

They are used for controlling machinery as part of a control system, as a safety interlocks, or to count objects passing a point.1 A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection.

Limit switches are used in a variety of applications and environments because of their ruggedness, ease of installation, and reliability of operation. They can determine the presence or absence, passing, positioning, and end of travel of an object. They were first used to define the limit of travel of an object; hence the name "Limit Switch".

Micro controller: (Fig 6): A microcontroller (sometimes abbreviated μC, μC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/ output peripherals.

Fig 6



MICRO CONTROLLER

TM21T0506

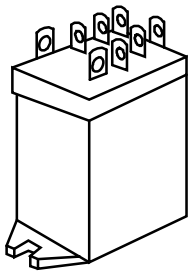
Power relays (Fig 7)

A power relay is a switch which uses an electromagnetic coil in order to close or open a circuit. Power relays also contain an armature, a spring and one or several contacts.

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If the power relay is designed to normally be open, when power is applied, the electromagnet attracts the armature, which is then pulled in the coil's direction until it reaches a contact, therefore closing the circuit. If the relay is designed to be normally closed, the electromagnetic coil pulls the armature away from the contact, therefore opening the circuit.

Fig 7



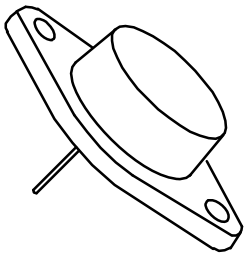
POWER RELAYS

TM21T0507

Bipolar transistor (Fig 8)

A bipolar transistor is a semiconductor device commonly used for amplification. The device can amplify analog or digital signals. It can also switch DC or function as an oscillator.

Fig 8

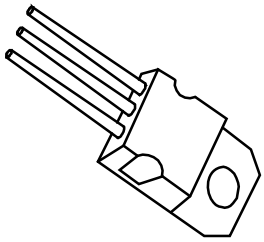


BIPOLAR TRANSISTOR

TM21T0508

Triacs (Fig 9): TRIAC, from triode for alternating current, is a genericized tradename for an electronic component that can conduct current in either direction when it is triggered (turned on), and is formally called a bidirectional triode thyristor or bilateral triode thyristor

Fig 9

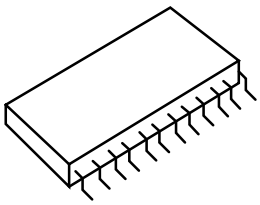


TRIACS

TM21T0509

Linear circuits (Fig 10): A linear circuit is an electronic circuit in which, for a sinusoidal input voltage of frequency f, any steady-state output of the circuit (the current through any component, or the voltage between any two points) is also sinusoidal with frequency f. Note that the output need not be in phase with the input.

Fig 10

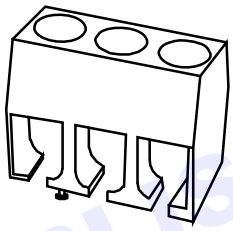


LINEAR CIRCUITS

TM21T0510

Terminal blocks (Fig 11): Terminal Blocks Connection Systems include screw-type IEC, spring-type IEC, IEC terminal block accessories, NEMA terminal blocks, NEMA terminal block accessories, finger-safe terminal blocks, and panel mount terminal blocks. We offer many terminal block products including double level plug-in, thermocouple, tab-connect feed through, grounding, space-saver feed through, fuse, sensor, plug-in connection, multi-circuit, mini, single circuit, neutral disconnect, isolation and more.

Fig 11



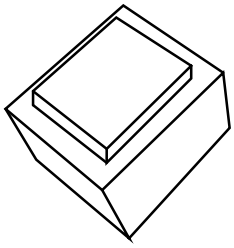
TERMINAL BLOCKS

TM21T0511

Encapsulated transformers (Fig 12)

General purpose encapsulated transformers rated 0.050 KVA to 25 KVA for lighting, industrial and commercial applications. Can be used indoors or outdoors

Fig 12

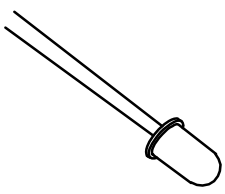


ENCAPSULATED TRANSFORMERS

TM21T0512

LED diode (Fig 13)

Fig 13



LED DIODE

TM21T0513

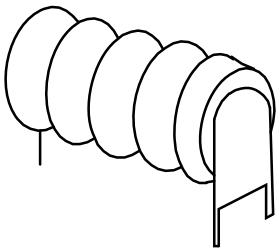
A light-emitting diode (LED) is a two-lead semiconductor light source. It is a pn-junction diode, which emits light

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when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.

Kinetic rechargeable cell (Fig 14)

Fig 14



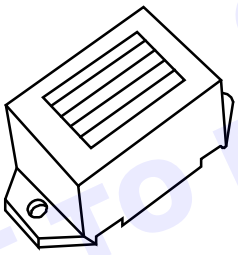
KINETIC RECHARGEABLE CELL

TM21T0514

A nickel-metal hydride battery, abbreviated NiMH or Ni-MH, is a type of rechargeable battery. The chemical reaction at the positive electrode (cathode) is similar to that of the nickel-cadmium cell (NiCd), with both using nickel oxyhydroxide (NiOOH). However, the negative electrodes use a hydrogen-absorbing alloy instead of cadmium. A NiMH battery can have two to three times the capacity of an equivalent size NiCd, and its energy density can approach that of a lithium-ion battery.

Magnetic transducers (Fig 15)

Fig 15



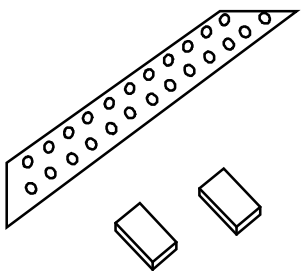
MAGNETIC TRANSDUCERS

TM21T0515

A device for transforming mechanical into electrical energy, which consists of a magnetic field including a variable-reluctance path and a coil surrounding all or a part of this path, so that variation in reluctance leads to a variation in the magnetic flux through the coil and a corresponding induced emf (electromotive force).

Multichip ceramic capacitors (Fig 16)

Fig 16



MULTICHIP CERAMIC CAPACITORS

TM21T0516

An MLCC consists of a number of individual capacitors stacked together in parallel and contacted via the terminal surfaces. The starting material for all MLCC chips is a mixture of finely ground granules of paraelectric or ferroelectric raw materials, modified by accurately determined additives.12 These powdered materials are mixed homogeneously. The composition of the mixture and the size of the powder particles, as small as 10 nm, reflect the manufacturer's expertise.

A thin ceramic foil is cast from a suspension of the powder with a suitable binder. This foil is rolled up for transport. Unrolled again, it is cut into equal-sized sheets, which are screen printed with a metal paste. These sheets become the electrodes. In an automated process, these sheets are stacked in the required number of layers and solidified by pressure. Besides the relative permittivity, the size and number of layers determines the later capacitance value.

Capacitor (Fig 17)

Fig 17



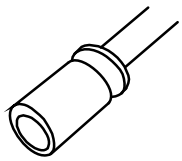
CAPACITOR

TM21T0517

A capacitor (originally known as a condenser) is a passive two-terminal electrical component used to store energy electrostatically in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors (plates) separated by a dielectric (i.e. insulator).

Capacitor polarized (Fig 18)

Fig 18



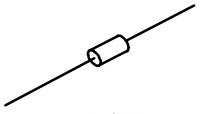
CAPACITOR POLARIZED

TM21T0518

All electrolytic capacitors (e-caps) are polarized capacitors whose anode electrode (+) are made of a special metal on which an insulating oxide layer originates by anodization (forming), which acts as the dielectric of the electrolytic capacitor. A non-solid or solid electrolyte which covers the surface of the oxide layer in principle serves as the second electrode (cathode) (-) of the capacitor.

Diode (Fig 19)

Fig 19



DIODE

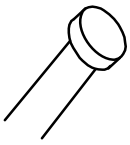
TM21T0519

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Current passing through a diode can only go in one direction, called the forward direction. Current trying to flow the reverse direction is blocked. They're like the one-way valve of electronics. If the voltage across a diode is negative, no current can flow*, and the ideal diode looks like an open circuit.

Optocoupler (Fig 20)

Fig 20



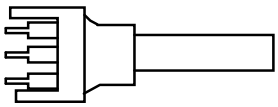
OPTOCOUPLER

TM21T0520

In electronics, an opto-isolator, also called an optocoupler, photocoupler, or optical isolator, is a component that transfers electrical signals between two isolated circuits by using light.1 Opto-isolators prevent high voltages from affecting the system receiving the signal. Commercially available opto-isolators withstand input-to-output voltages up to 10 kV and voltage transients with speeds up to 10 kV/ Fs.

Potentiometer (Fig 21)

Fig 21



POTENTIOMETER

TM21T0521

A potentiometer informally a pot, is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider.1 If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat.

The measuring instrument called a potentiometer is essentially a voltage divider used for measuring electric potential (voltage); the component is an implementation of the same principle, hence its name.

Resistor (Fig 22)

Fig 22



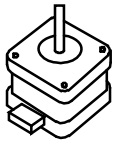
RESISTOR

TM21T0522

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits.

Stepper motor (Fig 23)

Fig 23



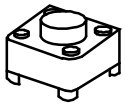
STEPPER MOTOR

TM21T0523

A stepper motor (or step motor) is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller), as long as the motor is carefully sized to the application.

Switch (Fig 24)

Fig 24



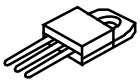
SWITCH

TM21T0524

In electrical engineering, a switch is an electrical component that can break an electrical circuit, interrupting the current or diverting it from one conductor to another. The mechanism of a switch may be operated directly by a human operator to control a circuit (for example, a light switch or a keyboard button), may be operated by a moving object such as a door-operated switch, or may be operated by some sensing element for pressure, temperature or flow. A relay is a switch that is operated by electricity. Switches are made to handle a wide range of voltages and currents; very large switches may be used to isolate high-voltage circuits in electrical substations.

Transistor (Fig 25)

Fig 25



TRANSISTOR

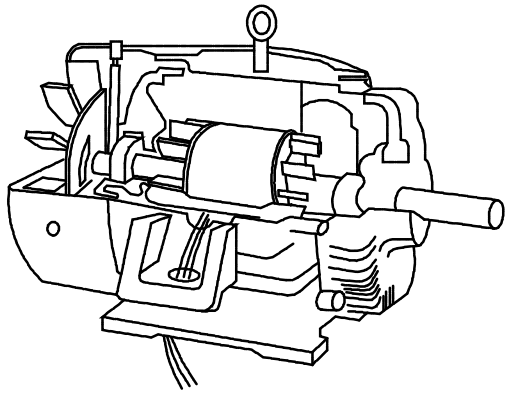
TM21T0525

A transistor is a semiconductor device used to amplify and switch electronic signals and electrical power. It is composed of semiconductor material with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals changes the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal. Today, some transistors are packaged individually, but many more are found embedded in integrated circuits.

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Motor (Fig 26)

Fig 26



MOTOR

TM21T0526

An electric motor is an electrical machine that converts electrical energy into mechanical energy. The reverse of this would be the conversion of mechanical energy into electrical energy and is done by an electric generator. In normal motoring mode, most electric motors operate through the interaction between an electric motor's magnetic field and winding currents to generate force within the motor. In certain applications, such as in the transportation industry with traction motors, electric motors can operate in both motoring and generating or braking modes to also produce electrical energy from mechanical energy.

Found in applications as diverse as industrial fans, blowers and pumps, machine tools, household appliances, power tools, and disk drives, electric motors can be powered by direct current (DC) sources, such as from batteries, motor vehicles or rectifiers, or by alternating current (AC) sources, such as from the power grid, inverters or generators. Small motors may be found in electric watches. General-purpose motors with highly standardized dimensions and characteristics provide convenient mechanical power for industrial use. The largest of electric motors are used for ship propulsion, pipeline compression and pumped-storage applications with ratings reaching 100 megawatts. Electric motors may be classified by electric power source type, internal construction, application, type of motion output, and so on.

Control panels (Fig 27)

A control panel is a flat, often vertical, area where control or monitoring instruments are displayed. They are found in factories to monitor and control machines or production lines and in places such as nuclear power plants, ships, aircraft and mainframe computers. Older control panels are most often equipped with push buttons and analog instruments, whereas today in many cases touch screens are used for monitoring and control purposes.

Fig 27

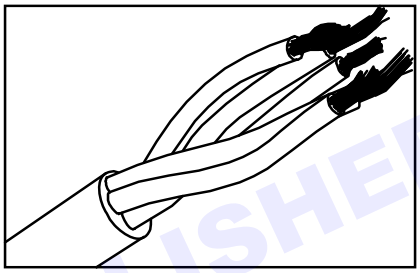


CONTROL PANELS

TM21T0527

Electrical wires (Fig 28)

Fig 28



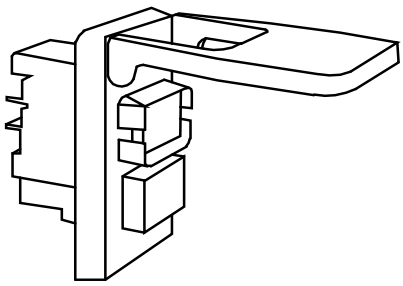
ELECTRICAL WIRES

TM21T0528

A length of such material, consisting either of a single filament or of several filaments woven or twisted together and usually insulated with a dielectric material, used as a conductor of electricity.

Push buttons (Fig 29)

Fig 29



PUSH BUTTONS

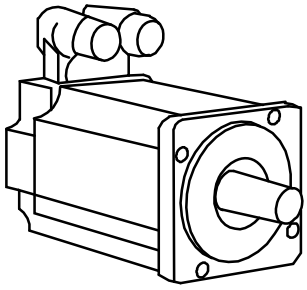
TM21T0529

A push-button (also spelled pushbutton) or simply button is a simple switch mechanism for controlling some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal. The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, though even many un-biased buttons (due to their physical nature) require a spring to return to their un-pushed state. Different people use different terms for the "pushing" of the button, such as press, depress, mash, and punch.

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Servo motor (Fig 30)

Fig 30



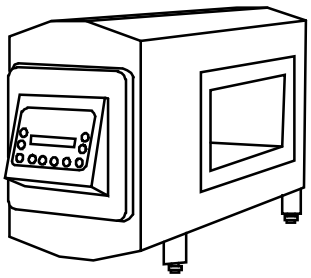
SERVO MOTOR

TM21T0530

A servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor although the term servomotor is often used to refer to a **motor suitable for use in a closed-loop control system.**

Metal detector (Fig 31)

Fig 31



METAL DETECTOR

TM21T0531

Featuring a full-color touch screen, membrane key panel and product inspection data collection capability, the Mettler Toledo Signature metal detector is designed for cost-effective easy integration into food production lines. When Signature is combined with material handling systems such as conveyors, product inspection can be fully automated.

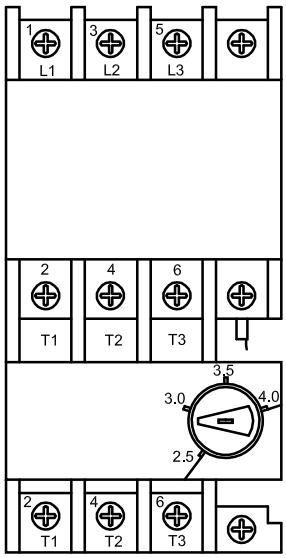
Contactor (Fig 32)

In process industries a contactor is a vessel where two streams interact, for example, air and liquid. See Gas-liquid contactor. A contactor is an electrically controlled switch used for switching a power circuit, similar to a relay except with higher current ratings.

MCB fuse (Fig 33)

Nowadays we use more commonly miniature circuit breaker or MCB in low voltage electrical network instead of fuse.

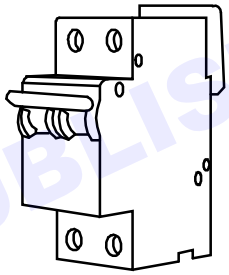
Fig 32



CONTACTOR

TM21T0532

Fig 33

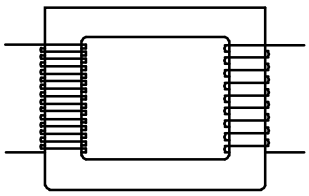


MCB FUSE

TM21T0533

Single phase transformer (Fig 34)

Fig 34



SINGLE PHASE TRANSFORMER

TM21T0534

These high AC transmission voltages and currents are then reduced to a much lower, safer and usable voltage level were it can be used to supply electrical equipment in our homes and workplaces, and all this is possible thanks to the basic Voltage Transformer.

A Typical voltage transformer

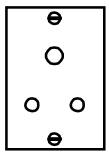
The Voltage Transformer can be thought of as an electrical component rather than an electronic component. A transformer basically is very simple static (or stationary) electro-magnetic passive electrical device that works on the principle of Faraday's law of induction by converting electrical energy from one value to another.

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3 pin wall socket (Fig 35)

AC power plugs and sockets are devices that allow electrically operated equipment to be connected to the primary alternating current (AC) power supply in a building. Electrical plugs and sockets differ in voltage and current rating, shape, size and type of connectors. The types used in each country are set by national standards, some of which are listed in the IEC technical report TR 60083, Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC.

Fig 35



3 PIN WALL SOCKET

TM21T0535

Electrical circuit diagrams

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

- **state about electrical circuit and different electrical circuit diagrams.**

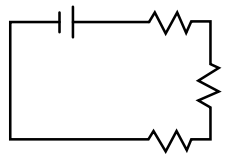
Electrical circuit

An electric circuit is a path in which electrons from a voltage or current source flow. Electric current flows in a closed path called an electric circuit.

Series circuit (Fig 1)

A series circuit is one with all the loads in a row. There is only ONE path for the electricity to flow. If this circuit was a string of light bulbs, and one blew out, the remaining bulbs would turn off.

Fig 1



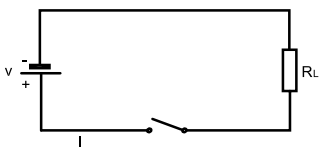
SERIES CIRCUIT

TM21T0601

Open circuit (Fig 2)

The box is any two-terminal device, such as a battery or solar cell. The two terminals are not connected to anything (an "open circuit"), so no current can flow into or out of either terminal. The voltage voc between the terminals is the open-circuit voltage of the device.

Fig 2



OPEN CIRCUIT

TM21T0602

Different types of circuit (Figs 3 - 40)

1 Temperature normally open

Fig 3



TEMPERATURE NORMALLY OPEN

TM21T0603

2 Temperature normally closed

Fig 4



TEMPERATURE NORMALLY CLOSED

TM21T0604

3 Flow normally open

Fig 5



FLOW NORMALLY OPEN

TM21T0605

4 Flow normally closed

Fig 6

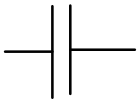


FLOW NORMALLY CLOSED

TM21T0606

5 Relay contact normally open

Fig 7

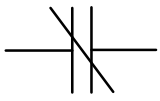


RELAY CONTACT NORMALLY OPEN

TM21T0607

6 Relay contact normally closed

Fig 8



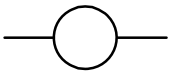
RELAY CONTACT NORMALLY CLOSED

TM21T0608

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7 Relay coil

Fig 9

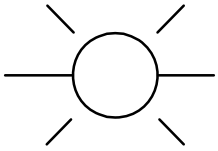


RELAY COIL

TM21T0609

8 Indicator lamp

Fig 10



INDICATOR LAMP

TM21T0610

9 Relay time delay on 'NO'

Fig 11

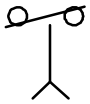


RELAY TIME DELAY ON 'NO'

TM21T0611

10 Relay time delay on 'NC'

Fig 12



RELAY TIME DELAY ON 'NC'

TM21T0612

11 Relay time delay off 'NO'

Fig 13



RELAY TIME DELAY OFF 'NO'

TM21T0613

12 Relay time delay 'NC'

Fig 14

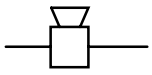


RELAY TIME DELAY 'NC'

TM21T0614

13 Horn

Fig 15

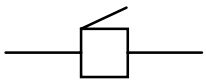


HORN

TM21T0615

14 Buzzer

Fig 16

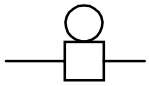


BUZZER

TM21T0616

15 Bell

Fig 17

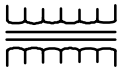


BELL

TM21T0617

16 Control transformer

Fig 18



CONTROL TRANSFORMER

TM21T0618

17 Solenoid

Fig 19



SOLENOID

TM21T0619

18 Two position hydraulic solenoid

Fig 20

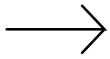


POSTION HYDRAULIC SOLENOID

TM21T0620

19 Male contactor

Fig 21

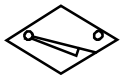


MALE CONTACTOR

TM21T0621

20 Normally open proximity switch

Fig 22

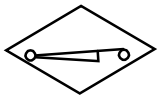


NORMALLY OPEN PROXIMITY SWITCH

TM21T0622

21 Normally open proximity switch

Fig 23

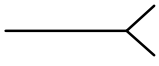


NORMALLY OPEN PROXIMITY SWITCH

TM21T0623

22 Female connector

Fig 24



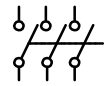
FEMALE CONNECTOR

TM21T0624

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23 Disconnect (3 phase AC)

Fig 25

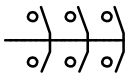


DISCONNECT (3 PHASE AC)

TM21T0625

24 Circuit interrupter (3 phase AC)

Fig 26

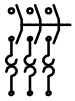


CIRCUIT INTERRUPTER (3 PHASE AC)

TM21T0626

25 Breaker 3 phase AC

Fig 27



BREAKER 3 PHASE AC

TM21T0627

26 Normally open limit switch

Fig 28



NORMALLY OPEN LIMIT SWITCH

TM21T0628

27 Normally closed limit switch

Fig 29

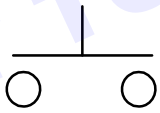


NORMALLY CLOSED LIMIT SWITCH

TM21T0629

28 'NO' push button

Fig 30

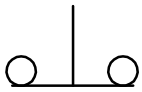


'NO' PUSH BUTTON

TM21T0630

29 'NC' push button

Fig 31

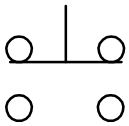


'NC' PUSH BUTTON

TM21T0631

30 Double pole push button

Fig 32

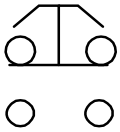


DOUBLE POLE PUSH BUTTON

TM21T0632

31 Mushroom head push button

Fig 33



MUSHROOM HEAD PUSH BUTTON

TM21T0633

32 Thermal overload relay

Fig 34

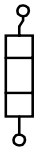


THERMAL OVERLOAD RELAY

TM21T0634

33 Fuse

Fig 35

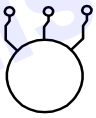


FUSE

TM21T0635

34 Motor (3 phase AC)

Fig 36



MOTOR (3 PHASE AC)

TM21T0636

35 Vacuum pressure 'NC'

Fig 37



VACCUM PRESSURE 'NC'

TM21T0637

36 Liquid level 'NO'

Fig 38



LIQUID LEVEL 'NO'

TM21T0638

37 Liquid level 'NC'

Fig 39

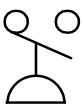


LIQUID LEVEL 'NC'

TM21T0639

38 Vacuum pressure 'NO'

Fig 40



VACCUM PRESSURE 'NO'

TM21T0640

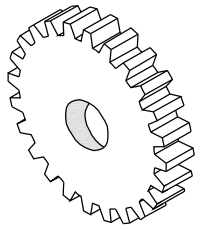
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Different types of gears, belt, tool kits and bearing

Objectives: At the end of this lesson you shall be able to
- **state the different types of gears**
- **state the different types of belt drives**
- **state about bearing**
- **state the different types of tools.**

Spur gear (Fig 1)

Fig 1



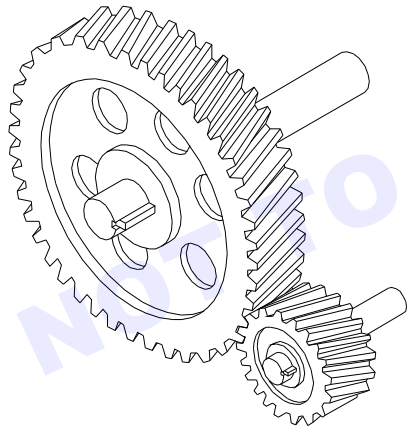
SPUR GEAR

TM20N164411

It is the simplest and most common type of gear that is used to connect two parallels and coplanar shafts, which rotate in opposite direction. Spur gear has teeth parallel to the axis of the shaft and is similar in profile throughout. It can be observed that line of contact between corresponding teeth is always parallel to the axis of shaft. These gears can only mesh correctly if they are fitted to parallel axles. The major advantages of these gears are simplicity in design and economic to manufacture. These gears are used for slow speed but if run on high speed they create noise.

Helical gears (Fig 2)

Fig 2



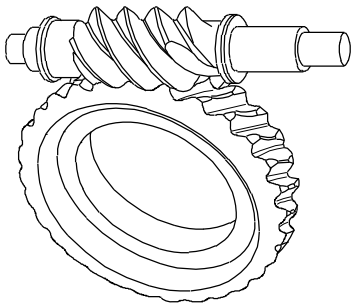
HELICAL GEARS

TM20N164412

Helical gears are similar to spur gears except that their teeth are cut at an angle to the hole (axis) rather than straight and parallel to the hole like the teeth of a spur gear. The line of contact between two teeth is not parallel to the teeth but inclined. This ensures gradual engagement of teeth from one end of tooth to other rather than a sudden engagement as in case of spur gear. This gradual engagement makes the gears function smoothly without much noise. Pair of helical gears can be meshed in two ways: with shafts oriented at either the sum or the difference of the helix angles of the gears. These configurations are referred to as parallel or crossed, respectively.

Worm gears (Fig 3)

Fig 3



WORM GEAR

TM20N164413

A worm is a gear that resembles a screw. It is a species of helical gear, but its helix angle is usually somewhat large (i.e., somewhat close to 90 degrees) and its body is usually fairly long in the axial direction; and these attributes give it its screw-like qualities. A worm is usually meshed with an ordinary looking, disk-shaped gear, which is called the 'gear', the 'wheel', the 'worm gear', or the 'worm wheel'. The prime feature of a worm-and-gear set is that it allows the attainment of a high gear ratio with few parts, in a small space. Helical gears are, in practice, limited to gear ratios of 10:1 and under; worm gear sets commonly have gear ratios between 10:1 and 100:1, and occasionally 500:1. The worm gear gives a line of contact between mating teeth unlike the point of contact.

Note: Worm gears differ from spur gears in that their teeth are somewhat different in shape and are always formed on an angle to the hole (axis) in order to mate with worms. In order to transmit motion and power at various speeds and speed ratios, worms and worm gears work in sets, rotating on shafts at right angles to one another. The worm usually drives the worm gear. In worms and worm gear sets, both the worm and worm gear are of the same hand. Right-hand sets are considered standard.

This improves the load carrying capacity and also reduces the speed. Worm gear is always changed in a set, i.e. both worm and worm wheel needs replacement at the time of wear. A worm wheel of one diameter will not operate satisfactorily with a worm of different diameter even if thread pitch is same.

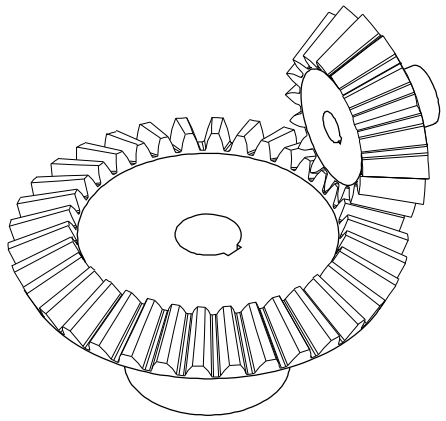
The thread of worm may be single start, double start and so on. The velocity ratio depends whether the worm is one start or multiple start. To determine the number of threads on a worm, look at an end view so you can see the 'start' of each thread. One start means that you have a single thread, two starts a double thread, three starts a triple thread, and four starts a quadruple thread.

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Bevel gears: These are used to connect two shaft axes which arc intersecting and coplanar. They are kinematically. equal to frustums of cone with their apices meeting at II point. The shaft angle may be of any value between 0° and 180o but one most common is 90o. The teeth of bevel gears are similar to that of spur gears in that they make a line contact across the face of teeth. The teeth are smaller at the front than at the back.

Straight tooth bevel gears (Fig 4)

Fig 4



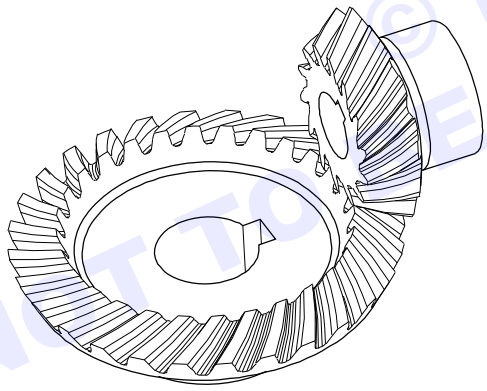
STRAIGHT TOOTH BEVEL GEAR

TM20N164414

In these gears the teeth of gear converge to the common point along straight lines. This point is called apex and also point of intersection of gear axis. At high speed they give more noise.

Spiral tooth bevel gears (Fig 5)

Fig 5



SPRIAL TOOTH BEVEL GEAR

TM20N164415

Spiral bevel gears have spiral angles, which give performance improvements. They are designed for an angle change of 90°, where the two axes are concurrent and in the same plane. These gears have a double function of being helical and beveled at the same time. The contact between the teeth starts at one end of the gear and then spreads across the whole tooth. In this type of gears the shaft must be perpendicular to each other and must be in the same plane.

They are the most complex forms of bevel gears. The teeth are curved by cutting them obliquely, resulting in higher overall contact ratios. Because of higher contact ratio, these have better load carrying capacity and this allows them to be of smaller in size for a given load capacity than an equivalent gear. Thus, they can transmit more power with smaller gears. These gears have the following advantages over the straight gears:

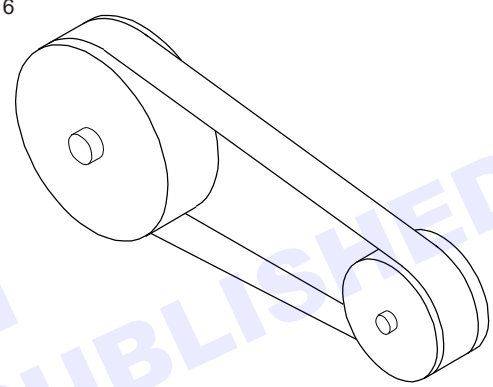
1 Due to curvature there is an overlapping of mesh and teeth mesh with each other gradually resulting in smooth and quiet operation.

2 There is a gradual transfer of load from one tooth to another eliminating sudden impacts and change in tooth pressure.

Note: Spiral bevel gears of the same hand will not operate together, a set of spiral bevel or spiral gears consists of one left-hand gear and one right-hand gear.

Flat belt drives (Fig 6): Flat belt mostly consists of two outer layer made of elastomer called friction cover and two intermediate layers covering the traction layer which absorbs the force extended on the belt when power is transmitted. Friction cover ensures the peripheral force acting on the belt pulley is transmitted to the belt and vice versa.

Fig 6



FLAT BELT DRIVE

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Advantages

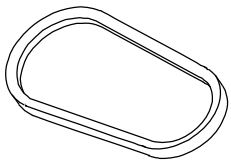
1 Flexibility, shock absorption and efficiency at high speed.

2 It allows long distances between the shafts.

3 Simplicity, low cost smoothness of operation, low maintenance cost long life and noiseless as compared with gear transmission.

V belts (Fig 7)

Fig 7



V-BELT

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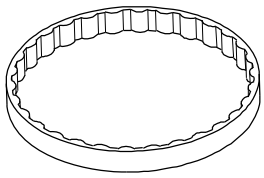
A V belt is required when a machine is driven by a separate motor located very close to the driven pulley. Hence V belts are used to transmit power from one pulley to another when the centre distance between two pulleys is less. These belts are trapezoidal in cross-section and are manufactured endless belts. These belts transmit power owing to wedging action between the belt and V groove in the pulley. The included angle is ?/2 = 40°. The more power and load to be

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transmitted, the more is the number of belts. In such multiple drives all the belts should get stretched at the same rate so that the load is equally distributed on the belts.

Timing Belts (Fig 8)

Fig 8



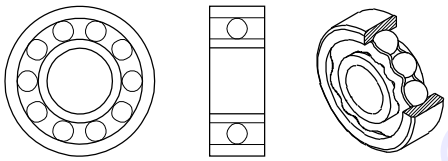
TIMING BELT

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Classical timing belts offer a maintenance free and economical alternative to conventional drives like chains and gears. Capable of transmitting up to 100kW and speeds of 10,000 rpm. Classical timing belts can be used in a wide range of applications from light duty office machinery to heavy duty industrial drives. To select a drive it is necessary to know the driver and driven shaft speeds, the demand power, proposed centre distance and duty cycle. The chart below can be used to select the optimum belt size for a drive.

Bearing (Fig 9)

Fig 9



BEARING

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1 Bearing consists of the following elements: inner ring rolling element, cage, outer ring and seal/shield.

Inner ring/outer ring

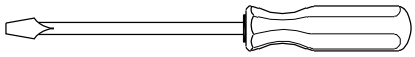
The surface on which the rolling elements roll is referred to as the 'raceway surface'. The load placed on the bearings is supported by this contact surface. The inner ring is used fitted on the shaft and the outer ring on the housing. These are made of high-grade carbon chromium steel with a high degree of cleanliness and surface finish. Both rings are made of different sizes and shapes depending upon the type of bearing. Both rings have a groove throughout the circumference compatible to the size and type of rolling element. Each ring is given heat treatment so as to possess hardness between 59 and 65 HRC.

Rolling elements come in two general shapes: balls or rollers. Rollers come in four basic styles: cylindrical, needle, tapers and spherical. Rolling elements function to support the load while rolling on the bearing ring. The rolling element is held by the cage at a certain distance from each other between the inner ring and the outer ring. Rolling elements are made of carbon chromium steel, stainless steel or alloyed quality steel with hardness between 58 and 65 HRC.

Different types of tools

Screw driver (Fig 10)

Fig 10

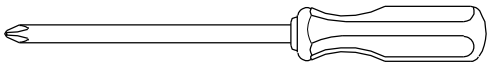


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It is very useful tool for rotating screw with line slots on their head. It consists of a wooden or plastic handle, and a steel blade shaped at the end. The flat end of the tool is inserted into the slot provided on the head of the screw for rotating it. Screw drivers are made in various sizes to suit the corresponding sizes of slot on the screw head and made of different lengths to tighten and to open screws with different torque. These are available in sizes 5 × 75, 6.5 × 80, 6.5 × 100, 8 × 125, 8 × 150, 11 × 200 and 13 × 250 mm.

Star screw driver (Fig 11)

Fig 11



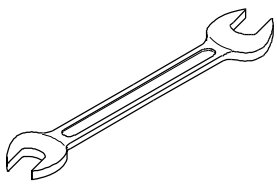
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For rotating screw with star shape at the head, it is necessary to use a star shaped driver. It is also made in different sizes to suit the corresponding star shape on the screw head. These are available in sizes in 5 × 100, 6.5 × 125, 8 × 150, 4 × 75 and 5 × 75. It is important not to use a simple screw driver to open or close a star headed screw so as to avoid damage to screw head.

Open-ended spanner (Fig 12)

These can be single-ended or double-ended. Single-ended spanners are provided with holding mouth at one end only and the size of mouth is different according to the size of the bolt and/or the nut. In double-ended spanner, openings are provided on both ends and are of different considerable sizes.

Fig 12



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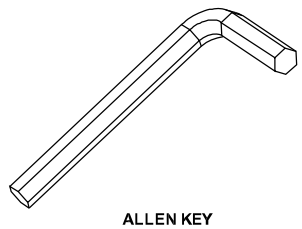
These spanners are forged from chrome vanadium steel and heat treated. The size of the opening between the jaws determines the size of the open end wrench. The length of the wrench is determined by the size of the opening since the lever advantage of the wrench is proportional to its length; spanners with larger openings are made longer and heavier to increase leverage and strength.

Allen key (Fig 13)

An allen key is used for tightening or loosening set-screws. The allen key is made of steel in hexagonal cross-section throughout its length. It is mostly made in L-shape, and in different shapes and sizes to suit the different sizes of set-screws. These are also available in sets, ranges from 1 to 18 mm.

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Fig 13



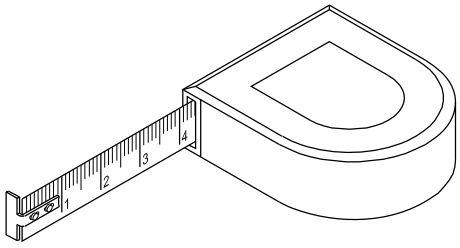
ALLEN KEY

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Measuring tape (Fig 14)

The tape is a thin flexible steel strip. It is folded around a centre pin attached with a small handle. It is marked with inches and millimetres. It is available in different lengths from 1 to 100 m. The tape is spring loaded, so that as soon as it is released it will automatically return to the case. On some cases a lock is provided to hold the tape when extended.

Fig 14



MEASURING TAPE

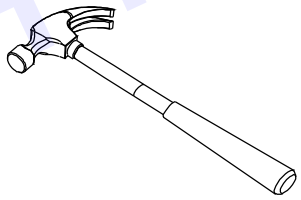
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Claw hammer: Hammer is used to hammering the nail and remove the nail (Fig 15)

1 Hammer is made of metal

A claw hammer is a tool primarily used for pounding nails into, or extracting nails from, some other object. Generally, a claw hammer is associated with woodworking but is not limited to use with wood products. It is not suitable for heavy hammering on metal surfaces (such as in machining work), as the steel of its head is somewhat brittle; the ball-peen hammer is more suitable for such metalwork.

Fig 15



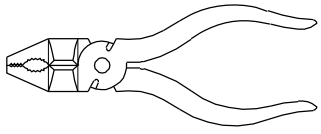
HAMMER

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Pliers: They are specified with their overall dimensions of length in mm. The pliers should have insulated grip.

Combination pliers with pipe grip, side cutter and insulated handle (Fig 16)

Fig 16



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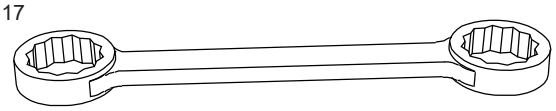
Size 150 mm, 200 mm etc

It is made of forged steel. It is used for cutting, twisting, pulling, holding and gripping small jobs in wiring assembly and repairing work.

Ring spanner set (Fig 17)

A spanner with an enclosed opening that grips the faces of the bolt or nut, the recess is generally a six-point or twelve-point opening for use with nuts or bolt heads with a hexagonal shape. The ring spanner is used in places where the space is restricted and where high leverage is required.

Fig 17



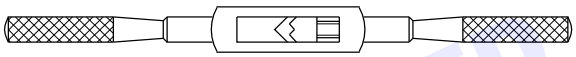
RING SPANNER

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Tapper thread (Fig 18)

Tool is used in the maintenance of textile machines. It is made of steel

Fig 18

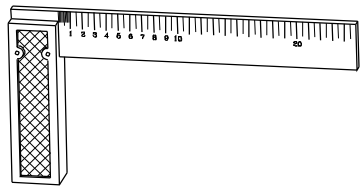


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Try square (Fig 19)

A try square is a woodworking or a metal working tool used for marking and measuring a piece of wood. The square refers to the tool's primary use of measuring the accuracy of a right angle (90 degrees); to try a surface is to check its straightness or correspondence to an adjoining surface. A piece of wood that is rectangular, flat, and has all edges (faces, sides, and ends) 90 degrees is called four square. A board is often milled four square in preparation for using it in building furniture.

Fig 19

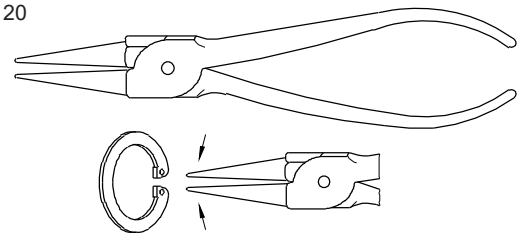


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Inner and outer circlip plier (Fig 20)

These pliers are widely used to assemble and disassemble circlips. The offered products are widely used in bore holes to fix the bearing

Fig 20



CIRCLIP PLIER

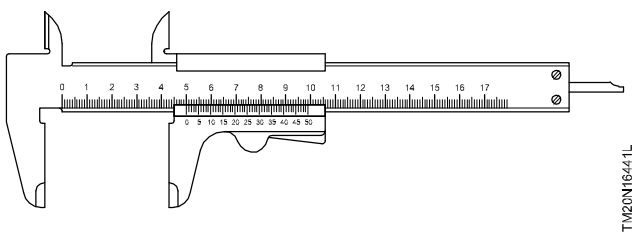
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Vernier scale (Fig 21)

A vernier scale is a device that lets the user measure more precisely than could be done unaided when reading a uniformly-divided straight or circular measurement scale. It is a scale that indicates where the measurement lies in between two of the marks on the main scale. Verniers are common on sextants used in navigation, scientific instruments used to conduct experiments, machinists' measuring tools (all sorts, but especially calipers and micrometers) used to work materials to fine tolerances, and on theodolites used in surveying.

Fig 21

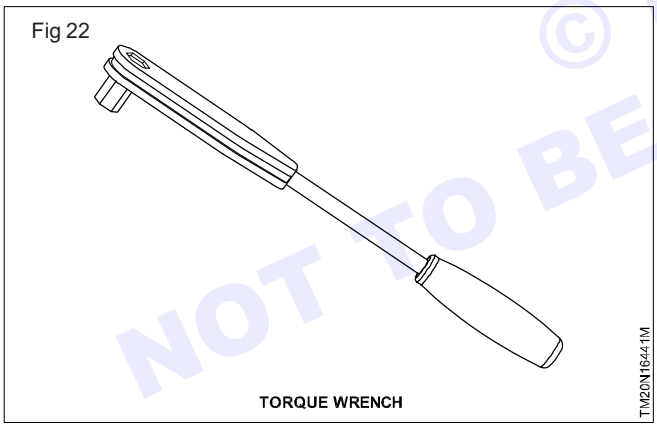


Torque wrench (Fig 22)

A torque wrench is a tool used to precisely apply a specific torque to a fastener such as a nut or bolt. It is usually in the form of a socket wrench with special internal mechanisms.

It was invented by Conrad Bahr in 1918 while working for the New York City Water Department. It was designed to prevent overtightening bolts on water main and steam pipe repairs underground.

Fig 22

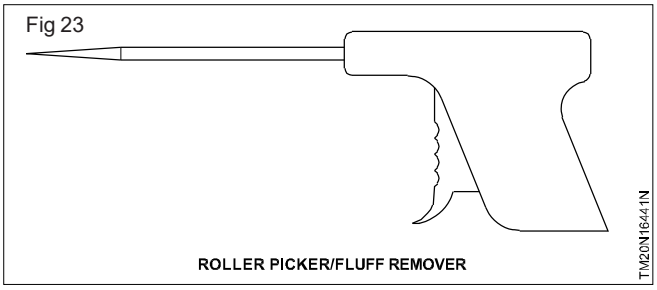


A torque wrench is used where the tightness of screws and bolts is crucial. It allows the operator to measure the torque applied to the fastener so it can be matched to the specifications for a particular application. This permits proper tension and loading of all parts. A torque wrench measures torque as a proxy for bolt tension. The technique suffers from inaccuracy due to inconsistent or uncalibrated friction between the fastener and its mating hole. Measuring bolt tension (bolt stretch) is more accurate but often torque is the only practical means of measurement

Roller picker / Fluff remover (Fig 23)

It provided gun is used to clean various spare parts of textile machines effectively without any manual intervention

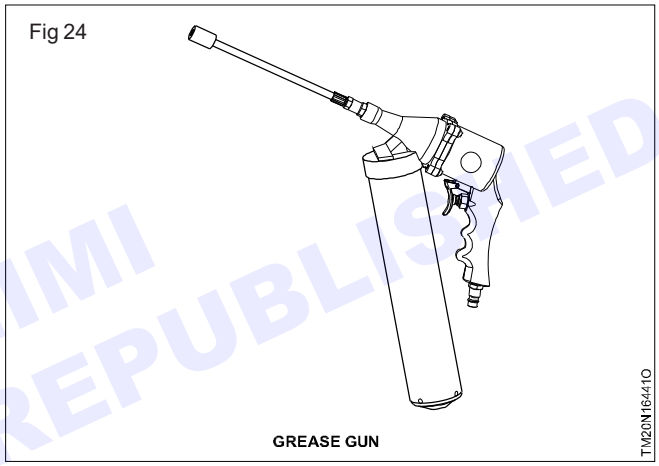
Fig 23



Grease gun (Fig 24)

A grease gun is a common workshop and garage tool used for lubrication. The purpose of the grease gun is to apply lubricant through an aperture to a specific point, usually on a grease fitting or 'nipple'. The channels behind the grease nipple lead to where the lubrication is needed. The aperture may be of a type that fits closely with a receiving aperture on any number of mechanical devices. The close fitting of the apertures ensures that lubricant is applied only where needed

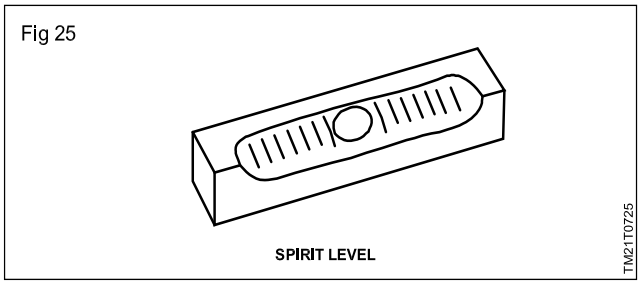
Fig 24



Spirit level (Fig 25)

A spirit level, bubble level or simply a level is an instrument designed to indicate whether a surface is horizontal (level) or vertical (plumb). Different types of spirit levels may be used by carpenters, stonemasons, bricklayers, other building trades' workers, surveyors, millwrights and other metalworkers, and in some photographic or video graphic work.

Fig 25



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General maintenance of electronics and electrical components

Objectives: At the end of this lesson you shall be able to
- **explain the maintenance of electronic components**
- **explain the maintenance of electrical components.**

Introduction

Corrective maintenance activities for the advance controller embrace troubleshooting activities and the subsequent remedial work to rectify the problem and return the controller to normal operation. In addition, some preventive testing and maintenance should be done to make sure the system is available and healthy

Making repairs promptly

A fault indication does not necessarily mean a vital part of the controller is not operational. Some faults have no immediate consequence - for example, the fault may be within one of the diagnostic systems. Nevertheless, the problem should still be rectified in a timely manner. System repair must be done promptly, to ensure faults do not accumulate. This principle applies as much to a redundant arrangement, which needs to ensure continued fault-tolerant operation, as to a simplex controller. Multiple failures can cause a plant shutdown.

Resolving multiple faults

The fault diagnosis procedures described in this manual will locate and resolve a single fault. If you follow one of the processes to its conclusion but a fault indication persists, one or more additional faults remain. Quarantine any defective items you have removed during your first investigation, then start again at the beginning of the appropriate procedure.

Required tools

Standard Tools

- Screwdriver, flat 0.8 x 9.0mm (1/25 c 3/8 inch), for the module clamp screws and blanking covers
- Screwdriver, cross head number 0, for battery cover on T9110 processor module
- Screwdriver, flat 0.8 x 4.0mm (1/25 x 5/32 inch), for locking screws on extension cables
- Torque screwdriver, flat 0.6 x 3.0 mm(1/40 x 1/8 inch, for dc power wiring terminals
- Torque screwdriver, flat 0.4 x 2.0mm (1/64 x 5/64), for field wiring terminals
- 2 x wrench, open end, 10mm, for ground stud nuts
- Allen key (hex wrench), 2.5mm, for plug and sockets assemblies used with extension cables

Special Tool

- Long nosed pliers to remove the fuses on termination assemblies.

Required test equipment

1 Digital voltmeter
   - DC voltage range 0 to 32V or better.
   - Resistance resolution 0.01? or better.

2 Current simulation instrument
   - Output range 4 to 20mA with an accuracy better than 0.05mA.

3 Bench power supply
   - Output range 0 to 32V dc.

Preventive maintenance

Safety systems are designed to run continuously without manual intervention. However, some preventive maintenance should be done to make sure the system is available and healthy. This chapter describes the preventive maintenance activities for an advance controller

Preventive Maintenance Task	Interval
Review status LEDs	Daily
Check fuses	3 months
Check wiring terminals	3 months
Check seating of plug-in components	3 months
Check for contamination, general condition and	3 months
Adequate environmental protection	3 months
Check ground connection	3 months
Check analogue input module calibration	2 years
Check digital input module calibration	3 years
Check analogue output module calibration	2 years
Perform manual test	Manual Test Interval

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Predictive maintenance

What is "predictive maintenance"? Predictive maintenance means using electronic pressure sensors and transmitters to monitor the smooth running of a production line and, more critically, to connect those sensors to software that can create models that accurately predict when equipment will degrade or performance will fall off. This adjustment can serve as an accurate predictor for optimal "just-in-time" equipment maintenance.

Predictive maintenance can eliminate the surprises of corrective maintenance, which happens after equipment fails. Predictive maintenance also cuts down on the unscheduled (and often unnecessary) equipment stoppages needed to perform scheduled preventive maintenance.

By taking accurate readings of conditions inside your critical machinery and equipment, an electronic pressure sensor helps you to zero in on problem areas before they impact operations. In the process, you can eliminate corollary problems or damage that can result when a component fails or breaks.

Most important of all, predictive maintenance techniques maximize your operation's productivity while cutting maintenance costs. As if that weren't enough, electronic pressure sensors and predictive maintenance can make your trend data much more accurate, enabling you to plan ahead for maintenance, repairs, and parts orders.

Calibration

To calibrate an instrument means to check and adjust (if necessary) its response so the output accurately corresponds to its input throughout a specified range. In order to do this, one must expose the instrument to an actual input stimulus of precisely known quantity. For a pressure gauge, indicator, or transmitter, this would mean subjecting the pressure instrument to known fluid pressures and comparing the instrument response against those known pressure quantities. One cannot perform a true calibration without comparing an instrument's response to known, physical stimuli.

To range an instrument means to set the lower and upper range values so it responds with the desired sensitivity to changes in input. For example, a pressure transmitter set to a range of 0 to 200 PSI (0 PSI = 4 mA output; 200 PSI = 20 mA output) could be re-ranged to respond on a scale of 0 to 150 PSI (0 PSI = 4 mA ; 150 PSI = 20 mA). In analog instruments, re-ranging could (usually) only be accomplished by re-calibration, since the same adjustments were used to achieve both purposes. In digital instruments, calibration and ranging are typically separate adjustments (i.e. it is possible to re-range a digital transmitter without having to perform a complete recalibration), so it is important to understand the difference.

Zero and span adjustments (analog instruments)

The purpose of calibration is to ensure the input and output of an instrument correspond to one another predictably throughout the entire range of operation. Things become more complicated when the input and output axes are represented by units of measurement other than "percent." Take for instance a pressure transmitter, a device designed to sense a fluid pressure and output an electronic signal corresponding to that pressure. Here is a graph for a pressure transmitter with an input range of 0 to 100 pounds per square inch

Zero adjustments typically take one or more of the following forms in an instrument:

- Bias force (spring or mass force applied to a mechanism)
- Mechanical offset (adding or subtracting a certain amount of motion)
- Bias voltage (adding or subtracting a certain amount of potential)

Span adjustments typically take one of these forms

- Fulcrum position for a lever (changing the force or motion multiplication)
- Amplifier gain (multiplying or dividing a voltage signal)
- Spring rate (changing the force per unit distance of stretch)

Electrical maintenance

General

This document is intended to establish standard practice as well as to give general advice and guidance in the maintenance of electrical equipment owned and operated by the Bureau of Reclamation. Specific technical details of maintenance are included in other documents which are referenced in this document.

Maintenance recommendations are based on industry standards and experience in Reclamation facilities. However, equipment and situations vary greatly, and sound engineering and management judgment must be exercised when applying these recommendations. Other sources of information must be consulted (e.g., manufacturer's recommendations, unusual operating conditions, personal experience with the equipment, etc.) in conjunction with these maintenance recommendations.

Preventive maintenance

Preventive maintenance (PM) is the practice of maintaining equipment on a regular schedule, based on elapsed time, run-time meter readings, or number of operations. The intent of PM is to "prevent" maintenance problems or failures before they take place by following routine and comprehensive maintenance procedures. The goal is to achieve fewer, shorter, and more predictable outages.

Some advantages of preventive maintenance are

- It is predictable, making budgeting, planning, and resource leveling possible.
- When properly practiced, it generally prevents most major problems, thus reducing forced outages, reactive maintenance and maintenance costs in general.
- It gives managers a level of assurance that equipment is being maintained.

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- It is easily understood and justified.

Preventive maintenance does have some drawbacks

- It is time consuming and resource intensive.
- It does not consider actual equipment condition when scheduling or performing the maintenance.
- It can cause problems in equipment in addition to solving them (e.g., damaging seals, stripping threads).

Reliability centered maintenance

Reliability-centered maintenance programs are gaining in popularity and have been piloted in a few Reclamation power facilities with good results. The goal of these programs is to provide the appropriate amount of maintenance at the right time to prevent forced outages while at the same time eliminating unnecessary maintenance.

Implemented properly, RCM can eliminate some of the drawbacks of preventive maintenance and may result in a more streamlined, efficient maintenance program. RCM seems very attractive in times of diminishing funding, scarcity of skilled maintenance staff, and the pressure to "stay online" due to electric utility industry deregulation.

Some features of RCM are

- Labor intensive and time consuming to set up initially.
- May require additional monitoring of quantities like temperature and vibration to be effective. This may mean new monitoring equipment with its own PM or more human monitoring with multiple inspections.
- May result in a orun-to-failure or deferred maintenance philosophy for some equipment with its own PM, which may cause concern for some staff and managers.
- May require initial and later revisions to the maintenance schedule in a otrialand-error fashion depending on the success of the initial maintenance schedule and equipment condition.
- Should result in a more manageable maintenance workload focused on the most important equipment.

RCM is not an excuse to move to a "breakdown maintenance" philosophy or to eliminate critical preventive maintenance in the name of reducing maintenance staff/funding. However, to mitigate problems associated with a PM program, maintenance managers may choose to apply a consciously chosen, effectively implemented, and properly documented

RCM program

Condition-based maintenance

This program relies on knowing the condition of individual pieces of equipment.

Some features of CBM include

- Monitoring equipment parameters such as temperatures, pressures, vibrations, leakage current, dissolved gas analysis, etc.
- Testing on a periodic basis and/or when problems are suspected such as double testing, vibration testing, and infrared scanning.
- Careful monitoring of operator-gathered data.
- Results in knowledgeable maintenance decisions which would reduce overall costs by focusing only on equipment that really needs attention.

Control circuits

General

Control circuits (usually 125 Vdc, 250 Vdc, or 120 Vac) provide the path for all control functions for major equipment in the power plant. Reliability of these circuits is paramount. Although tested during commissioning, these circuits can become compromised over time through various means:

- Modifications and construction work which unintentionally break circuit integrity or introduce wiring errors.
- Age and deterioration of wiring rendering the system nonfunctional.
- Connections that become loose.
- Failure of individual control and protection devices due to misuse, old age, or inadvertent damage.

Verifying the integrity of the control devices and interconnecting wiring requires a "functional test" of these circuits. Functional testing of control circuits may be considered completed in the course of normal plant operation. However, control circuits that rarely are used should be functionally tested on a periodic basis.

Relays and protection circuits

General

Western Electricity Coordinating Council (WECC) Minimum Operating Reliability Criteria requires that: "Each system shall provide for periodic testing of protective systems and remedial action schemes which impact the reliability and security of the interconnected system operation."

Protective relays monitor critical electrical and mechanical quantities and initiate emergency shutdown whenever they detect out-of-limits conditions. Protective relays must operate correctly when abnormal conditions require and must not operate at any other time.

Electrical protective relays are calibrated with settings derived from system fault and load studies. Initial settings are provided when relays are installed or replaced. However, electrical power systems change as new generation and transmission lines are added or modified. This may mean that relay settings are no longer appropriate. Outdated relay settings can be hazardous to personnel, to the integrity of the power plant and power system, and to the equipment itself. Therefore, it is necessary to periodically conduct a fault and load study and review protective relay settings to ensure safe and reliable operation.

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Fault and load studies and relay settings are provided by the Electrical Design Group (D-8440) at 303-445-2850. Field-initiated changes to relay settings should be verified by this group. Protective relays currently in use in Reclamation include electro-mechanical, solid-state, and microprocessor-based packages. Calibration and maintenance recommendations differ from type to type because of their different design and operating features.

Safety during maintenance: Performing maintenance on electrical equipment can be hazardous. Electrical and mechanical energy can cause injury and death if not managed properly. All maintenance activity must be conducted in accordance with FIST Volume 1-1, Hazardous Energy Control Program (HECP), and Reclamation Safety and Health Standards (RSHS). A job hazard analysis (JHA) must be conducted as well. Visitors, contractors, and others working under clearances must be trained in HECP and must follow all JHA and clearance procedures.

General maintenance of textile machines

Objectives: At the end of this lesson you shall be able to
- **state the introduction of maintenance**
- **list the two systems of maintenance and state it**
- **state the installation of flat belts and reinstalling an old belt**
- **state the maintenance of V belt and V pulley**
- **state the lubrication of gear wheel, bearing and its effects**
- **state the precautions while lubricating a bearing**
- **state the mounting of different bearings.**

Introduction

In the context of modern machinery and rising costs, the penalties for maintenance lapsed are too severe. For instance, if the production per spindle in a 25,000 spindle mill spinning 40sNe yarn is about 1% lower than that is possible by maintaining machinery in good condition, then this under-maintenance is costing that mill nearly Rs. 25 lakhs a year.

The modern textile machineries are very intricate. Some of the very advanced engineering techniques are incorporated and machineries are operated much closer to their limits. For their reliability and efficiency, they require more precise and finer settings, and demand closer attention than their predecessors. Also, high speed and unconventional spinning machineries introduced in the past decade are controlled with built-in electronic monitor devices, both on-line as well as off-line. They need prompt renovation and replacement as and when they are due. This is not, however, to suggest that old and ageing machines need any less attention. Whether it is old or modern machine, maintenance has to be planned and directed in a systematic manner for its efficient functioning.

There are also ever increasing economic pressures which compel a mill to use its high capital equipment to the fullest extent so that it can survive in the intensely competitive conditions of today. For this, a proper maintenance is essential.

Two systems of maintenance

Before going into these concepts, it is useful to make a few remarks about the maintenance systems in general. Basically, the systems can be distinguished into two types:

1 Breakdown Maintenance

2 Planned Maintenance

Breakdown maintenance

In this system, attention is given to a machine only when it breaks down. Essentially, this is an unplanned system and found wide acceptance chiefly because of the advantage of low direct costs.

The system suffers from two main drawbacks. Firstly, in this system the machinery and equipment will wear out prematurely, and as a consequence will produce sub-standard quality, the penalties for which are quite heavy. In the second place, because of the lack of regular servicing the machines will be prone to frequent breakdowns, which will lead to proportional losses in productivity. For these reasons, it is generally agreed today that this ideal of machinery maintenance is highly unsatisfactory and should, therefore, be best avoided to prevent obsolescence in spinning mills.

Planned maintenance

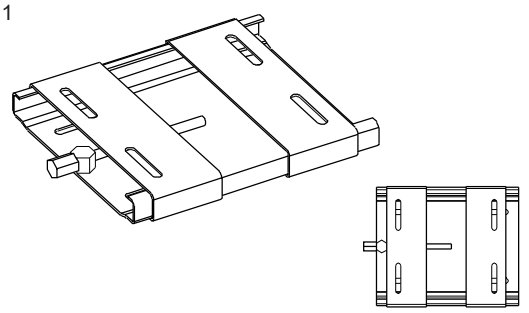
As the term implies, in this system, maintenance is planned in advance as against unplanned or haphazard activities characterising the previous system. But the differences are more fundamental than that. The system is based upon scientific and technical principals, and therefore provides for proper preservation of machinery and equipment and their rational, economical and technical use.

Motor plate (Fig 1)

A Sole plate is a base plate grouted into a concrete foundation in order to provide vibration support and leveling support for a machine, such as a pump or a compressor. Depending upon the design engineering, there are usually bolt holes or pre-installed anchor bolts required to secure the feet of the machine to the machined plate. Often times, leveling pads or steel footings or shims are required in order to adjust to a flat, level surface during installation.

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Fig 1



MOTOR BASE PLATE

TM20N164421

Although mainly used for inside machine floor support applications, many base plates are used to support heavy equipment such as compressors, generators, motors, and pumps outdoors. As an example, machine base plates are installed underneath machines located at utility distribution sites as well as alongside industrial buildings.

Belt and pulley systems

A belt and pulley system is characterised by two or more pulleys in common to a belt. This allows for mechanical power, torque, and speed to be transmitted across axles. If the pulleys are of differing diameters, a mechanical advantage is realised.

A belt drive is analogous to that of a chain drive, however a belt sheave may be smooth (devoid of discrete interlocking members as would be found on a chain sprocket, spur gear, or timing belt) so that the mechanical advantage is approximately given by the ratio of the pitch diameter of the sheaves only, not fixed exactly by the ratio of teeth as with gears and sprockets.

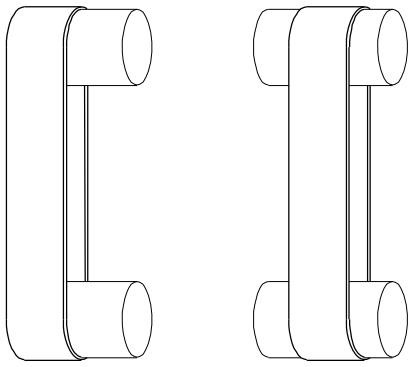
In the case of a drum-style pulley, without a groove or flanges, the pulley often is slightly convex to keep the flat belt centered. It is sometimes referred to as a crowned pulley. Though once widely used on factory line shafts, this type of pulley is still found driving the rotating brush in upright vacuum cleaners, in belt sanders and band saws. It has been replaced by other mechanisms with more flexibility in methods of use, such as power take-off and hydraulics.

Just as the diameters of gears (and, correspondingly, their number of teeth) determine a gear ratio and thus the speed increases or reductions and the mechanical advantage that they can deliver, the diameters of pulleys determine those same factors. Cone pulleys and step pulleys (which operate on the same principle, although the names tend to be applied to flat belt versions and V belt versions, respectively) are a way to provide multiple drive ratios in a belt-and-pulley system that can be shifted as needed, just as a transmission provides this function with a gear train that can be shifted. V belt step pulleys are the most common way that drill presses deliver a range of spindle speeds.

Installation of flat belts (Fig 2)

The procedure for installing new flat belt is different from those old belts.

Fig 2



BELT SHIFTED TO ONE SIDE

RUNNING IN CENTER

POSITION OF FLAT BELTS

TM20N164422

New flat belt

1 Before installing the belt, check parallelism of shaft and alignment of pulley and ensure that both are true/OK.

2 Make a mark 1000 mm apart on the un-tensioned belt. In case the centre distance is small make a mark of 500 mm and 200 mm apart.

3 Mount the belt on the pulley.

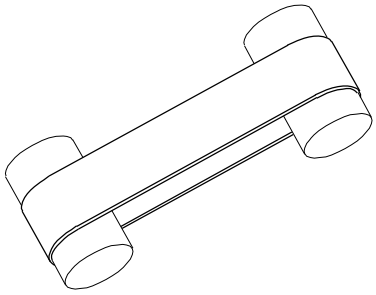
4 Tension the belt by increasing the distance between the driving and driven pulley till the distance between the measuring marks increases to the value of initial tension.

For example if the initial tension was 2.30%, then the distance between the measured mark on un-tensioned belt of 1000 mm should be increased till the it reaches 1023 mm.

To verify that tracking of belt is proper give several full turns to pulley and ensure that the belt does not run off.

Reinstalling an old belt (Fig 3)

Fig 3



FLAT BELT

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1 Before relaxing the belt for reinstalling, measure the distance between the existing measuring marks with the help of measuring tape.

2 Completely relax and demount the belt.

3 For reinstalling, mount the belt on, and increase the tension on the belt until originally measured distance between the marks is reached.

Maintenance of V belt

1 In a multiple V drive belt, always replace the set of belts if one or more belt breaks. Replacement of one belt only

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results in undue stretching of the new belt and which moves with a different velocity. This will reduce the life of new belt.

2 In multiple V drive, putting one or two belts less than the number required, reduces the life of the belt by 30-50%.

3 Check the pulley for wear before putting the belt.

4 When the drives are expected to remain stationary for long period, relax the operational tension.

5 Always give proper tension to the belt and check the belt tension regularly.

6 Do not use sharp tools to mount the belt forcibly.

7 Keep the free from oil and grease and belt dressing lubricant should never be used.

V pulley

These are used to transmit full power along with V belts without undue wear.

V pulleys must have correct groove dimensions. Other important factors are listed below.

1 V pulleys should be free from porosity or blow holes in the groove faces.

2 Sides of the grooves should be free from burrs.

3 Top corners of all grooves should be rounded.

4 Worn out pulleys should be replaced by new pulleys.

5 Any V pulley smaller than the recommended minimum pitch diameter should not be used.

6 Side wobble and run out should be within tolerances.

Lubrication of gear wheel

1 Open gear

Gears should be properly lubricated to: minimize wear, prevent the generation of excessive heat, improve efficiency through the reduction of friction between the mating tooth surfaces, reduce noise and inhibit the formation of rust. Good lubrication depends on the formation of a film thick enough to prevent contact between the mating surfaces. The relative motion between gear teeth helps to produce the necessary film from the small wedge formed adjacent to the area of contact. It is important that an adequate supply of the correct lubricant is properly applied. In open gears mostly extreme pressure grease are used.

Gear box lubrication

i **Recommended oil:** In all machineries, a certain amount of power is required to overcome friction within the lubricating film itself. Friction of this kind is largely a function of the viscosity of the lubricant. To minimize power consumption, it is necessary to use oil with optimum viscosity compatible with satisfactory lubrication, while taking account of considerations like splashing and the rate of oil consumption. Oxidation tends to cause thickening of oil in service; therefore, it is advantageous to use lubricants with high oxidation stability. Such lubricants change less in viscosity with increase in temperature.

ii Recommended oil level

Industrial gears may be either of the enclosed type or of the open type. In the enclosed type a minimum level of oil is maintained. In the gearbox, teeth of the bottom gears are just dipped into the oil and gear are lubricated by means of splash. In case of splash lubrication it is necessary that oil level should not be too high. A high level results in churning of oil which in turn results in consequent rise in oil temperature and in power loss. The depth to which the bottom wheel is dipped is twice the tooth depth. This is sufficient for splash lubrication and to keep the churning effect to the minimum. Secondly, a pressure circulating system may be used in which oil is sprayed on the teeth close to the point of engagement.

The oil is then recirculated either directly from the bottom of the gear box or by way of a separate tank with the help of oil pump.

Reasons for the failure of gear teeth

1 Fatigue - When two gears mesh with each other to transmit a load, the teeth of each gear are under bending action. The bending stress will be maximum at the root of tooth. Due to the periodical effect of the load, fatigue cracks may occur near the tooth base resulting in ultimate failure of tooth.

2 Wear - When some foreign material like dust particles deposited in between the mating teeth there will be wear of tooth surface.

3 Improper meshing.

Lubrication of bearing

The objective of lubricating a bearing is to form a film of oil on the rolling and sliding surfaces to prevent metal parts from making direct contact with each other.

Lubrication provides the following effects

1 Reduces friction and wear,

2 Discharges friction heat,

3 Extends bearing life,

4 Prevents rust and

5 Prevents foreign material from getting inside.

In order to get the most from the lubricant, one must choose a lubricant and lubrication method that suits your usage conditions, and must make use of sealing devices for preventing dirt from getting in and lubricant from leaking out.

Grease is widely used because it is easy to handle, it facilitates sealing device design, and is the most economical lubricant. The technique of varies lubrication according to whether bearings are either separable or non separable and whether their housing are split type or one piece.

Sealed bearing: Sealed bearings where the grease is sealed inside the bearing. These sealed bearings do not need any re- lubrication. It is not advisable to open the seal/ shield for lubrication, as the seal/shield will not fit tight properly again.

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Non-separable bearing

The deep groove and angular contact ball bearing are non-separable bearings. These should be filled with grease from both ends. In self-aligning and spherical roller bearings, the outer ring can be swivelled so that rolling elements are accessible. Grease can be then injected into all free spaces between them.

Separable bearing

These include cylindrical, taper roller and all types of thrust bearings. These bearings are greased in separate steps, the same order to determine by mounting sequence.

After mounting the first ring, if this ring has a non-separable ball/roller and cage assembly attached to it then grease the ring and fill the internal space with grease. If the ring is separate, it is sufficient to grease it lightly so that it will not get damaged when the outer ring with cage and ball/ roller is pushed on it.

Ball bearing in housing

When ball bearings are contained in housing with removable cover and no grease nipple, they are managed with long-greasing intervals. Before regreasing, these bearings are to be dismounted and flushed out thoroughly. When fitting the bearing again the bearing and its housing is to be filled with grease, about one-third for shafts running at more than 500 rip. If the bearings are packed full then balls have no room to turn and the bearing gets hot. Slow running bearings may be packed full.

Bearing with grease nipple

These bearings are lubricated with a grease gun as per schedule. These bearing require a very little quantity of grease (one or two strokes of the grease gun). Bearings in housing equipped with grease nipple require 10 - 15 stroke of grease gun (10 - 15 g) of grease at every re-lubricating interval).

Precautions while lubricating a bearing

1 Use only the recommended grade of grease. If a higher grade of grease is used, it would become stiff at very low temperature results in poor lubrication. The rolling elements of the bearing rotate with difficulty and may slow down or stop completely in unloaded zone. When the elements pass back into the loaded zone, they are immediately forced to accelerate under load which results in heavy sliding. Lower grade grease is used then at high temperature, there is a risk of leakage of grease. At extremely high temperatures, the lubricate grease particularly metallic soap grease oxidize rapidly and then grease hardens and bleeding oil stops completely.

2 When a bearing is to be lubricated then first clean the grease nipple and area around the fitting to avoid any combination.

3 Never mix the grease of different thickener then resulting mixture will be either softer or sometime even much stiffer.

Mounting of different bearings

The following precautions should be taken while mounting the bearings:

1 Clean the shaft and abutment shoulders and check the seating with regard to the diameter tolerance and accuracy.

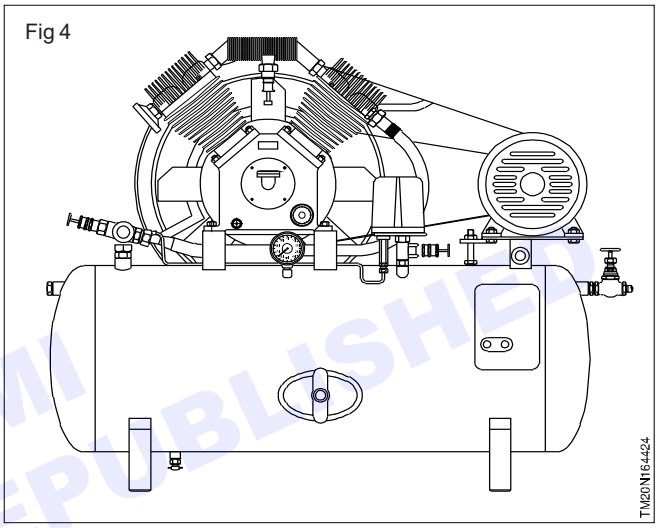
2 Do not remove the bearing from packaging till mounting.

3 Protect the new bearing from dirt to the extent possible.

4 Leave the rust inhibiting compound intact except in the bearing bore and on the outer ring's outside surface. Wash these surfaces with a petroleum-based solvent and dry.

Air compressor (Fig 4)

Fig 4



The basic components of the air compressor the electric motor, pump, pressure switch, and tank. The electric motor powers the pump. The electric motor is equipped with an overload protector and an automatic reset. If the motor becomes overheated, the overload protector will shut it down to prevent damage to the motor. When the motor sufficiently cools, it will automatically restart. The pump compresses the air and discharges it into the tank. The tank stores the compressed air. The pressure switch (located internally) shuts down the motor and relieves air pressure in the pump and transfer tube when the air pressure in the tank reaches the kick-out pressure. As compressed air is used and the pressure level in the tank drops to the kick-in pressure, the pressure, the pressure switch restarts the motor automatically, without warning, and the pump resumes compressing air. Body of the air compressor is made of metal

Maintenance Practices of air compressor: Good and proper maintenance practices will dramatically improve the performance efficiency of a compressor system. Following are a few tips for efficient operation and maintenance of industrial compressed air systems:

Lubrication: Compressor oil pressure should be visually checked daily, and the oil filter changed monthly.

Air Filters: The inlet air filter can easily become clogged, particularly in dusty environments. Filters should be checked and replaced regularly.

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Condensate traps

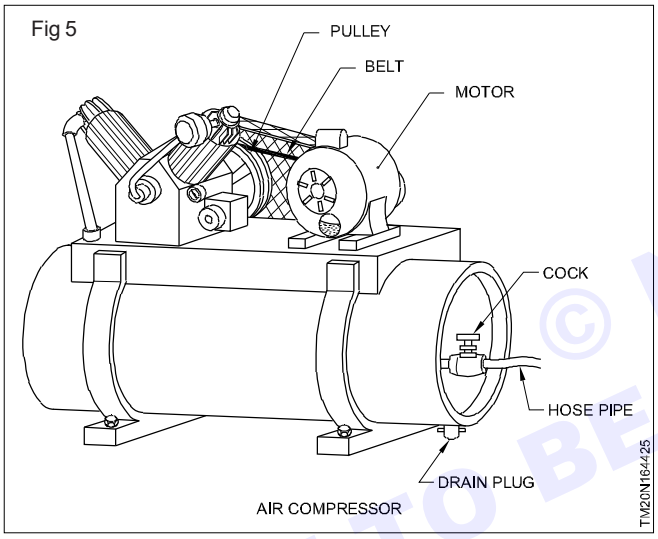
Many systems have condensate traps to gather and (for those traps fitted with a float operated valve) flush condensate from the system. Manual traps should be periodically opened and re-closed to drain any accumulated fluid; automatic traps should be checked to verify they are not leaking compressed air.

Air dryers

Drying air is energy-intensive. For refrigerated dryers, inspect and replace prefilters regularly as these dryers often have small internal passages that can become plugged with contaminants. Regenerative dryers require an effective oil-removal filter on their inlets, as they will not function well if lubricating oil from the compressor coats the desiccant. The temperature of deliquescent dryers should be kept below 100°F to avoid increased consumption of the desiccant material, which should be replenished every 3-4 months depending on the rate of depletion.

Parts of air compressor (Fig 5)

Fig 5



Basic principle of pneumatic transport: Air is not inherently a very efficient transport medium. Very large quantities must be moved at high speeds in order to keep the tufts that are being transported floating. The current of air itself is a further disadvantage, since the air flows in a turbulent fashion through the ducting, i.e. vortexes are created. Since the tufts are subjected to these vortexes, entangling of tufts can arise in long ducts and finally neps can be formed.

A closed duct (generally a pipe) and a source of partial vacuum (a fan) at one end of the duct are needed to move the air. The air speed should be at least 10 m/sec, and 12

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15 m/sec is better; it should never exceed 20 - 24 m/sec. At a given air speed, the required quantity of air can be calculated as:

L ({m^3}/s) = A \times v

where L is the quantity of air; A is the cross section of the duct in m2; v is the air speed in m/s. The duct must terminate in a device that separates the air from the material.

Separation of air and material

By far the most widely used assembly for this purpose is the perforated drum. It is used in various machines and parts, often in so-called suction boxes (condensers).

A partial vacuum is created in the drum, and thus in the duct, by a fan at one end of the drum. Air and material flow toward the drum. However, while the air can pass through the perforations in the drum, and is then passed to filters for cleaning, the fiber tufts remain on the surface of the rotating drum and are carried along with it. In the lower region, the drum surface is screened off from the partial vacuum in its interior. The tufts are no longer retained by suction and fall into a chute. Another assembly for separating air and material is the slotted chute, where the transport air is extracted through the slot, while the material slides down on the aluminum ribs of the rear wall of the chute.

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Safety gadgets

Objectives: At the end of this lesson you shall be able to
- **list the safety gadgets**
- **state the importance and use of safety gadgets.**

Personal protective equipment (PPE) refers to protective clothing, helmets, goggles, or other garment or equipment designed to protect the wearer's body from injury by blunt impacts, electrical hazards, heat, chemicals, and infection, for job-related occupational safety and health purposes

All safety gadgets should be of safe design and construction, and should be maintained in a clean and reliable fashion. Employers should take the fit and comfort of safety gadgets into consideration when selecting appropriate items for their workplace. Safety gadgets that fit well and are comfortable to wear will encourage employees to use the safety gadgets. Most protective devices are available in multiple sizes and care should be taken to select the proper size for each employee. If different types of safety gadgets are worn together; make sure they are compatible. If safety gadgets do not fit properly, it can make the difference between being safely covered or dangerously exposed. It may not provide the level of protection desired and may discourage employee while in use.

Some of the safety gadgets as well as their uses are given below;

- **Gloves - protect hands (Fig 1)**

Fig 1



GLOVES

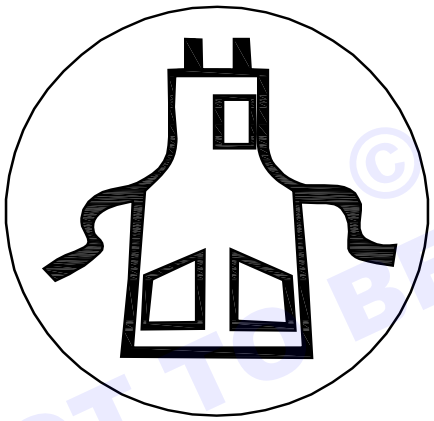
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Hand gloves are used to prevent the hands from chemicals, sharp edges, glass and against injury

- **Gowns/aprons - protect skin and/or clothing (Fig 2)**

An apron is an outer protective garment that covers primarily the front of the body. It may be worn for hygienic reasons as well as in order to protect clothes from wear and tear.

Fig 2

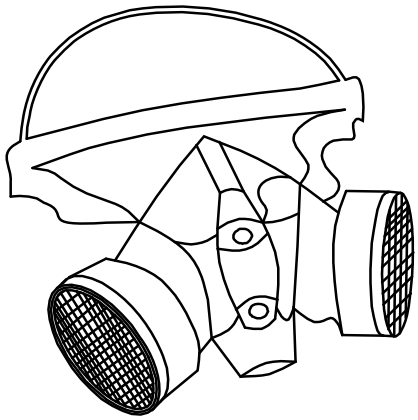


GOWN/APRONS

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- **Masks and respirators - protect mouth/nose (Fig 3)**

Fig 3



MASKS AND RESPIRATORS

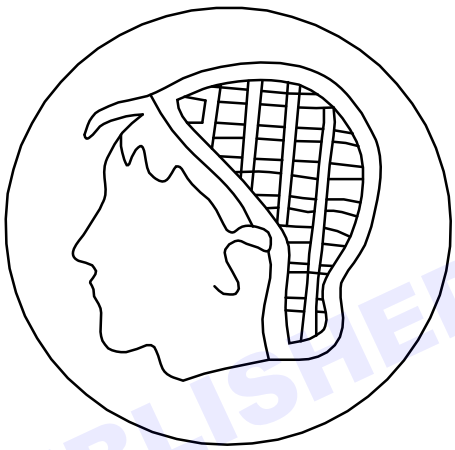
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A respirator is a device designed to protect the wearer from inhaling harmful dusts, fumes, vapors, or gases. Respirators come in a wide range of types and sizes used by the military, private industry, and the public. Respirators range from cheaper, single-use, disposable masks to reusable models with replaceable cartridges.

There are two main categories: the air-purifying respirator, which forces contaminated air through a filtering element, and the air-supplied respirator, in which an alternate supply of fresh air is delivered. Within each category, different techniques are employed to reduce or eliminate noxious airborne contents.

Head cap (Fig 4)

Fig 4



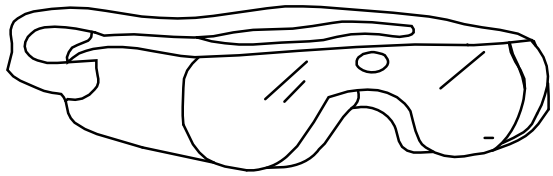
HEAD CAP

TM21T0804

A 'bouffant cap' (from its resemblance to the hairstyle) is a type of cap that completely covers the hair for use in clean rooms and other situations where it is important to avoid loose hairs. They are usually made of polypropylene or some other non-woven material, with an elastic band around the rim to keep it tight around the forehead and the back of the head below the hairline. Bouffant caps are a popular and economical choice of workplace head covering.

Goggle (Fig 5)

Fig 5



GOGGLE

TM21T0805

Safety goggles serve as protection from debris and hazardous materials. These goggles make certain your home-improvement projects, crafts activities and science experiments cause no damage to your eyes. They work well because they completely surround your eyes. Using safety goggles correctly can help preserve your eyesight. Be sure to choose adjustable goggles that cover the eye socket.

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Safety shoes (Fig 6)

Fig 6



SAFETY SHOES

TM21T0806

Foot protection is required when workers could suffer injuries from crushing or penetrating materials. When equipment such as nails or spikes could penetrate standard footwear, workers must wear safety shoes that are resistant to penetration while on the job. In work environments with rolling equipment such as forklifts or heavy tools that could drop on the feet, workers must wear safety shoes that protect the foot from crushing. Workers exposed to hot, poisonous or corrosive materials must use safety shoes to prevent injury, as well.

Safety shoes have impact-resistant toes and heat-resistant soles that protect the feet against hot work surfaces common in roofing, paving and hot metal industries. The metal insoles of some safety shoes protect against puncture wounds. Safety shoes may also be designed to be electrically conductive to prevent the buildup of static electricity in areas with the potential for explosive atmospheres or nonconductive to protect workers from workplace electrical hazards.

Benefits

Safety shoes protect workers from falling objects, chemical spills, wet or slippery flooring, sharp objects and other hazards. They are available for men and women.

Uses

Workers in the manufacturing and construction industries routinely wear safety shoes. Other workers who wear safety shoes include chemical laboratory employees and firefighters.

First aid

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

- **state what an accident is**
- **state the causes for accidents**
- **state about first aid and first aid kit**
- **state about electric shock and its effects**
- **state about fractures and its symptoms**
- **state about snake bite and its symptoms**
- **state about burns and its categories**
- **state about cut and bleeding**
- **state about fainting and its symptoms**
- **state about epilepsy and its symptoms**
- **state what is attitude**
- **state about safety signs and its types.**

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What is an accident?

An accident is an unforeseen and unplanned event or circumstance, often with lack of intention or necessity. It usually implies a generally negative outcome which may have been avoided or prevented had circumstances leading up to the accident been recognized, and acted upon, prior to its occurrence.

Causes for accidents

Some of the important causes are listed below.

- Unawareness of danger
- Disregard for safety
- Negligence
- Lack of understanding of proper safety procedures
- Untidy condition of work place
- Inadequate light and ventilation
- Improper use of tools
- Unsafe conditions

First aid: The first help given to the victim when an accident occurs.

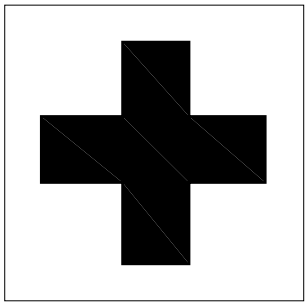
First aid kit: First aid kit is a collection of supplies and equipment for use in giving first aid, First aid kits should provide a basic range of products to deal with most types of injuries encountered in the workplace. Components should include treating the injuries like major wounds, minor wounds (i.e., cuts and abrasions), minor burns and eye injuries. Depending on the workplace additional first aid kit components should be selected in addition to the basic components to address these hazards.

ISO First Aid Symbol (Fig 1)

Under ANSI standard, Z308.1-2009, first aid kits are divided into three different categories or classifications.

Type I: Proposed for use in stationary, indoor applications where kit contents have minimal potential for damage

Fig 1



ISO FIRST AID SYMBOL

TM22T0201

These kits are not intended to be portable and should have a means for mounting in a fixed position. Some applications for Type I first aid kits are general indoor use, office use or in a light manufacturing facility. A first aid cabinet comes in this classification.

Type II: Proposed for use in portable indoor applications. Kit contents should have minimal potential for damage. These kits should be equipped with a carrying handle. Some applications for Type II first aid kits are general indoor use, office or manufacturing environments.

Type III: Proposed for portable use in mobile industries and/ or outdoor applications. Kits should be moisture resistant, equipped with a carrying handle, have the means for being mounted in a fixed position and should also be corrosion resistant.

The medicines that have to be kept in the First aid kit box are,

- Sterile adhesive bandages in assorted sizes
- Small roll of absorbent gauze or gauze pads of different sizes
- Adhesive tape
- Triangular and roller bandages
- Cotton (1 roll)
- Band-aids (Plasters)
- Scissors
- Pen torch
- Latex gloves (2 pair)
- Tweezers
- Needle
- Moistened towels and clean dry cloth pieces.
- Antiseptic lotions
- Thermometer
- Tube of petroleum jelly or other lubricant
- Assorted sizes of safety pins
- Cleansing agent/soap

Tourniquets are not recommended for general first aid kids. A tourniquet typically is a last resort in the event of life-threatening injuries and should be administered only by a trained person. Items other than the minimum fill and those recommended by a person knowledgeable in first aid and of the hazards in the specific workplace environment should not be first aid kit components.

First aid kit placement

There are not any specific requirements that outline where a first aid kit should be located or how it should be identified. As a general rule, a first aid kit should be unlocked, accessible and placed in a highly visible area. Kits should be easily identifiable by either a sign or other easily recognized markings that designate it as a first aid kit.

First aid kit inspection

First aid kits should be regularly inspected to ensure that they are full, in good condition and the contents have not expired. The first aid kit components list should be periodically reviewed to ensure that it meets the needs of the workplace hazards at all times.

First aid kit Use

The ANSI standard recommends that in addition to a first aid kit, each work location should have at least one individual available who is trained in first aid and CPR.

Electrical shock

Electric shock is caused by the passage of electric current through the body (as from contact with high voltage lines or being struck by lightning); usually involves burns and abnormal heart rhythm and unconsciousness.

Effect of electric shock in human

- Muscle contraction
- Seizures
- Dehydration
- Burns
- Fractures
- Clotting of blood
- Tissue death (narcosis)
- Respiratory/Heart/Kidney failure

Prevention of electric shock

- Proper design, installation, maintenance of electric devices
- Educating the public regarding electrical devices
- Keep electrical gadgets out of children's reach
- Learn to respect electricity and electrical devices

Fracture: Fracture is a medical condition in which there is a break in the continuity of the bone. Fracture occurs when pressure is applied to bone. Fracture can cause damage to adjacent structures such as nerves or vessels, spinal cord and nerve roots (for spine fractures), or cranial contents (for skull fractures).

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Types of fractures

- Open fracture: Skin breaks causing open wound
- Closed fracture: Skin not broken
- Complicated fractures: Damage of adjacent organs
- Stress fracture: Hairline crack due to repeated stress
- Greenstick fracture: In children's flexible bones

Symptoms

- Severe pain
- Difficulty in movement
- Swelling/ bruising / bleeding
- Deformity / abnormal twist of limb
- Tenderness on applying pressure

Prevention of fractures

- Wear protective equipments and safety gadgets during working.

Snake bite

Snakebite is an injury caused by a bite from a snake. Thousands suffer from snake bites, globally, every year. Even bite from a harmless snake can cause allergic reaction.

Snakes are most likely to bite when they feel threatened, are startled, are provoked, or have no means of escape when cornered. Encountering a snake is always considered dangerous and it is recommended to leave the surrounding area. There is no practical way to safely identify any snake species as appearances may vary dramatically.

Symptoms of snake bite

- Fang marks
- Swelling/severe pain at the site
- Bloody discharge from wound
- Burning
- Diarrhea
- Excessive sweating
- Blurred vision
- Numbness/tingling sensation
- Increased thirst
- Vomiting
- Fever
- Loss of muscle co-ordinations
- Convulsions
- Rapid pulse
- Weakness/Dizziness/Fainting

Burns

Burn is a type of injury to tissue caused by heat, electricity, chemicals, light, radiation or friction. Most burns affect only the skin. Rarely, deeper tissues, such as muscle, bone, and blood vessels can also be injured. Burns may be treated with first aid, in an out-of-hospital setting, or may require more specialized treatment.

Categories of burns

Categorized by first, second and third degree burns

- Categorization depends on severity of tissue damage
- Check extent of burn before deciding self treatment
- Seek help if burn is over a couple of inches in diameter, or
- If it involves large sections of the hands, feet, face, groin or buttocks, or a major joint

Cut

Cut is an injury due to opening in the skin. Two types of cuts are normally occurs.

a Minor Cuts / Scrapings

- No treatment is required
- Care required to prevent infection

b Deep cuts

- May bleed heavily
- May expose underlying tissues.

Deep cut requires stitching to close the cuts.

Points to note

- Do not try to clean a major wound
- Do not remove deeply- lodged debris
- Do not breathe on an open wound
- Do not push back exposed body parts

Bleeding

Bleeding is the loss of blood from the circulatory system. Bleeding can occur internally, where blood leaks from blood vessels inside the body, or externally, either through a natural opening such as the mouth, nose, ear or through a break in the skin. Severe bleeding involves loss of large amount of blood. A cut on the skin too can lead to bleeding. Internal bleeding occurs due to an injury to blood vessel.

Causes

- Accidents/Falls
- Blow to the head
- Injuries, like scalp wounds
- Tooth Extraction
- Certain medications and illness

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Symptoms

- Discharge of blood from a wound
- Bruising
- Blood in stool/urine
- Blood coming from other areas, like mouth/ear

Steps to avoid

- Do not try to replace a displaced organ
- Just cover the wound with a clean cloth
- Do not try to remove an embedded object

Fainting

Fainting occurs due to decreased blood supply to brain; it may or may not have medical significance. Fainting is a brief loss of consciousness. It can last from seconds to 30 minutes.

If a person falls and can't remember the fall itself, he or she has fainted.

Causes

Fainting is due to a sudden drop in blood flow or glucose supply to the brain. This causes a temporary drop in blood pressure and pulse rate. Medical reasons for this include:

- Low blood sugar (hypoglycemia). This can occur in diabetics, in early pregnancy, in persons on severe diets, etc.
- Anemia. Eating disorders.
- Conditions which cause rapid loss of blood.
- Abnormal heart rhythm. Heart attack. Stroke.
- Head injury. Heat stroke. Heat exhaustion

Other things that can lead to feeling faint or fainting include:

- A sudden change in body position like standing up too fast. This is called postural hypotension.
- A side effect of some medicines. Drinking too much alcohol.
- Anxiety or sudden emotional stress or fright.
- Being in hot, humid weather or in a stuffy room. Standing a long time in one place.
- Extreme pain.

Epilepsy

Epilepsy is a disorder of the central nervous system characterized by loss of consciousness and convulsions.

Symptoms

- Black out
- Confusion
- Deafness/Sounds
- Electric Shock Feeling
- Loss of consciousness
- Smell
- Spacing out
- Out of body experience
- Visual loss or blurring

Safety attitudes

People's attitudes govern what they do or fail to do. In most cases where someone is working with unsafe equipment or in an unsafe situation, somebody has allowed that state of affairs to come about by something they have done or failed to do.

Most accidents don't just happen; they are caused by people who (for example) damage equipment or see it is faulty but don't report it, or leave tools and equipment lying about for other people to trip over. Anybody who sees a hazard and does nothing about it is contributing to the possibility of an accident. A worker doesn't necessarily need to do anything to help bring about an accident; just going mindlessly about his work may be enough to ensure a workmate being crippled for life. He didn't do it, but by proper and timely thinking and acting, he could have prevented it.

Responsibilities

Safety doesn't just happen - it has to be organized and achieved like the work-process of which it forms a part. The law states that both an employer and his employees have a responsibility in this behalf.

Employer's responsibilities

The effort a firm puts into planning and organizing work, into training people, into engaging skilled and competent workers, maintaining plant and equipment, and checking, inspecting and keeping records all of this contributes to the safety in the workplace.

The employer will be responsible for the equipment provided, the working conditions, what the employees are asked to do, and the training given.

Employee's responsibilities

Employee will be responsible for the way they use the equipments, how to do the job and general attitude to safety. A great deal is done by employers and other people to make the working life safer; but always remember you are responsible for own actions and the effect they have on others.

Safety signs

There are variety of signs and notices. Some of these will be familiar to you - a 'no smoking' sign for example; others may not have seen before. It is up to the worker to learn what they mean - and to take notice of them. They warn of the possible danger, and must not be ignored.

Safety signs fall into four separate categories. These can be recognized by their shape and colour. Sometimes they may be just a symbol other signs may include letters or figures and provide extra information such as the clearance height of an obstacle or the safe working load of a crane.

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The four basic categories of signs are as follows

1 Prohibition signs

2 Mandatory signs

3 Warning signs

4 Information signs

1 Prohibition signs (Fig 2)

Fig 2



TM22T0202

SHAPE - Circular

COLOUR - Red border and cross bar.
Black symbol on white background

MEANING - Shows it must not be done

Example - Do not touch

2 Mandatory signs (Fig 3)

Fig 3



TM22T0203

SHAPE - Circular

COLOUR - White symbol on blue background

MEANING - Warns of hazard or danger

Example - Face mask

3 Warning signs (Fig 4)

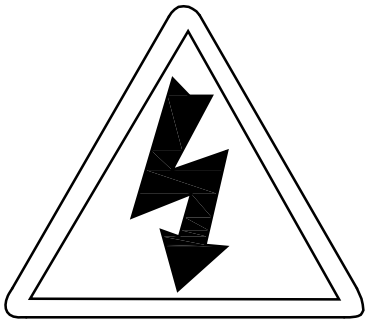
SHAPE - Triangular

COLOUR - Black symbol on Yellow back ground

MEANING - Warns of hazard or danger

Example - Electric shock risk

Fig 4



TM22T0204

4 Information signs (Fig 5)

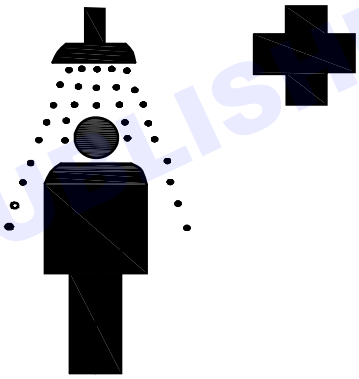
SHAPE - Square

COLOUR - White symbol on green background

MEANING - Indicates or gives information of safety provision

Example - Emergency shower

Fig 5



TM22T0205

Prohibition signs (Fig 6)

Fig 6



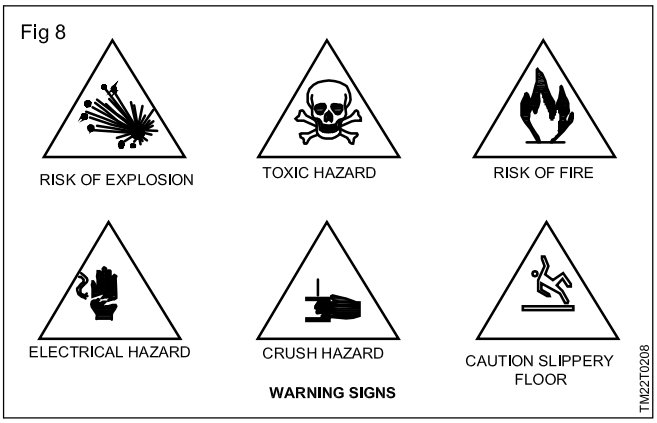
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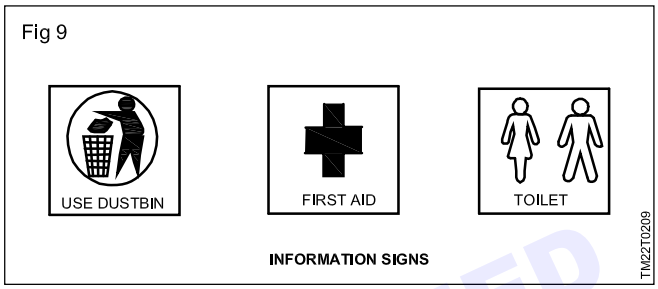
Mandatory signs (Fig 7)



Warning signs (Fig 8)



Information signs (Fig 9)



Heavy engineering division, machine shop and tool room section

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

- **state about lathe and its types**
- **explain care and maintenance of lathe**
- **explain about safety while operating lathe machine**
- **state about three important elements**
- **explain about machine shop and tool room section**
- **state about tail stock and its features.**

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Introduction

The lathe is a machine tool used principally for shaping pieces of metal (and sometimes wood or other materials) by causing the workpiece to be held and rotated by the lathe while a tool bit is advanced into the work causing the cutting action. The basic lathe that was designed to cut cylindrical metal stock has been developed further to produce screw threads, tapered work, drilled holes, knurled surfaces, and crankshafts. Modern lathes offer a variety of rotating speeds and a means to manually and automatically move the cutting tool into the workpiece. Machinists and maintenance shop personnel must be thoroughly familiar with the lathe and its operations to accomplish the repair and fabrication of needed parts.

Types of lathes

Lathes can be divided into three types for easy identification: engine lathe, turret lathe, and special purpose lathes. Some smaller ones are bench mounted and semiportable. The larger lathes are floor mounted and may require special transportation if they must be moved. Field and maintenance shops generally use a lathe that can be adapted to many operations and that is not too large to be moved from one work site to another. The engine lathe is ideally suited for this purpose. A trained operator can accomplish more machining jobs with the engine lathe than with any other machine tool. Turret lathes and special purpose lathes are usually used in production or job shops for mass production or specialized parts, while basic engine lathes are usually used for any type of lathe work. Further reference to lathes in this chapter will be about the various engine lathes.

Sizes

The size of an engine lathe is determined by the largest piece of stock that can be machined. Before machining a workpiece, the following measurements must be considered: the diameter of the work that will swing over the bed and the length between lathe centers.

Categories

Slight differences in the various engine lathes make it easy to group them into three categories: lightweight bench engine lathes, precision tool room lathes, and gap lathes, which are also known as extension type lathes. Different manufacturers may use different lathe categories.

Light weight

Lightweight bench engine lathes are generally small lathes with a swing of 10 inches or less, mounted to a bench or table top. These lathes can accomplish most machining jobs, but may be limited due to the size of the material that can be turned.

Precision

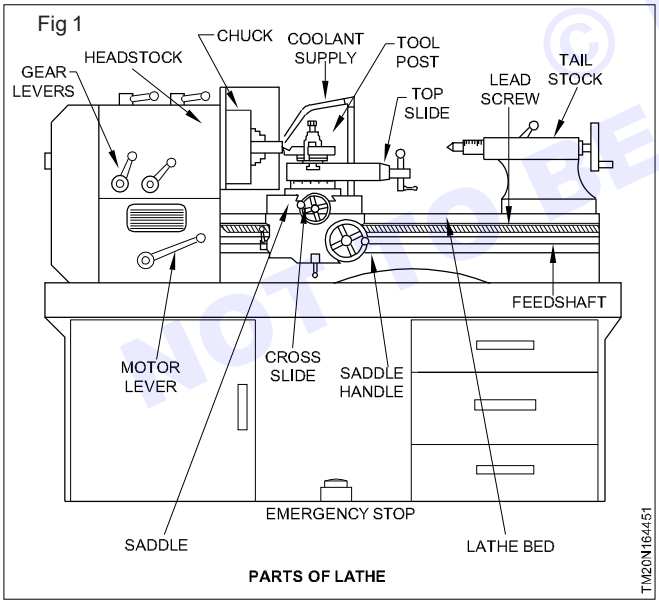
Precision tool room lathes are also known as standard manufacturing lathes and are used for all lathe operations, such as turning, boring, drilling, reaming, producing screw threads, taper turning, knurling, and radius forming, and can be adapted for special milling operations with the appropriate fixture. This type of lathe can handle workpieces up to 25 inches in diameter and up to 200 inches long. However, the general size is about a 15inch swing with 36 to 48 inches between centers. Many tool room lathes are used for special tool and die production due to the high accuracy of the machine.

Gap or extension type lathes

Gap or extension type lathes are similar to tool room lathes except that gap lathes can be adjusted to machine larger diameter and longer workpieces The operator can increase the swing by moving the bed a distance from the headstock, which is usually one or two feet. By sliding the bed away from the headstock, the gap lathe can be used to turn very long workpieces between centers.

Parts of lathe (Fig 1)

Fig 1



PARTS OF LATHE

Care and maintenance of lathes

Lathes are highly accurate machine tools designed to operate around the clock if properly operated and maintained. Lathes must be lubricated and checked for adjustment before operation. Improper lubrication or loose nuts and bolts can cause excessive wear and dangerous operating conditions.

The lathe ways are precision ground surfaces and must not be used as tables for other tools and should be kept clean of grit and dirt. The lead screw and gears should be checked frequently for any metal chips that could be lodged in the gearing mechanisms. Check each lathe prior to operation for any missing parts or broken shear pins.

Refer to the operator's instructions before attempting to lift any lathe. Newly installed lathes or lathes that are transported in mobile vehicles should be properly leveled before any operation to prevent vibration and wobble. Any lathes that are transported out of a normal shop environment should be protected from dust, excessive heat, and very cold conditions. Change the lubricant frequently if working in dusty conditions. In hot working areas, use care to avoid overheating the motor or damaging any seals. Operate the lathe at slower speeds than normal when working in cold environments.

Safety

All lathe operators must be constantly aware of the safety hazards that are associated with using the lathe and must know all safety precautions to avoid accidents and injuries. Carelessness and ignorance are two great menaces to personal safety. Other hazards can be mechanically related to working with the lathe, such as proper machine maintenance and setup. Some important safety precautions to follow when using lathes are:

1 Correct dress is important, remove rings and watches, roll sleeves above elbows.

2 Always stop the lathe before making adjustments.

3 Do not change spindle speeds until the lathe comes to a complete stop.

4 Handle sharp cutters, centers, and drills with care.

5 Remove chuck keys and wrenches before operating

6 Always wear protective eye protection.

7 Handle heavy chucks with care and protect the lathe ways with a block of wood when installing a chuck.

8 Know where the emergency stop is before operating the lathe.

9 Use pliers or a brush to remove chips and swarf, never your hands

10 Never lean on the lathe.

11 Never lay tools directly on the lathe ways. If a separate table is not available, use a wide board with a cleat on each side to lay on the ways.

12 Keep tools overhang as short as possible.

13 Never attempt to measure work while it is turning.

14 Never file lathe work unless the file has a handle.

15 File left handed if possible.

16 Protect the lathe ways when grinding or filing.

17 Use two hands when sanding the workpiece. Do not wrap sand paper or emory cloth around the workpiece.

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1 **Three important elements:** In order to get an efficient process, good surface finish and correct geometry on the lathe, it is important to adjust the rotating speed (RPM), a cutting depth and a feed speed. Please note that these important elements cannot be decided easily, because these suitable values are quite different for each material.

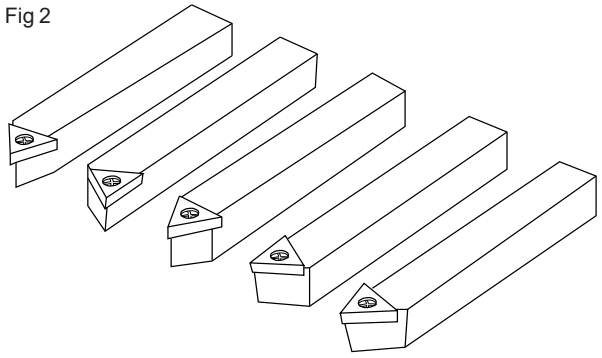
- **Rotation speed:** It is the number of rotations per minute (rpm) of the chuck or collet. When the rotating speed is high, higher removal rates are possible. But when too high, too much friction could be generated. However, since a little operation mistakes may lead to the serious accident, it is better to set lower rotating speed at the first stage.
- **Cutting depth:** The cutting depth of the tool affects to the processing speed and the roughness of surface. When the cutting depth is big, the processing speed becomes quick, but the surface temperature becomes high, and it has rough surface. Taking off too much material can break the tool or your workpiece. If you do not know a suitable cutting depth, it is better to set to small value. Always remove a very small amount of material on your final pass to assure a good surface finish.
- **Feed speed:** The feed speed of the tool also affects to the processing speed and the roughness of surface. When the feed is high, you can remove a lot of material quickly. When the feed is low, the surface improves. There are automatic feeds on these machines that can move the feed handles for you at a very accurate feed. These auto feeds maintain a consultant speed and result in nicer finishes. A beginner must always use the manual mode, until they have enough experience. A user should hold the handle of the automatic feed until the operation is complete and never walk away. Serious accidents may occur if the tool bit or any part of the post or the cross slides touch the collet or chuck!

Machine shop and tool room section

Common lathe cutting tools: Always use the correct and properly sharpened tool for the job. Dull tools lead to bad surface finishes, out of tolerance parts and potentially a hazard situation. Below are the three most common types of lathe tools.

Lathe bit (Fig 2)

Fig 2



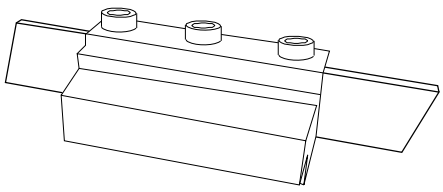
COMMON LATHE CUTTING TOOLS

TM20N1644452

The image above shows the most common lathe cutting tools, they are called lathe bits. These can cut outside surfaces and edges. There are versions that consist of a piece of carbide brazed onto a rectangular steel bar. The ones in the above image are called "insert lathe tools." It is because they have a carbide insert that can be replaced or rotated when they become dull. This is ideal for those that have little or no experience in grinding their own tools.

Cut off tool (Fig 3): This tool (shown above) is also called a "parting tool." It is primarily used for cutting off (aka, parting) the workpiece and making outside grooves. This tool can only cut "across" the part in one direction (along the X axis).

Fig 3

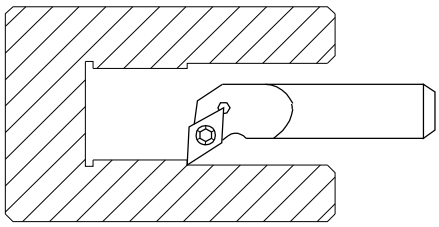


CUT OFF TOOL

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Boring bar (Fig 4): This tool (shown above) is mainly used to make diametrical (round) holes of any size and depth. Normally used to cut at an inside surface. It can make a hole that is much bigger and more accurate than a regular drill. The other big advantage is that a boring bar can make irregular diameter holes with flat bottoms. Drills and reamers are only available in "standard" sizes, but a boring bar does not have that limitation. In most cases, there needs to be an existing hole to fit the boring bar. This hole can be produced with the use of a regular drill bit.

Fig 4

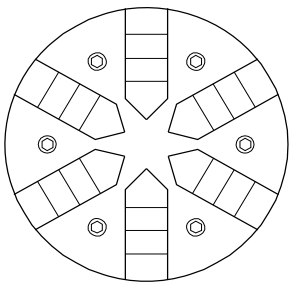


BORING BAR

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Clamping work-pieces using a lathe chuck (Fig 5): A chuck is directly attached to the drive mechanism (spindle) of the lathe and rotates at variable speeds up to as much as 1000 rpm on this machine. A 3 or 6 jaw chuck has the ability to hold a wide range of cylindrical parts from .250" diameter, all the way up to 8" diameter.

Fig 5



LATHE CHUCK

TM20N1644455

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To start, the operator clamps the piece of metal to be turned in the chuck. Depending on the size (diameter and/or length) of the part, will determine how much of it will need to be clamped in the chuck. These chucks are very accurate, but pieces of metal are not always perfectly straight and level. So it is recommended that you use a dial indicator to check the concentricity your workpiece in relationship to the machine. This can be done by placing the indicator on top of the tool post with the dial stem touching the part and with the machine turned OFF, rotating the chuck by hand. Depending on the required precision, it is important to check the trueness of the part to within one or two thousands of an inch.

Once you are sure that the part is true, tighten the chuck as tight as necessary to hold the part without damaging the clamping surface. This is done by placing the "chuck key" in the key receptacle on the side of the chuck and turning it clockwise. NEVER LEAVE THE KEY IN THE CHUCK!!!

Place the chuck key on the workbench, away from all moving parts. If the key is left in and the machine started, serious bodily harm will result! Check once more for "true" if the precision is necessary. Before even starting the machine, spin the chuck by hand to make sure it clears the carriage, cross slide, tools, tool post and/or all other parts of the machine!

Clamping work-pieces using the collet chuck

A collet chuck takes the place of a 3, 4/ or 6 jaw chuck. It uses collets to hold diameters ranging from .125" to 1.313". Since it relies on collets and has no spinning jaws, it is more accurate and safer way to hold your work. Make sure that the diameter of your workpiece matches the size of the collet within (+/-) .015" Any larger variations and the workpiece could slip or the collet could be damaged!

Make sure the spindle is OFF and not rotating before inserting or removing collets or work pieces! Also, you should move the tailstock and carriage/saddle away from the collet chuck. The collet is inserted into the collet chuck by aligning the "key". You have done this correctly when the collet slips almost completely into the collet chuck.

Place your workpiece into the collet (at least 1" in for most diameters!). Then tighten the collet by pressing and holding the spindle lock knob and simultaneously rotating the collet chuck wheel away from you. To loosen the collet, press and hold the spindle lock knob and simultaneously rotate the collet chuck wheel toward you. It might take several rotations to release your part.

Tool post and cutting tool set-up

The tool post is where the cutting tool and holder will be located. The tool post uses a dovetail design to enable a user to pre-set a number of tools for easy and accurate changes between cutting tools. The tool post is permanently mounted to the machine, but can be move and rotated. The tool holders have knob on top to quickly adjust cutting tool heights.

For safe and efficient cutting, the tip of the tool must be located directly on the center of the part in the chuck! Too high and the base of the tool will push on the part. This may damage your workpiece or break the cutting tool. If the tool is set too low, the tip of the tool will tend to gouge and/or cut too deep. It will also leave an undesirable "nub" when you reach the center of the workpiece.

Moving the carriage and cross slide

The carriage moves along the "ways" toward and away from the chuck (the Z axis). The cross slide moves toward and away from the center or the part (the X axis). The carriage and the cross slide are both moved manually by using hand wheels. The cross slide hand wheel has dials that show DIAMETRICAL distances. Each graduation on the hand wheel indicates .001"of diameter movement of your tool. Movement of the carriage is measure with the use of a dial indicator mounted on the left side of the carriage. It is limited to 2 inches of travel for measurement purposes, but can be set anywhere along the carriage's travels.

In addition, there are two levers on the carriage that turn on the carriage and cross feed "power feeds." One feeds (moves) the carriage at a predetermined speed and the other feeds the cross-slide. There is also a (push/pull) knob that changes the direction of both feed levers! To understand these features, you should test these operations well away from the chuck, at different speeds and while supervised. This will enable you to get the feel of the automated movements of the machine

Compound slide

A compound slide is a smaller version of the cross feed with one major difference, it can be set at any angle. It offers a way to turn tapers and cut angles on a lathe. Most commonly it is used to cut tapered holes and other conical shapes using a boring bar or lathe bits. There is a degree wheel directly underneath the compound slide that can be set to the specific angle that is needed. There is no "power feed" option and it must be operated manually.

Tailstock and its features

The tailstock is located on the opposite end of the lathe from the chuck. It is mounted on the ways of the machine and shares a centerline with the chuck. The tail-stock's most common use is to drill out the centers of work pieces. Into the tailstock you can insert a drill chuck (that has a compatible "Jacobs Taper"). The tailstock is slid toward the workpiece and LOCKED DOWN, leaving about 1" of room between the drill and the workpiece. The tailstock hand wheel is then used to feed the drill into the workpiece. Unlike other machines, the lathe workpiece spins and the cutting tool stays still.

The other common use is to support long work pieces (shafts / tubes / rods) with the use of a live center. A live center is a cone shaped object with a Jacobs taper adapter that is inserted into the tailstock (like a drill chuck). The cone portion spins on an internal ball bearing mechanism. This is used to fit into a center hole of the work piece to hold

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it firmly between the tailstock and chuck. It is VERY important to lock down the tailstock and set correct tension with the tailstock hand wheel whenever using the live center. This is done for pieces that are too long to be safely held in just a chuck or collet. Normally, if the length of piece is sticking out more than 5 times the diameter, a live center should be used. For example, if the part is 1" in diameter, it should not stick out more than 5" in length. Again, check with the shop supervisor for guidance! Live centers should not be used when the workpiece will be parted with a cut-off tool.

Application of mechatronics in blow room

Objectives: At the end of this lesson you shall be able to
- **state about the material flow control in blow room machine**
- **state about optical regulating device, uni-command control system**
- **state about magnetic metal extractor, electronic metal extractor and combo shield.**

Control of material flow in blow room machine

Since, as already discussed, the blow room line is a sequence of individual machines, each machine must always receive an exact quantity of material per unit of time from the preceding machine, and must pass on the same quantity per unit of time to the next. To ensure an adequate flow of material, the machines are adapted to each other so that each machine can produce a little more than the succeeding machine requires. Since each machine has excess capacity, a control system must be provided to ensure the correct delivery quantities. Two basic principles are used: batch operation and continuous operation.

In a hopper feeder, for example, the conveyor (1, Fig. 70) places material into the hopper until sensing lever (a) is pushed so far to the right that a contact is made to switch off the drive of conveyor belt (1). In exactly the same way, during filling of the reserve hopper (R), the pressure exerted by the column of material eventually becomes so great that sensing lever (b) is depressed; this causes the preceding machine to be switched off. When the column of material has again been largely removed by conveyor (1), the sensing lever rises, the preceding machine is switched on and the reserve chute is refilled. Unfortunately, in practice the individual machines actually produce during a period that is often only 50% of operating time and are unproductive during the remainder of the operating time.

On the other hand, in continuous operation created by changing the speeds of the machines, the machines' production rates are much more closely adapted to each other. They operate almost continuously and without stops. A fine control device serves to maintain material throughput by adjusting the production speeds of the individual machines. Batch operation has the advantage that the machines always run at the same speed and with the same production rate when they are in operation. The treatment of the material remains uniform all the time. That means that the raw material is always processed under the same conditions, since there are only two treatment levels - full on or off . In continuous operation, however, there are continual slowdowns and accelerations, with possibly varying intensities of treatment of the raw material.

Data provided by Trützschler indicate that there are no negative effects, provided variations in production rates do not exceed ± 20%. The disadvantage of batch operation lies in the incorrect handling of the material throughput.

As machines often do not operate during 50% of the time, in their productive periods they are not working at, e.g., 300 kg/h as calculated by the spinner; instead they are actually processing material at a rate of 600 kg/h. The loading of the machine is high, and that might lead to a correspondingly poor cleaning effect. In the mill, therefore - and this is very important - an attempt should be made to regulate the installation so that the productive time of the individual machines is very high, and only few non-productive periods occur.

Optical regulating device: Four optical monitoring devices are mounted in the filling chute, conveyor belt and mixing chamber of the machine.

If the column of material falls below light barrier (2), the preceding machine is switched on and delivers material. When the chute has been filled to such an extent that the material interrupts the light beam in light barrier (1), the machine is switched off again. Light barrier (1) is also an over-fill safety monitor. Light barrier (3) monitors the amount of material in the mixing chamber and controls the drive to conveyor belt (6) and the feed roller of the chute. Light barrier (4) will trigger an alarm if there is no material left on feed conveyor (5).

Continuous operation: As a concept, this is not new in the blow room; it has been used for a long time in the scorcher as pedal regulation of the feed to the beater. What is new is that now the whole blow room line operates continuously and regulation is performed electronically. This installation, developed by Trützschler, will be presented briefly.

The central regulating unit, to which all the individual machines are connected, is the "CONTIFEED". This receives an analog signal from the tacho-generators of the cards; the instantaneous demand for material is continuously calculated from this signal. Using this demand, the microcomputer can establish the basic speeds of all drives that determine the throughput and the drives can be correspondingly controlled. A second signal is superimposed on this basic speed signal, derived from the contents of the storage unit of the succeeding machine. In this way, the successive machines are linked via individual control loops. The programs for speeds, production quantities and allocation are first established manually, which represents a fairly substantial initial outlay. When balanced operation is achieved, they can be transferred to the "CONTIFEED" and stored there

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Uni-command control system

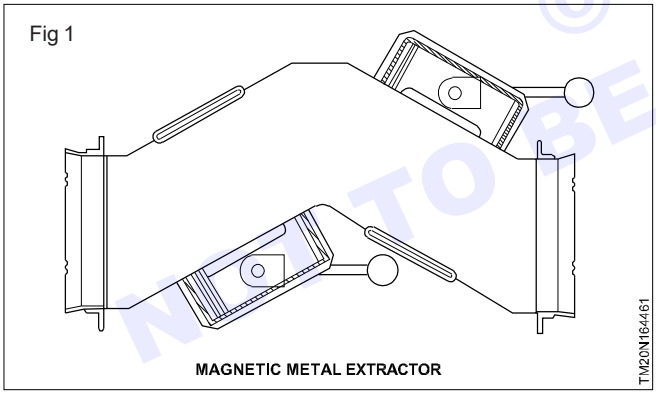
As already mentioned, the blow room line is a sequence of several machines. In their operation these machines have to be very well coordinated, requiring a good, reliable system for monitoring and controlling the individual machines, groups of machines and the total blow room line. UNI command works on an electronic basis, and is a combination of PLCs (programmable logic) and PCs with a central control unit somewhere near the blow room line, plus an additional PC in the supervisor's office as an option. No computer or software knowledge is required to handle the system. As everywhere, Reiter standardized panels are used. A language-independent color graphic representation and touch-sensitive monitors are chosen for the display. The main functional and operational requirements are:

- switching on/off
- display of operational status of all system components;
- simple switch-over of the process sequence, e.g. from one- to two- or three-blend operation;
- automatic shift switch referring to the shift schedule;
- alarm indication of malfunction;
- machine remote control for adjusting and changing the operating mode.

The user interface is exactly the same as on the machine itself.

Magnetic metal extractor (Fig 1)

Fig 1



Magnets have been used for decades in ducting or in special parts of machines in order to eliminate pieces of ferrous material. The most effective form of device is a knee-bend within the feed duct having permanent magnets at the two impact surfaces. When tufts are driven against the magnets, ferrous particles are retained and can be removed from time to time. Magnetic extractors provide only a partial solution to the problem because they can eliminate only magnetizable metal particles, and let all others pass. Electronic extractors are needed to remove the other particles, too.

Electronic metal extractor

The material is fed from an opening machine such as Blend mat. The next device, normally a fan in front of the mixing machine, extracts the material by suction. Spark sensor detects smoldering material and metal detector any kind of metal. In either case, active operating flap is opened by a signal from the detector and feeds the material into the receiving waste container, which is equipped with a fire extinguisher device and a temperature sensor to monitor the container.

Combo shield

This comprises a spark detector, a metal extractor and an eliminating device, and is built into the transport duct. The spark detector pivots the rapidly operating flap as soon as the latter detects sparks or burning material. The material passes into a receiving container, which preferably stands outside the room. Simultaneously, an alarm is given and the blow room line as well as the filter installation is switched off.

The pivoting flap remains in the eliminating condition until the line is switched on again. This device has a second function, the detection of metallic material. If such a piece of material is detected, the same rapidly operating flap is pivoted and the foreign material is ejected into a container. After an adjustable time, the flap moves back into its normal position. In contrast to detected sparks, the blow room line remains switched on.

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Application of mechatronics in carding

Objectives: At the end of this lesson you shall be able to
- **state the advantages of control system in carding machine**
- **state about sensofeed, magnotop flats, web feed and flat control**
- **state about tongue and groove measuring device and extended protection for the card**
- **explain auto leveling and its types**
- **explain different measuring device, coiler silver stop motion and production monitoring system.**

Introduction

Fundamentally, textile manufacturing is a labour intensive operation. An improvement in the textile technology is mainly confined to increase in productivity, cost reduction, quality Upgradation and product development. One of the main Upgradation in textile industry is the introduction of various control systems in almost all the processes.

Advantages of control systems are

1 Smooth running, increased production and improved quality

2 Savings in plant cost

3 Savings in raw material.

4 Increased safety

5 Improved working condition

6 Saving in manpower

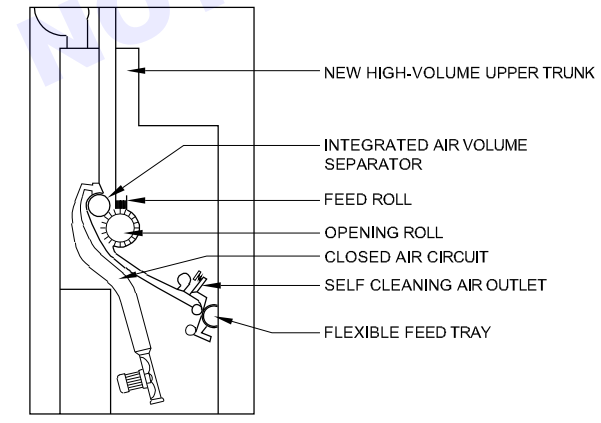
7 Improved plant management and supervision

The proverbs, "The card is the heart of the spinning mill" and "Well carded is half spun", demonstrate the immense significance of carding for the final result of the spinning operation. In carding machine the raw material is supplied to the feed arrangement consisting of feed roller and a feed plate. It pushes the material slowly into the licker in. The portion of sheet projecting from the feed roller must be combed and opened to flocks by taker- in. These flocks are passed over the grid equipment and transferred to the main cylinder. In the moving parts like mote knives, grids, carding segments the material lost most of its impurities. Suction ducts carry away the waste. Then along the cylinder they penetrate into the flats and open up into individual fibers. The actual carding action occurs here. The underside of carding cylinder is enclosed with grids. After the carding operation has been completed the main cylinder carries the material to the doffer. The doffer combines the fibre into web. A stripping device draws the web from the doffer after the calendar roller have compressed the sliver to some extent, the coiler deposit it in the can. The working roller, cylinder and flats are provided with clothing.

Sensofeed (Fig 1)

The flexible integral feed tray sensofeed ensures controlled web feeding to the web feed unit. Its feed table compacts the tuft web and guides it to a knife-shaped feed tray tip.

Fig 1

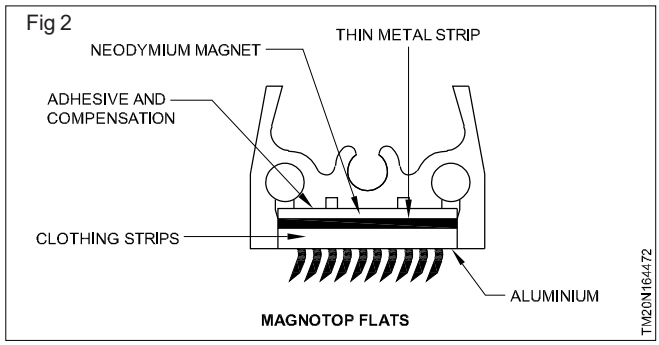


SENSOFEED

The material at this top allows a partial elastic deformation that occurs when material slubs are fed. This deformation is only a few hundredth of a millimeter and has hardly any influence on the overall deflection of the feed tray. As additional function, the integral feed plate sensofeed can also include feed monitoring for the card.

Magnotop flats (Fig 2)

Fig 2



MAGNOTOP FLATS

With MAGNOTOP, there is no longer a need for inhouse flats workshop, additional space, special machines, service, maintenance and according specialists. This corresponds to savings in investment costs. Operating costs are eliminated entirely. Another advantage is the quick and easy testing of new types of flat tops. The previous set of MAGNOTOP clothing strips can be reused at any time. The patented MAGNOTOP fastening system also compensates tolerances. This simplifies precision setting of flat tops even more, which in turn improves the carding results and leads to less naps in the yarn.

Advantages

1 Improved yarn quality through higher precision

2 Elimination of investments in a flats workshop, operating costs, etc.

3 Elimination of provider's service costs.

4 Elimination of investment for one or several spare flat bar sets

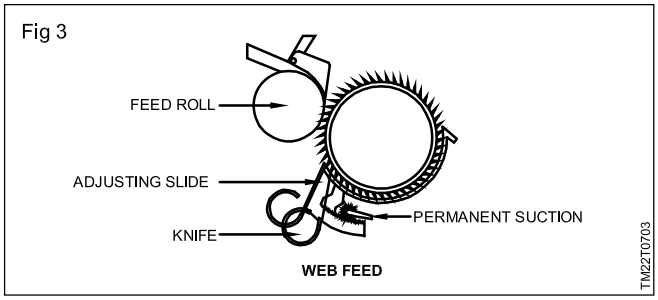
5 No storing of flat sets

6 No grinding of flat tops after re-clothing

7 No transport costs, instead simplified logistics

Web feed (Fig 3)

Fig 3



WEB FEED

The WEBFEED system consists of one large or three opening rolls connected in series. The tufts are opened in a gentler way and to a higher degree than is the case with conventional lickerins. This results in an even and fine web that increases the carding efficiency at the actual main working points (between cylinder and flats/ carding segments) during the transfer to the main cylinder.

The main cleaning zone of the TC 11 lies in the area of the first roll of the WEBFEED system. Here, an optimal waste composition requires an accurate mote knife setting. This is exactly what the successful Precision Knife Setting System PMS provides. The knife, which circles around the

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centre of the needle roll, is infinitely adjustable within seconds. Thus, the distance of the knife point to the needles is exactly the same in every position.

There is no need to stop the card, since the setting lever is freely accessible on the left machine side. A glance into the transparent suction ducts immediately shows the success of the readjustment.

Flat control

When it comes to fast and accurate calculation of the distance between cylinder and flat, the Measuring System FLATCONTROL TC-FCT from Trützschler offers numerous benefits:

1 Better card sliver quality due to smaller setting tolerances

2 Extended service life of clothing

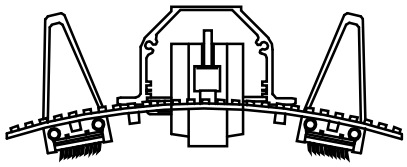
3 Quick flat setting

4 Reproducible, objectively verifiable settings

5 Independent of personal influences

Flat measuring system (Fig 4)

Fig 4



FLAT MEASURING SYSTEM

TM22T0704

When performing basic flat settings with FLATCONTROL TC-FCT, first the measuring flat is moved to the corresponding setting position via remote control. The colour monitor of the computer shows a diagram of the current distance to the cylinder. The technician can now adjust the distance of flat to cylinder within seconds - considerably more accurate than with feeler gauges.

Scope of flat measuring system

1 Measuring flat

2 Notebook PC with accessories

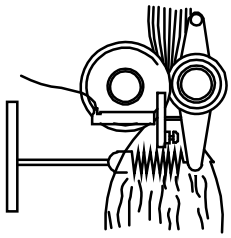
3 Calibration device

4 Solid metal case for transport and safekeeping

5 Service carriage for transport within the spinning mill

Tongue and groove measuring device (Fig 5)

Fig 5



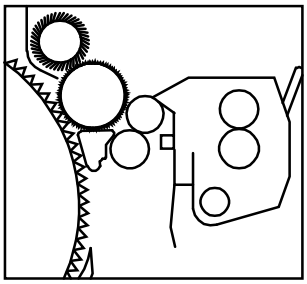
TONGUE AND GROOVE MEASURING DEVICE

TM22T0705

The sliver drawn between a pair of roller one fixed and one movable. The material when passing through displaces the movable roller depending upon the thickness. This movement is converted into signals by displacement transducer and is used to correct the variations.

Extended protection for the card (Fig 6)

Fig 6



EXTENDED PROTECTION FOR THE CARD

TM22T0706

As an additional function, the integral feed plate sensofeed has equipped with a feed monitoring device for the card. Metal particles or thick places in the web are detected and result in an immediate stop of the machine. Through an electrical reversing motion these foreign particles can be taken away befor causing damage to the card.

Autolevelling

A relatively high degree of evenness is required in the sliver. For various reasons the card cannot always operate absolutely even. So spinning mills are accordingly forced to use autolevelling equipments under highly varying circumstances. For export quality yarn, count CY is expected to meet user 10-25%. An extremely good count consistency is the most important condition for an excellent appearance of the woven or knitted end product. In order to achieve this, it is a must to control the evenness and coefficient of variation of count both at sliver as well as at yarn stage. Control of these cumulative factors can be taken care only by autolevellers. Autolevelling is usually performed by adjusting the feed rollers speed.

Different types of autolevellers

Long term autolevelling

Only the mean count value is autolevelled. A sensor in the delivery performs measuring. The pulses derived in this way are processed electronically so that the speed of the feed roller can be adapted to the delivered sliver weight via mechanical or electronic regulating devices.

Medium term autolevelling

In Zellweger equipment a medium term Autoleveller is provided as an addition to autolevellers. Both mean value and also to a large extent the complete variance length spectrum is autolevelled. The measuring device is built into the protective cover above the doffer. The device measures reflection of infra red light from the fibres. After comparison with the set value, a different signal is generated and passed to an electronic regulating unit. This operates via a regulating drive to adjust the in feed speed of the card.

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Short term auto leveling

The regulating lengths of the product are 10 to 25 cms. Its advantage is the correction of periodicities and other short disturbances.

Regulation at the delivery

A measuring point is provided upstream from the drafting arrangement to sense volume of the incoming sliver and transmit corresponding pulse signals to electron control unit. The control signal is passed to a regulating device which adopts the speed of the delivery roller to the measured sliver volume.

Autolevelling in the infeed

The volume of the incoming batt is detected by the reference to the movement of feed plate in relative to the feed roller. A signal corresponding to this volume is fed to the microcomputer that operates via a regulating gate transmission to continuously adopt to the speed of the feed roller to a predetermined set infeed volume. This is a feed plate measuring device used in Reiter C4 cards. Depending on the system of operations autolevellers can also be classified as follows:

Closed loop system

The sliver coming out at the delivery end is constantly monitored for any deviation from the standard value. Any deviation detected is fed to a correction system at the feed end which corrects the draft, this corrected sliver is again monitored at the delivery and any deviation detected is fed to the feed correction system.

Open loop system

In this system, sliver deviations are detected at the feed end itself and the corrections are made near the delivery end. No monitoring is possible after the deviation has been corrected.

Combination system

The latest trend is to have a combination of long term stability and accuracy of the closed loop system and speed of the open loop system. In this the detection and correction of faults are as that of open loop and after this the corrected sliver is checked by a monitor and if the deviation exceeds the preset limit stop the machine.

Measuring devices

Active measuring device

The sliver to be measured is drawn through a specially designed measuring trumpet by a calendar roller. The movement of the material through the trumpet compresses the sliver which in turn displaces the air trapped between the fibres. Hence as the thickness of the sliver varies the air pressure inside the trumpet also varies proportionately and this is measured by a pressure transducer. This is exclusively used by USTER. But it varies with the fibre fineness.

Strain gauge measuring device: The trumpet is used in coordination with the strain gauge mounted suitably at the entry point to measure the variation

Sensor measuring device

A transducer measures the sound waves along with sliver and accordingly changes are made in the draft.

Feed roller measuring device

The volume of incoming material displaces the feed roller and feed variations are sensed by measuring this movement in relation to the feed plate. The signal is sent to a microcomputer and necessary corrections are made. Used in LAKSHMI LC 100.

Feed plate measuring device

Similar to the above the only difference is feed plate is movable instead of feed roller.

Optical measuring device

An optical device detects the variations in the cross section of the fibre layer on the cylinder in carding over the whole width or the cylinders explained above medium term autolevelling. USTER M controller used this. Thus micro controllers may be used for closed loop control, constant sliver count production and shift counting. The doffer speed is continuously adjusted to the delivery by a frequency counter. A starting and breaking control prevents the sliver breaks.

Licker in system web feed

The web feed consists of three opening and cleaning roll in series arrangement. The tufts are open in a gentle way and to a higher degree than in the case of conventional licker-in. The first roller runs at a slower speed than the conventional one, and equipped with needles. The second and third clothing rolls open the tufts further and forms web.

Precision Flat Setting (PFS)

The PFS is a new system, the adjustment is made centrally. At each side of the card, an actuator is turned manually or by a motor. That way, the distance of all the flat bars in working position towards the cylinder is widened or reduced. In the case of manual adjustment, scale shows the actual setting in relation to the basic setting. In the case of adjustment by the motor, the position is chosen and shown on the display of the machine control. A procedure that formerly required the full attention of an experienced mechanic can now be done in a precise, reproducible way within a few seconds by pushing a button. New flexible bend disposes of six adjustments instead of four adjustment points.

Coiler sliver stop motion

Application

1 Immediate stopping of the machine for a sliver break

2 Mounted on the coiler stand

3 For web detection

4 Non contact detectors

5 Stray fluff will not interrupt the operation

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Photo control unit application

1 Stops immediately if the cotton enters the doffer after one revolution,

2 Kept in aligned condition above the doffer so that any fly shooting into the cylinder interrupts the signal path to stop the machine. Damage of cards by foreign bodies averted, low voltage application.

Thermistor protection unit

Application

Used for the protection of 4 nos. of motors with thermistor built in the motor coil. Trips the motor on excessive heat due to loading by sensing the changes in resistance of thermistor, thereby preventing the motor from burn out.

Safety switches

The safety system positively monitors the cylinder speed to avoid cylinder chocking, belt slippage or breakage. It observes the presence of the drive belt using an optical sensor and stops the feed when the belt slips or fails to safeguard the carding elements.

Production monitoring system

Neps

Neps are small entanglements or knots of fibers. In general, two types of neps can be distinguished: fiber neps and seedcoat neps, that is, small knots that consist only of fibers and others containing foreign particles such as husk, seed or leaf fragments. Investigations made by Artzt and Schreiber indicate that fiber neps predominate, particularly fiber neps having a core mainly of immature and dead fibers. Thus it is clear that there is a relationship between maturity index and neppiness. Neppiness is also dependent, exponentially, on fiber fineness, because fine fibers have less longitudinal. The slenderness ratio (stiffness) stiffness than coarser fibers. The processing method also has a considerable influence. A large proportion of the neps in raw cotton is produced by picking and hard ginning, and the amount of neps is substantially increased in the blow room. The card is the first machine to reduce the amount of neps to a usable level, and nep reduction at the card is achieved primarily by disentanglement rather than by elimination. Neps not only create disturbance in themselves as thick places, but also in dyed fabrics because they dye differently from the rest of the fibers, and thus become clearly visible in the finished cloth.

Based on the consolidated findings of Uster Technologies Inc. (Zellweger Luwa AG), the following scale represents the amount of neps per gram in 100% cotton bales:

- up to 150 = very low;
- 150-250 = low;
- 250-350 = average;
- 350-450 = high;
- above 550 = very high.

Coiler changing mechanism

The coiler mechanism The object of this mechanism is condense further the silver delivered by the calender rollers and to lay them in an orderly manner in a cylindrical can for easy withdrawal at subsequent processing. This coiler calender rollers are driven at a surface speed slightly higher than that of the calender rollers so that the sliver is maintained in a taut condition as it passes from the calender rollers through the trumpet and into the nip of the coiler calender roller below the trumpet.

A tube wheel driven by gear on the upright shaft, has an inclined tube with its upper end below the trumpet and coiler calender rollers. The lower end of the inclined tube is provided with an exit for the sliver at a point near to its periphery so that the sliver delivered by the rollers passes down the tube and is led in circular coil into the can.

The can is positioned on a plate driven through reduction gearing from the bottom of the upright shaft at a slow speed,

The slow rotation of the can changes the position at which each coil is laid, so that overlapping coils are formed around the can. This continues until the can is full. A stationery coiler plate, which surrounds the tube-wheel, assists in dressing the sliver firmly in the can and prevent the sliver from being damaged by the coiling mechanism.

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Application of mechatronics in draw frame, comber, speed frame, ring frame and open end spinning

Objectives: At the end of this lesson you shall be able to
- **state about control system in draw frame**
- **explain auto leveler in draw frame, principle of measurement**
- **explain the automation in draw frame, comber preparatory and comber machine**
- **explain the automation in speed frame, ring frame and open end spinning machine.**

Control systems in draw frame

Introduction

Drafting is the process of elongating a strand of fibres, with the intention of orienting the fibres in the direction of the strand and reducing its linear density. In a roller drafting system, the strand is passed through a series of sets of rollers, each successive set rotating at a surface velocity greater than that of the previous set. During drafting, the fibres must be moved relative to each other as uniformly as possible by overcoming the cohesive friction. Uniformity implies in this context that all fibres are controllably rearranged with a shift relative to each other equal to the degree of draft.

The parallel arrangement of fibres in the sliver is taken care by the draw frame to which 4 to 8 card slivers are presented. Feed roller pair taken care of the slivers. The slivers then running into the drafting arrangement consisting of three pairs of rollers forming the back and the main draft zone. The drafted sliver coming out of the drafting zone L condensed by a trumpet and is placed in a can.

- Parallelization of fibres
- Drafting and doubling
- Formation of sliver
- Hooks created in the card are straightened
- Autoleveller maintains absolute sliver fineness

1 Computer-controlled individual direct drives for short-wave correction lengths (For HSR 1000) Sliver Focus with Online quality monitoring

2 Good accessibility & simple operation

3 Maintenance-free servo motors instead of gears & change wheels

4 Leveling even during can changing (Perfect leveling of pieced-up sliver irregularities.

5 Power creel with creel suction device

6 Data obtained by reliable precise sensors

- High productivity
- High efficiency due to low maintenance & long cleaning cycles.
- Quick material change over due to step less electronic setting
- Consistent achievement of lower sliver U% and c.v. %
- Suitable drafting geometry for outstanding sliver evenness
- Pneumatically loaded top rollers with automatic relief during machine standstill
- Improved sliver evenness through short-term autolevelling
- Achievement of lowest correction length

Autoleveller in draw frame

The principle of open loop control is used in this autolevelling. The thickness of the incoming sliver is sensed by a pair of tongue and groove rollers called as scanning rollers. Displacement transducer converts this angular movement into voltages. A plate is connected to the rollers and is moved into the Electromagnetic field of the transducer. This movement of the plates cuts the flux and a voltage is induced. This signal is transferred to the electronic memory, which then transmits it to the set point stage with a certain delay.

The correction delay is determined by the pulses which can be set by FIFO (First in First out). The distance between the measuring rollers and the front draft zone is divided into 177to 192 pulses.

FIFO is a register with the first measured variation stored in the first register and so on. This system ensures the change in the draft takes place exactly when the corresponding deviating length of the sliver passes the main draft zone. The set point stage uses the measuring voltage and the machine speed which are measured by two tacho-generator to calculate the speed of the servo drive. The middle roller is driven by a differential gear arrangement, which has a constant drive from the front roller and variable speed from the servo motor. The correction length is further reduced now for effective autolevelling.

Speed of the variable speed motor is continuously measured and it does not correspond with the intended speed the machine is switched off. Accurate leveling is ensured by the high dynamic servo drive, so the correction times are of the order of few milliseconds and the correction lengths a few mm.

This system comprises of electronic unit, control drive using servo motor with control Tacho and differential gear with constant Tacho transducer, measuring trumpet, transformer, and power unit with brake resistance, and a capacitive measuring unit.

Principle of measurement and auto levelling

In case of short term variations, a control circuit with dead time and P-controller with delay and a capacitive measuring unit are capable of doing the job in a perfect manner. In case of medium and long term variations, a closed control loop with dead time and PI- controller can be used. A measuring unit can be used on request.

The draw frame Autoleveller was the first to achieve universal acceptance. In these systems the measurement is made either at the input or the output sliver. The sliver count automatically corrected with reference to the required value by variation of the draft. The version of the user ADC system which levels the sliver input. In this system count of the sliver at the output stage is measured. The Autoleveller detects deviations, if any, from the pre-set nominal value. If deviations are determined, the actuator changes the input speed of the drafting rollers changing the draft in proportion to the control signal. The Tacho - generator at the input roller and the actuator controller ensure that the actuator corrects the count in proportion to the deviation. The degree of correction' is automatically and continuously checked. This is a closed loop system which controls the mean sliver count and guarantees the best possible accuracy.

Sliver breakage stop motion

Most draw frames have contact rollers in stalled in the creel as stop motion. The problems with these rollers are known to the industry. Once the Sliver Watch detector installed, a sliver break age will be detected and the draw frame will be stopped. Another stop motion is no longer required.

Sliver watch on lappers

On lappers up to 24 detectors can be installed in the creel to monitor sliver. In case a contaminant is detected the lapper is stopped. A special communication logic avoids the use of long sensor cabling, which results in an easy, fast and reliable Sliver Watch installation on the machine.

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Production and quality data

Production data, such as machine efficiency, produced kg, produced sliver length, number of can changes, number of production stops as well as quality stops are available in real time and on shift base. Statistic evaluation: histogram of defects, number of contaminants per shift, number of sliver breaks, etc.

Monitoring on cards

The installation of a Sliver Watch on cards allows the mill to keep track of the level of contamination in the production. The purpose here is to monitor the contamination index of the sliver can, The contamination index of the can is an expression which relates to the number of contaminants per 1000 meters of sliver.

Automation material transport

With today's handling equipment, robots and transport devices designed with microprocessor controlled non contacting sensors and detection systems are used. Material transport between two machines has become fully mechanized. In the drawing section breaker and finisher draw frames are connected by CAN link or Can-connect system. Motor 2 drives the delivery cylinder, delivery roller and sliver coiling ring. Motor 3 drives the rotary can plate. All the three drives are synchronized with the card .The card sliver is scanned before entering the' drafting system, by the measuring funnel. The second measuring funnel after the drafting system permanently checks the sliver.

Comber

Within the overall spinning process comber serves to improve the raw material. It is mainly used to get fine yarns. The lap from the previous machine is feed in the feed roller to enter the nippers. The clamped fibres of the nippers are sweeped by the combing segment mounted on the combing cylinder .the opening of the nipper allow the fibres move towards the detaching rollers. The detaching rollers have the returned part of the previously drawn off stock by means of a reverse rotation, so that the web protrudes from the back of the detaching device. The new fibres corning towards the roller are placed on the returned web and top comb entry comb the trailing part of the comb and then it is pulled out of the previous nipper and piecing occur. In this way the combing cycle is continuing. The web is then collected by a trumpet, the calendar roller serve to condense the sliver. The slivers are then enter the drafting arrangement in this way 60r 8 slivers are drawn in the drafting system together to give single or double delivery.

- Elimination of the short fibres
- Elimination of remaining impurities
- Elimination of a large proportion of neps
- Formations of sliver having maximum possible evenness.

Sliver lap machine

Sliver stop motion model: It consists of separate units on either side of the table for sensing sliver break. immediate stoppage after an end break and Very easy piecing as sliver is stopped well before the rollers.

Extended features are

- Recording and processing of production data.
- Uster Sliver Data
- Data analyzing
- languages selection

Regulated lap loading

- The regulated automatic lap loading safe guards the ideal pressure of the lap on the lap rollers during the complete build up cycle.

Ribbon lap machine

Ribbon breakage photo cell: It is used to stop the machine, whenever there is a break of lap on the feed end or breakage of fleece on the table end. It consists of one control unit and two sensor units. One for the feed end and other for the lap end and Empty beam stop motion. Top roller lapping is avoided, as the machine stops immediately The raw material from the card is unsuitable for combing, as it need further disposition of fibres within the sheet. The suitable preparatory machines are sliver lap and ribbon lap machines or draw frames or the combination of the above two.

Comber photo control for entry lamp

Application

This unit consists of one control unit and eight sensors for sensing the empty lap. By fixing this unit, the continuity of the lap is maintained. Advantages: The lap is stopped well before the contact rollers, so piecing is very much easier and Non-contact detectors, Dual timer

Cyclic timer, where the machine is switched to slow speed for the pre-selected time interval. Machine run from slow speed to full speed is also controlled through this unit. The machine need not be switched off for cleaning. Timely switching to slow speed maintains the cleanliness of the machine. Waste removal can be done in programmed method.

Auto lap piecer

- The run out lap spool falls automatically beneath the lap rollers and lap is tom off. The remaining lap end is pieced automatically with the full lap supplied from SLM. Thus, the piecing is ensured and machine efficiency is improved.

Spool cleaner

- Spool cleaner strips automatically the remaining fleece on spools of comber preparatory machines and combers. The stripped spools are then automatically returned to the magazine of SLM or RLM.

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Automatic lap transport

- Automated processes call for gentle but reliable lap transport. Manual lap transport is not feasible for the comber. The automatic lap transport system SERVO lap meets the requirements of lap positioning best.
- The overhead SERVO lap - system transport 8 laps at the time from the combing preparation UNILAP to the 3 UNIlap and 18 combers set up in line.
- Comber and ROBO lap are controlled and monitored by a state of the art control system, designed for easy operation - also by unskilled labour.

In modern combers, a modular system based on overhead transport with suspended rail does the package handling automatically. The transport system is capable of conveying 8 laps from the UNIlap to the comber automatically. The empty tubes are automatically return to the UNIlap.

Transportation of roving packages to the ring frame and the return of empty bobbins to the speed frame are carried out by snake or Electro jet system.

Servolap

Operator effort is reduced to supervisory functions by the servolap automated lap transport system and the robolap fully automatic lap changer and batt piecer. Machine efficiency is thus boosted by a further 2 to 3%.

Speed frame

Machine controls

The sliver from the draw frame or from the comber is present to the roving frame. The sliver first enter the drafting arrangement the drafting arrangement attenuates the sliver with a draft of between 5 and 20. The delivered strand is passed through a flyer which impart twist to it . The turns are created by the rotating flyer and are transmitted into the unsupported length between the flyer and the delivery from the drafting zone. The flyers itself form a part of the driven spindle and is rotated with the spindle. The up and down movement of the flyer helps in building up of the roving strand on the bobbin which is placed on the spindle.

Automation in speed frame

Much of the work required on the roving frame is costly, time-consuming, physically demanding and ergonomically unfavorable. Automation is therefore most desirable in order to improve working conditions, to reduce errors, to prevent damage to the roving packages and to increase productivity.

The layout of a roving frame (with its double row of bobbins arranged one behind the other, flyers directly in the forefront, and the expansive creel), is far from ideal for automation. Nevertheless, considerable advances have recently been made. The following picture emerges.

Can changing: Full automation would be too complex and would bring only minor benefits because the change occurs too infrequently. However, can transport might be at least partly automated.

Piecing sliver breaks: This occurs even less frequently and is therefore hardly worth consideration.

Piecing roving breaks: This also occurs infrequently and could only be automated with considerable effort that would make it highly uneconomic.

Bobbin doffing: This is the most useful opportunity for automation and is long overdue since the doff is a costly, frequent and ergonomically unsatisfactory operation that has a significant influence on efficiency. Fortunately, bobbin doffing is state-of-the-art nowadays.

Bobbin transport: This is also an obvious candidate for automation, since about 60% of wage costs in a spinning mill using ring spinning machines can be attributed to the cost of transport. Such systems are now available with varying degrees of automation.

Cleaning: Cleaning has already been automated to a great extent by means of cleaning aprons, clearer rollers and suction systems at the drafting arrangement, and also by the traveling blowers that keep the machine clean.

Machine monitoring: Stop devices are now standard equipment on roving frames. In this area, automation has already been satisfactorily achieved and the burden on personnel has effectively been removed.

Production monitoring: Short-staple spinning mills operate with small profit margins that are generated at a number of individual positions. Many parameters exert an influence. Raw material is the main one, but utilization of personnel and of the installation are also important. An optimum is attained if the machines produce day and night with a minimum of interruptions. One possibility for optimizing efficiency and keeping it under control is a production monitoring system, such as the Zellweger Uster MILLDATA- SLIVERDATA system, in which interruptions in operation of all machines in the preparatory installation are recorded, evaluated and stored. Other companies offer similar systems (for instance, SPIDERweb by Rieter).

Quality monitoring: In contradistinction to the drawframe, where an almost complete quality check can be carried out on the machine itself, total quality control on the roving frame would be too expensive, since too many production positions would have to be checked. Checking roving quality remains the province of the laboratory.

Maintenance and servicing: Much, but not all, has already been achieved in this area by way of central lubrication, low-maintenance design and so on.

Builder Motion: Builder motion is used to wind the roving in a parallel wound package with conical ends as shown in Figure 1. The package is formed layer by layer. The lift of each layer is shortened by a small length which decides the taper angle 'a'. The animation A1 demonstrates the basics of formation of the roving package.

Cone drive transmission: The reduction in the rotational rate of the bobbin and the reduction in the speed of movement of bobbin rail are obtained with a cone drive mechanism. In this mechanism, shown in Figure 4 there

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are two cone drums out of which the top cone drum receive a constant rate of rotation from the motor. Depending up on the position of the drive belt between them, the speed of the bottom cone drum changes. Hence, at any given position of the belt the sum of diameter of the top cone drum (d1) and diameter of the bottom cone drum (d2) should be a constant.

Cone drum types and belt shifting

The cone drums can be of two types. In first type which is conventional one, a pair of convex and concave cone drums is used and in second type a pair of cone drums having straight surface is used. In the first type, the belt is moved a constant length every time to get the required speed profile for the bobbin. In the second case, the belt is shifted through different lengths throughout the bobbin build up.

Automation in ring frame

Automation replaces human activity with processes performed by machines, apparatus or electronics. In terms of cost accounting this substitutes capital costs for labor costs. Automation is therefore worthwhile wherever

- lots of manual work has to be done,
- manual work is monotonous or ergonomically unsuitable,
- personnel are scarce,
- the human error factor has to be eliminated.

Since ring spinning accounts for some 50% of labor costs in a spinning mill, this department is an obvious candidate for automation. However, if we look at the machine itself, it soon becomes obvious that automation is not easy to achieve, since it involves a huge number of tiny production components in a small space with poor accessibility. Even if one or other of these could be automated, it is often uneconomical. Certain operations will therefore have to continue to be performed manually in future.

Automatic doffing

Types of doffing

A distinction is made between two groups of so-called autodoffers (automatic doffing systems):

- stationary systems integrated in each ring spinning machine, and
- mobile systems which can serve several machines.

When new machines are equipped with automatic doffing systems, these are almost always stationary systems. Mobile systems are used, if at all, almost exclusively in existing ring spinning mills. They are somewhat susceptible to faults and require considerable maintenance effort. Whereas with stationary systems all cops on a machine are doffed simultaneously, mobile systems usually feature individual doffing, often also doffing in groups. A stationary system is described below as an example for many other options.

Doffing preparation

All the operations already referred to have to be performed fully automatically here. In addition, there is the special preparation of tubes at the tube loading station. Conveyor belt starts to move along under the loading unit some time before the cops are full. In the process the tubes supplied in tube boxes are inserted on the pegs of the conveyor belt so that every other peg is unoccupied. These pegs later accommodate the full cops. During this operation the conveyor belt moves slowly into its working position, until an empty tube and an empty peg are positioned in front of each spindle.

Individual spindle monitoring

This system features an optical sensor on the ring frame at each spinning position, which monitors the motion of the traveler. It can therefore perform 3 operations:

- recording ends down (incl. startup ends down following cop changes) and registering spindles rotating too slowly (so-called slipper spindles)
- convenient analysis and presentation of these data in the SPIDERweb system
- operator guidance in 3 steps:
- signal lamps at both ends of the machine indicate when an ends down limit has been exceeded
- a LED for each 24 spindles indicates that an end is down in this section
- a LED at each spinning position indicates an end down or a slipper spindle.

This individual spindle monitoring system has distinct advantages:

- No moving parts
- No maintenance
- Continuous monitoring of all spindles.

Ring data: A traveling sensor runs continuously back and forth at the height of the ring rail on each side of the machine on a single machine (pilot unit) or on all machines in the mill. This generates a magnetic field that is affected by the rapidly rotating traveler. If a yarn break occurs, the traveler ceases to rotate and the sensor displays the resulting impulse as an end down, also recording the number of the spindle. As a result of its rapid motion back and forth it registers the spindle several times until the end down is repaired. The spindle downtime is therefore also recorded. Another sensor fitted on the front roller records the delivery speed and machine stoppages, and another the number of doffs and their duration. All the information collected is ultimately transmitted to a computer with monitor and printer, which performs the necessary analysis and stores the data for preset periods. The following data are available via reports on individual machines, individual blends or the installation as a whole that are printed out or can be called up on the monitor:

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- Machine number
- Date
- Time
- Period monitored
- Production period
- Spindle speeds
- Yarn twist
- Output in kg
- Output in g/spi.h
- Efficiency
- Downtimes
- Doffing times
- Number of cops doffed
- Number of ends down
- Ends down per 1 000 spindle hours
- Mean duration of ends down
- Preset maximum number of ends down
- Number of spindles with ends down exceeding this limit.

Pneumatic speed variator

The Hydrostatic Speed Variator is an integrated hydrostatic transmission consisting of a variable displacement radial piston pump driving a fixed displacement radial piston motor. The pump-motor system is completely self contained within one case providing light weight and ease of maintenance and serviceability.

Importance of overhead cleaners

To set new standards in automatic cleaning was the aim of, when laying down the concept for a completely new generation of Overhead Travelling Cleaners. Under the guideline, ergonomical, economical and easy to handle, all the characteristics and features hitherto known as standard, were reconsidered and new target were set. The concept turned out well, with the new system generation SPBI-SML & SPBI - SSL developed for spinning. The overhead Travelling Cleaners which combines the positive features with the criteria mentioned before in a truly ideal way.

Quality Increase

Owing to considerably less accumulations of fly on the fabric.

Productivity Increase by

- Avoiding machine standstills because of manual cleaning works
- Decreasing thread breakages caused by fly
- Reduction of the standstills owing to wear

Reduction of Costs by

- Fewer personnel involved for supervision, repair of thread breakages and manual cleaning
- Less manual cleaning works when checking the cloth
- Lower expenditure for repairs and maintenance
- Saving in spare parts and parts subject to wear and tear

The units are operated on the rectangular Tube Track 50 X 25 X 2.5, which is featured by a high torsion strength and resistance against deflection, we achieve smoothest possible running which is very important easily at the ring spinning machine to maintain the best blowing position, combined with closed contact rail duct ensure the safety, it represents an almost perfect rail system which is also very easy to mount.

Only IEC standard motors are used as internal rotors for the fan units and offer with 2.2 KW and 3.0 KW. A suitable solution for every application. Also it is possible to vary pressure blow speed and Air volume. Easily exchangeable filters allow the filter capacity to be increased up to 2 fold compared to conventional units.

When coordinating unit and filter special attention was directed to an air guidance which following the concept line, is as far as possible free from losses.

All types of OHTCs have the emergency and reverse switches by means of push buttons as standard fittings; of course, the fully automatic collision control via light barriers can also be supplied. When spinning worsted yarn, the cleaners have to be specified one category higher in capacity. An increased air speed and pressure is achieved by the set up of the fan.

An extensive assortment of nozzles of different forms and diameters, bows and nozzle inserts is available for all cleaner types. The specially designed floor suction nozzles are worthy of particular note. For wide creels with finisher bobbins, the blow noses are cranked round the wide part of the creel, and then close in to the machine to direct the air at the elements to be cleaned.

Automation in open end spinning

Machine with a single operating robot

The use of only one robot per machine is economically justifiable only for very short machines, if at all. When starting spinning on a machine or during an accumulation of ends down or package changes it then takes a very long time for all spinning positions to be attended to. If the robot has to be serviced, ends down cannot be repaired and packages cannot be changed. The reduction in efficiency due to long downtimes usually exceeds the advantages of lower capital costs for a second robot.

Machine with a two operating robot

Two operating robots (on for each side of the machine) are usually adequate for serving the spinning positions efficiently on the machine lengths of 240 to 280 spinning positions that are customary nowadays. Each robot serves one side of the machine, and when one robot is being serviced the second robot can be programmed also to serve the other side of the machine. In this case the robot transfers from one side of the machine to the other via a loop on the headstock. The downtime due to stationary spinning

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positions is therefore reduced by half. Using 4 robots on machines of this length results in a significant improvement in efficiency only in extreme spinning conditions - e.g. a combination of coarse yarn counts, small package formats and high delivery speeds - and only then justifies the higher capital costs of the two additional robots.

Another possibility for optimizing travel strategy is useful when using 2 and 4 robots. The robots can be controlled in such a way that a robot changes its direction of travel if no spinning positions in the original direction of travel require the robot's services. All commands for robot control are entered via the machine control panel.

Machine with a three operating robot

The use of 3 robots per machine is theoretically possible. Two robots (RB 1 and RB 2) each serve one side of the machine, while the 3rd robot (RB 3) supports the other two robots by operating alternately on one side of the machine and then on the other. However, the long distances traveled by the 3rd robot via a loop from one side of the machine to the other - amounting to more than one-fourth of its working range - mean that only a very limited improvement in efficiency can be achieved. A major drawback of this concept is that the third robot seriously disrupts work at the end of the machine, such as the removal of full packages, due to its frequent movements back and forth around the loop on the tailstock. The concept with 3 robots per machine has not become established in mill operations to date.

Package transport between the machines

With automatic package change the cross-wound packages replaced by the robot are placed on package conveyor belts (one each for the right-hand and left-hand sides of the machine). When a preset number of finished packages has been placed on the conveyor belt, the package conveyor belt is automatically started and the packages are transported to the end of the machine. Various concepts are available for package removal itself. The previously customary manual package removal at the end of the machine has been complemented increasingly by systems with different degrees of automation.

The packages delivered to the end of the machine are placed automatically or manually in containers, on pallets or creel trolleys at the machine itself and taken away, or alternatively the packages are transported on overhead conveyors or conveyor belts (Fig. 65) to the subsequent process stages for immediate further processing or to the material store. In the material store they can be deposited in containers or boxes for packaging, palletized for onward dispatch or, depending on transport logistics, direct supply to weaving, warping or knitting operations.

Manufacturers of rotor spinning machines either offer their own systems for automatic doffing and/or provide appropriate interfaces that enable users to connect third party suppliers' doffing systems.

Supplying empty tubes

The tube loading system with empty tube magazine (a) and tube handling system (b) is standard equipment on rotor spinning machines where spinning is re-started on empty tubes after package change. The system supplies the robots with the empty tubes required for package change.

The tube handling system mounted on the front of the headstock accepts an empty tube from the tube magazine and places it on a pair of conveyor belts on the left-hand and right-hand side of the machine. At the request of the robot the empty tube is fed to the robot by means of the conveyor belts. This occurs whenever the robot performs a package change. The new empty tube replaces the tube carried by the robot and used for the current package change. The robot accepts the new empty tube from the conveyor belts and is thus already prepared again for the next package change.

Automation in auto coner

The direct link between the ring spinning machine and the package winder already saves around 30-40% on staff costs (compared with RM) in practice, and this trend is rising. But apart from economic efficiency, automation offers another convincing argument - quality. The bobbins are transported contact free, and therefore with the minimum impact on the yarn, from the ring spinning machine to the package winder. The quality of the spun yarn is fully retained. In addition, in an installation linked to the Autoconer X5 V, the yarn quality of each individual spinning unit on the ring spinning machine can be checked and safeguarded at the optimum level by the optional online spindle identification system SPID. The efficiency and safety of the material flow and process sequence no longer depend on the operators. In automated linked systems, the bobbins are wound into packages "just in time" by direct transfer to the winding machine. These "intact" bob-bins facilitate higher efficiency ratings of the package winder on account of greater readying reliability and better unwinding behaviour in the winding process.

The production capacities of the spinning and winding machine are coordinated to one another in the optimum manner for greater efficiency, i.e. for more kilograms of yarn each day.

The shortest route from the bobbin to the package

In the new Autoconer X5, type V machine, the bobbins are supplied to the central readying station once they have been transferred by the CTS to the Caddies of the Autoconer transport system. The number of readying stations and the equipping of these with suit-able yarn detachment device types are freely configurable according to the required cycle rates, materials and bobbin structures. The yarn end is deposited securely on the tube tip as a tip bunch, so that it does not get lost during transporting and the winding unit can fall back on it securely when winding on.

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Electrical wiring, AC relay coil, single phase transformer and control panel

Objectives: At the end of this lesson you shall be able to
- **describe about electrical wiring, relay coil, single phase transformer and control panel.**

Electrical wiring

Electrical wiring is the electrical wiring and associated devices such as switches, meters and light fittings used in buildings or other structures. Electrical wiring uses insulated conductors.

Wiring safety codes vary by country, and the International Electro technical Commission (IEC) is attempting to standardise wiring amongst member countries. Wires and cables are rated by the circuit voltage, temperature and environmental conditions (moisture, sunlight, oil, chemicals) in which they can be used. Colour codes are used to distinguish line, neutral and ground (earth) wires.

Wiring safety codes are intended to protect people and property from electrical shock and fire hazards. Regulations may be established by city, county, provincial/state or national legislation, usually by adopting a model code (with or without local amendments) produced by a technical standards-setting organisation, or by a national standard electrical code.

Electrical codes arose in the 1880s with the commercial introduction of electrical power. Many conflicting standards existed for the selection of wire sizes and other design rules for electrical installations.

The first electrical codes in the United States originated in New York in 1881 to regulate installations of electric lighting. Since 1897 the US National Fire Protection Association, a private non-profit association formed by insurance companies, has published the National Electrical Code (NEC). States, counties or cities often include the NEC in their local building codes by reference along with local differences. The NEC is modified every three years. It is a consensus code considering suggestions from interested parties. The proposals are studied by committees of engineers, tradesmen, manufacturer representatives, fire fighters and other invitees.

Since 1927, the Canadian Standards Association (CSA) has produced the Canadian Safety Standard for Electrical Installations, which is the basis for provincial electrical codes. The CSA also produces the Canadian Electrical Code, the 2006 edition of which references IEC 60364 (Electrical Installations for Buildings) and states that the code addresses the fundamental principles of electrical protection in Section 131. The Canadian code reprints Chapter 13 of IEC 60364, but there are no numerical criteria listed in that chapter to assess the adequacy of any electrical installation.

Although the US and Canadian national standards deal with the same physical phenomena and broadly similar objectives, they differ occasionally in technical detail. As part of the North American Free Trade Agreement (NAFTA) program, US and Canadian standards are slowly converging toward each other, in a process known as harmonisation.

In Germany, DKE (the German Commission for Electrical, Electronic and Information Technologies of DIN and VDE) is the organisation responsible for the promulgation of electrical standards and safety specifications. DIN VDE 0100 is the German wiring regulations document harmonised with IEC 60364.

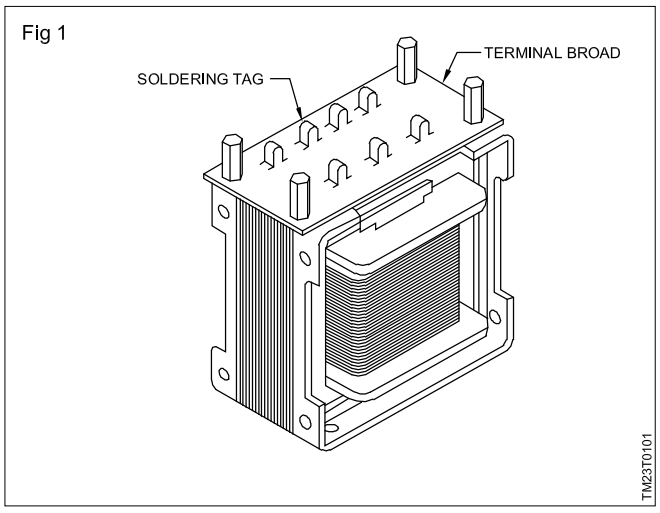
AC Relay coil:

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

Single phase transformer (Fig 1)

Fig 1



Michael Faraday propounded the principle of electro-magnetic induction in 1831. It states that a voltage appears across the terminals of an electric coil when the flux linked with the same changes. The magnitude of the induced voltage is proportional to the rate of change of the flux

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linkages. This finding forms the basis for many magneto electric machines. The earliest use of this phenomenon was in the development of induction coils. These coils were used to generate high voltage pulses to ignite the explosive charges in the mines.

As the DC power system was in use at that time, very little of transformer principle was made use of. In the DC supply system the generating station and the load center have to be necessarily close to each other due to the requirement of economic transmission of power.

Also the DC generators cannot be scaled up due to the limitations of the commutator. This made the world look for other efficient methods for bulk power generation and transmission. During the second half of the 19th century the alternators, transformers and induction motors were invented. These machines work on alternating power supply. The role of the transformers became obvious. The transformer which consisted of two electric circuits linked by a common magnetic circuit helped the voltage and current levels to be changed keeping the power invariant. The efficiency of such conversion was extremely high. Thus one could choose a moderate voltage for the generation of AC power, a high voltage for the transmission of this power over long distances and finally use a small and safe operating voltage at the user end. All these are made possible by transformers. The AC power systems thus got well established.

Transformers can link two or more electric circuits. In its simple form two electric circuits can be linked by a magnetic circuit, one of the electric coils is used for the creation of a time varying magnetic filed. The second coil which is made to link this field has an induced voltage in the same. The magnitude of the induced EMF is decided by the number of turns used in each coil. Thus the voltage level can be increased or decreased by changing the number of turns. This excitation winding is called a primary and the output winding is called a secondary. As a magnetic medium forms the link between the primary and the secondary windings there is no conductive connection between the two electric circuits. The transformer thus provides an electric isolation between the two circuits. The frequency on the two sides will be the same. As there is no change in the nature of the power, the resulting machine is called a 'transformer' and not a 'converter'. The electric power at one voltage/current level is only 'transformed' into electric power, at the same frequency, to another voltage/ current level.

Control panel

An electric switchboard is a device that directs electricity from one or more sources of supply to several smaller regions of usage. It is an assembly of one or more panels, each of which contains switches that allow electricity to be redirected.

The U.S. National Electrical Code (NEC) defines a switchboard as "a large single panel, frame, or assembly of panels on which are mounted, on the face, back, or both, switches, over-current and other protective devices, buses, and usually instruments". The role of a switchboard is to allow the division of the current supplied to the switchboard into smaller currents for further distribution and to provide switching, current protection and (possibly) metering for those various currents. In general, switchboards may distribute power to transformers, panel boards, control equipment, and, ultimately, to individual system loads.

Components

Inside a switchboard there will be one or more bus bars. These are flat strips of copper or aluminum, to which the switch gear is connected. Bus bars carry large currents through the switchboard, and are supported by insulators. Bare busbars are common, but many types are now manufactured with an insulating cover on the bars, leaving only connection points exposed.

The operator is protected from electrocution by safety switches and fuses. There may also be controls for the supply of electricity to the switchboard, coming from a generator or bank of electrical generators, especially frequency control of AC power and load sharing controls, plus gauges showing frequency and perhaps a synchro scope. The amount of power going into a switchboard must always equal to the power going out to the loads.

Modern industrial switchboards are metal enclosed and of "dead front" construction; no energized parts are accessible when the covers and panels are closed. Previously, open switchboards were made with switches and other devices were mounted on panels made of slate, granite, or ebony asbestos board. The metal enclosure of the switchboard is bonded to earth ground for protection of personnel. Large switchboards may be free-standing floor-mounted enclosures with provision for incoming connections at either the top or bottom of the enclosure. A switchboard may have incoming bus bars or bus duct for the source connection, and also for large circuits fed from the board. A switchboard may include a metering or control compartment separated from the power distribution conductors

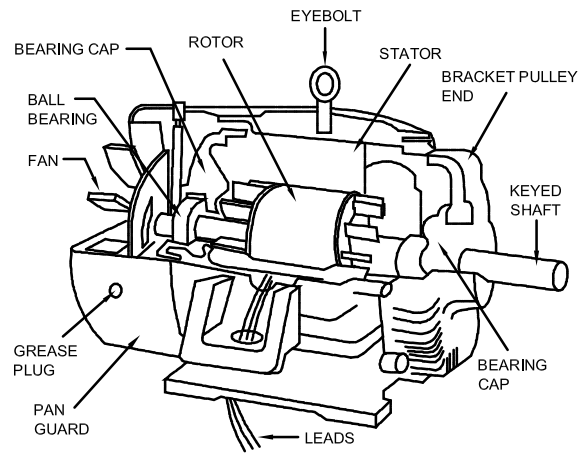
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Induction motor and its construction and hydraulic fluid coupling

Objectives: At the end of this lesson you shall be able to
- **describe induction motor and its construction**
- **describe hydraulic loading devices and fluid coupling.**

Induction motor (Fig 1)

Fig 1



INDUCTION MOTOR

An induction or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type.

Three-phase squirrel-cage induction motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and VFD applications.

Motor construction

Rotor

In an electric motor the moving part is the rotor which turns the shaft to deliver the mechanical power. The rotor usually has conductors laid into it which carry currents that interact with the magnetic field of the stator to generate the forces that turn the shaft.

However, some rotors carry permanent magnets, and the stator holds the conductors.

Stator

The stationary part is the stator, usually has either windings or permanent magnets. The stator is the stationary part of the motor's electromagnetic circuit. The stator core is made up of many thin metal sheets, called laminations. Laminations are used to reduce energy losses that would result if a solid core were used.

Air gap

In between the rotor and stator is the air gap. The air gap has important effects, and is generally as small as possible, as a large gap has a strong negative effect on the performance of an electric motor.

Windings

Windings are wires that are laid in coils, usually wrapped around a laminated soft iron magnetic core so as to form magnetic poles when energized with current.

Electric machines come in two basic magnet field pole configurations: salient-pole machine and nonsalient-pole machine. In the salient-pole machine the pole's magnetic field is produced by a winding wound around the pole below the pole face. In the nonsalient-pole, or distributed field, or round-rotor, machine, the winding is distributed in pole face slots. A shaded-pole motor has a winding around part of the pole that delays the phase of the magnetic field for that pole.

Some motors have conductors which consist of thicker metal, such as bars or sheets of metal, usually copper, although sometimes aluminum is used. These are usually powered by electromagnetic induction.

Commutator

A commutator is a mechanism used to switch the input of most DC machines and certain AC machines consisting of slip ring segments insulated from each other and from the electric motor's shaft. The motor's armature current is supplied through the stationary brushes in contact with the revolving commutator, which causes required current reversal and applies power to the machine in an optimal manner as the rotor rotates from pole to pole. In absence of such current reversal, the motor would brake to a stop. In light of significant advances in the past few decades due to improved technologies in electronic controller, sensor less control, induction motor, and permanent magnet motor fields, electromechanically commutated motors are increasingly being displaced by externally commutated induction and permanent-magnet motors.

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Machine drives

In a machine, drives are required to transmit power from electric motor (usually) to various elements and from one element to others so that the various elements could perform their desired operations. Between any two elements of a machine, the one which drives the other is called 'Driver'; and the other one is termed 'Driven'. The power/ motion is transmitted by means of various drives such as belts, chains and gears. The machine designer has the options of selecting the nature/type of drives. Different drives have certain advantages and limitations. The following factors have to be considered in selecting the natures of drives especially, gears, belts and chains:

1 Space constraint in housing the driver and driven elements. It is related to availability of space in the machine to house the drives. The compactness of the whole machine puts a limit on the availability of space in the machine.

2 Accuracy of speeds to be transmitted. In certain operations, the speed transmitted to an element must be very accurate. The speed variation must be kept within a very narrow limit due to process/product requirement.

3 The level of noise the drive system generates and that can be tolerated in the operating environment around the machine.

4 The level of vibrations/shocks the drives produce and their acceptability in terms of efficient functioning of the machines and quality of output from the machines.

5 Manufacturing accuracies of the drives and the cost associated with them.

The construction of flat-belt, v-belt, round belt, toothed belt, chain drives and various types of gears, analysis of forces, torque and power transmission, characteristics and applications of them are discussed in modules 2 to 5. The comparisons of these drives are also discussed. These modules help the reader on selecting a right type of drive for driving a specific machine element.

The belts must be kept under required tension in order transfer optimum power. Various methods of controlling the belt tensions such as movable-swinging motor and tension pulley are discussed in module 2. The module 3 discusses about chain drives. The classification of chain drives, geometrical relationships, inherent speed variation in chain drives (polygonal effect), characteristics, selection and applications in textile machines are also covered in the module 3.

Spur gears are extensively used in textile machines. The nomenclature used in spur gears and relationships between design parameters of spur gears, requirement of constant speed ratio (conjugate action), generation of involute teeth on spur gear, and effect of interference in gears on periodic drafting waves on fibre strands using roller drafting (drawing, roving and ring spinning machines), and elimination of interference are discussed in module 4. Derivatives of spur gears as internal gears, rack-and-pinion and their applications in textile machines are also discussed in this module. Parallel helical gears, crossed helical gears, different bevel gears and worm gears are used in textile machines. The geometry of these gears, thrust load acting on shaft mounted with these gears and applications are discussed in module 5. Gear trains (train of gears) widely used on machines to transfer motion from one element to many elements. Module 6 deals with many types of gear trains.

Hydraulic

Introduction

Hydraulics is a topic in applied science and engineering dealing with the mechanical properties of liquids or fluids. At a very basic level, hydraulics is the liquid version of pneumatics. Fluid mechanics provides the theoretical foundation for hydraulics, which focuses on the engineering uses of fluid properties.

Hydraulic loading devices

Hydraulic fluid

Hydraulic fluid must be essentially non-compressible to be able to transmit power instantaneously from one part of the system to another. At the same time, it should lubricate the moving parts to reduce friction loss and cool the components so that the heat generated does not lead to fire hazards. It also helps in removing the contaminants to filter. The most common liquid used in hydraulic systems is petroleum oil because it is only very slightly compressible. The other desirable property of oil is its lubricating ability. Finally, often, the fluid also acts as a seal against leakage inside a hydraulic component. The degree of closeness of the mechanical fit and the oil viscosity determines leakage rate.

Hydraulic pumps

The pump converts the mechanical energy of its prime-mover to hydraulic energy by delivering a given quantity of hydraulic fluid at high pressure into the system. Generically, all pumps are divided into two categories, namely, hydrodynamic or non-positive displacement and hydrostatic or positive displacement. Hydraulic systems generally employ positive displacement pumps only.

Hydraulic and pneumatic cylinder

Actuators are output devices which convert energy from pressurized hydraulic oil or compressed air into the required type of action or motion. In general, hydraulic or pneumatic systems are used for gripping and/or moving operations in industry. These operations are carried out by using actuators.

Actuators can be classified into three types

1 Linear actuators: These devices convert hydraulic/ pneumatic energy into linear motion.

2 Rotary actuators: These devices convert hydraulic/ pneumatic energy into rotary motion.

3 Actuators to operate flow control valves: these are used to control the flow and pressure of fluids such as gases, steam or liquid.

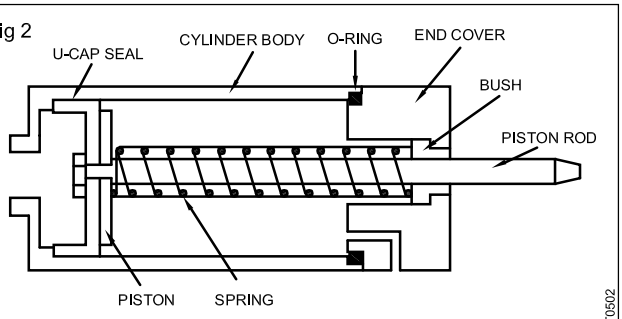
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The construction of hydraulic and pneumatic linear actuators is similar. However they differ at their operating pressure ranges. Typical pressure of hydraulic cylinders is about 100 bar and of pneumatic system is around 10 bar.

Single actuating cylinder (Fig 2)

These cylinders produce work in one direction of motion hence they are named as single acting cylinders. The compressed air pushes the piston located in the cylindrical barrel causing the desired motion. The return stroke takes place by the action of a spring. Generally the spring is provided on the rod side of the cylinder.

Fig 2

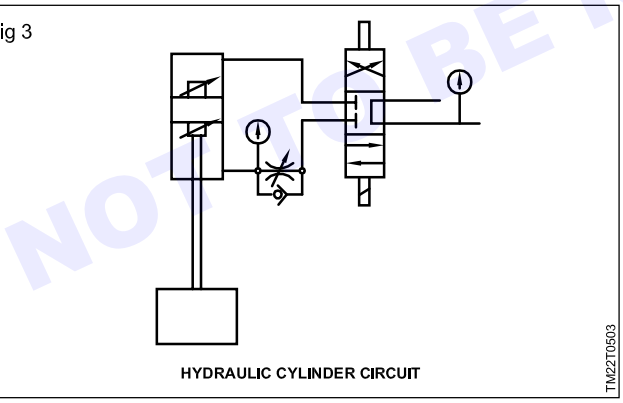


SINGLE ACTUATING CYLINDER

Hydraulic Cylinder Circuit (Fig 3)

If you have access to suitable test rig or simulation software, you should construct this circuit and try out the following demonstration. A hydraulic cylinder is mounted vertically and has a large weight on the rod that is lifted when pressure is applied to the annular side of the piston. This demonstration is to show that pressures higher than the operating pressure can be generated on a hydraulic cylinder with a restricted outlet.

Fig 3



HYDRAULIC CYLINDER CIRCUIT

Fluid coupling

It is a device for transmitting rotation between shafts by means of the acceleration and deceleration of a hydraulic fluid (such as oil). Also known as hydraulic coupling. Structurally, a fluid coupling consists of an impeller on the input or driving shaft and a runner on the output or driven shaft. The two contain the fluid. Impeller and runner are bladed rotors, the impeller acting as a pump and the runner reacting as a turbine. Basically, the impeller accelerates the fluid from near its axis, at which the tangential component of absolute velocity is low, to near its periphery, at which the tangential component of absolute velocity is high. This increase in velocity represents an increase in kinetic energy. The fluid mass emerges at high velocity from the impeller, impinges on the runner blades, gives up its energy, and leaves the runner at low velocity.

Advantages of fluidomat fluid couplings

1 Wear-free power transmission because of absence of mechanical connection between the input and output elements.

2 No-load start-up of motor irrespective of machine load. Motor peak torque utilized for machine acceleration.

3 Motor selection to operating HP rather than starting loads. Saving on energy cost and capital cost.

4 Simple control of maximum or limiting torque by easy variation of oil filling.

5 Added protection for motor and driven machine by limiting torque to a predetermined safe value.

6 Automatic unloading of prime mover in case of any sustained overload, by blowing-off of fusible plug on coupling, thus draining out oil.

7 Automatic synchronisation and load sharing in case of multi-motor drives

8 Effective dampening of shocks, load fluctuations and torsional vibrations. Helpful in improving the drive duty conditions in machines subjected to shock loads, frequent load changes, startups and reversals.

9 Smooth and controlled acceleration of driven machines. Important for machines such as conveyors, wire drawing and textile machines.

10 Stepless speed variation in wide range obtained in scoop type fluid couplings.

11 Continuous clutching and declutching of large drives obtained from SC type couplings.

12 Economy on machine and drive designs.

13 ENERGY SAVING

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Different parameters of textile machines

Objectives: At the end of this lesson you shall be able to
- **state parameters of blow room machine**
- **state parameters of carding machine**
- **state parameters of draw frame machine**
- **state parameters of speed frame machine**
- **state parameters of ring frame machine.**

Different parameters of blow room machine

Cleaning efficiency

It means the cleaning performance of cotton with extracting trash from material. Cleaning efficiency of the machine is the ratio of the trash removed by the machine to that of total trash fed to the machine, expressed as percentage

$$\text{Cleaning Efficiency (\%)} = \frac{\text{Trash in the feed material - Trash in the delivery material}}{\text{Trash in the feed material}} \times 100$$

Production of blow room machine

$$\text{Production} = \frac{\text{J x Diameter of BCR x Speed of BCR x 60 x 8 x 90}}{\text{36 x 840 x Lap hank (Ne) x 2.205 x 60 x 8 x 100}}$$

Trash and lint content

1 $$\text{Trash content (\%)} = \frac{\text{Weight of trash}}{\text{Weight of sample}} \ 100$$

2 $$\text{Lint content (\%)} = \frac{\text{Weight of lint fibre}}{\text{Weight of sample}} \ 100$$

Different parameters of carding machine

Draft calculations

a Calculated draft

$$\text{Calculated Draft} = \frac{\text{Surface speed coiler calendar roller}}{\text{Surface speed of feed roller}}$$

b Draft change wheel

$$\text{Draft change wheel} = \frac{\text{Draft constant}}{\text{Mechanical draft}}$$

c Mechanical draft

$$\text{Mechanical draft} = \frac{\text{Actual draft x (100 - Waste \%)}}{100}$$

d Actual draft

$$\text{Actual draft} = \frac{\text{Hank delivered}}{\text{Hank fed}}$$

e Draft constant

Draft constant = DCW x mechanical draft

f Production calculation

$$\text{Sliver hank} = \frac{\text{Length in yard / 840}}{\text{454 / weight in gram}}$$

$$\text{Production} = \frac{\text{J x Diameter of doffer x Speed of doffer x 60 x 8 x 90}}{\text{36 x 840 x sliver hank (Ne) x 2.205 x 60 x 8 x 100}}$$

Different parameters of draw frame machine

Draft calculations

a Front draft

$$\text{Front draft} = \frac{\text{Surface speed of second roller}}{\text{Surface speed of third roller}}$$

b Back draft (break draft)

$$\text{Back draft} = \frac{\text{Surface speed of fourth roller}}{\text{Surface speed of back roller}}$$

c Total draft (mechanical draft)

$$\text{Total draft} = \frac{\text{Surface speed of second roller}}{\text{Surface speed of back roller}}$$

d Draft constant

Draft constant = DCW x mechanical draft

e Production calculation of draw frame machine

$$\text{Production} = \frac{\text{0.2835 x delivery speed (mpm) x m/c efficiency (\%)}}{\text{Sliver hank (Ne) x 100}}$$

Different parameters of speed frame machine

a Front draft

$$\text{Front draft} = \frac{\text{Surface speed of front roller}}{\text{Surface speed of middle roller}}$$

b Back draft (break draft)

$$\text{Back draft} = \frac{\text{Surface speed of middle roller}}{\text{Surface speed of back roller}}$$

c Total draft

Total draft = Front draft x Break draft

d Draft constant

$$\text{Draft} = \frac{\text{Surface speed of front roller}}{\text{Surface speed of back roller}}$$

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Twist calculations

a Twist / metre

$$\text{Twist / metre} = \frac{\text{Twist constant}}{\text{Twist change wheel}}$$

b Twist factor (multiplier)

Twist multiplier = Twist / metre x Count

c Production calculation of speed frame machine

$$\text{Production (in Kg.) / spindle / 8 hrs} = \frac{\text{7.2 x spindle speed (rpm) x m/c efficiency (\%)}}{\text{Count (Ne) x TPI x 100000}}$$

Different parameters of ring frame machine

Draft calculations

a Front draft

$$\text{Front draft} = \frac{\text{Surface speed of front roller}}{\text{Surface speed of middle roller}}$$

b Back draft (break draft)

$$\text{Back draft} = \frac{\text{Surface speed of middle roller}}{\text{Surface speed of back roller}}$$

c Draft constant

Draft constant = Draft change wheel x Mechanical draft

Twist calculations

a Twist / cm

$$\text{Twist/cm} = \frac{\text{Twist factor (multiplier)}}{\sqrt{\text{Count in Tex}}}$$

b Twist factor (multiplier)

$$\text{Twist multiplier} = \text{Twist / cm} \times \sqrt{\text{Count in Tex}}$$

c Production calculation of ring frame machine

$$\text{Production (in grams) / spindle / 8 hrs} = \frac{\text{7.2 x spindle speed (rpm) x m/c efficiency (\%)}}{\text{Count (Ne) x TPI x 100}}$$

Different parameters of winding machine

Objectives: At the end of this lesson you shall be able to
- **state parameters of winding machine.**

Autoconer: Auto cone can be defined as "It is a type of winding machine in which ring bobbins are converted into large cones with removing of spinning faults. In order to form packages of the right weight for subsequent processing stages, the winding machine can be fed by ring-spun yarn bobbins. Different parameters of winding machine are discussed below.

Different parameters of winding machine

a Yarn diameter (Inches) = $\frac{1}{28 \times \sqrt{\text{Count (Ne)}}}$

b Slub catcher settings:

For carded yarn

Fixed blade = (2.0 to 2.5) x Diameter

For combed yarn

Fixed blade = (1.5 to 2.0) x Diameter

c Yarn clearer efficiency (%) =

$$\frac{\text{Number of objectionable faults detected}}{\text{Number of objectionable faults in yarn}} \times 100$$

d Knot factor = $\frac{\text{Total breaks during winding (at faults)}}{\text{Number of breaks due to objectionable faults}}$

e Retained splice strength (%) =

$$\frac{\text{Strength of spliced joint x 100}}{\text{Strength of parent yarn}}$$

f Winding tension (grams) = 0.1 x Single yarn strength in grams

Production calculation

$$\textbf{RPM of traverse cam (rpm)} = \text{Motor speed} \times \frac{\text{Motor pulley}}{\text{Machine pulley}}$$

Traverse rate = RPM of traverse cam x 2 x length of traverse

$$\text{Drum shaft speed (rpm)} = \text{Motor speed} \times \frac{\text{Motor pulley}}{\text{Machine pulley}}$$

Surface speed of drum (inches / minute) = J x Diameter of drum (in inches) x Drum speed

$$\text{Production / shift (Lbs/drum/shift)} = \frac{\text{J x Dia. of drum (in inches) x Drum speed x No. of drums x 60 x shift x Eff.}}{\text{36 x 100 x 30 x 840}}$$

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