Techno India NJR Institute of Technology

Lab Manual

Basic Electrical Engineering Lab (1FY3-26/2FY3-26)

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(Assistant Professor)

Department of Electrical Engineering

Syllabus:

RAJASTHAN TECHNICAL UNIVERSITY, KOTA

I & II Semester
Common to all branches of UG Engineering & Technology

1FY3-26/ 2FY3-26: Basic Electrical Engineering Lab

Credit: 1 **Max. Marks: 50 (IA:30, ETE:20)**
0L+0T+2P

1. Basic safety precautions. Introduction and use of measuring instruments – voltmeter, ammeter, multi-meter, oscilloscope. Real-life resistors, capacitors and inductors.
2. Transformers: Observation of the no-load current waveform on an oscilloscope. Loading of a transformer: measurement of primary and secondary voltages and currents, and power.
3. Three-phase transformers: Star and Delta connections. Voltage and Current relationships (line-line voltage, phase-to-neutral voltage, line and phase currents).Phase-shifts between the primary and secondary side.
4. Demonstration of cut-out sections of machines: dc machine (commutator-brush arrangement), induction machine (squirrel cage rotor), synchronous machine (field winging - slip ring arrangement) and single-phase induction machine.
5. Torque Speed Characteristic of separately excited dc motor.
6. Demonstration of (a) dc-dc converters (b) dc-ac converters – PWM waveform (c) the use of dc-ac converter for speed control of an induction motor and (d) Components of LT switchgear.

Overview:

This lab is mainly for undergraduate First-Year Engineering students from all Specializations. This lab will introduceand explain the fundamental concepts of basic electrical engineering. The basic concepts of DC and AC (Single Phase and Three Phase Circuits) network analysis, first order DC transients, steady state and phasor analysis of AC networks, series and parallel resonance and magnetic coupled circuits. This lab will also cover Single Phase Transformers, Single and Three Phase Induction Machines and DC Machines. This also includes the Power converter concepts ans analysis of single phase full wave rectifier using R load and Electrical installations in substations. By the end of the lab, the students should be able to gather high-quality knowledge of basic electrical engineering as well as the practical implementation of fundamental theory concepts.

Course Outcome:

CO. No.	Significance
CO1	Work with Cathode Ray Oscilloscope (CRO), voltmeter, ammeter, wattmeter and identify different types of electronic components viz resistors, inductors, capacitors, diodes, diac, triac, transistors, thyristors and observe the working of the same.
CO2	Measure and observe the no-load current waveform on an oscilloscope, and calculate the voltages, currents, power and efficiency of a transformer.
CO3	Perform the different possible connections of three-phase transformers and observe voltage and current relationships, as well as note down the Phase-shifts between the primary and secondary side.
CO4	Identify the cut-out sections, working and speed behavior of dc machine, synchronous machine, single-phase and three phase induction machine.
CO5	Plot torque speed characteristic of a separately excited dc motor, observe the working of dc-dc converters, dc-ac converters, dc-ac converter for speed control of an induction motor and explain the various components of LT switchgear.

Prerequisites:

1. Fundamentals of current electricity.
2. Students should be efficient in basic mathematics and solving an algebraic equation.
3. Students should be able to perform basic exponential, trigonometric and logarithm operations.

Course Outcome Mapping with Program Outcome:

Keywords (PO/PSO)	Apply Knowledge	Solve Problem	Design/Development of Solution	Conduct Investigation	Use Modern Tools	Engineering and Socity	Environment and sustainability	Professional Ethics	Individual and Team work	Communicate Effectively	Project management and Finance	Life long learning
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3	2	-	-	-	-	-	-	-	-	2
CO2	3	3	3	-	-	-	-	-	-	-	-	2
CO3	3	3	3	-	-	-	-	-	-	-	-	2
CO4	3	3	3	-	-	-	-	-	-	-	-	2
CO5	3	3	3	-	-	-	-	-	-	-	-	2
1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High)												

Text/Reference Books:

1. Electrical and Electronic Technology by Edward Hughes et al, Pearson Publication
2. Basic Electrical & Electronics Engineering by V. Jagathesan, K. Vinod Kumar & R. Saravan Kumar, Wiley India.
3. Basic Electrical & Electronics Engineering by Van Valkenburge, Cengage learning Indian Edition
4. Basic Electrical and Electronics Engineering by Muthusubrmaniam, TMH
5. Fundamentals of Electrical Engineering by Leonard S. Bobrow, Oxford University Press
6. Fundamentals of Electrical and Electronics Engineering by Ghosh, Smarajit, PHI India
7. Basic Electrical & Electronics Engineering by Ravish Singh, TMH

LAB ETHECS

Do's

1. Enter the lab on time and leave at proper time.
2. Keep the bags outside in the racks.
3. Utilize lab hours in the corresponding experiment.
4. Make the Supply off the Kits/Equipments after completion of Experiments.
5. Maintain the decorum of the lab.

Don'ts

1. Don't bring any external material in the lab.
2. Don't make noise in the lab.
3. Don't bring the mobile in the lab.
4. Don't enter in Faculty room without permission.
5. Don't litter in the lab.
6. Don't carry any lab equipments outside the lab

INSTRUCTIONS TO THE STUDENTS

General Instructions

1. Maintain separate lab record and lab copy for each laboratory.
2. Record the observations in lab copy & checked by the faculty.
3. Maintain Index column in the observation copy and get the signature of the faculty before leaving the lab.

Before Entering in the Lab

1. All the students are supposed to prepare the theory regarding the present Experiment.
2. Students are supposed to bring the lab record and the lab copy.
3. Object/aim, Required apparatus table, Circuit diagram/algorithm, Observational table (if any), Formula or calculation (if any), Graph(if any) & Brief Theory of the previous practical should be written in the lab record.
4. Object, Circuit diagram and observational Table of present experiment should be written in lab copy.
5. Any student not following these instructions will be denied entry in the lab and Seasonal Marks will be affected

While Working in the Lab

1. Adhere to experimental schedule as instructed by the faculty.
2. Each student should work on his/her assigned present table of the lab as per rotor chart.
3. Take responsibility of valuable accessories.
4. Concentrate on the assigned practical and be careful.
5. Never switch on the power supply before getting the permission from the faculty

Before Leaving the Lab

1. The equipments/components should be returned back to the lab assistant in good condition after the completion of the experiment.
2. The lab record of the student should be checked by the faculty and also counter signed in index.
3. If anyone is caught red-handed carrying any equipment of the lab, then he will have to face serious consequences.

BASIC SAFETY PRECAUTIONS

The following general rules and precautions are to be observed at all times in the laboratory. These rules are for the benefit of the experimenter as well as those around him/her.

1. Avoid loose wires, cables, and connections.
2. Familiarize oneself with all ON/OFF buttons on equipment, circuit breakers, and disconnect switches of a bench.
3. Only make changes to the experimental setup when the circuit power is turned off and all power sources read zero voltage and zero current, as applicable.
4. Use wires of suitable length for their appropriate applications. Long wires or connections can cause clutter on a bench, and very short wires or connections can be too tight and may be easily disconnected.
5. Separate higher power equipment and connections from lower power equipment, such as microcontrollers, ICs, to avoid both interference and electrical interconnections between sensitive electronic devices and higher power devices.
6. Make sure that all DC power supplies, AC sources, and other power sources start from a zero voltage and zero current output or as directed in an experiment. Starting from a non-zero voltage is possible in certain applications where a voltage source should have a specific initial condition.
7. Turn off all equipment before leaving the lab once an experiment concludes.
8. Do not allow a single user to perform an experiment alone. Make sure at least two users perform an experiment when operating more than 50 V DC and three-phase AC.
9. Use only tools and equipment with non-conducting handles when working with electrical devices.
10. Verify the connections you have made by faculty/lab assistant before switch on it to perform.

Experiment No-1

1. **OBJECT:** To understand working and use of the Cathode Ray Oscilloscope (CRO) and Identification and testing of different types of electronic components with study and demonstration of measuring instruments.

APPARATUS REQUIRED:

S.N.	Name of Equipment	Quantities	Types
1.	Function generator		
2.	CRO		
3.	Connecting probe		

THEORY:

Cathode ray oscilloscope: The cathode-ray oscilloscope (CRO) is a common laboratory instrument that provides accurate time and amplitude measurements of voltage signals over a wide range of frequencies. Its reliability, stability, and ease of operation make it suitable as a general purpose laboratory instrument. The heart of the CRO is a cathode-ray tube shown schematically in Fig.1.1

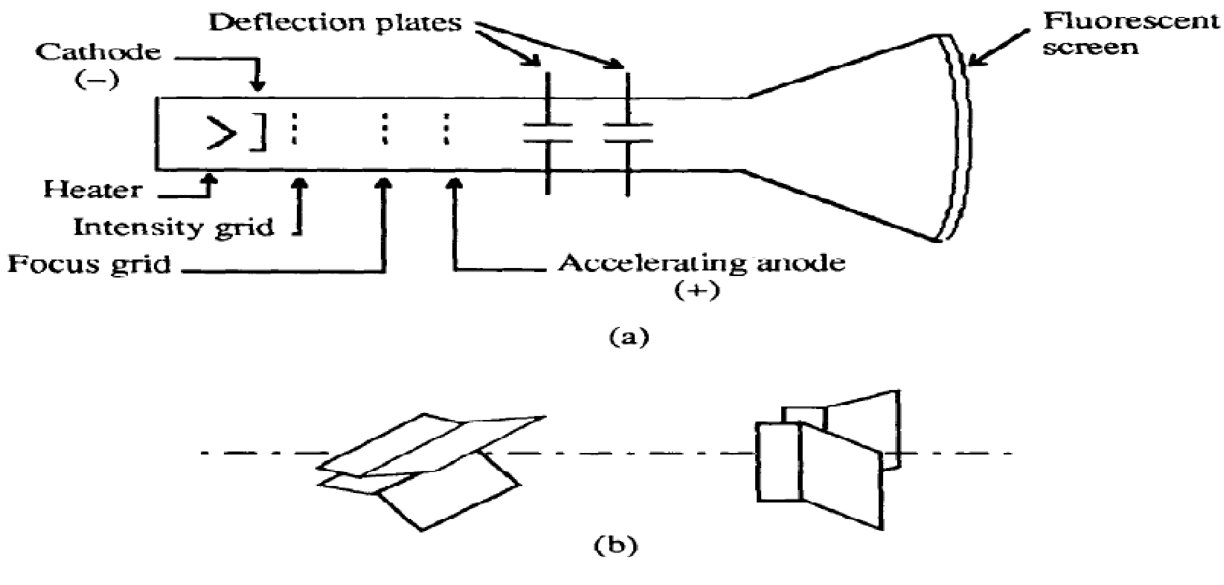


Fig: 1.1 Cathode-ray oscilloscopes (CRO) (a) Schematic (b) Details of deflection Plate

The cathode ray is a beam of electrons which are emitted by the heated cathode (negative electrode) and accelerated toward the fluorescent screen. The assembly of the cathode, intensity grid, focus grid, and accelerating anode (positive electrode) is called an electron gun. Its purpose is to generate the electron beam and control its intensity and focus. Between the electron gun and the fluorescent screen are two pair of metal plates - one oriented to provide horizontal deflection of the beam and one pair oriented to give vertical deflection to the beam.

These plates are thus referred to as the horizontal and vertical deflection plates. The combination of these two deflections allows the beam to reach any portion of the fluorescent screen. Wherever the electron beam hits the screen, the phosphor is excited and light is emitted from that point. This conversion of electron energy into light allows us to write with points or lines of light on an otherwise darkened screen.

CRO Operation: A simplified block diagram of a typical oscilloscope is shown in Fig. 1.2. In general, the instrument is operated in the following manner. The signal to be displayed is amplified by the vertical amplifier and applied to the vertical deflection plates of the CRT. A portion of the signal in the vertical amplifier is applied to the sweep trigger as a triggering signal. The sweep trigger then generates a pulse coincident with a selected point in the cycle of the triggering signal. This pulse turns on the sweep generator, initiating the sawtooth wave form. The sawtooth wave is amplified by the horizontal amplifier and applied to the horizontal deflection plates. Usually, additional provisions signal are made for applying an external triggering signal or utilizing the 60 Hz line for triggering. Also the sweep generator may be bypassed and an external signal applied directly to the horizontal amplifier.

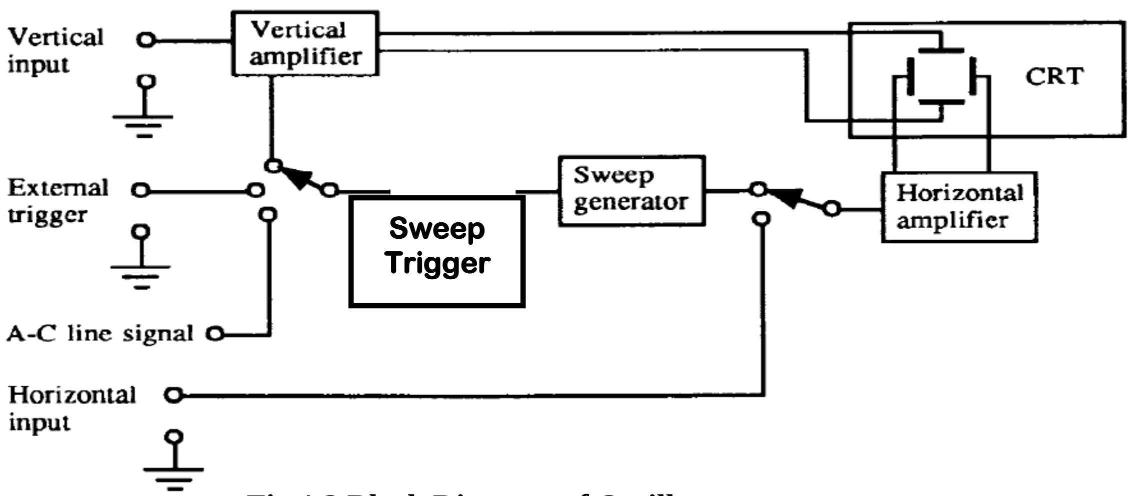


Fig 1.2 Block Diagram of Oscilloscope

Cathode-ray tube

Power and Scale Illumination: Turns instrument on and controls illumination of the graticule.

Focus: Focus the spot or trace on the screen.

Intensity: Regulates the brightness of the spot or trace.

Vertical amplifier section

Position: Controls vertical positioning of oscilloscope display.

Sensitivity: Selects the sensitivity of the vertical amplifier in calibrated steps.

Variable Sensitivity: Provides a continuous range of sensitivities between the calibrated steps. Normally the sensitivity is calibrated only when the variable knob is in the fully clockwise position.

AC-DC-GND: Selects desired coupling (ac or dc) for incoming signal applied to vertical amplifier, or grounds the amplifier input. Selecting dc couples the input directly to the amplifier; selecting ac send the signal through a capacitor before going to the amplifier thus blocking any constant component.

Horizontal-sweep section

Sweep time/cm: Selects desired sweep rate from calibrated steps or admits external signal to horizontal amplifier.

Sweep time/cm Variable: Provides continuously variable sweep rates. Calibrated position is fully clockwise.

Position: Controls horizontal position of trace on screen.

Horizontal Variable: Controls the attenuation (reduction) of signal applied to horizontal amplifier through External Horizontal connector.

Trigger

The trigger selects the timing of the beginning of the horizontal sweep.

Slope: Selects whether triggering occurs on an increasing (+) or decreasing (-) portion of trigger signal.

Coupling: Selects whether triggering occurs at a specific dc or ac level.

Source: Selects the source of the triggering signal.

INT - (internal) - from signal on vertical amplifier
EXT - (external) - from an external signal inserted at the **EXT. TRIG. INPUT.**
LINE - 60 cycle trigger

Level: Selects the voltage point on the triggering signal at which sweep is triggered. It also allows automatic (auto) triggering of allows sweep to run free (free run).

Connections for the oscilloscope

Vertical Input: A pair of jacks for connecting the signal under study to the Y (or vertical) amplifier. The lower jack is grounded to the case.

Horizontal Input: A pair of jacks for connecting an external signal to the horizontal amplifier. The lower terminal is graounted to the case of the oscilloscope.

External Tigger Input: Input connector for external trigger signal.

Cal. Out: Provides amplitude calibrated square waves of 25 and 500 millivolts for use in calibrating the gain of the amplifiers.

Accuracy of the vertical deflection is ± 3%. Sensitivity is variable.

Horizontal sweep should be accurate to within 3%. Range of sweep is variable.

Operating Instructions: Before plugging the oscilloscope into a wall receptacle, set the controls as follows:

(a) Power switch at off
(b) Intensity fully counter clockwise
(c) Vertical centering in the center of range

(d) Horizontal centering in the center of range

(e) Vertical at 0.2

(f) Sweep times 1

Plug line cord into a standard ac wall receptacle (nominally 118 V). Turn power on. Do not advance the Intensity Control. Allow the scope to warm up for approximately two minutes, then turn the Intensity Control until the beam is visible on the screen.

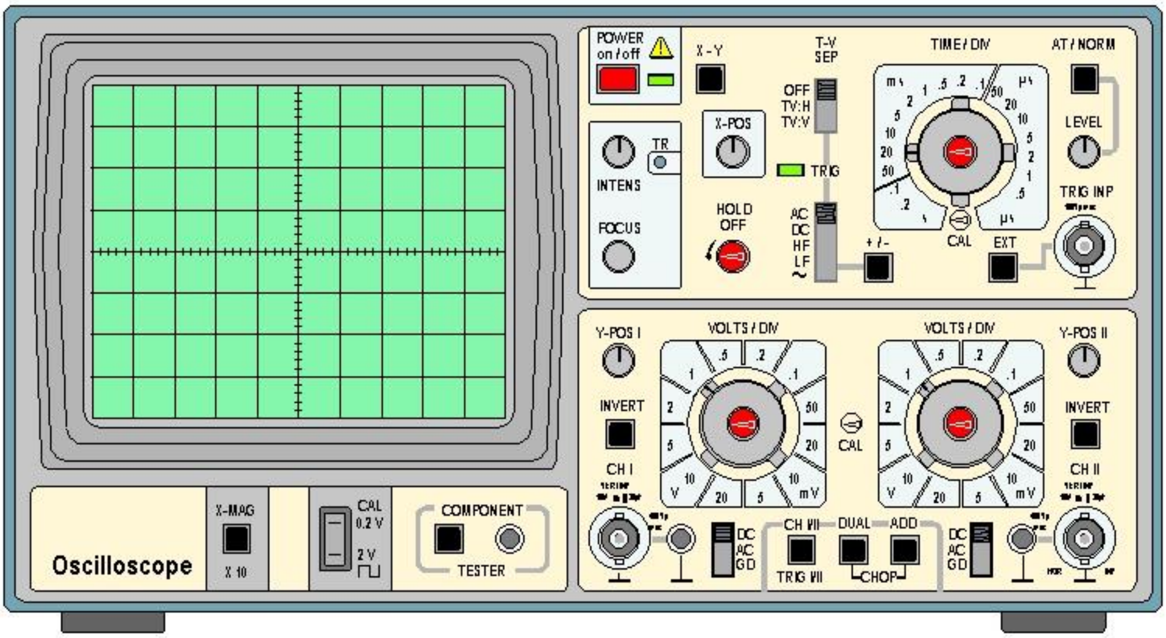


Fig 1.3 Cathode Ray Oscilloscope

PROCEDURE:

I. Set the signal generator to a frequency of 1000 cycles per second. Connect the output from the gererator to the vertical input of the oscilloscope. Establish a steady trace of this input signal on the scope. Adjust (play with) *all* of the scope and signal generator controls until you become familiar with the function of each. The purpose fo such "playing" is to allow the student to become so familiar with the oscilloscope that it becomes an aid (tool) in making measurements in other experiments and not as a formidable obstacle. Note: If the vertical gain is set too low, it may not be possible to obtain a steady trace.

II. <u>Measurements of Voltage:</u> Consider the circuit in Fig. 1.4(a). The signal generator is used to produce a 1000 hertz sine wave. The AC voltmeter and the leads to the verticle input of the oscilloscope are connected across the generator's output. By adjusting the Horizontal Sweep time/cm and trigger, a steady trace of the sine wave may be displayed on the screen. The trace represents a plot of voltage vs. time, where the vertical deflection of the trace about the line of symmetry CD is proportional to the magnitude of the voltage at any instant of time.

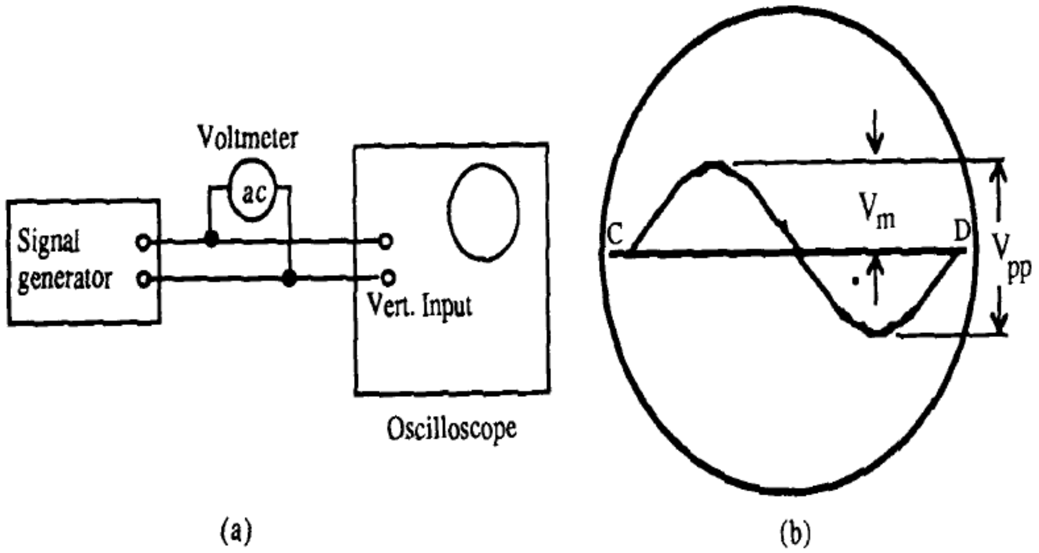


Fig 1.4 (a) Circuit for Procedure (b) Trace Seen on Scope

To determine the size of the voltage signal appearing at the output of terminals of the signal generator, an AC (Alternating Current) voltmeter is connected in parallel across these terminals (Fig. 4a). The AC voltmeter is designed to read the dc "effective value" of the voltage. This effective value is also known as the "Root Mean Square value" (RMS) value of the voltage.

The peak or maximum voltage seen on the scope face (Fig. 1.4(b)) is V_m volts and is represented by the distance from the symmetry line CD to the maximum deflection. The relationship between the magnitude of the peak voltage displayed on the scope and the effective or RMS voltage (V_{RMS}) read on the AC voltmeter is

$$V_{RMS} = 0.707\ V_m \text{ (for a sine or cosine wave).}$$

Agreement is expected between the voltage reading of the multimeter and that of the oscilloscope. For a symmetric wave (sine or cosine) the value of V_m may be taken as 1/2 the peak to peak signal $V_{pp.}$

The variable sensitivity control a signal may be used to adjust the display to fill a convenient range of the scope face. In this position, the trace is no longer calibrated so that you cannot just read the size of the signal by counting the number of divisions and multiplying by the scale factor. However, you can figure out what the new calibration is an use it as long as the variable control remains unchanged.

III. <u>Frequency Measurements:</u> When the horizontal sweep voltage is applied, voltage measurements can still be taken from the vertical deflection. Moreover, the signal is displayed as a function of time. If the time base (i.e. sweep) is calibrated, such measurements as pulse duration or signal period can be made. *Frequencies* can then be determined as reciprocal of the periods.

1. Set the oscillator to 1000 Hz. Display the signal on the CRO and measure the period of the oscillations. Use the horizontal distance between two points such as C to D in Fig.1.4 (b).
2. Set the horizontal gain so that only one complete wave form is displayed.
3. Then reset the horizontal until 5 waves are seen. Keep the time base control in a calibrated position. Measure the distance (and hence time) for 5 complete cycles and calculate the frequency from this measurement. Compare you result with the value determined above.
4. Repeat your measurements for other frequencies of 150 Hz, 5 kHz, 50 kHz as set on the signal generator.

IV. <u>Lissajous Figures</u>: When sine-wave signals of different frequencies are input to the horizontal and vertical amplifiers a stationary pattern is formed on the CRT when the ratio of the two frequencies is an integral fraction such as 1/2, 2/3, 4/3, 1/5, etc. These stationary patterns are known as *Lissajous figures* and can be used for comparison measurement of frequencies.

Use two oscillators to generate some simple Lissajous figures like those shown in Fig.1.5. You will find it difficult to maintain the Lissajous figures in a fixed configuration because the two oscillators are not phase and frequency locked. Their frequencies and phase drift slowly causing the two different signals to change slightly with respect to each other.

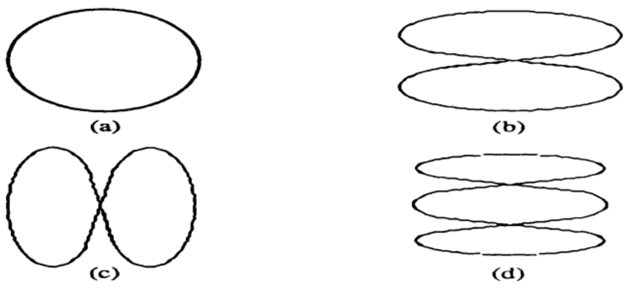


Fig.1.5 Lissajous figures for horizontal to vertical frequency ratios of (a) 1:1, (b) 2:1, (c) 1:2 and (d) 3:1

RESULT: We have studied about the construction, working of CRO and learn how to measure frequency, voltage with the help of CRO.

PRECAUTIONS:

1. All connection must be tight.
2. Get the circuit connections checked by the teacher before performing the experiment.
3. Power to the circuit must be switched on in the presence of the teacher.
4. Get the experimental readings checked by the teacher.
5. Don't touch directly the live parts of equipment and circuit.
6. Wear leather shoes in the lab.

VIVA QUESTIONS:

1. How is CRO superior to ordinary measuring instruments?
2. For what a triggering circuit is provided in CRO?
3. Explain what are the essential components of CRT?
4. Explain why is the grid in the CRO provided with a hole in it?
5. Explain what is sweep time?

Experiment No - 2

OBJECT: Identification and testing of passive components viz. resistors, inductors and capacitor.

APPARATUS REQUIRED:

S. N.	Name of apparatus	Type	Range	Quantity
1.	Resistors			
2.	Capacitors			
3.	Inductors			

THEORY:

<u>Resistor and Resistance</u>

Electrical resistance of an electrical conductor is a measure of the difficulty to pass an electric current through that conductor. The inverse quantity is **electrical conductance**, and is the ease with which an electric current passes. Electrical resistance shares some conceptual parallels with the notion of mechanical friction. The SI unit of electrical resistance is the ohm (Ω), while electrical conductance is measured in siemens (S).

Those components and devices which are specially designed to have a certain amount of resistance and used to oppose or limit the electric current are called resistors.

There are two basic types of resistors.

1. **Linear Resistors**
2. **Non Linear Resistors**

1. Linear Resistors:

Those resistors, which values change with the applied voltage and temperature, are called linear resistors. Generally, there are two types of resistors which have linear properties.

1.1. Fixed Resistors

1.2. Variable Resistors

1. 1. Fixed Resistors

As the name tells everything, fixed resistor is a resistor which has a specific value and we can't change the value of fixed resistors.

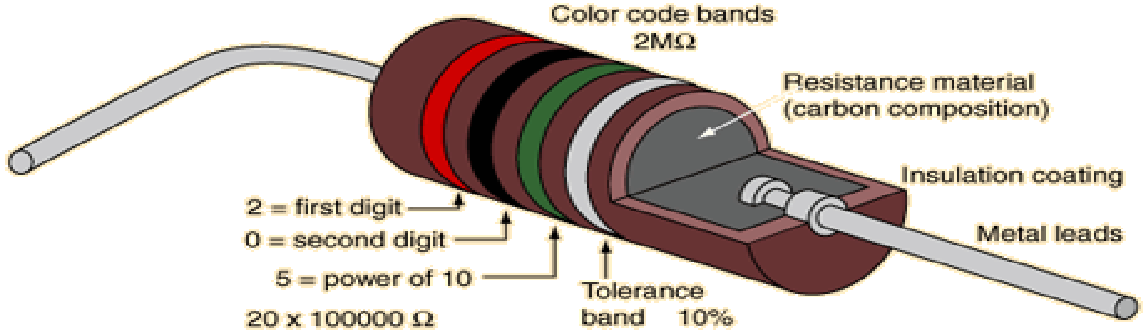
Types of Fixed resistors.

1. **Carbon Composition Resistors**
2. **Wire Wound Resistors**
3. **Thin Film Resistors**
4. **Thick Film Resistors**

1. 1) Carbon Composition Resistors

A typical fixed resistor is made from the mixture of granulated or powdered carbon or graphite, insulation filler, or a resin binder. The ratio of the insulation material determines the actual resistance of the resistor. The insulating powder (binder) made in the shape of rods and there are two metal caps on the both ends of the rod.

There are two conductor wires on the both ends of the resistor for easy connectivity in the circuit via soldering. A plastic coat covers the rods with different color codes (printed) which denote the resistance value. They are available in 1 ohm to 25 mega ohms and in power rating from ¼ watt to up to 5 Watts.



Carbon Composition Resistors

1. 1. 2) Wire wound Resistors

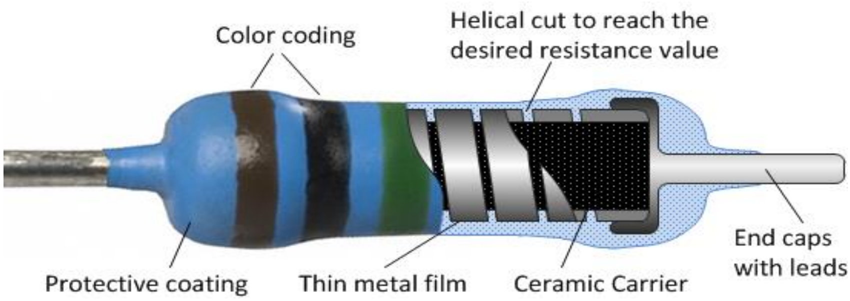
Wire wound resistor is made from the insulating core or rod by wrapping around a resistive wire. The resistance wire is generally Tungsten, manganin, Nichrome or nickel or nickel chromium alloy and the insulating core is made of porcelain, Bakelite, press bond paper or ceramic clay material.

They are available in the range of 2 watts up to 100 watt power rating or more. The ohmic value of these types of resistors is 1 ohm up to 200k ohms or more and can be operated safely up to 350°C.In addition, the power rating of a high power wire wound resistor is 500 Watts and the available resistance value of these resistors are is 0.1 ohm – 100k Ohms.

Wire wound Resistors

1. 1. 3) Thin Film Resistors

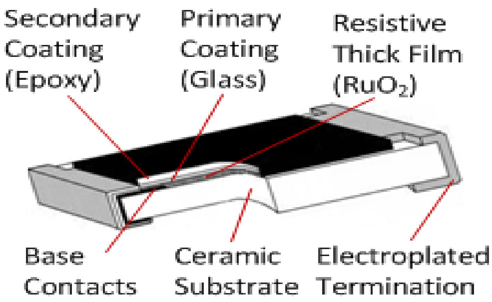
Basically, all thin film resistors are made of from high grid ceramic rod and a resistive material. A very thin conducting material layer overlaid on insulating rod, plate or tube which is made from high quality ceramic material or glass.



Thin Film Resistors

1.1.4) Thick Film Resistors

The production method of Thick film resistors is same like thin film resistors, but the difference is that there is a thick film instead of a thin film or layer of resistive material around. That's why it is called Thick film resistors.



Thick Film Resistors

1. 2) Variable Resistors

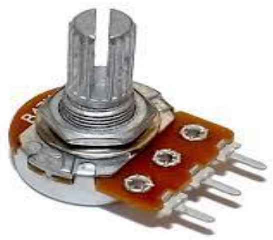
As the name indicates, those resistors which values can be changed through a dial, knob, and screw or manually by a proper method. In these types of resistors, there is a sliding arm, which is connected to the shaft and the value of resistance can be changed by rotating the arm. They are used in the radio receiver for volume control and tone control resistance.

Following are the further types of Variable Resistors

1. **Potentiometers**
2. **Rheostats**
3. **Trimmers**

1.2.1) Potentiometers

Potentiometer is a three terminal device which is used for controlling the level of voltage in the circuit. The resistance between two external terminals is constant while the third terminal is connected with moving contact (Wiper) which is variable. The value of resistance can be changed by rotating the wiper which is connected to the control shaft. They are available up to 10 Mega Ohms.



Potentiometers

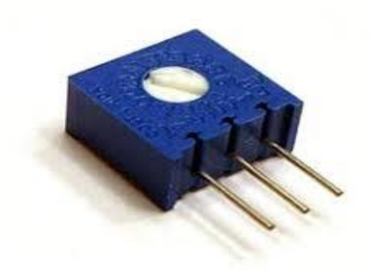
1.2.2) Rheostats

Rheostats are a two or three terminal device which is used for the current limiting purpose by hand or manual operation. Rheostats are available in the range of 1 ohm up to 150 Ohms. The available power rating of these resistors is 3 to 200 Watts.

Rheostats

1.2.3) Trimmers

There is an additional screw with Potentiometer or variable resistors for better efficiency and operation and they are known as Trimmers. They are available in the range of 50 Ohms up to 5 mega ohms. The power rating of Trimmers potentiometers are from 1/3 to ¾ Watts.



Trimmers

2. Non Linear Resistors

We know that, nonlinear resistors are those resistors, where the current flowing through it does not change according to Ohm’s Law but, changes with change in temperature or applied voltage.

In addition, if the flowing current through a resistor changes with change in body temperature, then these kinds of resistors are called Thermisters. If the flowing current through a resistor change with the applied voltages, then it is called a Varistors or VDR (Voltage Dependent Resistors).

Following are the additional types of Non Linear Resistors.

1. Thermisters
2. Varisters (VDR)
3. Photo Resistor or Photo Conductive Cell or LDR

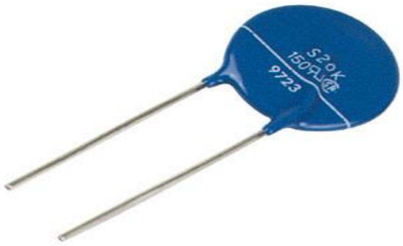
2.1) Thermisters

Thermisters is a two terminal device which is very sensitive to temperature. The Resistance of a Thermister is inversely proportional to the temperature.

Thermisters

2.2) Varisters (VDR)

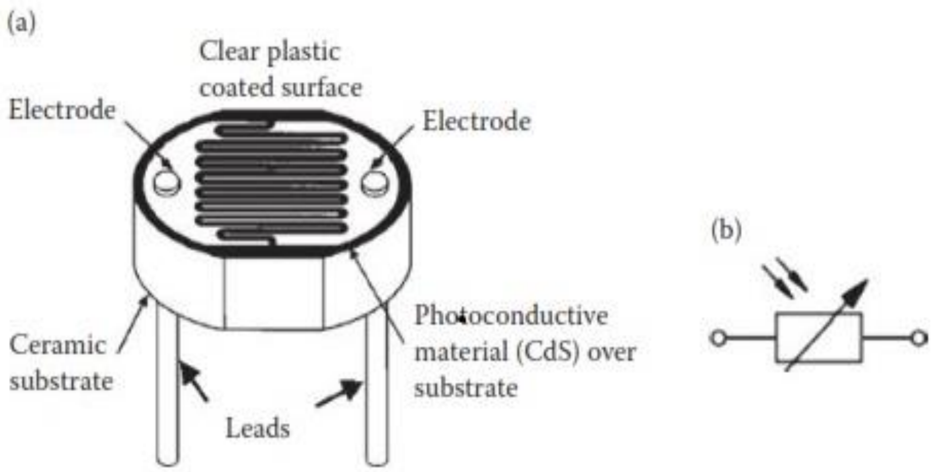
Varisters are voltage dependent Resistors (VDR) which is used to eliminate the high voltage transients.



Varisters (VDR)

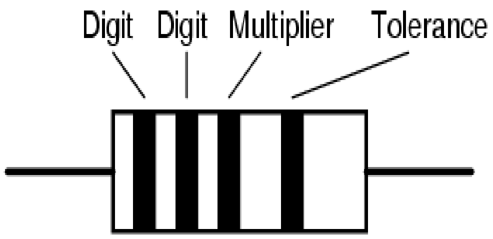
2.3) Photo Resistor or Photo Conductive Cell or LDR (Light Dependent Resistors)

Photo Resistor or LDR (Light Dependent Resistors) is a resistor which terminal value of resistance changes with light intensity. In other words, those resistors, which resistance values changes with the falling light on their surface is called Photo Resistor or Photo Conductive Cell or LDR (Light Dependent Resistor).

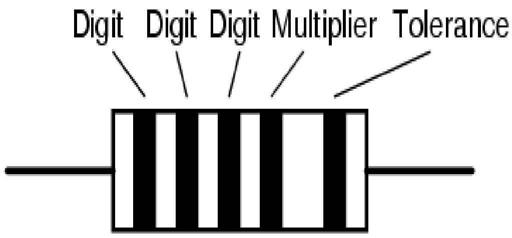


LDR (Light Dependent Resistors)

Color Coding:



4-band code



5-band code

Color	Digit	Multiplier	Tolerance (%)
Black	0	10^0 (1)	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20

Capacitor and Capacitance

A **capacitor** is a passive two-terminal electrical component that stores potential energy in an electric field. The effect of a capacitor is known as capacitance. Capacitance is defined as the ratio of the electric charge on each conductor to the potential difference between them. The unit of capacitance in the International System of Units (SI) is the farad (F), defined as one coulomb per volt (1 C/V).Electronic capacitors are one of the most widely used forms of electronics components. However there are many different types of capacitor including electrolytic, ceramic, tantalum, plastic, sliver mica, and many more. Each capacitor type has its own advantages and disadvantages can be used in different applications. They are of two types

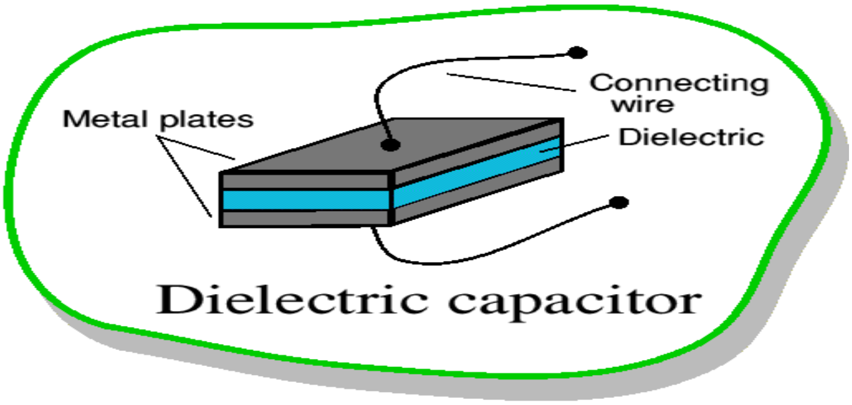
2. Variable type
3. Fixed type

Variable type capacitor

1. Dielectric Capacitor

Dielectric Capacitors are usually of the variable type were a continuous variation of capacitance is required for tuning transmitters, receivers and transistor radios. Variable dielectric capacitors are multi-plate air-spaced types that have a set of fixed plates (the stator vanes) and a set of movable plates (the rotor vanes) which move in between the fixed plates.

The position of the moving plates with respect to the fixed plates determines the overall capacitance value. The capacitance is generally at maximum when the two sets of plates are fully meshed together. High voltage type tuning capacitors have relatively large spacing or air-gaps between the plates with breakdown voltages reaching many thousands of volts.



Fixed type capacitor

1. Film Capacitor Type

Film Capacitors are the most commonly available of all types of capacitors, consisting of a relatively large family of capacitors with the difference being in their dielectric properties. These include polyester (Mylar), polystyrene, polypropylene, polycarbonate, metalised paper, Teflon etc. Film type capacitors are available in capacitance ranges from as small as 5pF to as large as 100uF depending upon the actual type of capacitor and its voltage rating.

Film Capacitor Type

2. Ceramic Capacitors

Ceramic Capacitors or **Disc Capacitors** as they are generally called, are made by coating two sides of a small porcelain or ceramic disc with silver and are then stacked together to make a capacitor. Ceramic capacitors have a high dielectric constant (High-K).

Ceramic Capacitor

It's a also non-polarized devices. Ceramic capacitors have values ranging from a few picofarads to one or two microfarads, (μF) but their voltage ratings are generally quite low.

Ceramic types of capacitors generally have a 3-digit code printed onto their body to identify their capacitance value in pico-farads. Generally the first two digits indicate the capacitors value and the third digit indicates the number of zero's to be added. For example, a ceramic disc capacitor with the markings 103 would indicate 10 and 3 zero's in pico-farads which is equivalent to 10,000 pF or 10nF.

Letter codes are sometimes used to indicate their tolerance value such as: J = 5%, K = 10% or M = 20% etc.

3. Electrolytic Capacitors

Electrolytic Capacitors are generally used when very large capacitance values are required.

Electrolytic Capacitor

The majority of electrolytic types of capacitors are **Polarised**, that is the DC voltage applied to the capacitor terminals must be of the correct polarity.

Electrolytic Capacitors are generally used in DC power supply circuits due to their large capacitance's and small size to help reduce the ripple voltage or for coupling and decoupling applications. Electrolytic's generally come in two basic forms; **Aluminium Electrolytic Capacitors** and **Tantalum Electrolytic Capacitors**.

Inductance and inductor

An **inductor**, also called a **coil**, **choke** or **reactor**, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil around a core. An inductor is characterized by its inductance, which is the ratio of the voltage to the rate of change of current. In the International System of Units (SI), the unit of inductance is the henry (H) named for 19th century American scientist Joseph Henry. In the measurement of magnetic circuits, it is equivalent to weber/ampere.

There are different types of inductors. Depending on their material type they are basically categorized as follows

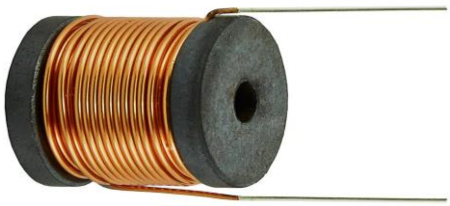
1. **Air Core Inductor**

Ceramic core inductors are referred as "**Air core inductors**". Ceramic is the most commonly used material for inductor cores. The main advantage of these inductors are very low core losses, high Quality factor. These are mainly used in high frequency applications where low inductance values are required.

Air Core Inductor

2. Iron Core Inductor

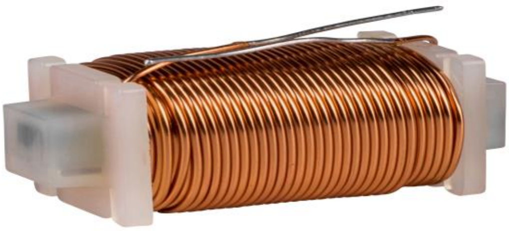
In the areas where low space inductors are in need then these iron core inductors are best option. These inductors have high power and high inductance value but limited in high frequency capacity. These are applicable in audio equipment's.



Iron Core Inductor

3. **Laminated Core Inductor**

These core materials are formed by arranging many number of laminations on top of each other. These laminations are made up of steel with insulating material between them. They have high power levels so, they are mostly used at power filtering devices for excitation frequencies above several KHz.



Laminated Core Inductor

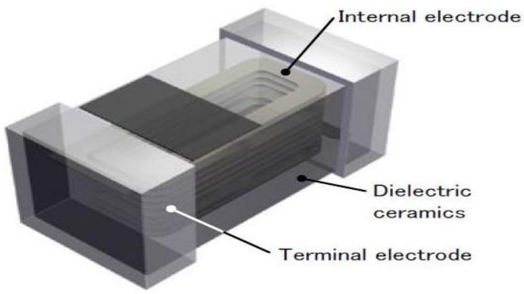
4. Toroidal Inductor

Wire wounded on core which has ring or donut shaped surface. These are generally made up of different materials like ferrite, powdered iron and tape wound etc. .It has high energy transferring efficiency and high inductance values at low frequency applications. These inductors mainly used in medical devices, switching regulators, air conditioners, refrigerators, telecommunications and musical instruments etc.

Toroidal Inductor

5. Multi-layer Ceramic Inductors

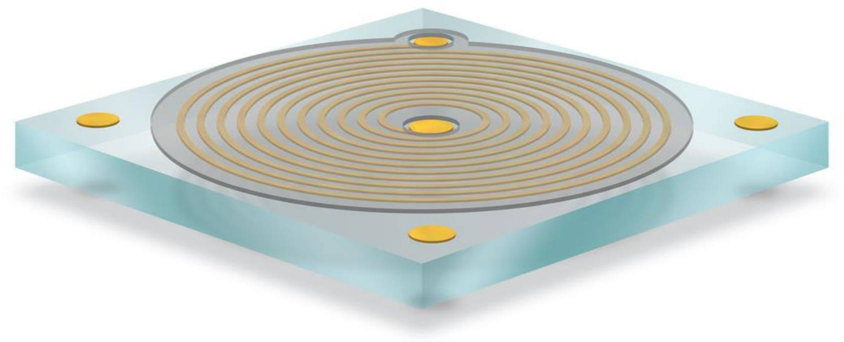
The name itself indicates that it consist of multi layers. Simply by adding additional layers of coiled wire that is wound around the central core to the inductor gives multi-layer inductor. Generally for more number of turns in a wire , the inductance is also more.In these multi-layer inductors not only the inductance of the inductor increases but also the capacitance between the wires also increases.



Multi-layer Ceramic Inductors

6. Film Inductor

These uses a film of conductor on base material. Thus according to the requirement this film is shaped for conductor application. Film inductors in thin size are suitable for DC to DC converters that serve as power supplies in smart phones and mobile devices. The RF thin film inductor is shown below:



Film Inductor

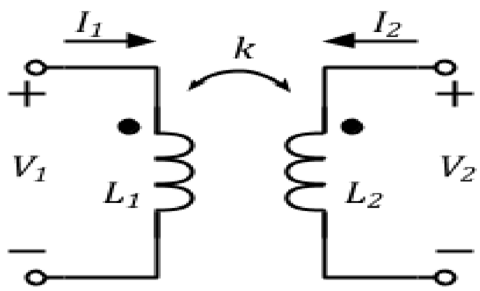
7. Variable Inductor

It is formed by moving the magnetic core in and outside of the inductor windings. By this magnetic core we can adjust the inductance value. When we consider a ferrite core inductor , by moving its core inside and outside on which the coil is wounded , variable ferrite core inductor can be formed.These type of inductors are used in radio and high frequency applications where the tuning is required. These inductors are typically ranged from 10 µH to 100 µH and in present days these are ranged from 10nH to 100 mH.

Variable Inductor

8. Coupled Inductors

The two conductors connected by electromagnetic induction are generally referred as coupled inductors. We already seen that whenever the AC current is flowing in one inductor produces voltage in second inductor gives us mutual inductance phenomenon. Coupled inductors will work on this phenomenon only. These can isolate two circuits electrically by transferring impedance through the circuit. A transformer is one of the type of coupled inductor.



Coupled Inductor

9. **Molded inductors**

These inductors or molded by plastic or ceramic insulators. These are typically available in bar and cylindrical shapes with wide option of windings.

Molded inductors

OBSERVATION TABLE:

S. N.	Component for identification/testing	Types of Component	Measured Value		Remark
			By Multi meter	By Color Coding	
1.	Resistors	(i)			
		(ii)			
2.	Capacitor	(i)			
		(ii)			
3.	Inductors	(i)			
		(ii)			

PROCEDURE:

For Resistors

1. Identify the type of element and write in observation table.
2. Find different vale of resistor using color coding and multi meter, note down in observation table
3. Using multi meter test given resistor for open and short conditions.

For Inductors

1. Identify the type of element and write in observation table.
2. Find different vale of resistor using color coding and multi meter, note down in observation table.
3. Using multi meter test given resistor for open and short conditions.

For Capacitor

1. Identify the type of element and write in observation table.
2. Find different vale of resistor using color coding and multi meter, note down in observation table
3. Using multi meter test given resistor for open and short conditions.

RESULT:

Study of various passice components viz. resistance, capacitance, inductor and testing and identification has done.

PRECAUTIONS:

1. All connection must be tight.
2. Get the circuit connections checked by the teacher before performing the experiment.
3. Power to the circuit must be switched on in the presence of the teacher.
4. Get the experimental readings checked by the teacher.
5. Don’t touch directly the live parts of equipment and circuit.
6. Wear leather shoes in the lab.

VIVA QUESTION:

1. List different types of electronic components
2. What are the characteristics of passive components?
3. Define active component
4. Which types of materials are used to construct transistors?
5. What is the ohm's law equation for resistance?
6. List various applications of wire wound resistors
7. Define supercapacitor.

Experiment No - 3

OBJECT:

Study and demonstration of measuring instruments viz.ammeter (moving coil and moving iron), voltmeter (moving coil and moving iron), wattmeter (electrodynamic and induction) and Digital multi-meter.

APPARATUS REQUIRED:

S. N.	Name of Apparatus	Type	Range	Quantity
1	Ammeter			
2	Voltmeter			
3	Wattmeter			
4	Multi-meter			

THEORY:

Ammeters and voltmeters operate on the same principle. The ammeters carry the current to be measured or a definite fraction of it and this current and its definite fraction produces the deflecting torque whereas voltmeters carries the current proportional to the voltage to be measured which produces the deflecting torque. The various type of instruments used for measurement of current and voltage along with suitability for the types of measurements (AC and/or DC) and applications. The common construction of ammeters and voltmeters are moving coil (for DC measurements) and moving iron (for AC and DC both measurements) types. These are:

Moving Coil type:

Moving coil type of instruments are used to measure only DC currents as deflection torque is proportional to applied current. This instrument consists of a coil suspended by two hair springs. This coil is placed in a magnetic field created by a fixed permanent magnet. A torque is experienced when current passes through this coil which is proportional to the current. When the coil turns, the springs will exert a restoring force proportional to the angle turned. By these two forces, the coil will stop at some point and the angular deflection will be proportional to the current. The deflection torque T_d is

$$T_d = NBLDI$$

Where

N is number of turns,

B is magnetic flux density in air gap,

L is the length of moving coil,

D is the width of the moving coil,

I is the electric current.

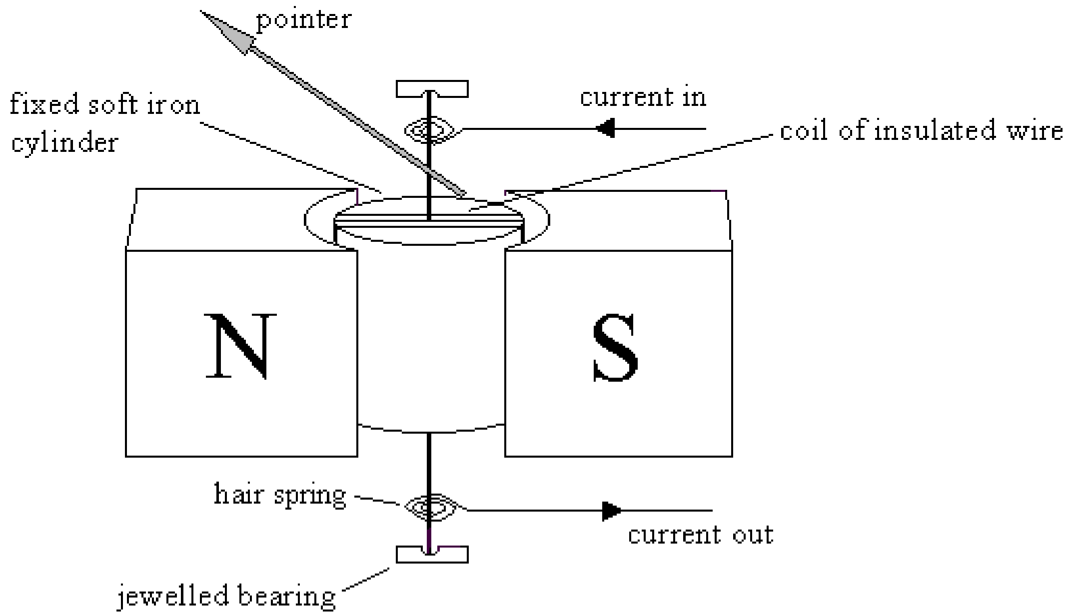


Fig. 2.1 Moving Coil Type Instrument

Moving Iron Type:

Moving iron type instruments can be used for measuring both direct and alternating currents as the deflecting torque is proportional to square of currents. A piece of soft iron is used which constitutes of a moving vane and a fixed vane. Current to be checked flows through a fixed coil placed around the iron piece. This coil produces a magnetic field proportional to the current so the iron pieces will get magnetized with the same polarity. The movable vane turns away from the fixed vane due to magnetic repulsion. As the iron turns, the spring of the instruments will exert a restoring force and stop the vane, when both the forces become equal. The pointer of the ammeter is attached to the movable vane, which will point to the proper current reading using a calibrated scale.

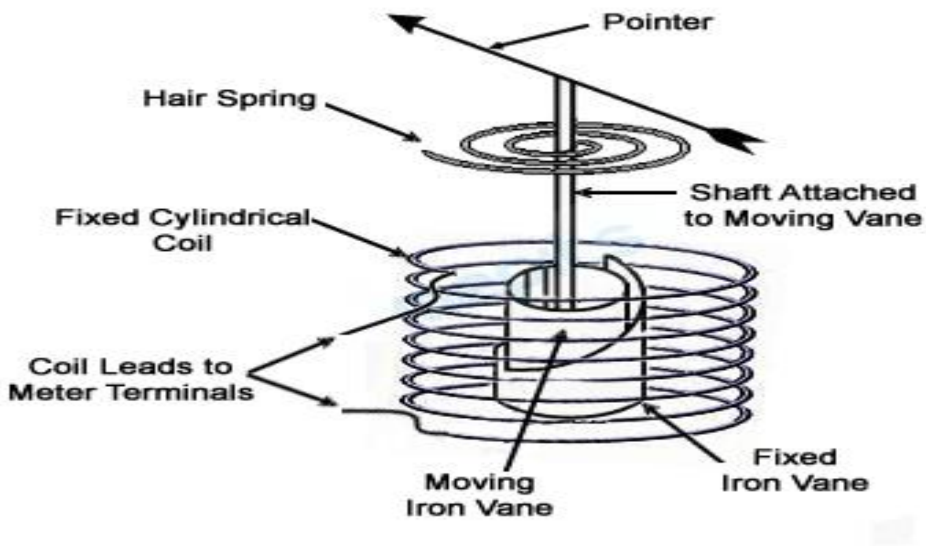


Fig.2.2 Moving Iron Type Instrument

Moving iron type instruments are of mainly two types. Attraction type and repulsion type instrument.

Attraction Type:

Whenever a piece of iron is placed nearer to a magnet it would be attracted by the magnet. The force of this attraction depends upon the strength said magnetic field. If the magnet is electromagnet then the magnetic field strength can easily be increased or decreased by increasing or decreasing current through its coil. Accordingly the attraction force acting on the piece of iron would also be increased and decreased. Depending upon this simple phenomenon attraction type moving iron instrument was developed.

Repulsion Type:

Whenever two pieces of iron are kept side by side and a magnet is brought nearer to them the iron pieces will repulse each other. This repulsion force is due to same magnetic poles induced in same sides the iron pieces due external magnetic field. This repulsion force increases if field strength of the magnet is increased. If the magnet is electromagnet, then magnetic field strength can easily be controlled by controlling input current to the magnet. Hence if the current increases the repulsion force between the pieces of iron is increased and it the current decreases the repulsion force between them is decreased. Depending upon this phenomenon repulsion type moving iron instrument was constructed.

Ammeter:

Ammeter is an instrument used to determine the electric current flowing through a circuit. Ammeters measuring current in milli-ampere range is known as milli-ammeters. Ammeters are connected in series to the circuit whose current is to be measured; hence these instruments are designed to have as minimum resistance/ loading as possible.

Voltmeter:

Voltmeter is an instrument used in an electric circuit to determine the potential difference or voltage between two different points. Digital and analog voltmeters are used to measure voltage. They are usually connected in parallel (shunt) to the circuit, hence they are designed to have maximum resistance as possible to reduce the loading effect.

Wattmeter:

The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic wattmeter is used for measurement of utility frequency and audio frequency power; other types are required for radio frequency measurements.

Electrodynamometer Wattmeter

The instrument whose working depends on the reaction between the magnetic field of moving and fixed coils is known as the Electrodynamo-meter Wattmeter. It uses for measuring the power of both the AC and DC circuits. The working principle of the Electrodynamometer Wattmeter is very simple and easy. Their working depends on the theory that the current carrying conductor placed in a magnetic field experiences a mechanical force**.** This mechanical force deflects the pointer which is mounted on the calibrated scale.

The Electrodynamometer Wattmeter has two types of coils; fixed and the moving coil. The fixed coil connects in series with the circuit whose power consumption use to be measured. The supply voltage applies to the moving coil. The resistor controls the current across the moving coil, and it is connected in series with it.The pointer is fixed on the moving coil which is placed between the fixed coils. The current and voltage of the fixed and moving coil generate the two magnetic fields. And the interaction of these two magnetic fields deflects the pointer of the instrument. The deflection of the pointer is directly proportional to the power flows through it. Figure 2.6 shows the construction diagram of Electrodynamometer Wattmeter

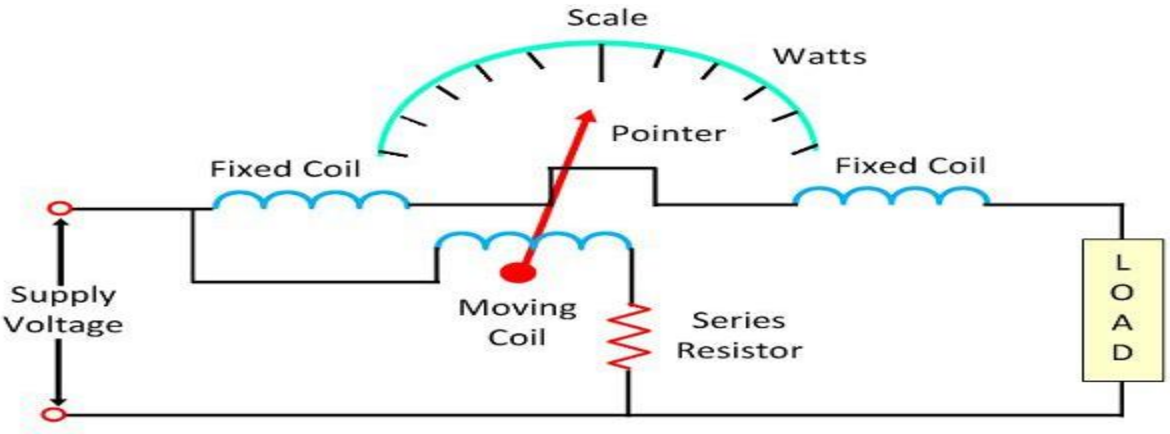


Fig. 2.6 Electrodynamometer Wattmeter

Induction type wattmeter:

Induction type wattmeter can only be used on ac supply system. This type of watt-meters is useful only when the supply and frequency remains constant. A watt-meter has two laminated electromagnet, one of which is excited by load current or definite fraction of it, and is connected in series with the circuit, known as series magnet and the other is excited by the current proportional to the applied voltage or fraction of it and is always connected across the supply, known as shunt magnet. An aluminum disc is so mounted so that it cuts the fluxes produced by both the magnets. As a result of which, two emf's are produced which induces two eddy currents in the disc. C - Magnet is used to provide necessary damping torque to the pointer, to damp out the oscillations. Deflecting torque is produced due to interaction of these eddy currents and the inducing flux. Copper shading bands are provided either on central limb or on the outer limb of the shunt magnet, and can be so adjusted as to make the resultant flux in the shunt magnet lag behind the applied voltage by 90 degree. Both the watt-meters are provided with spiral springs A and B, for producing controlling torque to counter

balance the deflecting torque. Figure 2.7 shows the construction diagram of Induction type Wattmeter.

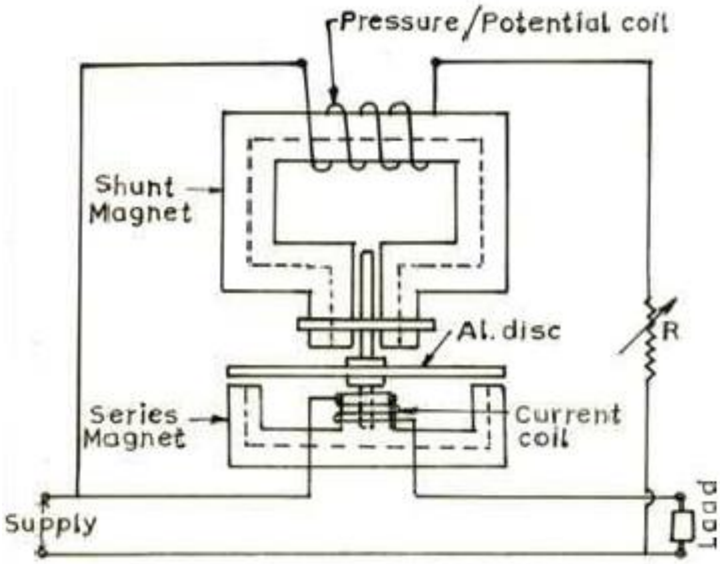


Fig. 2.7 Induction type Wattmeter

Connection diagram of Electrodynamometer Wattmeter:

The connection diagram of the electrodynamometer wattmeter is shown in the figure below. The terminal M & L represents current coil which connected in series with the load hence it carries the circuit current while C & V represents potential coil which is connected across the load so it carries current proportional to the voltage. Here M stands for Main terminal, 'L' stands for Line, 'C' stands for Common and ‘V' stands for Voltage.

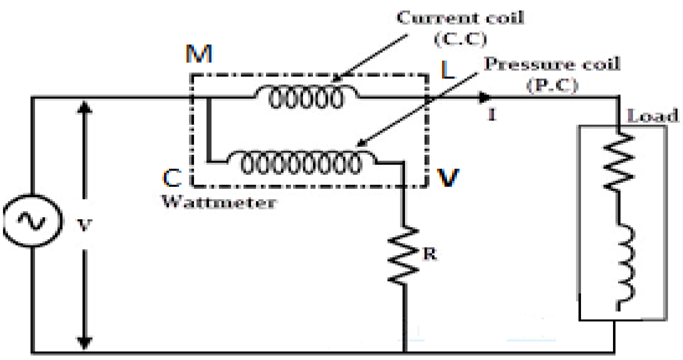


Fig. 2.8 Connection Diagram of Wattmeter

Digital Multi Meter (DMM)

A multimeter or a multitester, also known as a VOM (Volt-Ohm meter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter would include basic features such as the ability to measure voltage, current, and resistance. Analog multimeters use a micro ammeter whose pointer moves over a scale calibrated for all the different measurements that can be made. Digital multimeters (DMM, DVOM) display the measured value in numerals, and may also display a bar of a length proportional to the quantity being measured. Digital multimeters are now far more common than analog ones, but analog multimeters are still preferable in some cases, for example when monitoring a rapidly-varying value.

A multimeter can be a hand-held device useful for basic fault finding and field service work, or a bench instrument which can measure to a very high degree of accuracy. They can be used to troubleshoot electrical problems in a wide array of industrial and household devices such as electronic equipment, motor controls, domestic appliances, power supplies, and wiring systems.

Operation: A multimeter is a combination of a multirange DC voltmeter, multirange AC voltmeter, multirange ammeter, and multirange ohmmeter. An un-amplified analog multimeter combines a meter movement, range resistors and switches.

For an analog meter movement, DC voltage is measured with a series resistor connected between the meter movement and the circuit under test. A set of switches allows greater resistance to be inserted for higher voltage ranges. The product of the basic full-scale deflection current of the movement, and the sum of the series resistance and the movement's own resistance, gives the full-scale voltage of the range. As an example, a meter movement that required 1 mill ampere for full scale deflection, with an internal resistance of 500 ohms, would, on a 10-volt range of the multimeter, has 9,500 ohms of series resistance. For analog current ranges, low-resistance shunts are connected in parallel with the meter movement to divert most of the current around the coil. Again for the case of a hypothetical 1 mA, 500 ohm movement on a 1 Ampere range, the shunt resistance would be just over 0.5 ohms.

Moving coil instruments respond only to the average value of the current through them. To measure alternating current, a rectifier diode is inserted in the circuit so that the average value of current is non-zero. Since the rectified average value and the root-mean-square value of a waveform need not be the same, simple rectifier-type circuits may only be accurate for sinusoidal waveforms. Other wave shapes require a different calibration factor to relate RMS and average value. Since practical rectifiers have non-zero voltage drop, accuracy and sensitivity is poor at low values.

To measure resistance, a small battery within the instrument passes a current through the device under test and the meter coil. Since the current available depends on the state of charge of the battery, a multimeter usually has an adjustment for the ohms scale to zero it. In the usual circuit found in analog multimeters, the meter deflection is inversely proportional to the resistance; so full-scale is 0 ohms, and high resistance corresponds to smaller deflections. The ohms scale is compressed, so resolution is better at lower resistance values.

Amplified instruments simplify the design of the series and shunt resistor networks. The internal resistance of the coil is decoupled from the selection of the series and shunt range resistors; the series network becomes a voltage divider. Where AC measurements are required, the rectifier can be placed after the amplifier stage, improving precision at low range.

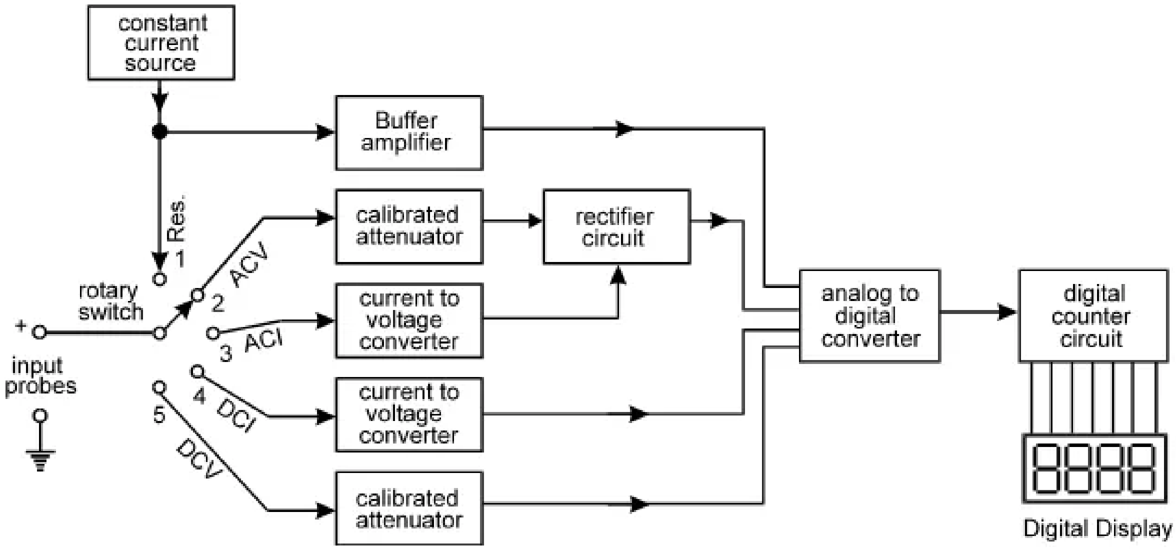


Fig 2.9 Basic block diagram of Digital Multi meter

Digital instruments, which necessarily incorporate amplifiers, use the same principles as analog instruments for range resistors. For resistance measurements, usually a small constant current is passed through the device under test and the digital multimeter reads the resultant voltage drop; this eliminates the scale compression found in analog meters, but requires a source of significant current. An auto ranging digital multimeter can automatically adjust the scaling network so that the measurement uses the full precision of the A/D converter.

In all types of multimeters, the quality of the switching elements is critical to stable and accurate measurements. Stability of the resistors is a limiting factor in the long-term accuracy and precision of the instrument.

Quantities measured

Contemporary multimeters can measure many quantities. The common ones are:

- Voltage, alternating and direct, in volts.
- Current alternating and direct in amperes.The frequency range for which AC measurements are accurate must be specified.
- Resistance in ohms.

Additionally, some multimeters measure:

- Capacitance in farads.
- Conductance in Siemens.
- Decibels.
- Duty cycle as a percentage.
- Frequency in hertz.
- Inductance in henrys.
- Temperature in degrees Celsius or Fahrenheit, with an appropriate temperature test probe, often a thermocouple.

Digital multimeters may also include circuits for:

- Continuity tester; sounds when a circuit conducts
- Diodes (measuring forward drop of diode junctions), and transistors (measuring current gain and other parameters)
- Battery checking for simple 1.5 volt and 9 volt batteries. This is a current loaded voltage scale which simulates in-use voltage measurement.

RESULT

Thus we have studied the construction and working of different types of ammeter,voltmeter , wattmeter and digital multimeter and their connection diagram.

PRECAUTIONS

1. All connection must be tight.
2. Get the circuit connections checked by the teacher before performing the experiment.
3. Power to the circuit must be switched on in the presence of the teacher.
4. Get the experimental readings checked by the teacher.
5. Don’t touch directly the live parts of equipment and circuit.
6. Wear leather shoes in the lab.

VIVA VOICE:

Q: 1 What is the difference between an ammeter and voltmeter?

Q: 2 Why are the moving iron indicating instruments popular for the ordinary measurement work?

Q: 3 What are the major differences between attraction and repulsion type of moving iron instruments?

Q: 4 Why are dynamometer type instruments suitable for both DC and AC measurements?

Q: 5 Draw the symbols of moving coil and moving iron instruments.

Q: 6 Name the types of moving iron type instruments.

Experiment No. 4

OBJECT:

Observe the voltage, current and active power for a given resistive circuit using suitable measuring instruments.

APPARATUS REQUIRED:

S. N.	Name of Apparatus	Type	Range	Quantity
1	Ammeter	Moving Iron		
2	Voltmeter	Moving Iron		
3	Wattmeter	Electro dynamo-meter		
4	Potentiometer	Rheostat		
5	Load	Resistive		

THEORY:

An ammeter is used to measure the current passing through it, which means the current which is to be measure should flow through that meter. So there should be very low resistance, then only the current can pass through the meter, and the meter shows deflection. Since it has low resistance if it is connected in parallel the circuit will be shorted. So that ammeter is always connected in series. A voltmeter is used to measure the voltage across the input terminals. As voltage is equal in parallel connection then it should be connect in parallel with the supply or load (both means same).For a parallel connection it should have high resistance because if it has low resistance then the circuit will be shorted. So the voltmeter should be connected in parallel.

The electro dynamo-meter type wattmeter consists of two coils namely: fixed coil (Current coil) and moving coil (Pressure Coil). The terminal M & L represents Current coil While C & V Potential coil. The M (Main) terminal connects to the power supply. 'L' (Line) is used to connect load. 'C' (Common) is shorted with M. 'V'(Voltage) is a voltage to connect neutral. The common circuit diagram of ammeter, voltmeter and wattmeter along with a resistive load is shown in figure. The active power (P)

$P = V * I * Cos\phi$ .... (2(b).1)

Where

V=Voltage across the load in Volt.

I=Current flowing in the load in Ampere.

ϕ= Phase angle between voltage and current in degree

Here, we use resistive load so the phase angle between V and I is 0˚, and Cosϕ =1.So the active power for the circuit is the product of voltage and current.

CIRCUIT DIAGRAM:

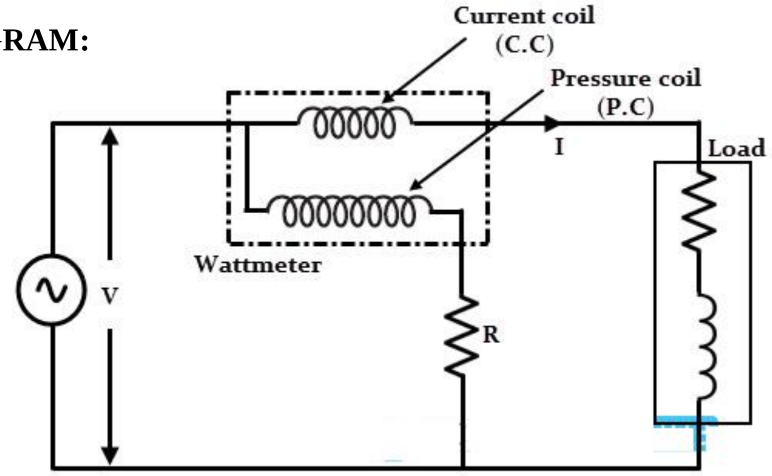


Figure 2 (b) .1 Connection diagrams of voltmeter, ammeter and wattmeter

OBSERVATION TABLE:

S.No	Supply Voltage (Volt)	Resistive Load	Ammeter Reading (Amp)	Voltmeter Reading(volt)	Wattmeter Reading(Watt)
1					
2					
3					

RESULT

Thus we have studied the connection and observations of ammeter,voltmeter and wattmeter for different resistive loads.

PRECAUTIONS

1. All connection must be tight.
2. Get the circuit connections checked by the teacher before performing the experiment.
3. Power to the circuit must be switched on in the presence of the teacher.
4. Get the experimental readings checked by the teacher.
5. Don't touch directly the live parts of equipment and circuit.
6. Wear leather shoes in the lab.

VIVA VOICE:

Q 1: What happen when a voltmeter is connected in series?

Q: 2 Why is the ammeter is connected in series?

Q: 3 For AC measurements which type of voltmeter can be used and why?

Q: 4 What is rheostat? Also mention the unit of rheostat.

Q: 5 What are the terminals of wattmeter?

Q: 6 Why an ammeter should be of very low resistance?

Experiment No. 5

Object To make observation of the no-load current for single-phase transformer on CRO and to measure the voltage, current, active power and efficiency of single-phase transformer.

Apparatus Required

S. N.	Name of apparatus	Type	Specification	Quantity
1	Single phase Transformer	Core Type	2 KVA	1
2	Cathode Ray Oscilloscope	Dual Channel	30 MHz	1
3	Ammeter	Moving Iron	0-5 A	2
4	Voltmeter	Moving Iron	0-300 V	2
5	Wattmeter	Electrodynamic	0-1500 W	2
6	Load	Resistive	3KW	
7	Connecting leads		1.5 sq mm,9 A	

Introduction

Transformers are one of the most important components of any power system. It basically changes the level of voltages from one value to the other at constant frequency. Being a static machine the efficiency of a transformer could be as high as 99%. The transformer is a static device (means that has no moving parts) that consists of one, two or more windings which are magnetically coupled and electrically separated with or without a magnetic core. It transfers the electrical energy from one circuit to the other by electromagnetic induction principle. The winding connected to the AC main supply is called primary winding and the winding connected to the load or from which energy is drawn out is called as secondary winding. These two windings with proper insulation are wound on a laminated core which provides a magnetic path between windings.

When the primary winding is energized with alternating voltage source, an alternating magnetic flux or field will be produced in the transformer core. This magnetic flux amplitude depends on the applied voltage magnitude, frequency of the supply and the number of turns on the primary side. This flux circulates through the core and hence links with the secondary winding. Based on the principle of electromagnetic induction, this magnetic linking induces a voltage in the secondary winding. This is called as mutual induction between two circuits. The secondary voltage depends on the number of turns on the secondary as well as magnetic flux and frequency.

Construction of single phase transformer

Generally, the name associated with the construction of a transformer is dependent upon how the primary and secondary windings are wound around the central laminated steel core. The two most common and basic designs of transformer construction are the **Closed-core Transformer** and the **Shell-core Transformer**.

In the "closed-core" type (core form) transformer, the primary and secondary windings are wound outside and surround the core ring. In the "shell type" (shell form) transformer, the primary and secondary windings pass inside the steel magnetic circuit (core) which forms a shell around the windings as shown below.

In both types of transformer core design, the magnetic flux linking the primary and secondary windings travels entirely within the core with no loss of magnetic flux through air. In the core type transformer construction, one half of each winding is wrapped around each leg (or limb) of the transformers magnetic circuit as shown above.

The coils are not arranged with the primary winding on one leg and the secondary on the other but instead half of the primary winding and half of the secondary winding are placed one over the other concentrically on each leg in order to increase magnetic coupling allowing practically all of the magnetic lines of force go through both the primary and secondary windings at the same time. However, with this type of transformer construction, a small percentage of the magnetic lines of force flow outside of the core, and this is called "leakage flux".

Shell type transformer cores overcome this leakage flux as both the primary and secondary windings are wound on the same centre leg or limb which has twice the cross-sectional area of the two outer limbs. The advantage here is that the magnetic flux has two closed magnetic paths to flow around external to the coils on both left and right hand sides before returning back to the central coils.

This means that the magnetic flux circulating around the outer limbs of this type of transformer construction is equal to Φ/2. As the magnetic flux has a closed path around the coils, this has the advantage of decreasing core losses and increasing overall efficiency.

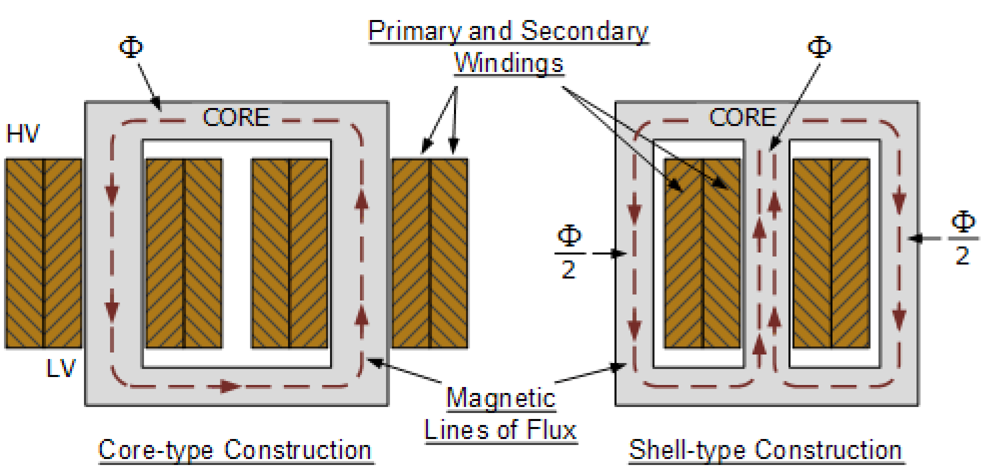


Fig3.1 Core type and shell type transformer

Laminating the Iron Core

Eddy current losses within a transformer core can not be eliminated completely, but they can be greatly reduced and controlled by reducing the thickness of the steel core. Instead of having one big solid iron core as the magnetic core material of the transformer or coil, the magnetic path is split up into many thin pressed steel shapes called “laminations”.

The laminations used in a transformer construction are very thin strips of insulated metal joined together to produce a solid but laminated core as we saw above. These laminations are insulated from each other by a coat of varnish or paper to increase the effective resistivity of the core thereby increasing the overall resistance to limit the flow of the eddy currents.

The result of all this insulation is that the unwanted induced eddy current power-loss in the core is greatly reduced, and it is for this reason why the magnetic iron circuit of every transformer and other electro-magnetic machines are all laminated. Using laminations in a transformer construction reduces eddy current losses.

The losses of energy, which appears as heat due both to hysteresis and to eddy currents in the magnetic path, is known commonly as “transformer core losses”. Since these losses occur in all magnetic materials as a result of alternating magnetic fields. Transformer core losses are always present in a transformer whenever the primary is energized, even if no load is connected to the secondary winding. Also these hysteresis and the eddy current losses are sometimes referred to as “transformer iron losses”, as the magnetic flux causing these losses is constant at all loads.

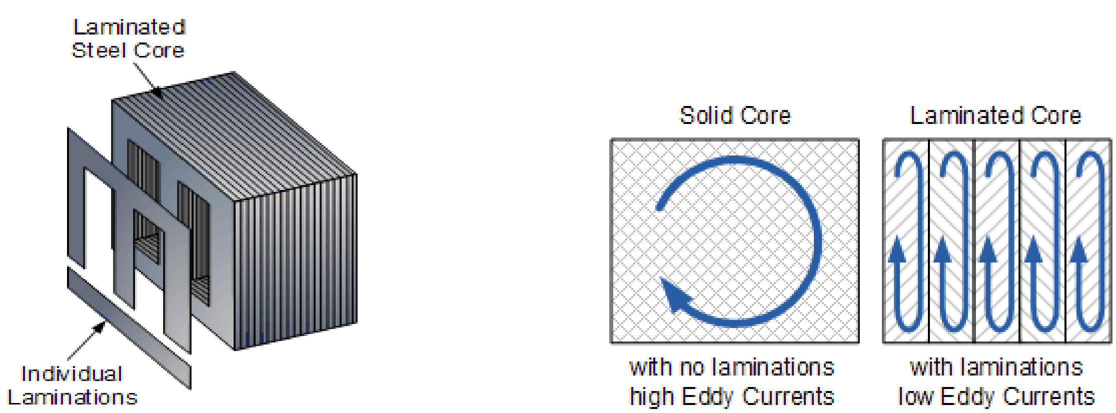


Fig. 3.2 Lamination of transformer core

Principle of operation Ideal Transformer

A transformer is a device used to change voltages and currents of AC electric power by mutual induction principle. In the simplest version it consists of two windings wrapped around a magnetic core; windings are not electrically connected, but they are coupled by the magnetic field, as it shown in Figure 3.1. When one winding is connected to the AC electric power, the electric current is generated.

This winding is called the primary winding. The primary current produces the magnetic field and the magnetic flux links the second winding, called the secondary winding. The AC flux through the secondary winding produces an AC voltage, so that if some impedance is connected to the terminals, an AC electric current is supplied.

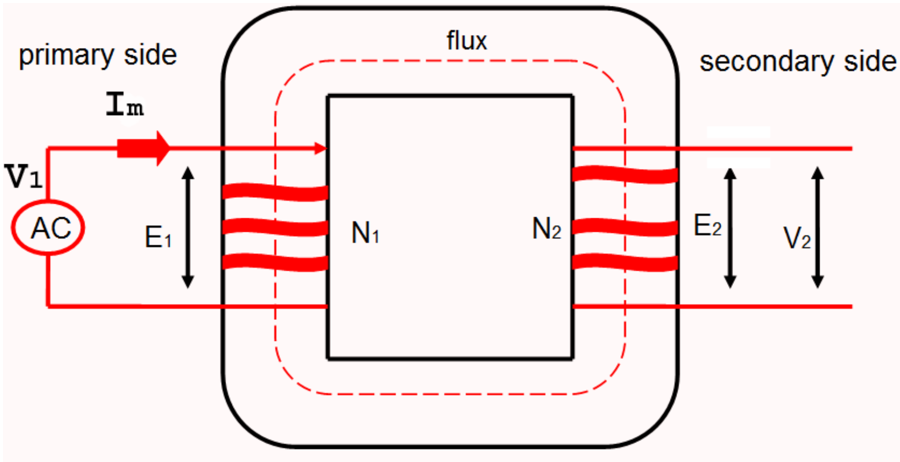


Figure 3.3 Ideal transformer on no load

Transformer on No Load Condition

When the transformer is operating at no load, the secondary winding is open circuited, which means there is no load on the secondary side of the transformer and, therefore, current in the secondary will be zero, while primary winding carries a small current I_0 called no load current which is 2 to 10% of the rated current. This current is responsible for supplying the iron losses (hysteresis and eddy current losses) in the core and a very small amount of copper losses in the primary winding. The angle of lag depends upon the losses in the transformer. The power factor is very low and varies from 0.1 to 0.15.

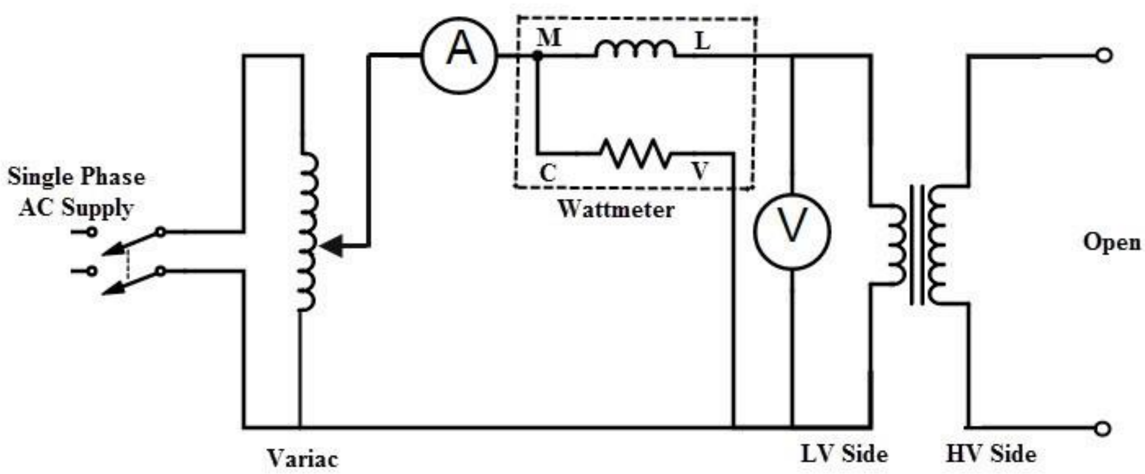


Fig.3.4 Single phase transformer on no load condition

The no load current consists of two components

- Reactive or magnetizing component I_m
  (It is in quadrature with the applied voltage V_1. It produces flux in the core and does not consume any power)

- Active or power component I_w, also know as working component
  (It is in phase with the applied voltage V_1. It supplies the iron losses and a small amount of primary copper loss)

The following steps are given below to draw the phasor diagram

1. The function of the magnetizing component is to produce the magnetizing flux, and thus, it will be in phase with the flux.
2. Induced emf in the primary and the secondary winding lags the flux ϕ by 90 degrees.
3. The primary copper loss is neglected, and secondary current losses are zero as $I_2 = 0$. Therefore, the current I_0 lags behind the voltage vector V_1 by an angle ϕ_0 called no-load power factor angle shown in the phasor diagram above.
4. The applied voltage V_1 is drawn equal and opposite to the induced emf E_1because the difference between the two, at no load, is negligible.
5. Active component I_w is drawn in phase with the applied voltage V_1.
6. The phasor sum of magnetizing current I_m and the working current I_w gives the no load current I_0.

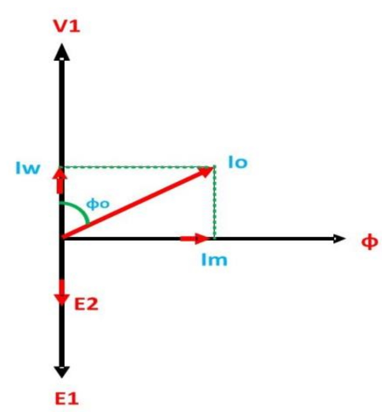


Fig.3.5 Phasor diagram of transformer no load condition

Observation of no load current in transformer

Method :-Oscilloscope typically doesn't measure current but instead it measures **voltage**. Thus to observe current waveform you could simply use current-to-voltage component like resistor, and probe the voltage **across** that resistor. The current information can be obtained by using Ohm Law formula: V = I.R or I = V/R which means current waveform will match exactly the observed voltage, despite the magnitude may be different.

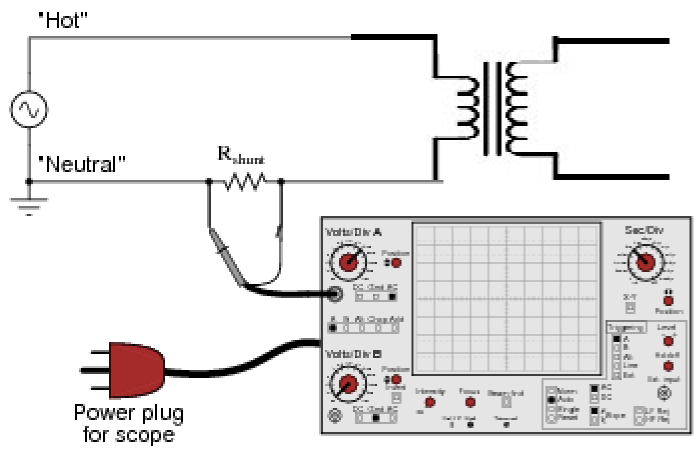


Fig.3.6 Observation of no load current in transformer

S. No	Current observed by Ammter(A)	Current observed by CRO(A)

Transformer "On-load"

When an electrical load is connected to the secondary winding of a transformer and the transformer loading is therefore greater than zero, a current flows in the secondary winding and out to the load. This secondary current is due to the induced secondary voltage, set up by the magnetic flux created in the core from the primary current.

The secondary current, I_S which is determined by the characteristics of the load, creates a self-induced secondary magnetic field, Φ_S in the transformer core which flows in the exact opposite direction to the main primary field, Φ_P. These two magnetic fields oppose each other resulting in a combined magnetic field of less magnetic strength than the single field produced by the primary winding alone when the secondary circuit was open circuited.

This combined magnetic field reduces the back EMF of the primary winding causing the primary current, I_P to increase slightly. The primary current continues to increase until the cores magnetic field is back at its original strength, and for a transformer to operate correctly, a balanced condition must

always exist between the primary and secondary magnetic fields. This results in the power to be balanced and the same on both the primary and secondary sides. Transformer "On-load"

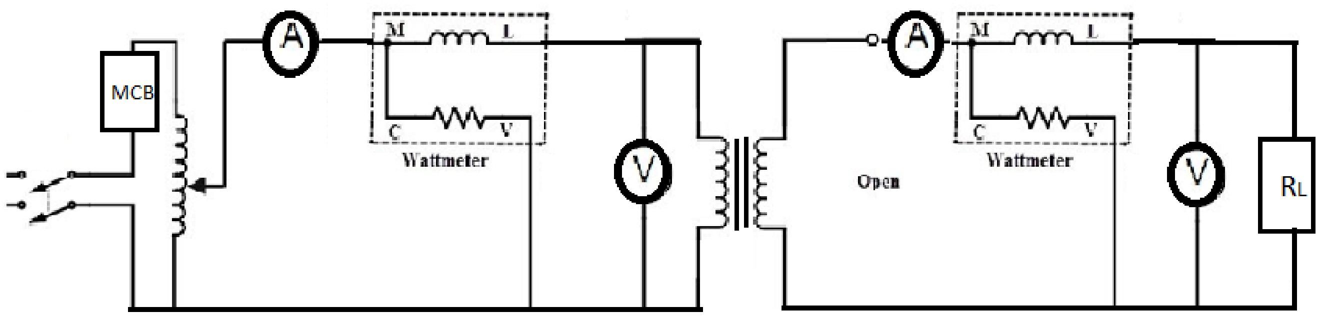


Fig.3.7 Transformer On-load

We know that the turns ratio of a transformer states that the total induced voltage in each winding is proportional to the number of turns in that winding and also that the power output and power input of a transformer is equal to the volts times amperes, (V x I). Therefore:

$$(\text{Power})_{primary} = (\text{Power})_{secondary}$$

$$V_p * I_p = V_s * I_s$$

$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

But we also know previously that the voltage ratio of a transformer is equal to the turns ratio of a transformer as: "voltage ratio = turns ratio". Then the relationship between the voltage, current and number of turns in a transformer can be linked together and is therefore given as

Transformer Ratio(n)

$$\frac{Ns}{Np} \qquad \frac{V_p}{V_s} \qquad \frac{I_s}{I_p}$$

Where:

- $N_P/N_S = V_P/V_S$ - represents the voltage ratio
- $N_P/N_S = I_S/I_P$ - represents the current ratio

Note that the current is inversely proportional to both the voltage and the number of turns. This means that with a transformer loading on the secondary winding, in order to maintain a balanced power level across the transformers windings, if the voltage is stepped up, the current must be stepped down and vice versa. In other words, "higher voltage — lower current" or "lower voltage — higher current".

As a transformers ratio is the relationships between the number of turns in the primary and secondary, the voltage across each winding, and the current through the windings, we can rearrange the above transformer ratio equation to find the value of any unknown voltage, (V) current, (I) or number of turns, (N) as shown.

The total current drawn from the supply by the primary winding is the vector sum of the no-load current, Io and the additional supply current, I_1 as a result of the secondary transformer loading and which lags behind the supply voltage by an angle of Φ.

Observation Table:-

S. No.	Load	Primary Side			Secondary Side			Efficiency(%)
		Vp	Ip	Wp	Vs	Is	Ws	(Ws/Wp)*100
1								
2								
3								

Result:- Observation of the no-load current waveform has been done on an oscilloscope.

Measurement of primary and secondary voltages and currents, and power is done after loading of a transformer with different resistive load condition.

Efficiency of transformer is calculate for direct loading condition.

Vi-Vas questions

1. What happen when Transformer is given DC supply?
2. For a transformer with primary turns 100, secondary turns 400, if 200 V is applied at primary what voltage we will get in secondary?
3. What is difference between transformer and amplifier?
4. How can eddy current loss be minimized?
5. What is auto transformer?
6. Does the transformer draw any current when its secondary is open?
7. What is current transformer?
8. What type of transformer a distribution transformer is? step-up or step-down.
9. What is transformer regulation?

Experiment No - 6

Object:- Demonstration of cut-section model of :

1. DC Machines (Commutator and brush arrangement)
2. Induction Machines (Squirrel cage rotor)
3. Synchronous Machines (Field winding-slip ring arrangement)
4. Single Phase Induction Machine(Ceiling Fan)

Theory:-

DC Machine

A DC Machine is an electro-mechanical energy conversion device. There are two types of DC machines; one is DC generator, and another one is known as DC motor. A DC generator converts mechanical power (ω.T) into electrical power (E.I), whereas, a DC motor converts dc electrical power into mechanical power.

The dc generators and dc motors have the same general construction. In fact, when the machine is being assembled, the workmen usually do not know whether it is a dc generator or motor. Any dc generator can be run as a dc motor and vice-versa.

Operating principle

When the field coil is energized, it creates a magnetic field (excitation flux) in the air gap, in the direction of the radii of the armature. This magnetic field enters the armature from the North pole side of the field coil and exits the armature from the South pole side of the field coil.

The conductors located under the other pole are subject to a force of the same intensity in the opposite direction. The two forces create a torque which causes the motor armature to rotate .

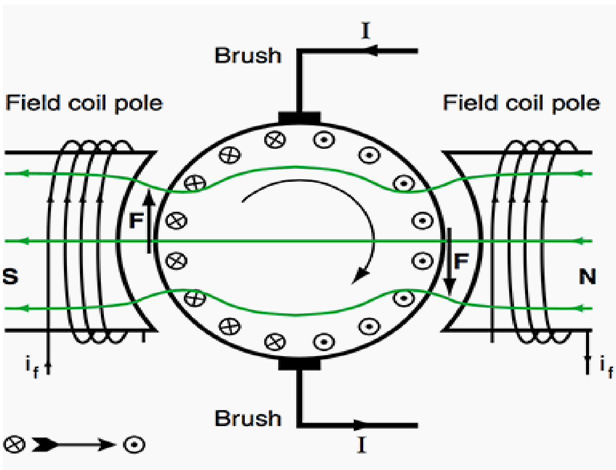


Fig 1. Production of torque in a dc motor

All dc machines have following principal components:

1. Magnetic frame or Yoke
2. Pole Cores and Pole Shoes
3. Pole Coils or Field Coils
4. Armature core
5. Armature winding
6. Commutator
7. Brushes and Bearings

The diagram given below represents the various parts of a DC machine.

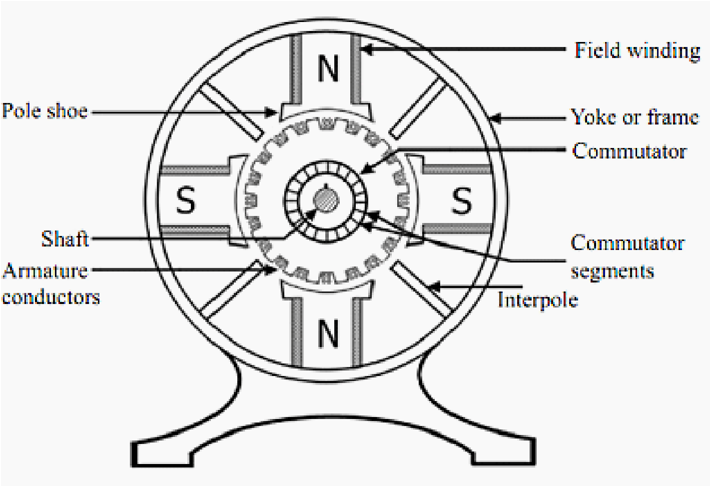


Fig 2. DC Motor Construction parts

Yoke

The outer frame or yoke serves double purpose :

1. It provides mechanical support for the poles and acts as a protecting cover for the whole machine
2. It carries the magnetic flux produced by the poles.

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 employed.

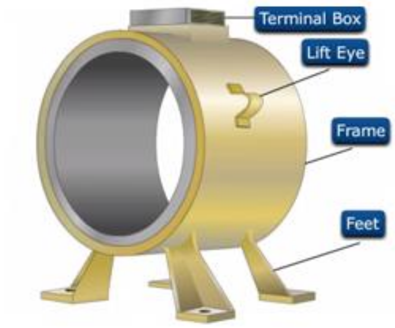


Fig 3. Yoke or Frame of a dc machine

Pole Cores and Pole Shoes

The field magnets consist of pole cores and pole shoes. The pole shoes serve two purposes:

1. they spread out the flux in the air gap and also, being of larger cross-section, reduce the reluctance of the magnetic path
2. they support the exciting coils (or field coils)

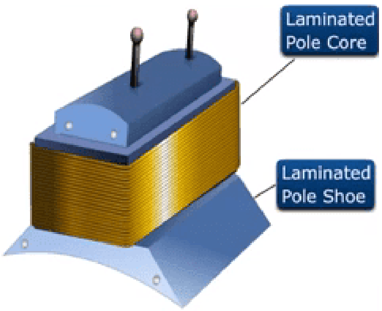


Fig 4. Laminated pole core and pole shoe

Field coils

Field coils are mounted on the poles and carry the dc exciting current. The field coils are connected in such a way that adjacent poles have opposite polarity. The m.m.f. developed by the field coils produces a magnetic flux that passes through the pole pieces, the air gap, the armature and the frame.

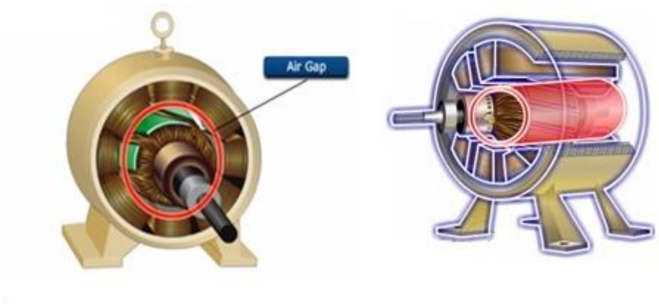


Fig 5. Air Gap

By reducing the length of air gap, we can reduce the size of field coils (i.e. number of turns).

Armature core and Armature windings

The armature core is keyed to the machine shaft and rotates between the field poles. It consists of slotted soft-iron laminations (about 0.4 to 0.6 mm thick) that are stacked to form a cylindrical core as shown in figure.

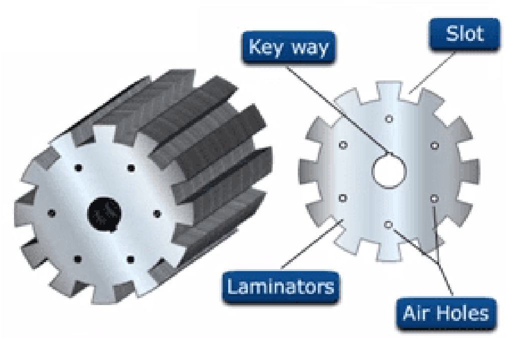


Fig 6. Laminated Armature Core

The purpose of laminating the core is to reduce the eddy current loss. Thinner the lamination, greater is the resistance offered to the induced e.m.f., smaller the current and hence lesser the I^2R loss in the core. The laminations are slotted to accommodate and provide mechanical security to the armature winding and to give shorter air gap for the flux to cross between the pole face and the armature "teeth".

The slots of the armature core hold insulated conductors that are connected in a suitable manner. This is known as armature winding. This is the winding in which "working" e.m.f. is induced. The armature conductors are connected in series-parallel; the conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current.

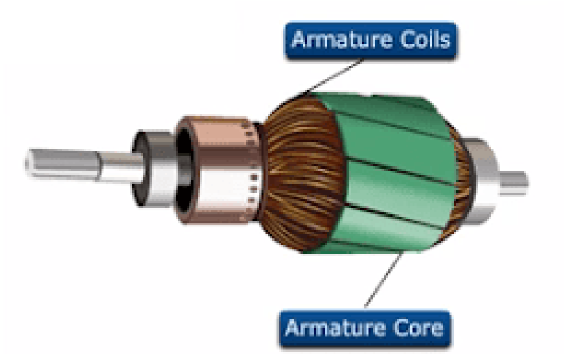


Fig 7. Armature Coils

The armature winding of a d.c. machine is a closed-circuit winding; the conductors being connected in a symmetrical manner forming a closed loop or series of closed loops.

Commutator

A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes.

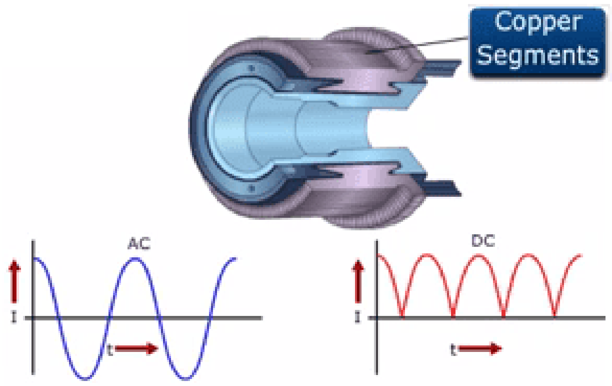


Fig 8. Commutator Segments

The commutator is made of copper segments insulated from each other by mica sheets and mounted on the shaft of the machine. The armature conductors are soldered to the commutator segments in a suitable manner to give rise to the armature winding.

Brushes

The purpose of brushes in a dc generator is to ensure electrical connections between the rotating commutator and stationary external load circuit. The brushes are made of carbon and rest on the commutator. The brush pressure is adjusted by means of adjustable springs.

Three Phase Induction Motor

The three phase induction motor is the most widely used electrical motor. Almost 80% of the mechanical power used by industries is provided by three phase induction motors because of its simple and rugged construction, low cost, good operating characteristics, the absence of commutator and good speed regulation. In three phase induction motor, the power is transferred from stator to rotor winding through induction. The induction motor is also called asynchronous motor as it runs at a speed other than the synchronous speed.
Like any other electrical motor induction motor also have two main parts namely rotor and stator.

1. **Stator:** As its name indicates stator is a stationary part of induction motor. A stator winding is placed in the stator of induction motor and the three phase supply is given to it.
2. **Rotor:** The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft.

The rotor of the three phase induction motor are further classified as:

1. Squirrel cage rotor,
2. Slip ring rotor or wound rotor or phase wound rotor.

The construction of stator for both the kinds of three phase induction motor remains the same.

Stator of Three Phase Induction Motor

The stator of the three-phase induction motor consists of three main parts :

1. Stator frame
2. Stator core
3. Stator winding or field winding

Stator Frame

It is the outer part of the three phase induction motor. Its main function is to support the stator core and the field winding. It acts as a covering, and it provides protection and mechanical strength to all the inner parts of the induction motor. The frame is either made up of die-cast or fabricated steel.

Stator Core

The main function of the stator core is to carry the alternating flux. In order to reduce the eddy current loss, the stator core is laminated. The stamping is made up of silicon steel, which helps to reduce the hysteresis loss occurring in the motor.

Stator Winding or Field Winding

The slots on the periphery of the stator core of the three-phase induction motor carry three phase windings. We apply three phase ac supply to this three-phase winding. The three phases of the winding are connected either in star or delta depending upon which type of starting method we used.

Squirrel Cage Three Phase Induction Motor

The rotor of the squirrel cage three phase induction motor is cylindrical and have slots on its periphery. The slots are not made parallel to each other but are bit skewed as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of the motor more smooth and quieter. The squirrel cage rotor consists of aluminum, brass or copper bars (copper bras rotor is shown in the figure beside). The rotor conductors are permanently shorted by the copper, or aluminum rings called the end rings. The below diagram shows a squirrel cage induction rotor having aluminum bars short circuit by aluminum end rings.

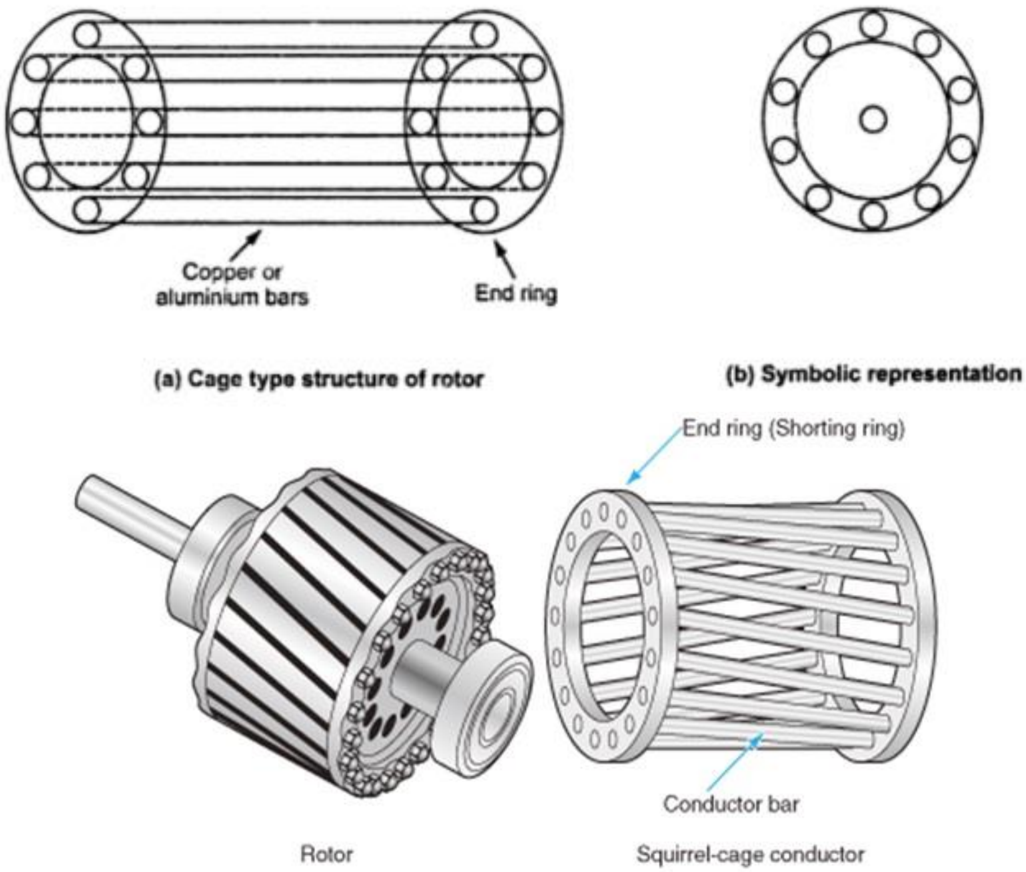


Fig 9. Squirrel cage rotor

Advantages of Squirrel Cage Induction Rotor

1. Its construction is very simple and rugged.
2. As there are no brushes and slip ring, these motors requires less maintenance.

Applications of Squirrel Cage Induction Rotor:

The squirrel cage induction motors are used in lathes, drilling machine, fan, blower printing machines, etc.

Synchronous Machines

Synchronous Machine constitutes of both synchronous motors as well as synchronous generators. An AC system has some advantages over DC system. Therefore, the AC system is exclusively used for generation, transmission and distribution of electric power. The machine which converts mechanical power into AC electrical power is called as Synchronous Generator or Alternator. However, if the same machine can be operated as a motor is known as Synchronous Motor. A synchronous machine is an AC machine whose satisfactory operation depends upon the maintenance of the following relationship.

$$Ns = \frac{120*f}{P} \quad (1)$$

Where,

- N_s is the synchronous speed in revolution per minute (r.p.m), f is the supply frequency and P are the number of poles of the machine.
- When connected to an electric power system, a synchronous machine always maintains the above relationship shown in the equation (1).

Salient pole rotor

The rotor is a large magnet with poles constructed of steel lamination projecting out of the rotor's core. The poles are supplied by direct current or magnetized by permanent magnets.The field winding is wound on the rotor which produces the magnetic field and the armature winding is on the stator where voltage is induced.

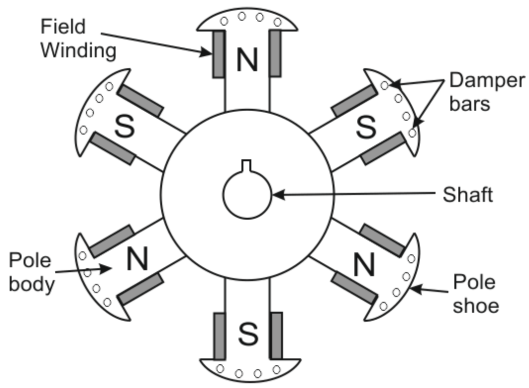


Fig 10. Salint pole rotor

- Salient pole rotors have large diameter and shorter axial length.
- They are generally used in lower speed electrical machines, say 120 RPM to 400 RPM.
- Flux distribution is relatively poor than non-salient pole rotor, hence the generated emf waveform is not as good as cylindrical rotor.
- Salient pole rotors generally need damper windings to prevent rotor oscillations during operation.
- Salient pole synchronous generators are mostly used in hydro power plants and in diesel-electric locomotives using 12 to 20 cylinders.

Cylindrical rotor or Non-Salient Pole Rotor

The cylindrical shaped rotor is made of a solid steel shaft with slots running along the outside length of the cylinder for holding the field windings of the rotor which are laminated copper bars inserted into the slots and is secured by wedges. The slots are insulated from the windings and are held at the end of the rotor by slip rings.

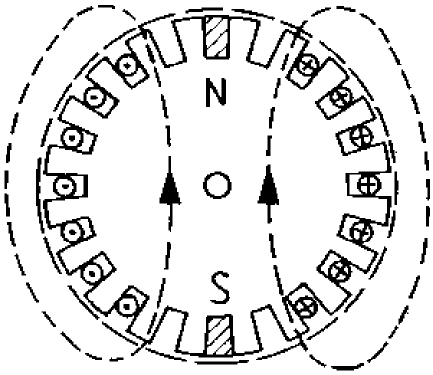


Fig 11. Cylindrical rotor

- They are smaller in diameter but having longer axial length.
- Cylindrical rotors are used in high speed electrical machines, usually 1500 RPM to 3000 RPM.
- Windage loss as well as noise is less as compared to salient pole rotors.
- Their construction is robust as compared to salient pole rotors.
- Number of poles is usually 2 or 4.
- Damper windings are not needed in non-salient pole rotors.
- Flux distribution is sinusoidal and hence gives better emf waveform.
- Non-salient pole rotors are used in nuclear, gas and thermal power plants.

Single Phase Induction Motor

Single phase induction motors are not self- starting. They are made self -starting by providing an additional flux by some additional means. Now depending upon these additional means the single phase induction motors are classified as:

1. **Split phase induction motor**.
2. **Capacitor start inducto**r **motor**.
3. **Capacitor start capacitor run induction motor (two valve capacitor method)**.
4. **Permanent split capacitor (PSC) motor** .
5. **Shaded pole induction motor**.

Ceiling Fan

A ceiling fan consists of a few basic parts, namely an electric motor with a housing, blades and the "irons" that hold most types in place, and a downrod or other mounting device. In addition, many fans are designed to receive decorative "fitters" beneath the blades that hold lamps and glass or crystal shades. Some have a control that is wall-mounted or a hand-held remote.

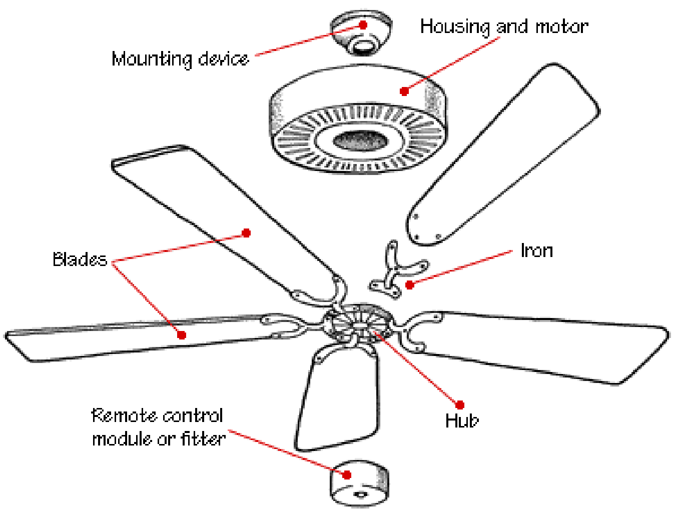


Fig 12. Parts of a ceiling fan

Capacitor Start Capacitor Run Motor (Ceiling Fan)

The **Capacitor Start Capacitor Run Motor** has a cage rotor, and its stator has two windings known as Main and Auxiliary Windings. The two windings are displaced 90 degrees in space. There are two capacitors in this method one is used at the time of the starting and is known as starting capacitor. The other one is used for continuous running of the motor and is known as RUN capacitor.

So this motor is named as Capacitor Start Capacitor Run Motor. This motor is also known as Two Value Capacitor Motor. Connection diagram of the **Two value Capacitor Motor** is shown:

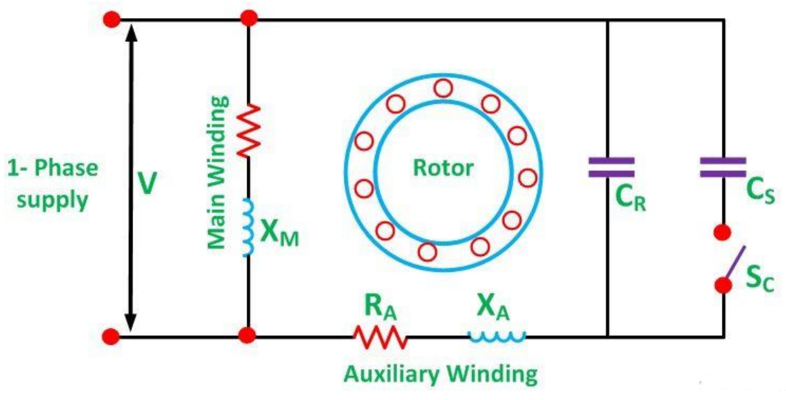


Fig 13. Capacitor start capacitor run motor

There are two capacitors in this motor represented by C_S and C_R. At the starting, the two capacitors are connected in parallel. The Capacitor Cs is the Starting capacitor is short time rated. It is almost electrolytic. A large amount of current id required to obtain the starting torque. Therefore, the value of the capacitive reactance X should be low in the starting winding. Since, $X_A = 1/2\pi fC_A$, the value of the starting capacitor should be large.The rated line current is smaller than the starting current at the normal operating condition of the motor. Hence, the value of the capacitive reactance should be large. Since, $X_R = 1/2\pi fC_R$, the value of the run capacitor should be small.

As the motor reaches the synchronous speed, the starting capacitor C_s is disconnected from the circuit by a centrifugal switch Sc. The capacitor C_R is connected permanently in the circuit and thus it is known as RUN Capacitor. The run capacitor is long time rated and is made of oil filled paper.

The Torque Speed Characteristic of a Two Value Capacitor Motor is shown below.

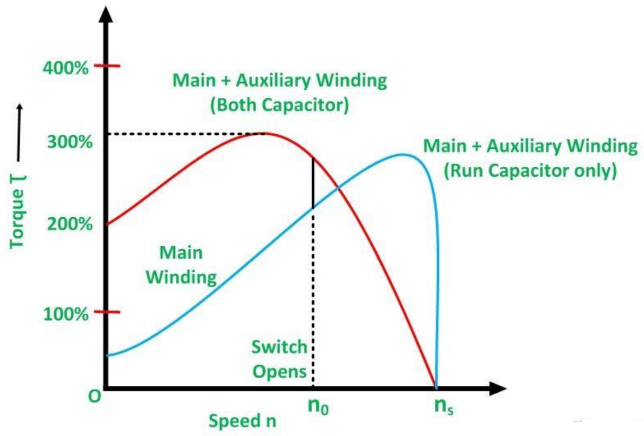


Fig 14. Torque -speed characteristics

The Two Value Capacitor Motors are used in pumping equipment, refrigeration, air compressors, etc.

Result:-We have successfully observed and studied cut–section models of dc machine, induction machine, synchronous machine and single phase induction machine.

Experiment No - 7

Object- Draw Torque speed characteristics of a separately excited DC motor.

Observation Table

S No.	Name of Apparatus	Specification	Quantity
1	DC motor		
2	Voltmeter		
3	Ammeter		
4	DC Power supply		
5	Mechanical Spring balance load		
6	Conneting Leads		

Theory

For a dc drive, it is important to study the torque-speed characteristics of a dc motor since the motor characteristics should match with that of the load to which the drive is going to connect. A schematic representation of a dc machine is shown here. Separately excited DC motors are often used as actuators in trains and automotive traction applications.

A separately excited dc motor is shown in figure 7.1.The armature and the field winding is excited from separate dc sources, V_a and V_f respectively. The effective resistance of the armature winding is given by R_a and current I_a flowing into the armature. The motor back emf or speed voltage is given by E_b. The KVL for the separately excited motor from fig. will be $V_a = E_b + I_a R_a$.

The motor torque is given by $\tau = K e \o Ia$.

Schematic representation of a dc machine

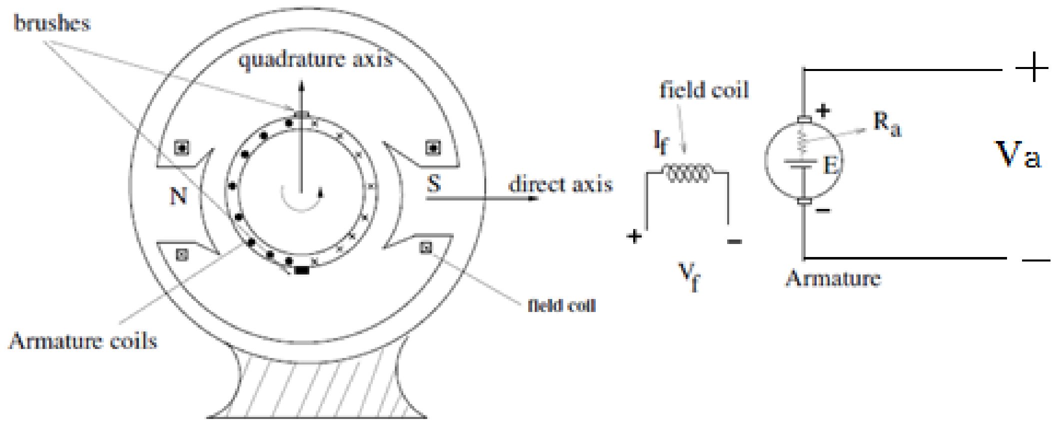


Figure 5.1 Separately excited dc motor

τ-ω characteristics with variation in mechanical load

A **separately excited dc motor** is a motor whose field circuit is supplied from a separate constant-voltage power supply.When the load increases,the output torque required to drive the load will increase.Hence,the motor speed will slow down.Consequently the internal generated voltage drops ($E_a=K\emptyset\omega_m\downarrow$),increasing the armature current in motor $I_a=(V_s-E_a\downarrow)/R_A$.As the armature current increases,the developed torque increase ($T_{dev}=K\emptyset I_a\uparrow$) and finally the developed torque will be equal the load torque at a lower mechanical speed of rotation ω_m.

Mechanical Load $\uparrow\omega_m\downarrow$, $I_a\uparrow$, $T_{dev}\uparrow$

where $\omega_m=2\pi N/60$

Torque :- Mechanical loading is the most common type of method employed in laboratories, A brake drum is coupled to the shaft of the motor and the load is applied by tightening the belt, provided on the brake drum. The net force exerted at the brake drum in kg is obtained from the readings S1 and S2 of the spring balances i.e.

$$P_{output} = \text{Torque x Speed}$$

Thus as the speed of motor does not vary appreciably with load, torque will increase with increasing load.

Net force exerted, W = (S1 – S2) kg

Then, load torque, T = W x d/2 kg – m

= W x d/2 x 9.8 Nw– m

where, d – effective diameter of the brake drum in meters.

Experimental Diagram

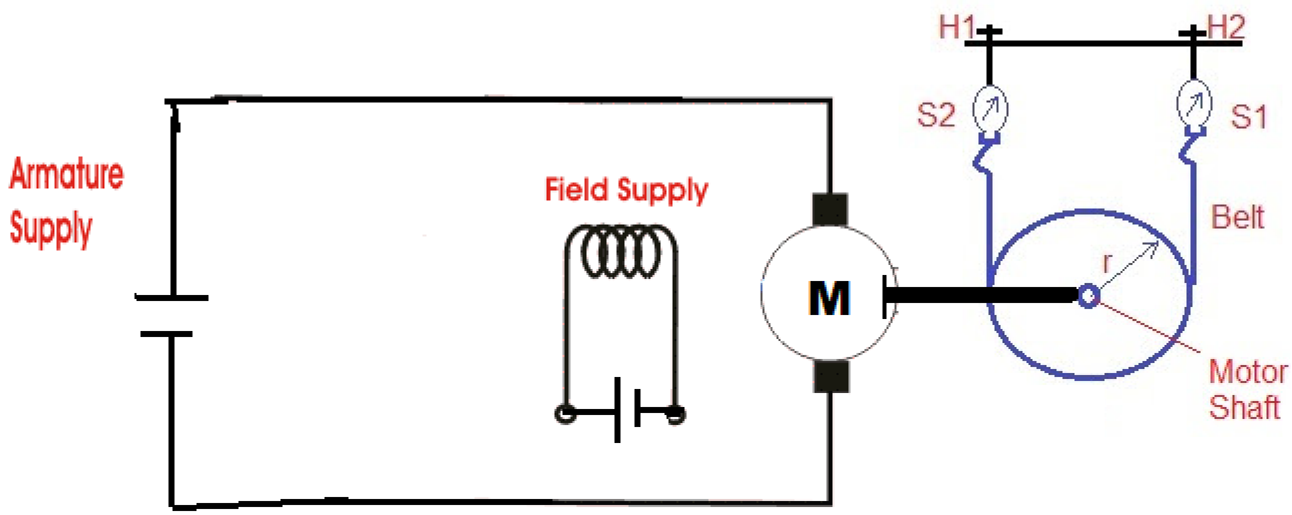


Figure 5.2 : Separately excited dc motor connected with mechanical spring balance load

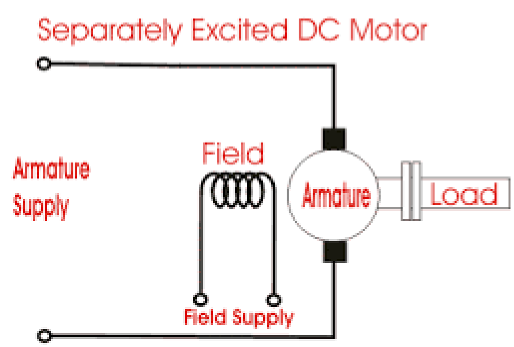


Figure 5.3: Seperately excited dc motor circuit diagram

Torque vs. speed characteristics:

$$T_{dev} = \frac{K\emptyset}{\mathrm{Ra}}(V\mathrm{s} - K\emptyset\ \omega_{\mathrm{m}})$$

As flux Φ is assumed constant, the speed decreases with developed torque increase. But practically, due to armature reaction, Φ decreases with increase in armature current, and hence the speed decrease slightly. Thus, at heavy loads, the motor speed is almost constant.

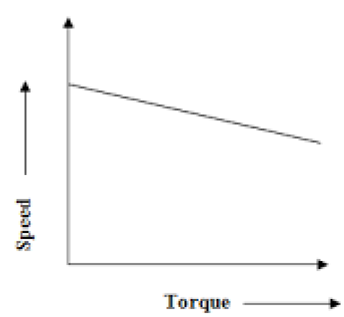


Figure 53 Torque speed characteristics of a separately excited dc motor

Factors Affecting The Torque Speed Characteristics:

1. Adjusting the supply voltage applied to the armature without changing the voltage applied to the field. Hence, the flux is kept constant. This can be applied to separately excited motors only. Hence, at a certain load, since the flux is fixed, increasing the armature voltage increases the motor speed.

2. Adjusting the field resistance $I_f = V_s / R_f$ (and thus the field flux). This can be applied to separately excited shunt motors. Hence, for a constant supply voltage, at a certain load, increasing the flux decreases the motor speed.

3. Inserting a resistor in series with the armature circuit. This can be applied to separately excited shunt motors. Hence, for a constant supply voltage and fixed flux, at a certain load, increasing R_a decreases the motor speed.

Observation Table:-

d=….m

S No	Spring Balance S1(kg)	Spring Balance S2(kg)	Net force W = (S1 – S2) kg	Load Torque τ =W x d/2 x 9.8 Nw– m	Speed $\omega_m = 2\pi N/60$
1					
2					
3					
4					

Calculation :-

APPLICATIONS:

- Separately excited DC motors are often used as actuators in trains and automotive traction applications.
- For their constant speed characteristics, shunt DC motors are used in fixed speed applications such as fans.
- Since the series motors can give high torque per ampere (since their toque is directly proportional to the square of armature current), they can be used in applications that require high starting torque. Examples of these applications include; starter motors in cars, and elevator motors.

Result :- The performance Torque speed characteristics of a separately excited dc motor is plotted.

Precaution:-

1. Turn off the power to equipment before inspecting it.

2. All current transmitting parts of any electrical devices must be enclosed.

3. Avoid contacting circuits with wet hands or wet materials.

4. Check circuits for proper grounding with respect to the power source.

5. Shoes must be worn at all times.

VIVA- VOICE:

1. At a very low speed, increase in field resistance will be

2. Small DC motors have best speed control by

3. The torque limit of speed for a shunt motor

4. To implement armature voltage control, it must be ensured that

5. The PWM control of DC motor varies

6. In which of the following motor, ratio of starting torque to full-load torque will be least?

7. As the load is increased the speed of DC shunt motor will ___________

8. Why The Field of a DC Shunt Motor Should Not Be Open?

9. What Is Speed Regulation?

10. With the increase in temperature, the speed of series and shunt motor will be

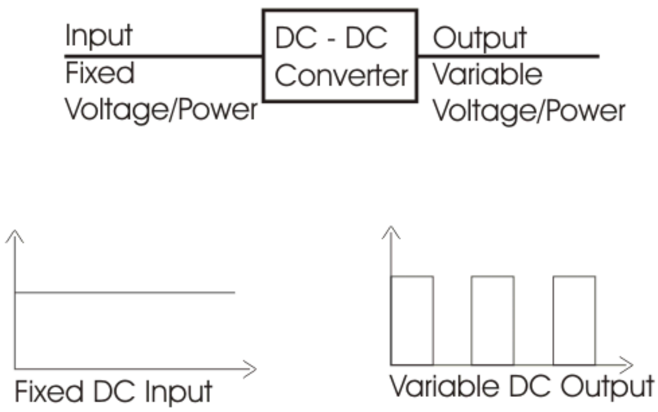
Experiment No - 8

OBJECT:

To understand working of dc-dc converters, dc-ac converters-PWM waveform, use of dc-ac converter for speed control of an induction motor and to familiar the student about construction and working components of LT switchgear.

Introduction

DC to DC converter is very much needed nowadays as many industrial applications are dependent upon DC voltage source. The performance of these applications will be improved if we use a variable DC supply. It will help to improve controllability of the equipments also. Examples of such applications are subway cars, trolley buses, battery operated vehicles etc. We can control and vary a constant DC voltage with the help of a **chopper**. Chopper is a basically static power electronics device which converts fixed DC voltage/power to variable DC voltage or power. It is nothing but a high speed switch which connects and disconnects the load from source at a high rate to get variable or chopped voltage at the output.

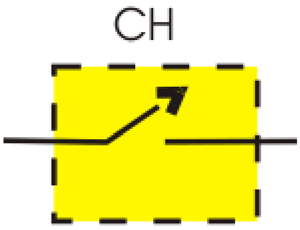


Chopper can increase or decrease the DC voltage level at its opposite side. So, chopper serves the same purpose in DC circuit transfers in case of ac circuit. So it is also known as DC transformer.

Devices used in Chopper

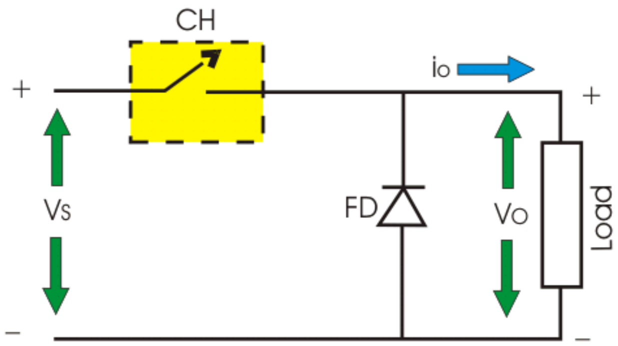
Low power application: GTO, IGBT, Power BJT, Power MOSFET etc.
High power application: Thyristor or SCR.

These devices are represented as a switch in a dotted box for simplicity. When it is closed current can flow in the direction of arrow only.

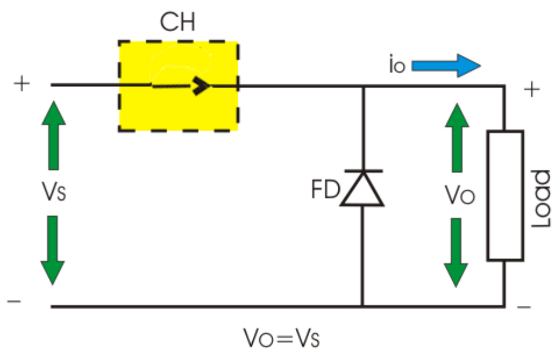


1) Step down Chopper :

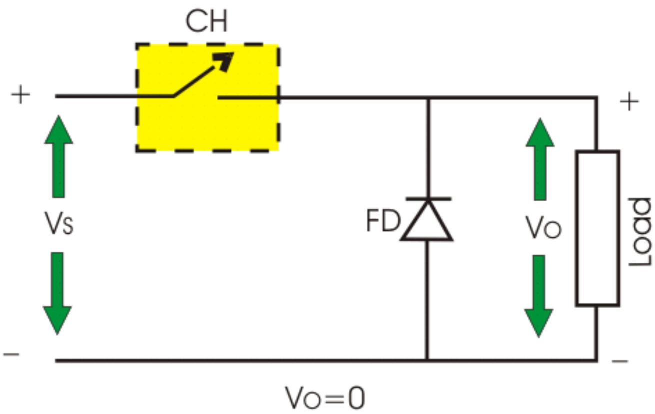
   Step down chopper as Buck converted is used to reduce the i/p voltage level at the output side. Circuit diagram of a step down chopper is shown in the adjacent figure.



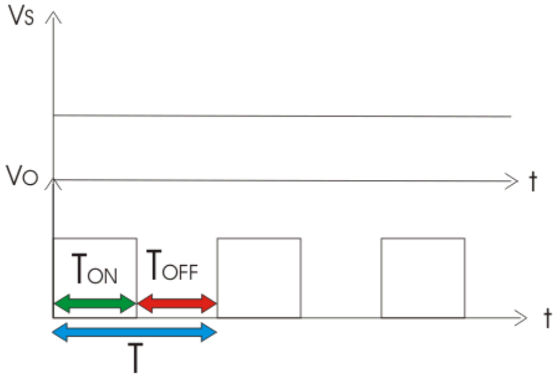
When CH is turned ON, V_s directly appears across the load as shown in figure. So $V_o = V_S$.



When CH is turned off, V_s is disconnected from the load. So output voltage $V_o = 0$.



The voltage waveform of step down chopper is shown below:



T_{ON} → It is the interval in which chopper is in ON state.

T_{OFF} → It is the interval in which chopper is in OFF state.

V_S → Source or input voltage.

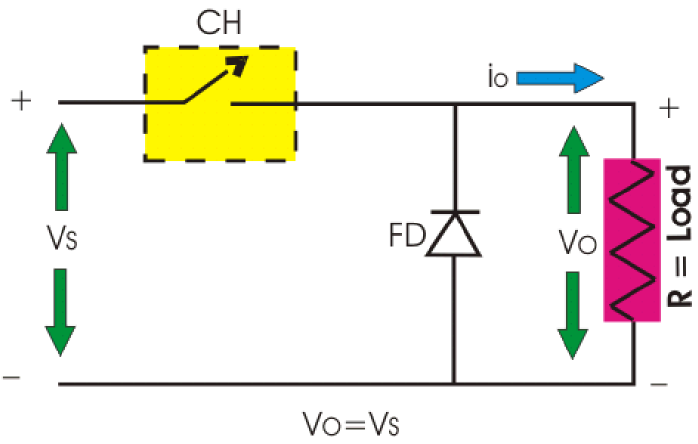
V_o → Output or load voltage.

T → Chopping period = $T_{ON} + T_{OFF}$

Operation of Step Down Chopper with Resistive Load

When CH is ON, $V_o = V_S$

When CH is OFF, $V_o = 0$



$$Average\ output\ voltage\ V_O = \frac{1}{T}\int_0^{T_{ON}} V_s dt = \frac{V_s T_{ON}}{T} = DV_s$$

Where, D is duty cycle = T_{ON}/T.

T_{ON} can be varied from 0 to T, so $0 \le D \le 1$. Hence output voltage V_o can be varied from 0 to V_S.

$$RMS\ output\ voltage\ V_{or} = \sqrt{\frac{1}{T}\int_0^{T_{ON}} V_s^2 dt} = V_s\sqrt{\frac{T_{ON}}{T}} = \sqrt{D}V_s$$

$$Therefore, Effective\ input\ resistance\ R_i = \frac{V_s}{T_{savg}} = \frac{V_s}{DV_s/R} = \frac{R}{D}$$

So, we can conclude that output voltage is always less than the input voltage and hence the name step down chopper is justified. The output voltage and current waveform of step down chopper

Experiment No - 9

Objective-To study working operation of DC-AC converter for speed control of single-phase induction motor.

Apparatus Required

S. N.	Name of apparatus	Type	Range	Quantity
1	DC-AC converter Kit			
2	Ammeter			
3	Voltmeter			
4	Load			
5	Connecting leads			

Introduction:-

With the development of power electronics during the last several decades, semi-conductor devices are now frequently used to convert direct current (d.c.) to a.c. to power conventional alternating current systems. Devices used to convert d.c. to a.c. are called inverters. These are used numerous applications, including PV systems, battery storage systems, traction drives, variable speed drives and others. While they are said to convert d.c. to a.c., this is a simplification, and as we will see, the output of any inverter is built up by pulsed d.c. voltages.

Types of Inverter:-

Converting a d.c. voltage to a sine wave, the general approach is to chop (pulse) the d.c. voltage so that it approximately resembles a sine wave. This waveform can then be filtered to bring it closer to that of a sine wave.The level (and associated costliness) to which these techniques are applied determine the final quality of any sine wave produced.

When considering inverters, the quality of their output is often classified into general categories:

- Square Wave Inverter
- Modified Sine Wave Inverter

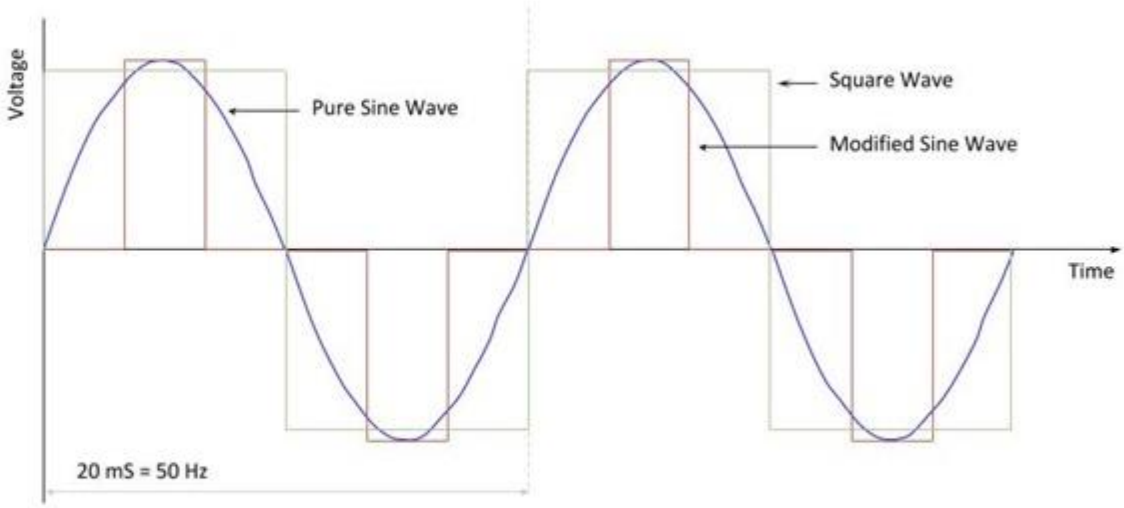


Fig 1 Comparison of various waveform types

A square wave is very simple, with the d.c. supply switched between positive and negative. Depending on the circuitry, the simple square wave can be adapted to give a modified sine wave as shown. By utilising Pulse Width Modulation (see below) and filtering techniques, the waveform can be refined until it closely resembles that of a pure sine wave.

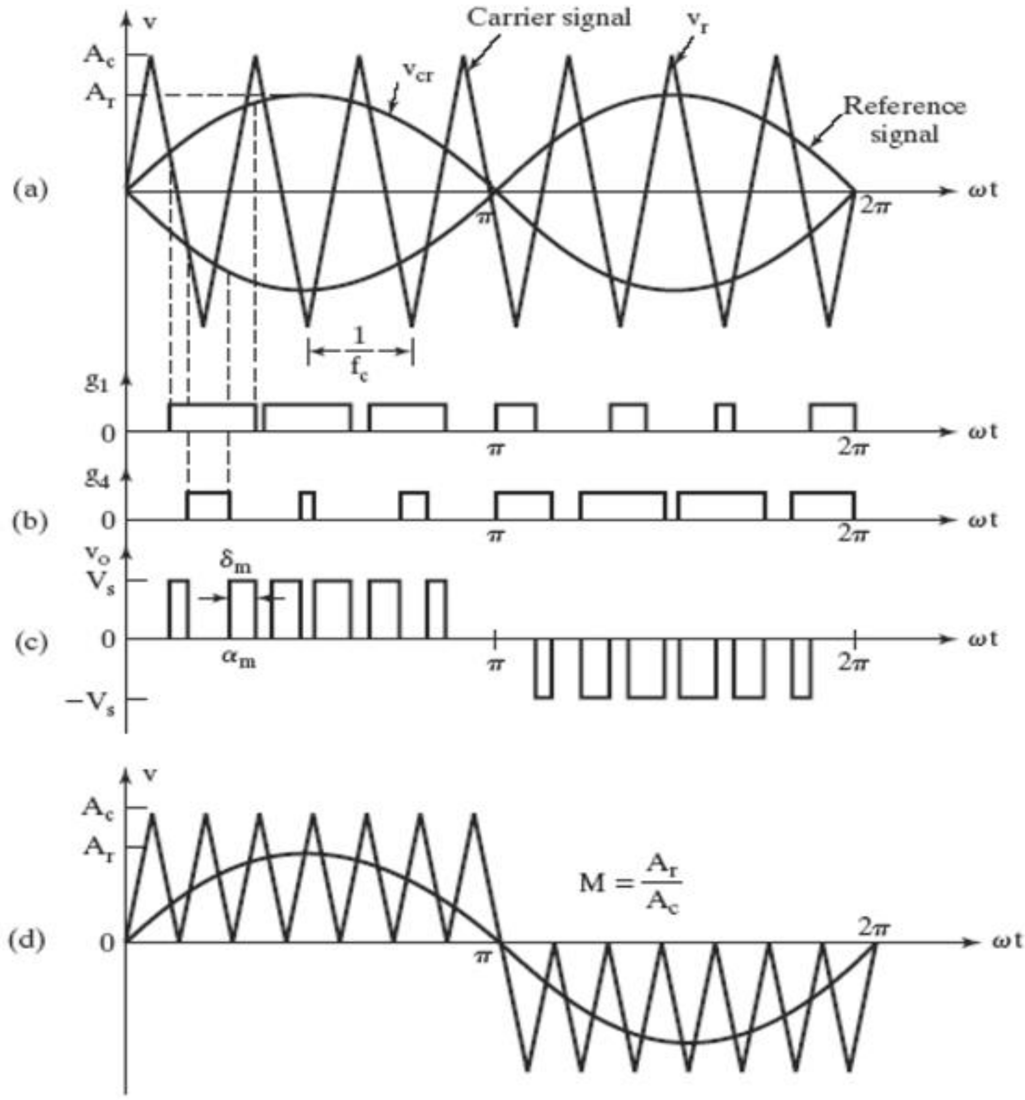
Pulse Width Modulation:-

Advantage of Pulse Width Modulation

In a standard Inverter without the PWM technology, the output voltage changes according to the power consumption of the load. The PWM technology corrects the output voltage according to the value of the load by changing the Width of the switching frequency in the oscillator section. As a result of this, the AC voltage from the Inverter changes depending on the width of the switching pulse. To achieve this effect, the PWM Inverter has a PWM controller IC which takes a part of output through a feedback loop. The PWM controller in the Inverter will makes corrections in the pulse width of the switching pulse based on the feedback voltage. This will cancel the changes in the output voltage and the Inverter will give a steady output voltage irrespective of the load characteristics.

Sinusoidal Pulse Width Modulation (SPWM)

The generation of a sinusoidal Pulse Width Modulation signal has been shown in Figure below. The gating signal can be generated by comparing a sinusoidal reference signal with a triangular carrier wave. The width of each pulse is changed proportionally to the amplitude of a sine wave evaluated at the center of the same pulse. The output frequency 'fo' of the inverter can be determined by using the frequency of the reference signal 'fr '. The output voltage (Vo) can be controlled by modulation index 'M' and in turn peak amplitude 'Ar' controlled the modulation index. The output voltage can be determined by Vo = Vs(S1 – S4). The number of pulses per half cycle depends on the carrier frequency. The gating signal can be generated by using an unidirectional triangular carrier wave



INTRODUCTION

Power Electronics is the technology associated with efficient conversion, control and conditioning of electric power by static means from its available input form into the desired electrical output form. Power electronic converters can be found wherever there is a need to modify the electrical energy form (i.e., modify its voltage, current or frequency). Therefore, their power ranges from some mill watts (as in a mobile phone) to hundreds of mega watts (e.g.in a HVDC transmission system).With “classical” electronics, electrical currents and voltage are used to carry information, whereas with power electronics, they carry power. Therefore the main metric of power electronics becomes the efficiency.

An inverter is a circuit which converts a DC power into an AC power at desired output voltage and frequency. The AC output voltage could be fixed or variable voltage and frequency. This conversion can be achieved either by controlled turn on and turnoff devices (e.g. **BJT**, **MOSFET** , **IGBT** , and MCT etc.) or by forced commutated thyristors, depending on application. The output voltage waveform of an ideal inverter should be sinusoidal. The voltage waveforms of practical inverter are however, non-sinusoidal and contain certain harmonics. Square wave or quasi-square wave voltage maybe acceptable for low and medium power application and for high power application low distorted, sinusoidal waveform are required. The output frequency of an inverter is determined by the rate at which the semiconductor devices are switched on and off by the inverter control circuitry and consequently, an adjustable frequency AC output is readily provided. The harmonics content of output voltage can be minimized or reduced significantly by switching technique of variable high speed power semiconductor devices.

The DC power input to the inverter maybe battery, fuel cell, solar cell or other DC source. But in most industrial applications, it is fed by a rectifier. This configuration of AC to DC converter and DC to AC inverter is called a DC link at network frequency is rectified and then filtered in the DC link before being inverter to AC at adjustable frequency. Rectification is achieved by standard diode or thyristors converter circuits and inversion is achieved by the circuit techniques.

Power Circuit

The power circuit of Single Phase Unipolar inverter consists of four bidirectional **IGBT** arranged in bridge form. The circuit diagram of the power circuit is shown in figure 1

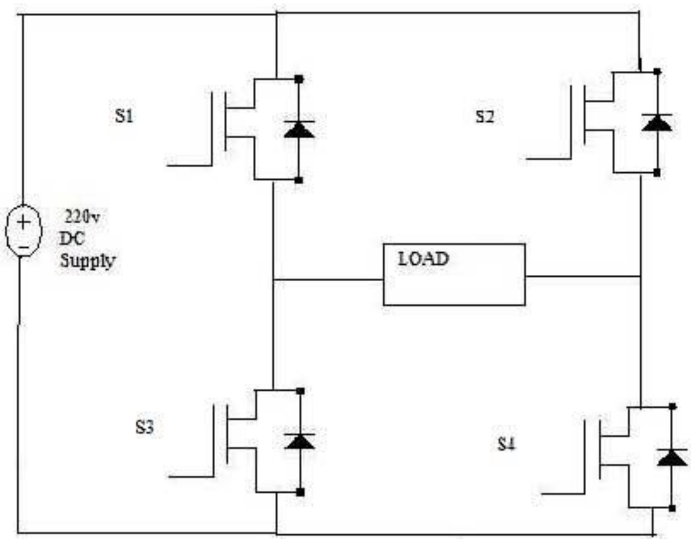


Figure 1 Power circuit

The circuit diagram consists of four distinct **IGBT** such that they are connected as the bridge circuit. The input to the circuit is the 220v DC supply from the rectifier unit. The **IGBT** are triggered accordingly such that the AC output voltage is obtained at the output. The operation of the circuit is as follows.

First the **IGBT** S1 and S4 are turned on by triggering the gate of the **IGBT** . During this time the input supply is 220v DC and at the output the 220v is applied across the load. The current starts from the supply positive, S1, S2, load and to the negative of the supply. The conduction path for the first cycle of operation is shown in figure 2.

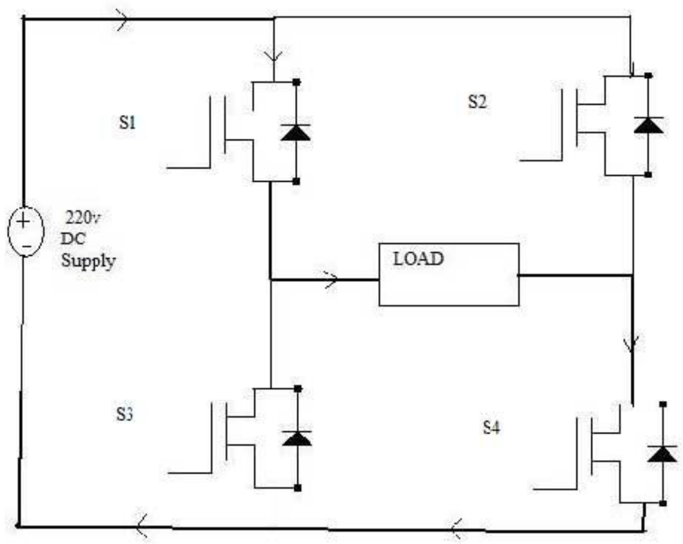


Figure 2: Current conduction when S1 and S4 is ON

During the next phase or the cycle the **IGBT** S2 and S3 are turned on by giving trigger pulse to the gate of the **IGBT** . During this period the input voltage is applied at the output but in the negative direction. The current conduction starts from the supply, S2, S3, load and to the negative of the supply. The current conduction is showed in the figure 3.

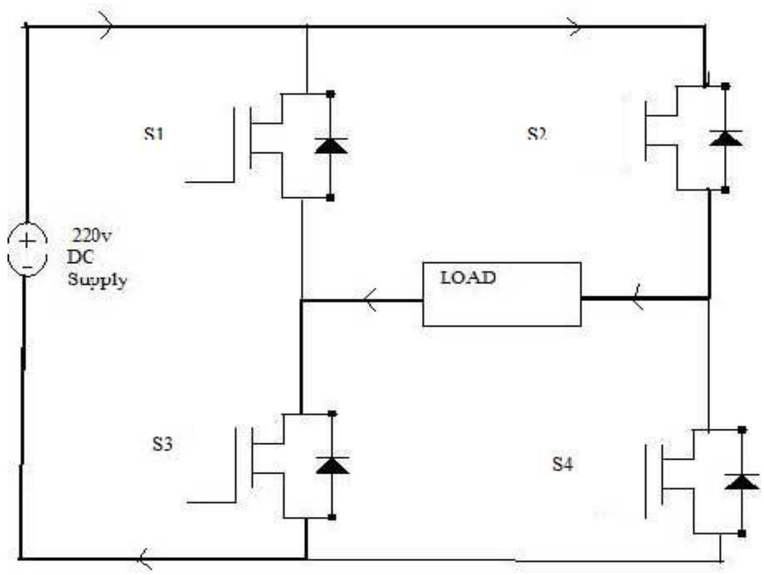


Figure 3: Current conduction during when S2 and S3 is ON

As the two cycles continue the positive and the negative voltage is applied at the load and the current direction changes in the two cycles. As the current direction changes the alternative voltage is obtained at the load thus converting Dc voltage to AC voltage.

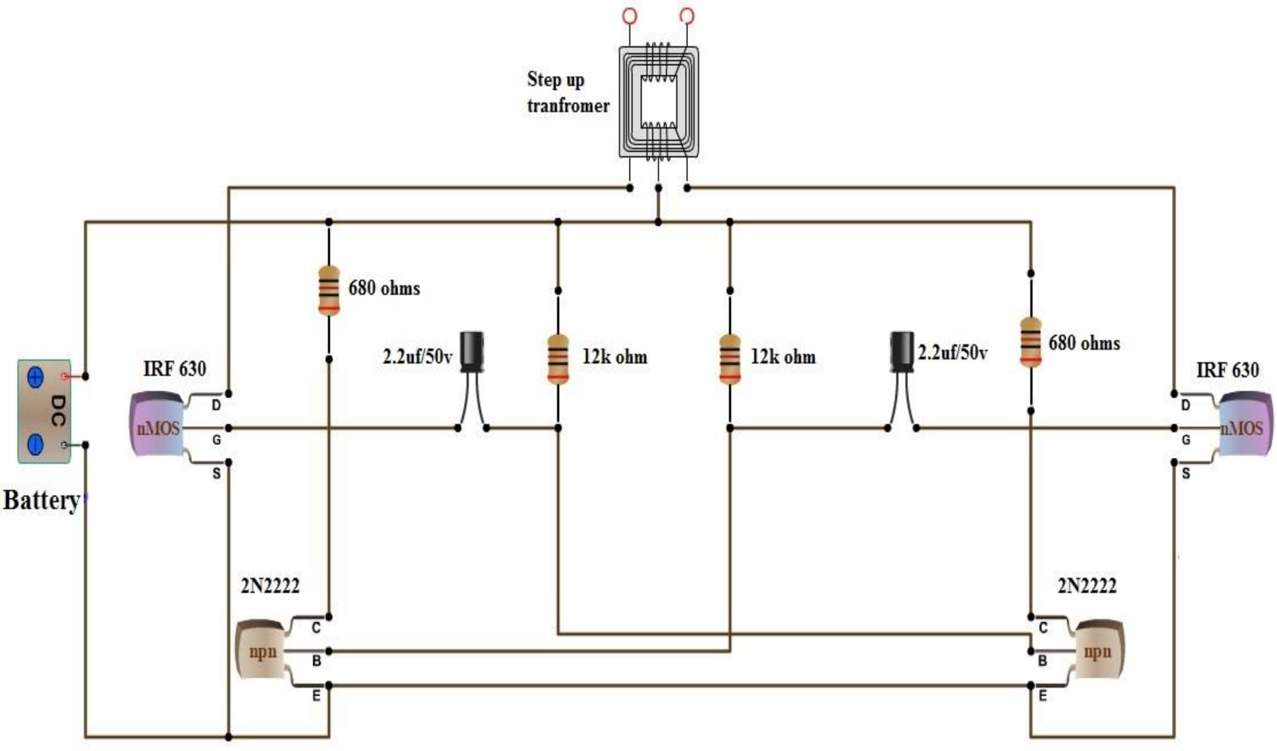
12V DC to 220V AC Converter

Principle Behind this Circuit

The basic idea behind every inverter circuit is to produce oscillations using the given DC and apply these oscillations across the primary of the transformer by amplifying the current. This primary voltage is then stepped up to a higher voltage depending upon the number of turns in primary and secondary coils. A 12V DC to 220 V AC converter can also be designed using simple transistors. It can be used to power lamps up to **35W** but can be made to drive more powerful loads by adding more MOSFETS.

The inverter implemented in this circuit is a square wave inverter and works with devices that do not require pure sine wave AC.

<u>CircuitDiagram</u>



Components required

- 12v Battery
- MOSFET IRF 630 -2

- 2N2222 Transistors
- 2.2uf capacitors-2
- Resistor
    - 680 ohm-2
    - 12k-2
- 12v-220v center tapped step up transformer.

Working

The circuit can be divided into three parts: oscillator, amplifier and transformer. A 50Hz oscillator is required as the frequency of AC supply is 50Hz.This can be achieved by constructing an Astable multivibrator which produces a square wave at 50Hz. In the circuit, R1, R2, R3, R4, C1, C2, T2 and T3 form the oscillator. Each transistor produces inverting square waves. The values of R1, R2 and C1 (R4, R3 and C2 are identical) will decide the frequency. The formula for the frequency of square wave generated by the astable multivibrator is

$$F = 1/(1.38*R2*C1)$$

The inverting signals from the oscillator are amplified by the Power MOSFETS T1 and T4. These amplified signals are given to the step-up transformer with its center tap connected to 12V DC. The turns ratio of the transformer must be 1:19 in order to convert 12V to 220V. The transformer combines both the inverting signals to generate a 220V alternating square wave output.

By using a 24V battery, loads up to 85W can be powered, but the design is inefficient. In order to increase the capacity of the inverter, the number of MOSFETS must be increased.

Experiment No - 10

Object-To study construction (cut-section model), working principle of different components of LT switchgear.

Circuit Breaker:

An electrical circuit breaker is a switching device that can be operated manually or automatically for controlling and protecting the electrical power system. There are different types of circuit breakers which are based on voltage, installation location, external design and interrupting mechanism.

Miniature Circuit Breaker

There are two arrangement of operation of miniature circuit breaker. One due to thermal effect of over current and other due to electromagnetic effect of over current. The thermal operation of miniature circuit breaker is achieved with a bimetallic strip whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts.

But during short circuit condition, sudden rising of current, causes electromechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts. This was a simple explanation of miniature circuit breaker working principle.

Molded Case Circuit Breaker

A *molded case circuit breaker*, abbreviated MCCB, is a type of electrical protection device that can be used for a wide range of voltages, and frequencies of both 50 Hz and 60 Hz. The main distinctions between molded-case and miniature circuit breaker are that the MCCB can have current ratings of up to 2,500 amperes, and its trip settings are normally adjustable. An additional difference is that MCCBs tend to be much larger than MCBs. As with most types of circuit breakers, an MCCB has three main functions:

- Protection against overload – currents above the rated value that last longer than what is normal for the application.
- Protection against electrical faults – During a fault such as a short circuit or line fault, there are extremely high currents that must be interrupted immediately.
- Switching a circuit on and off – This is a less common function of circuit breakers, but they can be used for that purpose if there isn't an adequate manual switch.

Difference Between MCB and MCCB

The wide range of current ratings available from molded-case circuit breakers allows them to be used in a wide variety of applications. MCCBs are available with current ratings that range from low values such as 15 amperes, to industrial ratings such as 2,500 amperes. This allows them to be used in both low-power and high-power applications.

The main difference between the two is their capacity, with the MCB rated under 100 amps with an interrupting rating of under 18,000 amps. Consequently, their trip characteristics may not be adjusted since they basically cater to low circuits.

On the other hand, an MCCB comes with an adjustable trip characteristic for the higher models. Usually, this type of circuit breaker would provide amps as high as 2,500 or as low as 10, depending on what is necessary. Their interrupting rating ranges from around 10,000 amps to 200,000 amps.

Earth Leakage Circuit Breaker (ELCB)

An ECLB is one kind of safety device used for installing an electrical device with high earth impedance to avoid shock. These devices identify small stray voltages of the electrical device on the metal enclosures and intrude the circuit if a dangerous voltage is identified. The main purpose of Earth leakage circuit breaker (ECLB) is to stop damage to humans & animals due to electric shock.

An ELCB is a specific type of latching relay that has a structure's incoming mains power associated through its switching contacts so that the circuit breaker detaches the power in an unsafe condition. The ELCB notices fault currents of human or animal to the earth wire in the connection it guards. If ample voltage seems across the ELCB's sense coil, it will turn off the power, and remain off until manually rearrange. A voltage sensing ELCB doesn't detect fault currents from human or animal to the earth.

Earthing

To connect the metallic (conductive) Parts of an Electric appliance or installations to the earth (ground) is called **Earthing** or **Grounding**.

In other words, to connect the metallic parts of electric machinery and devices to the earth plate or earth electrode (which is buried in the moisture earth) through a thick conductor wire (which has very low resistance) for safety purpose is known as *Earthing or grounding*.

Types of Earthing

Earthing can be done in many ways. The various methods employed in earthing (in house wiring or factory and other connected electrical equipment and machines) are discussed as follows:

1). Plate Earthing:

In plate earthing system, a plate made up of either copper with dimensions 60cm x 60cm x 3.18mm (i.e. 2ft x 2ft x 1/8 in) or galvanized iron (GI) of dimensions 60cm x 60cm x 6.35 mm (2ft x 2ft x ¼ in) is buried vertical in the earth (earth pit) which should not be less than 3m (10ft) from the ground level.

2). Pipe Earthing:

A galvanized steel and a perforated pipe of approved length and diameter is placed vertically in a wet soil in this kind of system of earthing. It is the most common system of earthing.

The size of pipe to use depends on the magnitude of current and the type of soil. The dimension of the pipe is usually 40mm (1.5in) in diameter and 2.75m (9ft) in length for ordinary soil or greater for dry and rocky soil. The moisture of the soil will determine the length of the pipe to be buried but usually it should be 4.75m (15.5ft).

3). Rod Earthing

it is the same method as pipe earthing. A copper rod of 12.5mm (1/2 inch) diameter or 16mm (0.6in) diameter of galvanized steel or hollow section 25mm (1inch) of GI pipe of length above 2.5m (8.2 ft) are buried upright in the earth manually or with the help of a pneumatic hammer. The length of embedded electrodes in the soil reduces earth resistance to a desired value.

4).Strip or Wire Earthing:

In this method of earthing, strip electrodes of cross-section not less than 25mm x 1.6mm (1in x 0.06in) is buried in a horizontal trenches of a minimum depth of 0.5m. If copper with a cross-section of 25mm x 4mm (1in x 0.15in) is used and a dimension of 3.0mm^2 if it's a galvanized iron or steel.

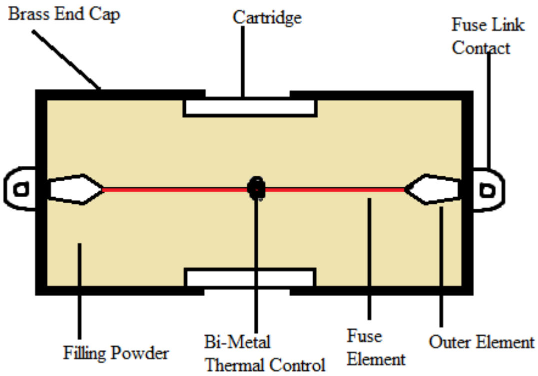
Fuses

Fuses are the protectors, these are the safety devices which are used to protect the home appliances like televisions, refrigerators, computers with damage by high voltage. The fuse is made up of thin strip or strand of metal, whenever the heavy amount of current or an excessive current flow is there in an electrical circuit, the fuse melts and it opens the circuit and disconnects it from the power supply.

Types

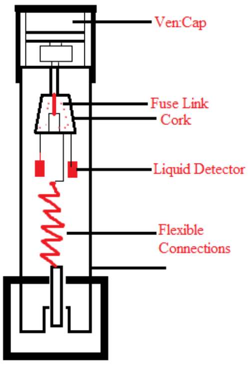
- **<u>Rewireable/ Kit-Kat Type</u>:-** In this type of fuse, the main advantage is that the fuse carrier is easier to remove without having any electrical shock or injury. The fuse base acts as an incoming and outgoing terminal which is made up of porcelain & fuse carrier is used to hold the fuse element which is made up of tin, copper, aluminum, lead, etc. This is used in domestic wiring, small industries etc.

- **Cartridge Type HRC Fuses:-** It is similar to low voltage type, only some designing features are different.



Cartridge Type HRC Fuses

<u>Liquid Type HRC Fuses</u>:- These are used for circuit up to 100A rated current& systems up to 132Kv. These fuses have the glass tube filled with carbon tetrachloride. The one end of the tube is packed and another is fixed by phosphorous bronze wire. When fuse operation starts, the liquid uses in the fuse extinguish the arc. This increase the short circuit capacity.



Liquid Type HRC Fuse