RAJIV GANDHI UNIVERSITY OF KNOWLEDGE TECHNOLOGIES- BASAR

BEEE
LABARATORY MANUAL

DEPARTMENT OF ELECTRICAL ENGINEERING

PREFACE

Engineering institutions have been modernizing and updating their curriculum to keep pacewith the continuously developing technological trends so as to meet the correspondinglychanging educational demands of the industry. As the years passed by, multi-disciplinaryeducation system also has become more and more relevant in the present global industrialdevelopment. Thus, just as Computer Systems & Applications, *Basic Electrical & ElectronicsEngineering* also has become an integral part of all the industrial and engineering sectors beit infrastructure, power generation, minor & major Industries, Industrial Safety or processindustries where automation has become an inherent part. Accordingly, several universitieshave been bringing in a significant change in their graduate programs of engineering startingfrom the first year to meet the needs of these important industrial sectors to enhance theemployabilityoftheirgraduates.Thus,atcollegeentrylevelitself*Basic Electrical &Electronics Engineering* has become the first Multidisciplinary core engineering subject foralmost all the other core engineering branches like Civil, Mechanical, Production engineering,IndustrialEngineering,Aeronautical,Instrumentation,ControlSystemsandCompu terEngineering.Asafurtherimpetus,sinceforunderstandingofthissubjectapracticalknowledge is equally important, a laboratory course is also added in the curriculum. Theexperimentsaresochosenthatthestudentcomprehendsalltheimportanttheoreticalconcep tswithgood practical insight.

This handbook of Laboratory manual cum Observations for *Basic Electrical and ElectronicsEngineering* isbroughtoutinasimpleandlucidmannerhighlightingtheimportantunderlying concepts & objectives along with sequential steps to conduct the experiment.Every experiment is further provided with format of test results and most importantly thesafetyprecautions tobe taken.

INSTRUCTIONSTO STUDENTS

1. Beforeenteringthelab,thestudentshouldcarrythefollowingthings.
   - Identitycardissuedbythecollege.
   - Classnotes.
   - Labobservationbook/LabManual.
   - LabRecord.
2. Studentmustsigninandsignoutintheregisterprovidedwhenattendingthelabsessionwithoutfail.Studentsneedtomaintain100%attendanceinlabifnotastrictactionwillbe.
3. Cometothelaboratoryintime.Students,whoarelatemorethan15min.,willnotbeallowedtoattend thelab.
4. Allstudentsmustfollowa**DressCode**whileinthelaboratory
5. Foods,drinksareNOT allowedandallbagsmustbeleftattheindicatedplace.
6. The objective of the laboratory is learning. The experiments/ demonstrations are designed toillustrate the need and operation of an equipment/ machine and to expose you, how to usedifferent measuring instruments in industry or our daily life, conduct the experiments withinterest and anattitudeoflearning
7. Studentsmusttakecareof theirvaluablethings,Workquietlyand carefully.
8. Behonestinrecordingandrepresenting yourdata.
9. If a particular reading appears wrong repeat the measurement carefully, to get a better fit foragraph
10. Allpresentationsofdata,tablesandgraphscalculationsshouldbeneatlyandcarefullydone
11. Ifyoufinishearly,spendtheremainingtimetocompletethecalculationsanddrawinggraphs. Graphs should be neatly drawn with pencil. Always label graphs and the axes anddisplayunits.
12. Come equipped with calculator, scales, pencils etc. Before entering to lab, must **prepare forViva**forwhichthey are goingto conductexperiment.
13. Do not fiddle with apparatus. Handle instruments with care. Report any breakage to theInstructor.
14. Whentheexperimentiscompleted,studentsshoulddisconnectthesetupmadebythem,andshouldreturnallthecomponents/instruments takenfor thepurpose.
15. Any damage of the equipment or burn-out of components will be viewed seriously either byputtingpenaltyorby dismissingthe totalgroupof studentsfromthelabforthesemester/year.

DO'SANDDON'TS

DO'S:

- ProperDressHastoBeMaintainedWhileEnteringinTheLab.(BoysTuckinAndShoes,Girlswith Apron).
- StudentsShouldCarryObservationNotesandRecordCompletedinAllAspects.
- Correct SpecificationsofTheEquipmentHavetoBe MentionedinTheCircuitDiagram.
- StudentShould BeAware ofOperatingEquipment.
- StudentsShouldBeatTheirConcernedExperimentTable,UnnecessaryMomentIsRestricted.
- StudentShouldFollowtheIndentProceduretoReceiveandDepositthe EquipmentfromTheLabStoreRoom.
- AfterCompletingtheConnectionsStudentsShouldVerifytheCircuitsbyTheLabInstructor.
- TheReadingsMust BeShown toTheLecturerIn-Chargefor Verification.
- BeforeLeavingtheLab,StudentsMustEnsureThatAllSwitchesAreinTheOffPositionandAllth e ConnectionsAreRemoved.
- AllPatchCordsandStoolsShouldBePlacedatTheirOriginalPositions.

DON'Ts:

- **Don't** Come Late toTheLab.
- **Don't**EnterintoTheLabwithGoldenRings,BraceletsandBangles.
- **Don't**MakeorRemovetheConnectionswithPowerOn.
- **Don't**SwitchonTheSupplyWithout Verifying byTheStaffMember.
- **Don't**SwitchOfftheMachine withLoad.
- **Don't** Leavethe LabWithoutthe Permissionof TheLecturerIn-Charge.

COURSE OBJECTIVES:

The courseshouldenablethe student'sabilityto

1. Toverify thebasicelectrical circuitlawsandtheorems.
2. Toplot the V-IcharacteristicsofPNjunctionDiode.
3. Toplotthe inputandoutput characteristicsofTransistorin **CE**configurations.
4. TodeterminethecharacteristicsofTransformers.

COURSE OUTCOMES:

Atthe endofthecourse,thestudents areexpected to

1. Understandthecircuitanalysistechniques.
2. PlottheV-IcharacteristicsofPNjunctionDiode
3. Plot the inputandoutput characteristicsofTransistor in CBandCEconfigurations.
4. Understandthe basic characteristicsoftransformer.

<u>**List of Experiments**</u>

ExperimentNo. 01(a)

Aim:

Basicsafetyprecaution, Introductionanduseofmeasuringinstruments–voltmeter,ammeter,multi-meter.Real-liferesistors, capacitorsandinductors.

APPARATUSREQUIRED:

S. No.	Name of apparatus	Type	Range	Quality
1.	Ammeter	MI, MC	(0-2)A AC, (0-1) A DC	As required
2.	Voltmeter	MI, MC	(0-300)V AC, (0-20) V DC	As required
3.	Multimeter	DIGITAL	-	1
4.	Resistors	Fixed, Variable	-	As required
5.	Capacitors	Fixed, Variable	-	As required
6	Inductors	Fixed, Variable		As required

THEORY

Ammeter:

Ammeterisanelectronicinstrumentsdeviceusedtodeterminetheelectriccurrentflowingthroughacircuit.Ammeter smeasuringcurrentinmilli-ampererangeisknownasmilli-ammeters.Commontypesofammetersaremoving-coilammeterandmoving-ironammeter.Ammetersareconnectedinseriestothecircuitwhosecurrent is to be measured. Hence this electronic instruments are designed to have as minimum resistance/loadingaspossible.

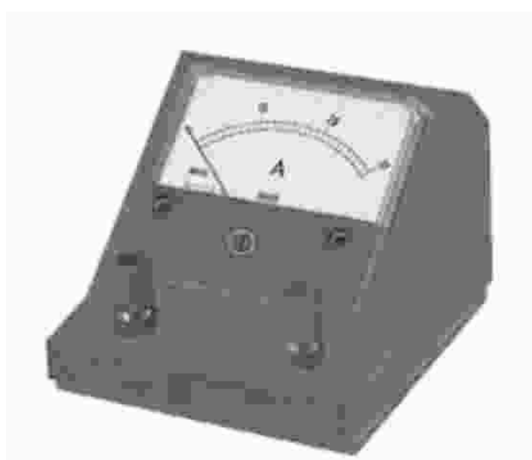
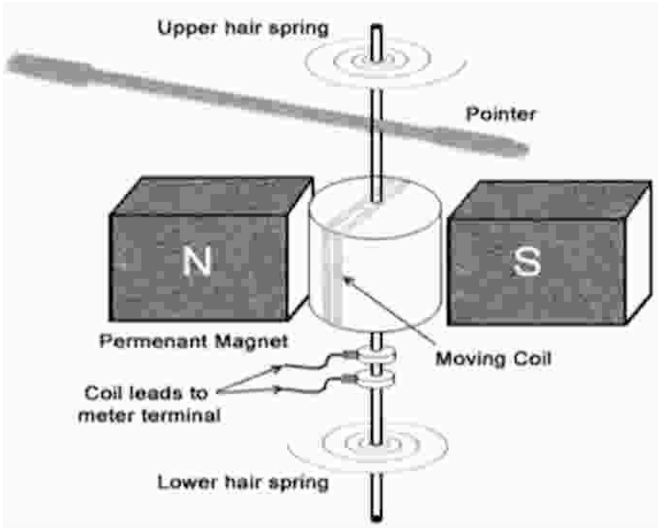


Fig. 1(a).1Ammeter- Electronic Instruments

MovingCoilAmmeter:

Moving coil ammeters are used to measure DC Currents. This electronic instruments consists of a coilsuspended by two hair springs. This coil is placed in a magnetic field created by a fixed permanent magnet. Atorque is experienced when current passes through this coil which is proportional to the current. When the coilturns,thespringswillexertarestoringforceproportionaltotheangleturned.Bythesetwoforces,thecoilwillstopats



omepointandtheangulardeflectionwillbeproportionaltothecurrent.

Fig. 1(a).2 Moving coil ammeter

MovingIronAmmeter:

Moving iron ammeters as electronic instruments can be used for measuring both direct and alternatingcurrentsinelectronicslab.Inthistypeofammeter,apieceofsoftironisused.Thisironpiececonstitutesofam ovingvaneandafixedvane.Currenttobecheckedflowsthroughafixedcoilplacedaroundtheironpiece.Thiscoilprod ucesamagneticfieldproportionaltothecurrent.Sotheironpieceswillgetmagnetizedwiththesamepolarity.Themova blevaneturnsawayfromthefixedvaneduetomagneticrepulsion.Astheironturns,the spring of the electronic instruments will exert a restoring force and stop the vane, when both the forcesbecome equal. The pointer of the ammeter is attached to the movable vane, which will point to the propercurrentreadingusingacalibratedscale.

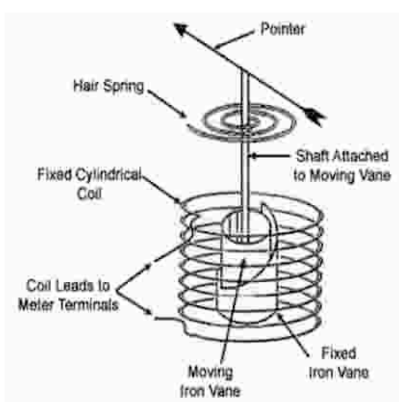


Fig. 1(a).3 Moving IronAmmeter

Voltmeter:

Voltmeterisanelectronicinstrumentsusedinanelectriccircuittodeterminethepotentialdifferenceorvoltagebetweentwodifferentpoints.Digitalandanalogvoltmetersareavailableinelectronicslab.Theyareusuallyconnectedinparallel(shunt)tothecircuit.Hencetheyaredesignedtohavemaximumresistanceaspossibletoreducetheloadingeffect.Thisdeviceisalsocommoninelectronicslab.

Fig.1(a).4(i)AnalogVoltmeter (ii) Digital Voltmeter

AnalogVoltmeter:

Analog voltmeter is a type of voltmeter and electronic instruments with an extra connection of a series resistor(highresistance).Itconsistsofamovablecoilplacedinamagneticfield.Thecoilendsareconnectedtothemeasuringterminals.Ascurrentflowsacrossthecoil,itwillstartturningduetomagneticforceexcretedonthecoil and thus the hair spring will stop the coil by an equal and opposite restoring force. Angular rotation will beproportionaltothevoltageinthiselectronicinstruments.

DigitalVoltmeter

Digital voltmeters can measure both AC and DC measurements with high accuracy as an electronicsinstrument.Itcanmeasureahighvoltageupto1kV.MaincomponentofadigitalvoltmeterisanAnalogtoDigital Converter (ADC). Voltage to be measured is amplified or attenuated properly by the circuit and theoutputissenttoanAnalogtoDigitalConverter(ADC)IC.ThisICwillconverttheanalogsignalinputtodigitalsignal output.AdigitaldisplaydrivenbythisICwilldisplaytheproperVoltagevalue.

DigitalMultiMeter(DMM)

Amultimeteroramultitester,alsoknownasaVOM(Volt-Ohmmeter),isanelectronicmeasuringinstrumentthat combines several measurement functions in one unit. A typical multimeter would include basic featuressuch as the ability to measure voltage, current, and resistance. Analog multimeters use a micro ammeterwhose pointer moves over a scale calibrated for all the different measurements that can be made. Digitalmultimeters(DMM,DVOM)displaythemeasuredvalueinnumerals,andmayalsodisplayabarofalengthproportionaltothequantitybeingmeasured.Digitalmultimetersarenowfarmorecommonthananalogones,but analog multimeters are still preferable in some cases, for example when monitoring a rapidly-varyingvalue.
Amultimetercanbeahand-helddeviceusefulforbasicfaultfindingandfieldservicework,orabench instrument which can measure to a very high degree of accuracy. They can be used to troubleshoot electricalproblemsinawidearrayofindustrialandhouseholddevicessuchaselectronicequipment,motorcontrols,Domestic appliances,powersupplies,andwiringsystems.

Operation:

Amultimeteris acombinationof a multi rangeDC voltmeter, multi rangeAC voltmeter, multi rangeammeter,andmulti rangeohmmeter.Anun-

amplifiedanalogmultimetercombinesametermovement,rangeresistorsandswitches.
Forananalogmetermovement,DCvoltageismeasuredwithaseriesresistorconnectedbetweenthemeter movement and the circuit under test. A set of switches allows greater resistance to be inserted for highervoltage ranges. The product of the basic full-scale deflection current of the movement, and the sum of theseries resistance and the movement's own resistance, gives the full-scale voltage of the range. As anexample,ametermovementthatrequired1millampereforfullscaledeflection,withaninternalresistanceof500 ohms, would, on a 10-volt range of the multimeter, have 9,500 ohms of series resistance. For analogcurrent ranges, low-resistance shunts are connected in parallel with the meter movement to divert most of thecurrentaroundthecoil.Againforthecaseofahypothetical1mA,500ohmmovementona1Amperange,theshuntresistancewouldbejustover0.5ohms.
Movingcoilinstrumentsrespondonlytotheaveragevalueofthecurrentthroughthem.Tomeasurealternating current, a rectifier diode is inserted in the circuit so that the average value of current is non-zero. Since therectifiedaveragevalueandtheroot-mean-squarevalueofawaveformneednotbethesame,simplerectifier-typecircuitsmayonlybeaccurateforsinusoidalwaveforms.Otherwaveshapesrequireadifferentcalibrationfactortorelate RMSandaveragevalue.Sincepracticalrectifiershavenon-zerovoltagedrop,accuracyandsensitivityispooratlowvalues.
Tomeasureresistance,asmallbatterywithintheinstrumentpassesacurrentthroughthedeviceundertest and the meter coil. Since the current available depends on the state of charge of the battery, a multimeterusuallyhasanadjustmentfortheohmsscaletozeroit.Intheusualcircuitfoundinanalogmultimeters,themeter deflection is inversely proportional to the resistance; so full-scale is 0 ohms, and high resistancecorrespondstosmallerdeflections.Theohmsscaleiscompressed,soresolutionisbetteratlowerresistancevalues.
Amplifiedinstrumentssimplifythedesignoftheseriesandshuntresistornetworks.Theinternalresistanceof the coil is decoupled from the selection of the series and shunt range resistors; the series network becomes avoltagedivider.WhereACmeasurementsarerequired,therectifiercanbeplacedaftertheamplifierstage,improving precisionatlowrange.

Fig 1(a).5Digital Multi meter

Digitalinstruments,whichnecessarilyincorporateamplifiers,usethesameprinciplesasanaloginstrumentsfor range resistors. For resistance measurements, usually a small constant current is passed through thedevice under test and the digital multimeter reads the resultant voltage drop; this eliminates the scalecompression found in analog meters, but requires a source of significant current. An auto ranging digitalmultimeter can automatically adjust the scaling network so that the measurement uses the full precision of theA/Dconverter.
Inalltypesofmultimeters,thequalityoftheswitchingelementsiscriticaltostableandaccurate measurements. Stability of the resistors is a limiting factor in the long-term accuracy and precision of

theinstrument.

Quantitiesmeasured

Contemporarymultimeterscanmeasuremanyquantities.Thecommononesare:

- Voltage,alternatinganddirect,involts.
- Currentalternatinganddirectinamperes.

ThefrequencyrangeforwhichACmeasurementsareaccuratemustbespecified.

- Resistanceinohms.

Additionally,somemultimetersmeasure:

- Capacitanceinfarads.
- ConductanceinSiemens.
- Decibels.
- Dutycycleasapercentage.
- Frequencyin hertz.
- Inductanceinhenrys.
- TemperatureindegreesCelsiusorFahrenheit,withanappropriatetemperaturetestprobe,oftenathermocouple.

Digitalmultimetersmayalsoincludecircuitsfor:

- Continuitytester;soundswhenacircuitconducts
- Diodes(measuringforwarddropofdiodejunctions),andtransistors(measuringcurrentgainandotherparameters)
- Batterycheckingforsimple1.5voltand9voltbatteries.Thisisacurrentloadedvoltagescalewhich simulatesin-usevoltagemeasurement.

RESISTANCE&RESISTOR

The electrical resistance of an electrical element measures its opposition to the passage of an electric current;the inverse quantity is electrical conductance, measuring how easily electricity flows along a certain path.Electrical resistance shares some conceptual parallels with the mechanical notion of friction. The SI unit ofelectricalresistanceistheohm(Ω),whileelectricalconductanceismeasuredinSiemens(S).

Anobjectofuniformcrosssectionhasaresistanceproportionaltoitsresistivityandlengthandinversely proportional to its cross-sectional area. All materials show some resistance, except for superconductors,whichhavearesistanceofzero.

Theresistanceofanobjectisdefinedastheratioofvoltageacrossittocurrentthroughit:

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

Such materials are called Ohmic materials. For objects made of ohmic materials the definition of theresistance, with R being a constant for that resistor, is known as Ohm's law.In the case of a nonlinearconductor (not obeying Ohm's law), this ratio can change as current or voltage changes; the inverse slope of achordtoanI–Vcurveissometimesreferredtoasa"chordalresistance"or"staticresistance".

Fig.1(a).6 Resistor

DCresistance

The resistance of a given resistor or conductor grows with the length of conductor and specific resistivity of thematerial,anddecreasesforlargercross-sectionalarea.TheresistanceRandconductanceGofaconductorofuniformcrosssection,therefore,canbecomputed as

$$R = \rho \frac{L}{A}$$

$$G = \sigma \frac{A}{L}$$

whereis the length of the conductor, measured in meters [m], A is the cross-section area of the conductormeasuredinsquaremeters[m^2],σ(sigma)istheelectricalconductivitymeasuredinSiemenspermeter(Sm-1), and ρ (rho) is the electrical resistivity (also called specific electrical resistance) of the material, measured inohm-meters (Ωm). Resistivity is a measure of the material's ability to oppose electric current. For purelyresistivecircuitsconductanceisrelatedtoresistanceRby:

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

For practical reasons, any connections to a real conductor will almost certainly mean the current density is nottotally uniform. However, this formula still provides a good approximation for long thin conductors such aswires.

ACresistance

Awirecarryingalternatingcurrenthasareducedeffectivecrosssectionalareabecauseoftheskineffect.

Adjacentconductorscarryingalternatingcurrenthaveahigherresistancethantheywouldinisolationorwhencarrying directcurrent,duetotheproximityeffect.Atcommercialpowerfrequency,theseeffectssignificantforlargeconductor scarryinglargecurrents,suchasbusbarsinanelectricalsubstation,orlargepowercablescarryingmorethanafewhund

redamperes.
Whenanalternatingcurrentflowsthroughthecircuit,itsflowisnotopposedonlybythecircuitresistance,but also by the opposition of electric and magnetic fields to the current change. That effect is measured byelectricalreactance.Thecombinedeffectsofreactanceandresistanceareexpressedbyelectricalimpedance.

Measuringresistance

An instrument for measuring resistance is called an ohmmeter. Simple ohmmeters cannot measure lowresistancesaccuratelybecausetheresistanceoftheirmeasuringleadscausesavoltagedropthatinterfereswiththe measurement,somoreaccuratedevicesusefour-terminalsensing.

Temperaturedependence

Near room temperature, the electric resistance of a typical metal increases linearly with rising temperature,whiletheelectricalresistanceofatypicalsemiconductordecreaseswithrisingtemperature.Theamount ofthatchangeinresistancecanbecalculatedusingthetemperaturecoefficientofresistivityofthematerialusingthefoll owingformula:

$$R(T) = R_0[1 + \alpha(T - T_0)]$$

Where T is its temperature, T0 is a reference temperature (usually room temperature), R0 is the resistance atT0, and α is the percentage change in resistivity per unit temperature. The constant α depends only on thematerial being considered. The relationship stated is actually only an approximate one, the true physics beingsomewhatnon-linear,orlookingatitanotherway,αitselfvarieswithtemperature.Forthisreasonitisusualtospecifythetemperatureth atαwasmeasuredatwithasuffix,suchasα15andtherelationshiponlyholdsinarangeoftemperaturesaroundtherefere nce.

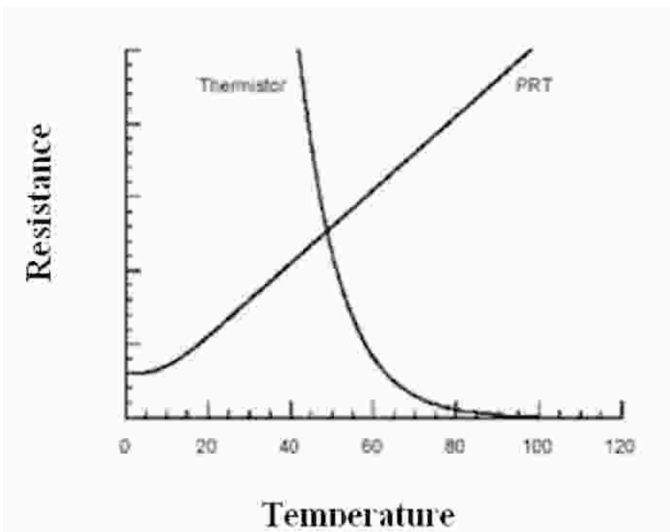


Fig.1(a).7:Temperaturecharacteristicsofresistance

INDUCTANCEANDINDUCTOR

I.ElementaryCharacteristics

The coil in the figure simulates an inductor. The main issue is how the magnetic field lines go across theinductor(lineswitharrows).Thereissomemagneticfieldatthetopbottomofthecoiltoo.

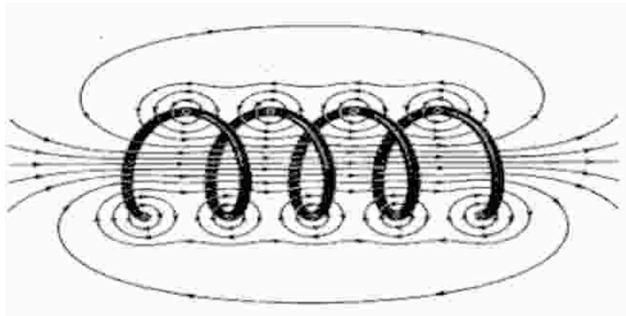
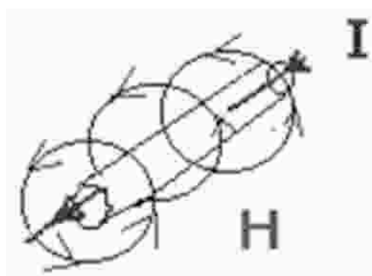


Fig.1(a).8 Elementary characteristics

ThecurrentIgoingthroughtheinductorgenerateamagneticfieldwhichisperpendiculartoI.TheMagneticFieldHisgivenbytheloopsthatsurroundthecurrentI.ThedirectionoftheMagneticFieldisgivenbythearrowsaroundtheloops.IfthecurrentwastoflowintheoppositedirectiontheMagneticFieldarrowswouldbereversed.Forapracticaldisplayofthis



phenomenasee:Magneticfieldonwire.

Fig. 1(a).8 Magnetic field on wire

ItistheMagneticFieldwhichcontainsthecurrentthroughthecoilwhichbytheprinciplecalledSelf-Inductionwill induce a voltage V.More specifically speaking, the voltage V across the inductor Lis given by:V =ΔΦ/ΔTwhichreads–thevoltageViscausedbythechangeinfluxoverthecorrespondentchangeintime,but since the change in flux is given by the inductance L and the change in current across the coil ΔI,thevoltageVbecomes:

$$V = \mathrm{L}\frac{\Delta \mathrm{I}}{\Delta \mathrm{T}} \textbf{(Electrical definition for inductance)}$$

On the other hand the physical definition of inductance L is given by:

$$L = \mu \mathrm{N}^2 \frac{\mathrm{A}}{\mathrm{l}} \textbf{(Physical definition for inductance)}$$

whereμ stands for the relative ease with which current flows through the inductor or Permeability of themedium.N stands for the number of turns in the coil, A stands for its cross-sectional area, and the length of thecoilis given by l.Hence this formula tells us that the more number of turns the larger the inductance (i.e.:currentcanbecontainedbetter),alsothelargerthecross-sectionalareathelargertheinductance(sincethereismorefluxofcurrentthatcanbecontained)andthelongerthecoilthesmallertheinductance(sincemorecurrent can be lost through the turns). L is also proportional toμ , since the better the permeability current willflowwithmoreease.

InductanceandEnergy

BycontainingthecurrentviathemagneticfieldtheinductoriscapableofstoringEnergy.ATransformersuchas the one on the Figure will certainly remind us of the ability of storing Energy associated with Inductors.WhereasforacapacitortheEnergystoreddependsontheVoltageacrossit,fortheinductortheEnergystored dependsonthecurrentbeingheld,suchthat:

$$W = \frac{1}{2}\mathrm{LI}^2$$ Where W stands for the energy on the inductor

Basic Inductor Circuit

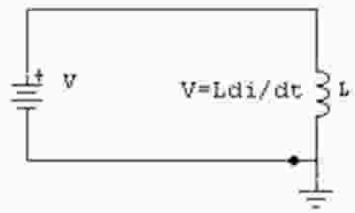


Fig. 1(a).9 Basic inductor circuit

The electrical parameters V and L (the inductance -measured in Henrys-H - review DC Basics or go to are given. The current I is implicitly given by the relationship:

$$V = \mathrm{L}\frac{\mathrm{di}}{\mathrm{dt}}$$

Inasimilarcaseaswiththebasiccapacitorcircuitweareimplyingthatattime0aswitchclosesconnectingthebattery to the coil and the inductor starts to get charged.Also, in all real cases there will be a small resistanceinserieswiththeinductor,butwewillgettothiscaseinthediscussionofR-Lcircuits.

AtaspecificpointoftimethevoltageacrosstheinductorisexpressedbyV=Ldi/dtwhichisbasicallythe electrical definition of inductance, except that since we are just focusing at a point in time and not at an intervaloftimedelta=ΔTwewillneedtousethetermdtandsimilarlyforthecurrentdiinsteadofΔI.Theelectricaldefinitionstillholds,sinceallwearesayingisthatthefluxorchangeincurrentovertimetimestheinductanceistheInducedVoltageacrosstheInductor.

CAPACITOR

A capacitor is a passiveelectrical component that can store energy in the electric field between a pair ofconductors (called "plates"). The process of storing energy in the capacitor is known as "charging", andinvolves electric charges of equal magnitude, but opposite polarity, building up on each plate. A capacitor'sabilitytostorechargeismeasuredbyitscapacitance,inunitsoffarads.

Capacitorsareoftenusedinelectricandelectroniccircuitsasenergy-storagedevices.Theycanalsobeused todifferentiatebetweenhigh-frequencyandlow-frequencysignals.

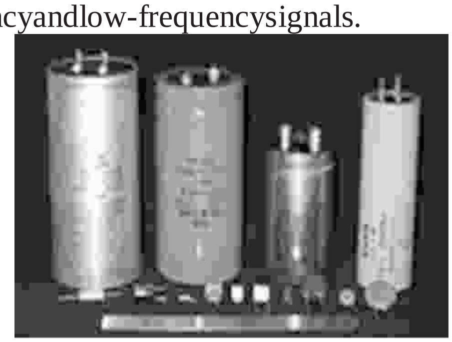


Fig 1(a).10 Capacitor

TheoryofOperation

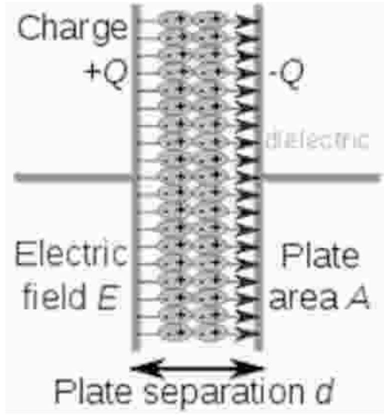


Fig1(a).11Parallel-Platecapacitor

Chargeseparationinaparallel-platecapacitorcausesaninternalelectricfield.Adielectric(orange)reducesthefieldandincreasesthecapacitance.

Acapacitorconsistsoftwoconductorsseparatedbyanon-conductiveregion.Thenon-conductiveregionis called the dielectric or sometimes the dielectric medium. In simpler terms, the dielectric is just an electricalinsulator.Examplesofdielectricmediumsareglass,air,paper,vacuum,andevenasemiconductordepletionregion chemically identical to the conductors. A capacitor is assumed to be self-contained and isolated, with nonet electric charge and no influence from any external electric field. The conductors thus hold equal andopposite charges on their facing surfaces, and the dielectric develops an electric field. In SI units, acapacitanceofonefaradmeansthatonecoulombofchargeoneachconductorcausesavoltageofonevoltacrossthedevice.

Fig 1(a).12 Demonstration of a parallel-plate capacitor

The capacitor is a reasonably general model for electric fields within electric circuits. An ideal capacitor iswhollycharacterizedbyaconstantcapacitanceC,definedastheratioofcharge±Qoneachconductortothevoltage V betweenthem:

$$C = \frac{Q}{V}$$

Sometimeschargebuild-upaffectsthecapacitormechanically,causingitscapacitancetovary.Inthiscase,capacitanceisdefinedintermsofincr

$$C = \frac{dq}{dt}$$

ementalchanges:

Energystorage

Workmustbedonebyanexternalinfluenceto"move"chargebetweentheconductorsinacapacitor.Whenthe external influence is removed the charge separation persists in the electric field and energy is stored to bereleased when the charge is allowed to return to its equilibrium position. The work done in establishing theelectricfield,andhencetheamountofenergystored,isgivenby:

$$W\int_{q=0}^{Q} V dq = \int_{q=0}^{Q} \frac{q}{c} dq = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}VQ$$

OBSERVATIONTABLE

S.No.	Components for identification/Testing	Type	Measured Value		Quality
			By multimeter	By Color Coding	
1.	Resistors	i.			
		ii.			
2.	Capacitors	i.			
		ii.			
3.	Inductors	i.			
		ii.			

PROCEDURE

ForResistors

1. Identifythetypeofelementandwriteinobservationtable.
2. Finddifferentvaleofresistorusingcolorcodingandmultimeter,notedowninobservationtable
3. Usingmultimetertestgivenresistorforopenandshortconditions.

ForInductors

1. Identifythetypeofelementandwriteinobservationtable.
2. Finddifferentvaleofresistorusingcolorcodingandmultimeter,notedowninobservationtable.
3. Usingmultimetertestgivenresistorforopenandshortconditions.

ForCapacitor

1. Identifythetypeofelementandwriteinobservationtable.
2. Finddifferentvaleofresistorusingcolorcodingandmultimeter,notedowninobservationtable
3. Usingmultimetertestgivenresistorforopenandshortconditions.

RESULT

Studyofvariouspassivecomponentsviz.resistor,capacitor,inductorandtheirtestingandidentificationhasdone.

PRECAUTIONS

1. Allconnectionmustbetight.
2. Getthecircuitconnectionscheckedbytheteacherbeforeperformingtheexperiment.
3. Powertothecircuitmustbeswitchedoninthepresenceoftheteacher.
4. Gettheexperimentalreadingscheckedbytheteacher.
5. Don'ttouchdirectlythelivepartsofequipmentandcircuit.
6. Wearleathershoesinthelab.

VIVAVOICE:

1) What arethevarious usesofmultimeter?
2) Whatisacapacitor?
3) Whichdeviceisuse tomeasureaccurrent?
4) Whatisavoltmeter?

OSCILLOSCOPE

OBJECTIVE:

Introductionanduseofoscilloscope.

APPARATUSREQUIRED:

S.No	Name of the equipment	Quantities	Type
1.	Function Generator	1	
2.	CRO	1	
3.	Connecting Probe	As Required	

THEORY

CATHODERAYOSCILLOSCOPE

The cathode-ray oscilloscope (CRO) is a common laboratory instrument that provides accurate time andamplitudemeasurementsofvoltagesignalsoverawiderangeoffrequencies.Itsreliability,stability,andeaseofope rationmakeitsuitableasageneralpurposelaboratoryinstrument.TheheartoftheCROisacathode-raytubeshownschematicallyinFig.2.1

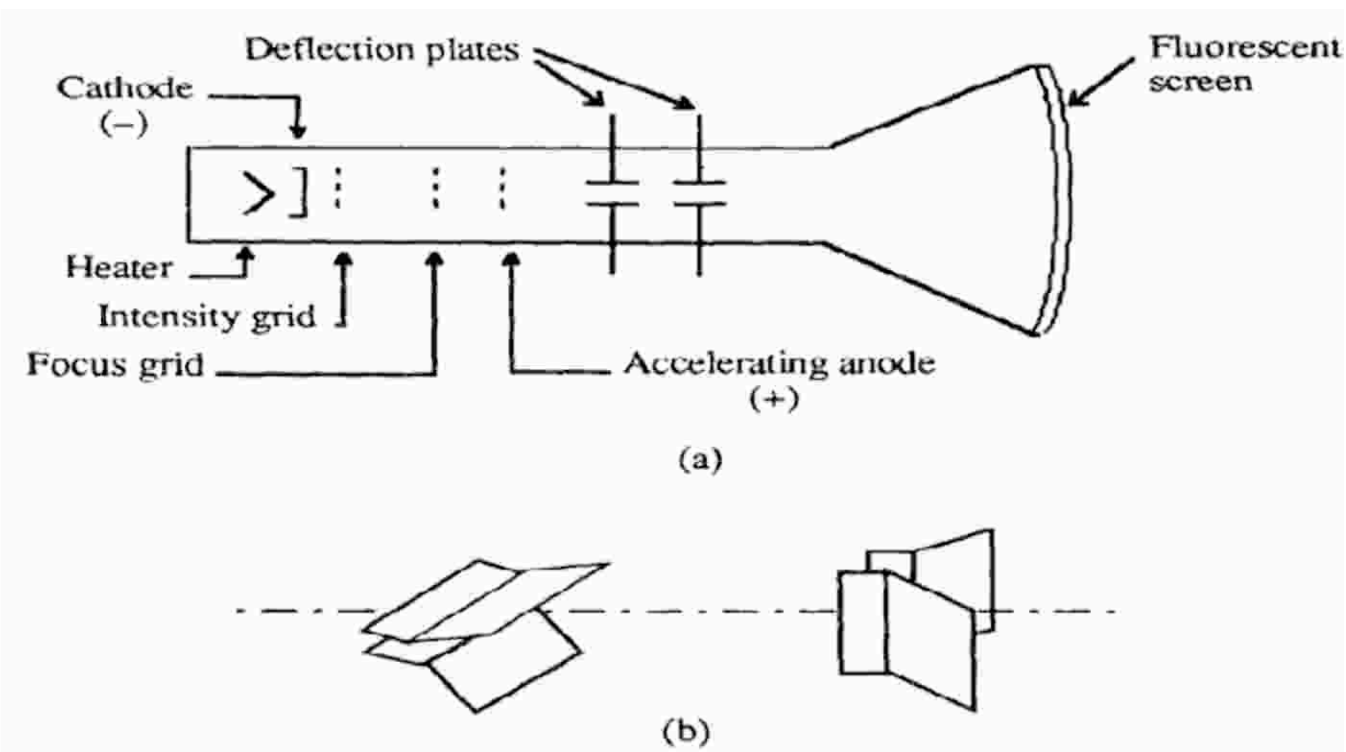


Fig: 1(b).1 Cathode-ray oscilloscopes (CRO) (a) Schematic (b) Details of deflection Plate

The cathode ray is a beam of electrons which are emitted by the heated cathode (negative electrode) andaccelerated toward the fluorescent screen. The assembly of the cathode, intensity grid, focus grid, andaccelerating anode (positive electrode) is called an electron gun. Its purpose is to generate the electron beamandcontrolitsintensityandfocus.Betweentheelectrongunandthefluorescentscreenaretwopairofmetalplates - one oriented to provide horizontal deflection of the beam and one pair orientedto give

verticaldeflectiontothebeam.
Theseplatesarethusreferredtoasthehorizontalandverticaldeflectionplates.Thecombinationofthesetwo deflectionsallowsthebeamtoreachanyportionofthefluorescentscreen.Wherevertheelectronbeamhitsthe screen, the phosphor is excited and light is emitted from that point. This conversion of electron energy intolightallowsustowritewithpointsorlinesoflightonanotherwisedarkenedscreen.

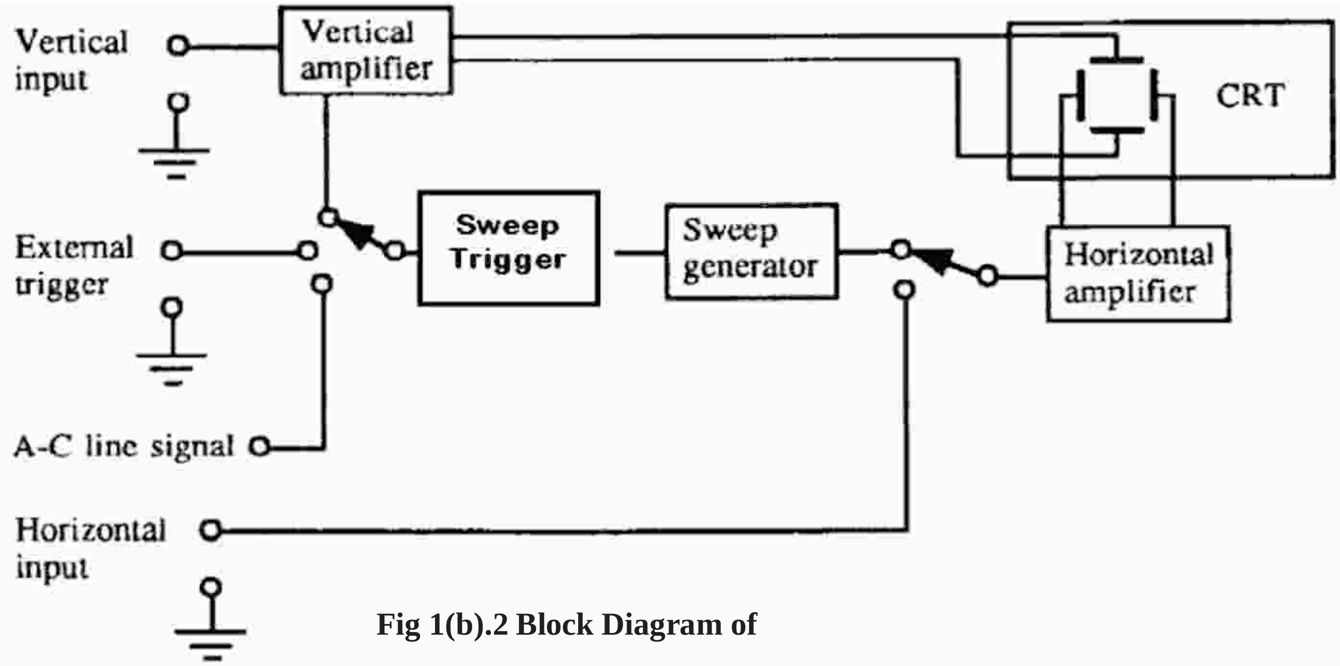


Fig 1(b).2 Block Diagram of Oscilloscope

CONNECTIONSFORTHEOSCILLOSCOPE

VerticalInputApairofjacksforconnectingthesignalunderstudytotheY(orvertical)amplifier.Thelowerjackisgroundedtothecase.
HorizontalInputApairofjacksforconnectinganexternalsignaltothehorizontalamplifier.Thelowerterminal isgroundedtothecaseoftheoscilloscope.
ExternalTriggerInputInputconnectorforexternaltriggersignal.
Cal.OutProvidesamplitudecalibratedsquarewavesof25and500milivoltsforuseincalibratingthegainoftheamplifiers.

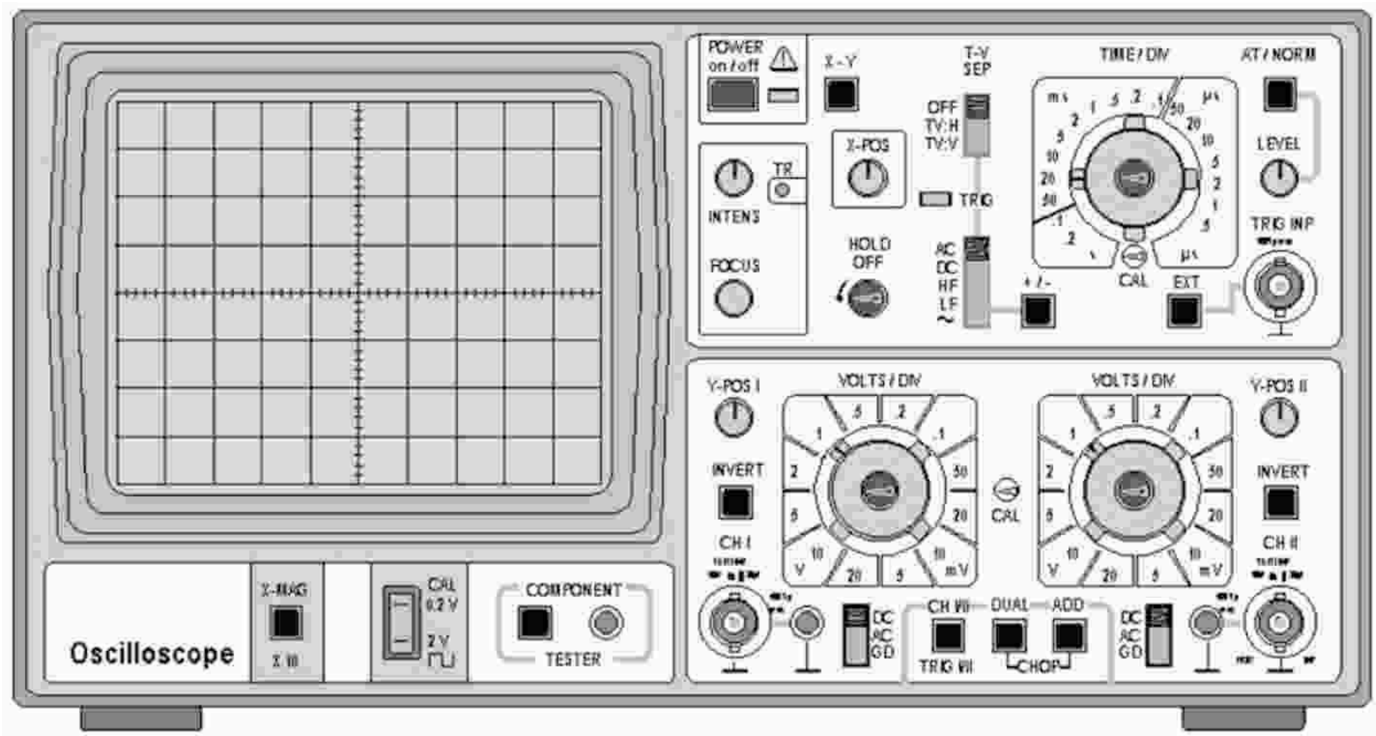


Fig 1(b).3 Cathode Ray Oscilloscope

Accuracyoftheverticaldeflectionis+3%.Sensitivityisvariable.
Horizontalsweepshouldbeaccuratetowithin3%.Rangeofsweepisvariable
OperatingInstructions:Beforepluggingtheoscilloscopeintoawallreceptacle,setthecontrolsasfollows:

(a) Powerswitchatoff
(b) Intensityfullycountersclockwise
(c) Verticalcenteringinthecenterofrange
(d) Horizontalcenteringinthecenterofrange
(e) Verticalat0.2
(f) Sweeptimes1

WARNINGNeveradvancetheIntensityControlsofarthatanexcessivelybrightspotappears.Brightspotsimplyburningofthescreen.Asharpfocusedspotofhighintensity(greatbrightness)shouldneverbeallowedtoremainfixedinonepositiononthescreenforanylengthoftimeasdamagetothescreenmayoccur.

PROCEDURE

I. Set the signal generator to a frequency of 1000 cycles per second. Connect the output from the generator tothe vertical input of the oscilloscope. Establish a steady trace of this input signal on the scope. Adjust (playwith)allofthescopeandsignalgeneratorcontrolsuntilyoubecomefamiliarwiththefunctionofeach.
II. MeasurementsofVoltage:ByadjustingtheHorizontalSweeptime/cmandtrigger,asteadytraceofthesine wavemaybedisplayedonthescreen.Thetracerepresentsaplotofvoltagevs.time,wherethevertical

deflectionofthetraceaboutthelineofsymmetryCDisproportionaltothemagnitudeofthevoltageatanyinstantoftime.

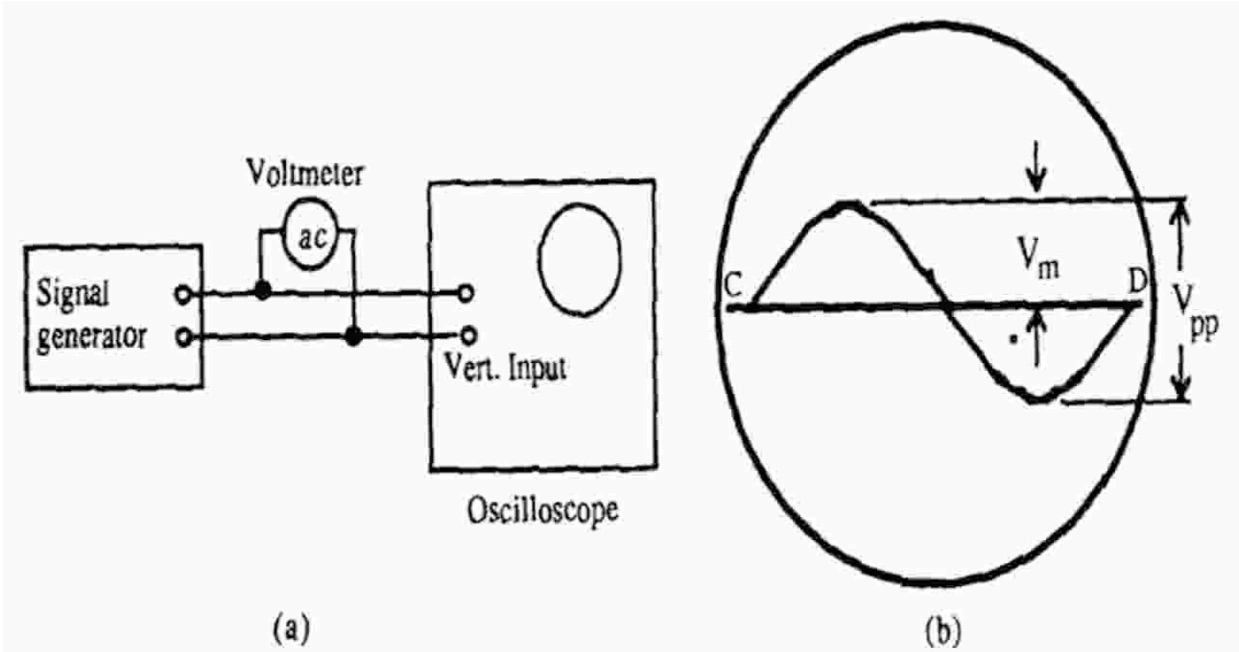


Fig1(b).4(a)CircuitforProcedure(b)TraceSeenonScope

TherelationshipbetweenthemagnitudeofthepeakvoltagedisplayedonthescopeandtheeffectiveorRMSvoltage(VRMS)readontheACvoltmeteris
VRMS=0.707Vm(forasineorcosinewave).Thus

$$V_m = \frac{V_{rms}}{0.707}$$

III. FrequencyMeasurements:Whenthehorizontalsweepvoltageisapplied,voltagemeasurementscanstillbetakenfromtheverticaldeflection.Moreover,thesignalisdisplayedasafunctionoftime.Ifthetimebase(i.e.sweep)iscalibrated,suchmeasurementsaspulsedurationorsignalperiodcanbemade.Frequenciescanthenbedeterminedasreciprocaloftheperiods.
IV. LissajousFigures:Whensine-wavesignalsofdifferentfrequenciesareinputtothehorizontalandvertical amplifiersastationarypatternisformedontheCRTwhentheratioofthetwofrequenciesisanintegralfractionsuchas1/2,2/3,4/3,1/5,etc.ThesestationarypatternsareknownasLissajousfiguresandcanbeusedforcomparisonmeasurementoffrequencies.
UsetwooscillatorstogeneratesomesimpleLissajousfigureslikethoseshowninFig.Youwillfinditdifficultto maintaintheLissajousfiguresinafixedconfigurationbecausethetwooscillatorsarenotphaseandfrequencylocked. Their frequencies and phase drift slowly causing the two different signals to change slightly withrespecttoeachother.

FUNCTIONGENERATOR
A function generator is a device that can produce various patterns of voltage at a variety of frequencies andamplitudes.Itisusedtotesttheresponseofcircuitstocommoninputsignals.

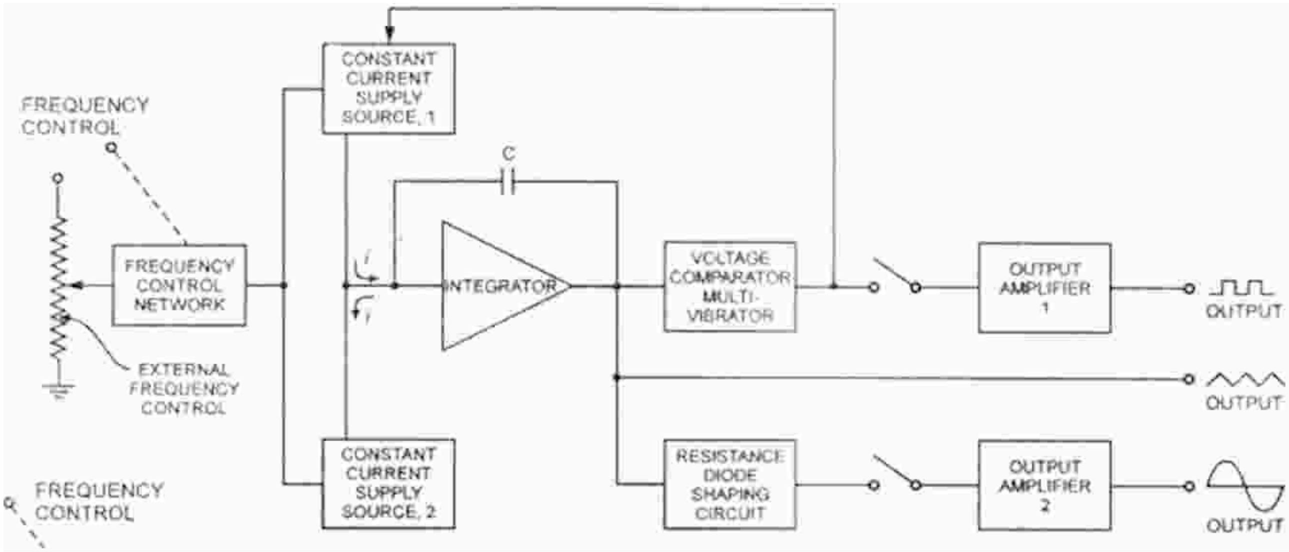


Fig 1(b).5 Function Generator

Afunctiongeneratorisusuallyapieceofelectronictestequipmentorsoftwareusedtogeneratedifferenttypesof electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced bythe function generator are the sine, square, triangular and saw tooth shapes. These waveforms can be eitherrepetitive or single-shot (which requires an internal or external trigger source) Integrated circuits used togenerate waveforms may also be described as function generator ICs. Although function generators coverboth audio and RF frequencies, they are usually not suitable for applications that need low distortion or stablefrequencysignals.Whenthosetraitsarerequired,othersignalgeneratorswouldbemoreappropriate. Somefunctiongeneratorscanbephase-lockedtoanexternalsignalsource(whichmaybeafrequency reference)oranotherfunctiongenerator.Functiongeneratorsareusedinthedevelopment,testandrepairofelectronice quipment.Forexample,theymaybeusedasasignalsourcetotestamplifiersortointroduceanerrorsignalintoacontroll oop.

Working

Simple function generators usually generate triangular waveform whose frequency can be controlledsmoothly as well as in steps. This triangular wave is used as the basis for all of its other outputs. The triangularwaveisgeneratedbyrepeatedlychargingandd ischargingacapacitorfromaconstantcurrentsource.Thispro duces a linearly ascending or descending voltage ramp. As the output voltage reaches upper and lowerlimits, the charging and discharging is reversed using a comparator, producing the linear triangle wave. Byvaryingthecurrentandthesizeofthecapacitor,differentfrequenciesmaybeobtained.Sawtoothwavescanbe produced by charging the capacitor slowly, using a current, but using a diode over the current source todischargequickly- thepolarityofthediodechangesthepolarityoftheresultingsawtooth,i.e.slowriseandfastfall,orfastriseandslowfall.

A 50% duty cycle square wave is easily obtained by noting whether the capacitor is being charged ordischarged, which is reflected in the current switching comparator output. Other duty cycles (theoretically from0% to 100%) can be obtained by using a comparator and the saw tooth or triangle signal. Most functiongeneratorsalsocontainanon-lineardiode shapingcircuitthatcanconvertthetrianglewaveintoareasonablyaccurate sine wave by rounding off the corners of the triangle wave in a process similar to clipping in audiosystems.

Atypicalfunctiongeneratorcanprovidefrequenciesupto20MHzRFgeneratorsforhigherfrequenciesare not function generators in the strict sense since they typically produce pure or modulated sine signals only.Functiongenerators,likemostsignalgenerators,mayalsocontainanattenuator,variousmeansofmodulatingtheoutputwaveform,andoftentheabilitytoautomaticallyandrepetitively"sweep"thefrequencyoftheoutputwaveform(bymeansofavoltage-controlledoscillator)betweentwooperator-determinedlimits.Thiscapabilitymakesitveryeasytoevaluatethefrequencyresponseofagivenelectroniccircuit. Somefunctiongeneratorscanalsogeneratewhiteorpinknoise.

Moreadvancedfunctiongeneratorsarecalledarbitrarywaveformgenerators(AWG).Theyusedirectdigitalsynthesis (DDS)techniquestogenerateanywaveformthatcanbedescribedbyatableofamplitudes.

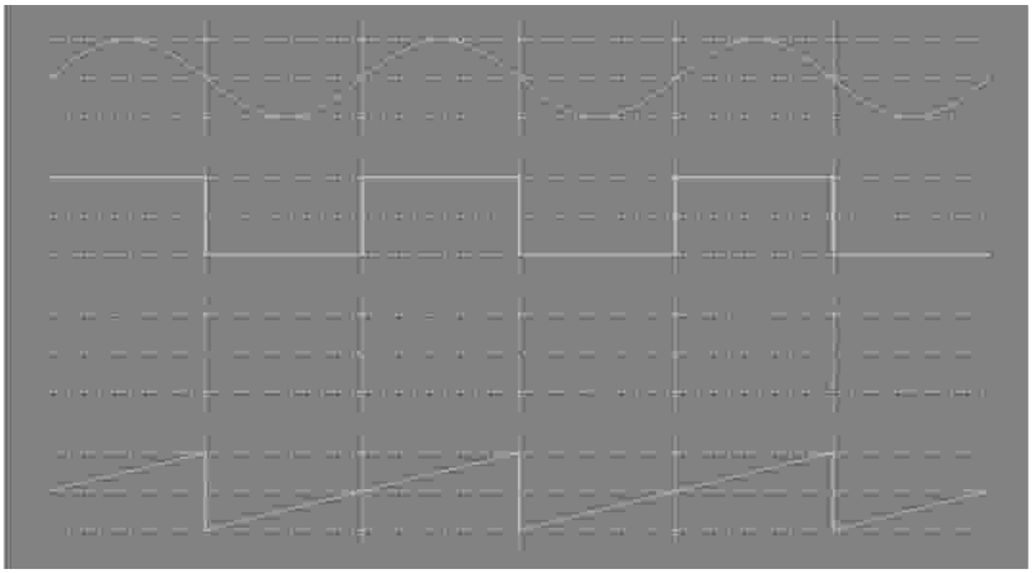


Fig. 1(b).6 Function generators output waveforms

RESULT

Wehavestudiedabouttheconstruction,workingofCRO,functiongeneratorandlearnhowtomeasurefrequency,voltagewiththehelpofCRO.

PRECAUTIONS

1. Allconnectionmustbetight.
2. Getthecircuitconnectionscheckedbytheteacherbeforeperformingtheexperiment.
3. Powertothecircuitmustbeswitchedoninthepresenceoftheteacher.

ExperimentNo. 01(b)

Aim:

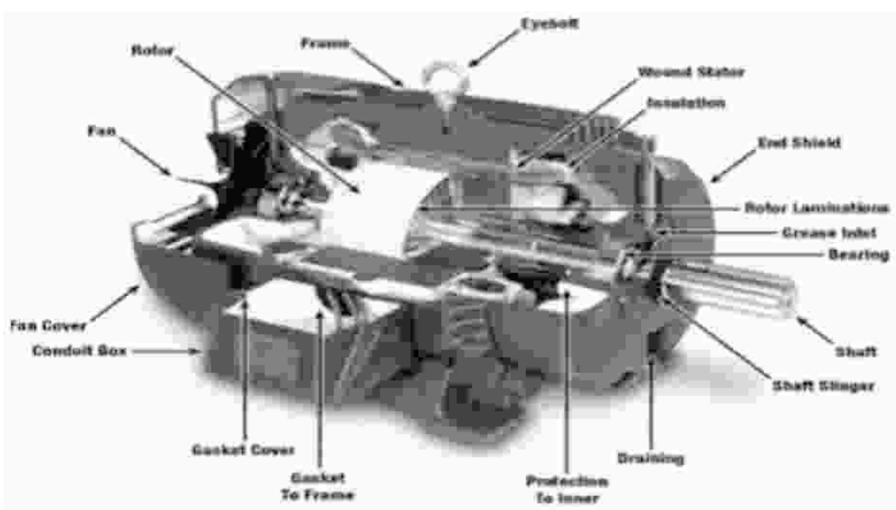
Demonstration of cut-out sections of machines: dc machine (Commutator brush arrangement), inductionmachine(squirrelcagerotor),synchronousmachine(fieldwinging-slipringarrangement)andsingle-phaseinductionmachine.

DCMachine:ConstructionandtheirApplications

The DC machine can be classified into two types namely DC motors as well as DC generators. Most of the DCmachinesareequivalenttoACmachinesbecausetheyincludeACcurrentsaswellasACvoltagesinthem.The output of the DC machine is DC output because they convert AC voltage to DC voltage. The conversion ofthismechanismisknownasthecommutator,thusthesemachinesarealsonamedascommutatingmachines.DCmachineismostfrequentlyusedforamotor.Themainbenefitsofthismachineincludetorqueregulationaswellaseasyspeed.TheapplicationsoftheDCmachineislimitedtotrains,mills,andmines.Asexamples,undergroundsubwaycars,aswellastrolleys,mayutilizeDCmotors.Inthepast,automobilesweredesignedwithDCdynamosforchargingtheirbatteries.

WhatisaDCMachine?

A DC machine is an electromechanical energy alteration device. The working principle of a DC machine iswhen electric current flows through a coil within a magnetic field, and then the magnetic force generates atorquewhichrotatesthedcmotor.TheDCmachinesareclassifiedintotwotypessuchasDCgeneratoraswellasDCmotor.ThemainfunctionoftheDCgeneratoristoconvertmechanicalpowertoDCelectricalpower,whereas a DC motor converts DC power to mechanical power. The AC motor is frequently used in theindustrialapplicationsforalteringelectricalenergytomechanicalenergy.However,aDCmotorisapplicablewher



ethegoodspeedregulation&amplerangeofspeedsarenecessarylikeinelectric-transactionsystems.

Fig 4.1: DC machine

ConstructionofDCMachine

TheconstructionofDCmachinecanbedoneusingsomeoftheessentialpartslikeYoke,Polecore&poleshoes,Polecoil&fieldcoil,Armaturecore,Armaturewindingotherwise conductor,commutator,brushes&bearings.SomeofthepartsoftheDCmachineisdiscussedbelow.

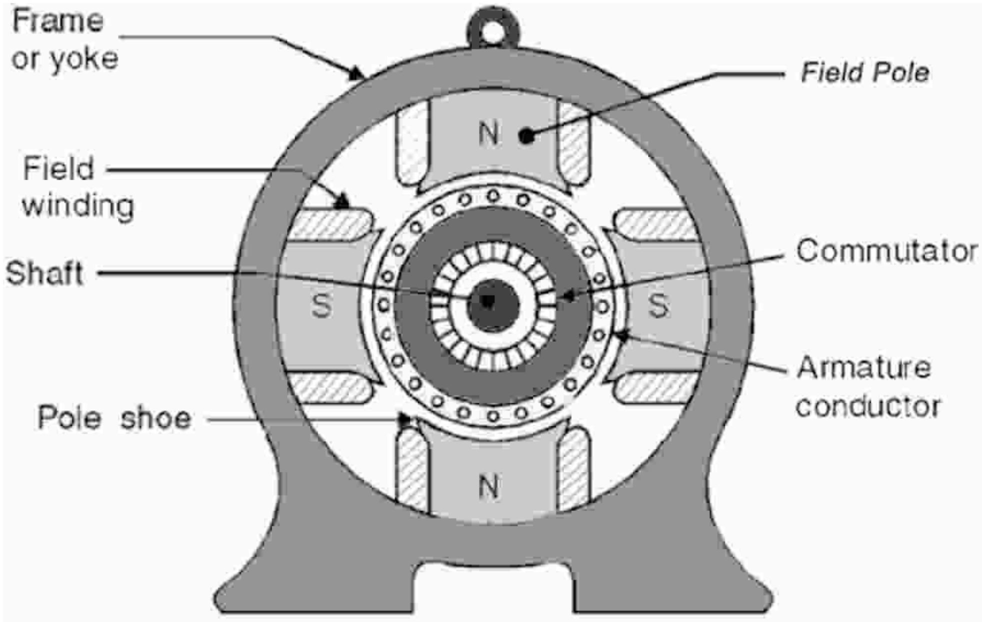


Fig 4.2 : parts of dc machine

Yoke

Another name of a yoke is the frame. The main function of the yoke in the machine is to offer mechanicalsupport intended for poles and protects the entire machine from the moisture, dust, etc. The materials used intheyokearedesignedwithcastiron,caststeelotherwiserolledsteel.

PoleandPoleCore

ThepoleoftheDCmachineisanelectromagnetandthefieldwindingiswindingamongpole.Wheneverfieldwinding is energized then the pole gives magnetic flux. The materials used for this are cast steel, cast ironotherwise pole core. It can be built with the annealed steel laminations for reducing the power drop because oftheeddycurrents.

PoleShoe

Pole shoe in DC machine is an extensive part as well as enlarge the region of the pole. Because of this region,flux can be spread out within the air-gap as well as extra flux can be passed through the air space towardarmature. The materials used to build pole shoe is cast iron otherwise cast steed, and also used annealedsteellaminationtoreducethelossofpowerbecauseofeddycurrents.

FieldWindings

In this, the windings are wounded in the region of pole core & named as field coil. Whenever current is suppliedthroughfieldwindingthenitelectromagneticsthepoleswhichgeneraterequiredflux.Thematerialusedforfie ldwindingsiscopper.

ArmatureCore

Armaturecoreincludesthehugenumberofslotswithinitsedge.Armatureconductorislocatedintheseslots

It provides the low-reluctance path toward the flux generated with field winding. The materials used in this coreare permeability low-reluctance materials like iron otherwise cast. The lamination is used to decrease the lossbecauseoftheeddycurrent.

ArmatureWinding

The armature winding can be formed by interconnecting the armature conductor. Whenever an armaturewinding is turned with the help of prime mover then the voltage, as well as magnetic flux, gets induced within it.This winding is allied to an exterior circuit. The materials used for this winding are conducting material likecopper.

Commutator

ThemainfunctionofthecommutatorintheDCmachineistocollectthecurrentfromthearmatureconductoras well as supplies the current to the load using brushes. And also provides uni-directional torque for DC-motor.Thecommutatorcanbebuiltwithahugenumberofsegmentsintheedgeformofharddrawncopper.TheSegmentsinthecommutatorareprotectedfromthinmicalayer.

Brushes

Brushes in the DC machine gather the current from commutator and supplies it to exterior load. Brushes wearwith time to inspect frequently. The materials used in brushes are graphite otherwise carbon which is inrectangularform.

ACMachine:Constructionandworkingofsquirrelcageinductionmotor.

A 3 phase squirrel cage induction motor is a type of three phase induction motor which functions based on theprinciple of electromagnetism. It is called a 'squirrel cage' motor because the rotor inside of it – known as a'squirrelcagerotor'–lookslikeasquirrelcage.

Thisrotorisacylinderofsteellaminations,withhighlyconductivemetal(typicallyaluminumorcopper) embedded into its surface. When an alternating current is run through the stator windings, a rotating magneticfieldisproduced.

This induces a current in the rotor winding, which produces its own magnetic field. The interaction of themagneticfieldsproducedbythestatorandrotorwindingsproducesatorqueonthesquirrelcagerotor.

Onebigadvantageofasquirrelcagemotorishoweasilyyoucanchangeitsspeed-torquecharacteristics.

Thiscanbedonebysimplyadjustingtheshapeofthebarsintherotor.Squirrelcageinductionmotorsareusedalotinindustry–astheyarereliable,self-starting,andeasytoadjust.

SquirrelCageInductionMotorWorkingPrinciple

When a 3 phase supply is given to the stator winding it sets up a rotating magnetic field in space. This rotatingmagneticfieldhasaspeedwhichisknownasthesynchronousspeed.

Thisrotatingmagneticfieldinducesthevoltageinrotorbarsandhenceshort-circuitcurrentsstartflowingin the rotor bars. These rotor currents generate their self-magnetic field which will interact with the field of thestator.Nowtherotorfieldwilltrytoopposeitscause,andhencerotorstartsfollowingtherotatingmagneticfield.

Themomentrotorcatchestherotatingmagneticfieldtherotorcurrentdropstozeroasthereisnomore relative motion between the rotating magnetic field and rotor. Hence, at that moment the rotor experienceszerotangentialforcehencetherotordeceleratesforthemoment.

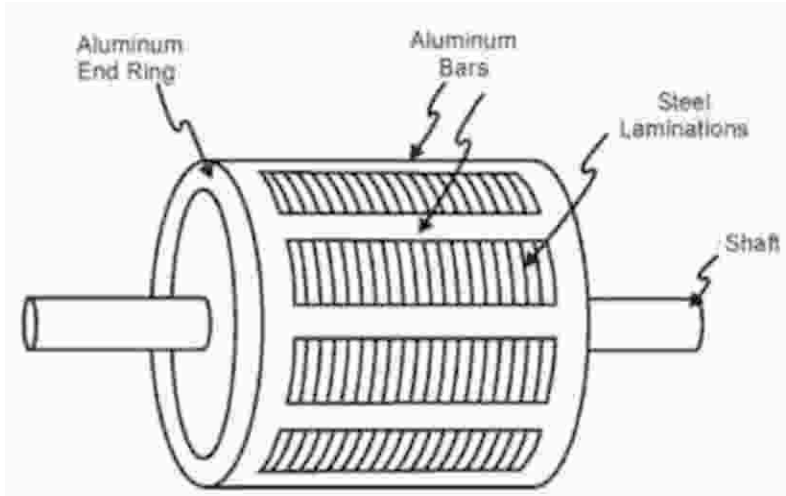
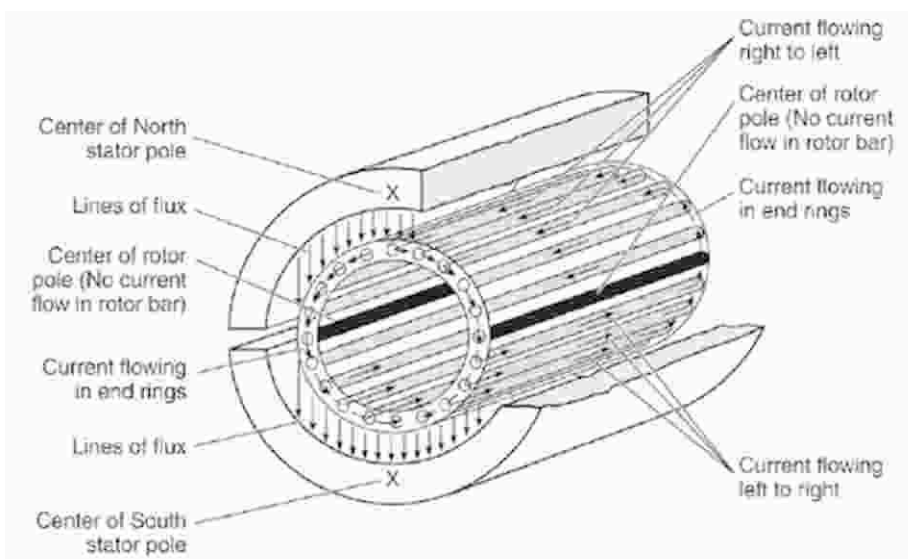


Fig 4.3 rotor

Afterdecelerationoftherotor,therelativemotionbetweentherotorandtherotatingmagneticfieldreestablisheshencer otorcurrentagainbeinginduced.Soagain,thetangentialforceforrotationoftherotorisrestored,andthereforeagaintheroto rstartsfollowingrotatingmagneticfield,andinthisway,therotormaintains aconstant speedwhich isjustless thanthe speedofrotating magneticfield orsynchronousspeed.Slipisameasureofthedifferencebetweenthespeedoftherotatingmagneticfieldandrotorspeed.
Thefrequencyoftherotorcurrent=slip×supplyfrequency
SquirrelCageInductionMotorConstruction
Asquirrelcageinductionmotorconsistsofthefollowingparts:

- Stator
- Rotor
- Fan

Bearings



Stator

It consists of a 3 phase winding with a core and metal housing. Windings are such placed that they areelectrically and mechanically 120o apart from in space. The winding is mounted on the laminated iron core toprovidelowreluctancepathforgeneratedfluxbyACcurrents.

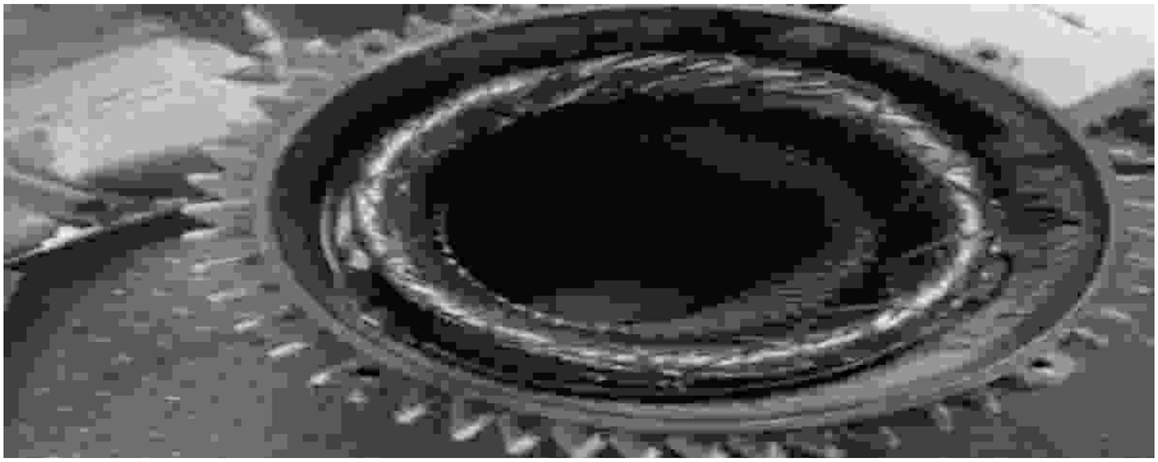


Fig 4.5:stator

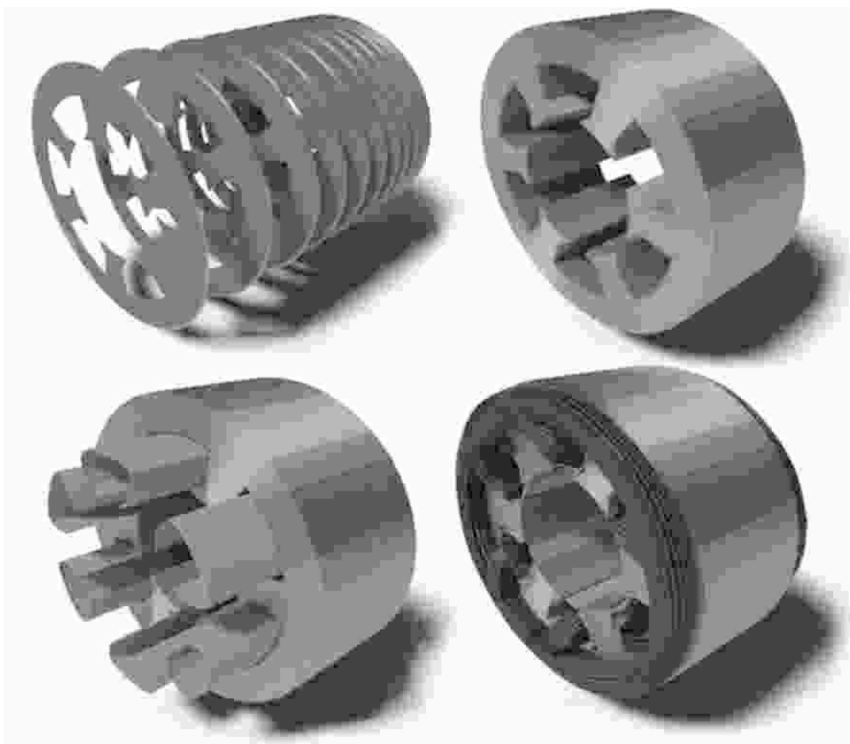


Fig 4.6:stator

Rotor

Itisthepartofthemotorwhichwillbeinarotationtogivemechanicaloutputforagivenamountofelectricalenergy. The rated output of the motor is mentioned on the nameplate in horsepower. It consists of a shaft,short-circuitedcopper/aluminumbars,andacore.

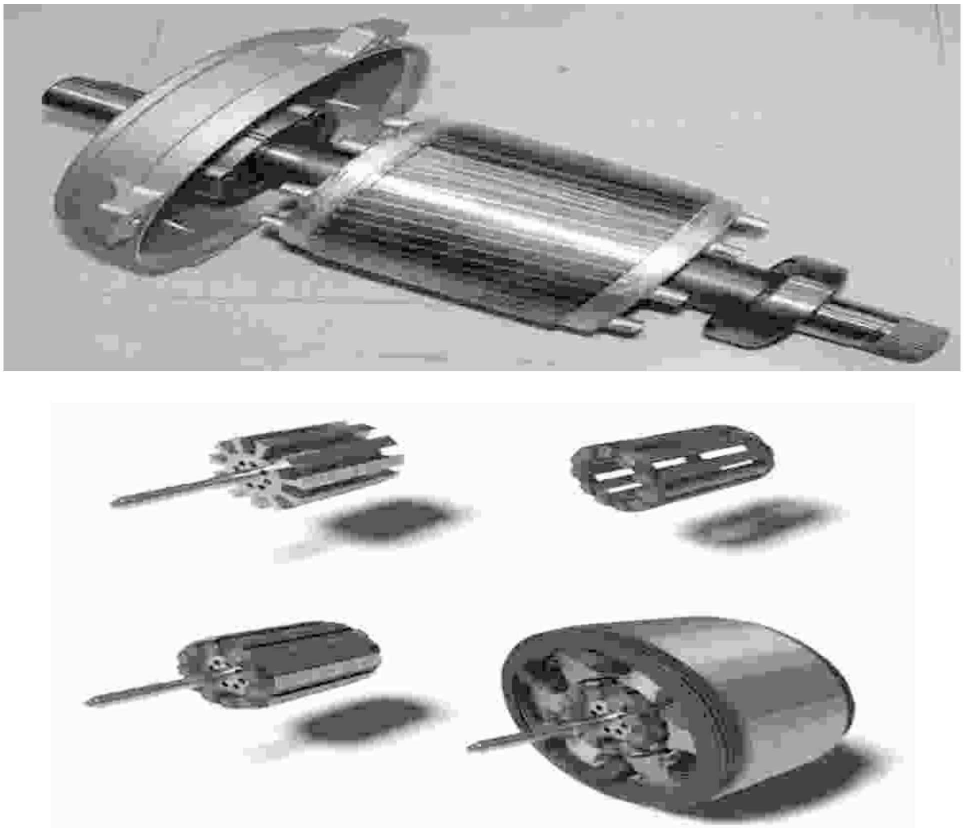


Fig 4.6:Rotor

Therotorcoreislaminatedtoavoidpowerlossfromeddycurrentsandhysteresis.Conductorsareskewedtopreventcog gingduringstartingoperationandgivesbettertransformationratiobetweenstatorandrotor.

Fan

Afanisattachedtothebacksideoftherotortoprovideheatexchange,andhenceitmaintainsthetemperatureofthemotorunde ralimit.

Bearings

Bearingsareprovidedasthebaseforrotormotion,andthebearingskeepthesmoothrotationofthemotor.

ApplicationofSquirrelCageInductionMotor

Squirrel cage induction motors are commonly used in many industrial applications. They are particularlysuitedforapplicationswherethemotormustmaintainaconstantspeed,beself-starting,orthereisadesireforlowmaintenance.

Thesemotorsarecommonlyusedin:

- Centrifugalpumps

- Industrialdrives(e.g.torunconveyorbelts)
- Largeblowersandfans
- Machinetools
- Lathesandotherturningequipment

AdvantagesofSquirrelCageInductionMotor

Someadvantagesofsquirrelcageinductionmotorsare:

- Theyarelowcost
- Requirelessmaintenance(astherearenoslipringsorbrushes)
- Goodspeedregulation(theyareabletomaintainaconstantspeed)
- Highefficiencyinconvertingelectricalenergytomechanicalenergy(whilerunning,notduringstartup)
- Havebetterheatregulation(i.e.don'tgetashot)
- Smallandlightweight
- Explosionproof(astherearenobrusheswhicheliminatetherisksofsparking)

DisadvantagesofSquirrelCageInductionMotor

Althoughsquirrelcagemotorsareverypopularandhavemanyadvantages– theyalsohavesomedownsides.Somedisadvantagesofsquirrelcageinductionmotorsare:

- Verypoorspeedcontrol
- Althoughtheyareenergyefficientwhilerunningatfullloadcurrent,theyconsumealotofenergyonstartup
- Theyaremoresensitivetofluctuationsinthesupplyvoltage.Whenthesupplyvoltageisreduced, inductionmotordrawsmorecurrent.Duringvoltagesurges,increaseinvoltagesaturatesthemagneticcomponentsofthesquirrelcageinductionmotor
- They havehighstartingcurrentandpoorstartingtorque(thestartingcurrentcanbe5-9timesthefull loadcurrent; the starting torque can be 1.5-2 timesthe full load torque)

ConstructionofSynchronousMachines

Synchronousmachinesrunatsynchronousspeed.Thesynchronousspeedisgivenby

$$N_s = \frac{120f}{p}$$

Where, Ns = synchronous speed, f = supply frequency and p = number of poles. As we can see from theequation,thesynchronousspeeddependsonthefrequencyofthesupplyandthenumberofpoles.

Theconstructionofasynchronousmachineisverysimilartotheconstructionofanalternator.Bothare synchronousmachineswhereoneweuseasamotorandtheotherasagenerator.Justlikeanyothermotor,thesynchronousmotoralsohasastatorandarotor.Wewilllookintotheconstructiondetailsofthevariouspartinonedetail.

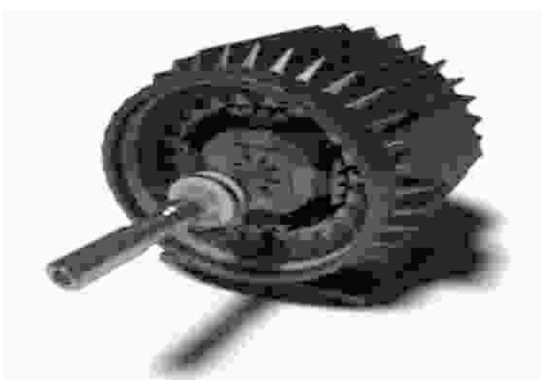


Fig 4.7: Stator of Synchronous Motor

Themainstationarypartofthemachineisstator.Thestatorconsistsofthefollowingparts.

StatorFrame

Thestatorframeistheouterpartofthemachineandismadeupofcastiron.Itprotectstheenterinnerpartsofthemachine.

Fig 4.8: Stator frame of Synchronous Motor

StatorCore

The stator core is made up of thin silicon laminations. It is insulated by a surface coating to minimize hysteresisand eddy current losses. Its main purpose is to provide a path of low reluctance for the magnetic lines of forceandaccommodatethestatorwindings.

Fig 4.9: Stator core of Synchronous Motor

StatorWinding

Thestatorcorehascutsontheinnerperipherytoaccommodatethestatorwindings.Thestatorwindingscouldbeeitherthree-phasewindingsorsinglephasewindings.

Fig 4.10: Stator winding of Synchronous Motor

Enamelledcopperisusedasthewindingmaterial.Inthecaseof3phasewindings,thewindingsaredistributedoverseveralslots.ThisisdonetoproduceasinusoidaldistributionofEMF.

RotorofSynchronousMotor

Therotoristhemovingpartofthemachine.Rotorsareavailableintwotypes:

- SalientPoleType
- CylindricalRotorType

Thesalientpoletyperotorconsistsofpolesprojectingoutfromtherotorsurface.Itismadeupofsteellaminationstoreduceeddycurrentlosses.

Fig4.11:Rotor ofSynchronousMotor

A salient pole machine has a non-uniform air gap. The gap is maximum between the poles and is minimum atthepolecentres.Theyaregenerallyusedformediumandlow-speedoperationsastheyhavealargenumberofpoles.Theycontaindamperwindingswhichareusedforstartingthemotor.

Acylindricalrotorismadefromsolidforgingsofhigh-gradenickelchromemolybdenumsteelforgingsofhigh-gradenickelchromemolybdenumsteel.Thepolesarecreatedbythecurrentflowingthroughthewindings.Theyareusedforhigh-speedapplicationsastheyhavelessnumberofpoles.Theyalsoproducelessnoiseand windage losses as they have a uniform air gap. DC supply is given to the rotor windings via slip-rings.Oncetherotorwindingsareexcited,theyactlikepoles.

SinglePhaseInductionMotor

We use the single-phase power system more widely than three phase system for domestic purposes,commercial purposes and some extent in industrial uses. Because, the single-phase system is moreeconomicalthanathree-phasesystemandthepowerrequirementinmostofthehouses,shops,officesaresmall,whichcanbeeasilymetbyasinglephasesystem.

Thesinglephasemotorsaresimpleinconstruction,cheapincost,reliableandeasytorepairandmaintain.

Duetoalltheseadvantages,thesinglephasemotorfindsitsapplicationinvacuumcleaners,fans,washingmachines,centrifugalpumps,blowers,washingmachines,etc.

ThesinglephaseACmotorsarefurtherclassifiedas:

1. Singlephaseinductionmotorsorasynchronousmotors.
2. Singlephasesynchronousmotors.
3. Commutatormotors.

Thisarticlewillprovidefundamentals,descriptionandworkingprincipleofsinglephaseinductionmotor.ConstructionofSinglePhaseInductionMotor

Likeanyotherelectricalmotorasynchronousmotoralsohavetwomainpartsnamelyrotorandstator.

Stator:

Asitsnameindicatesstatorisastationarypartofinductionmotor.AsinglephaseACsupplyisgiventothestatorofsingle phaseinductionmotor.

Rotor:
Therotorisarotatingpartofaninductionmotor.Therotorconnectsthemechanicalloadthroughtheshaft.Therotorinthes ingle-phaseinductionmotorisofsquirrelcagerotortype.
Theconstructionofsinglephaseinductionmotorisalmostsimilartothesquirrelcagethree-phaseinduction motor.Butincaseofasinglephaseinductionmotor,thestatorhastwowindingsinsteadofonethree-phasewindinginthreephaseinductionmotor.

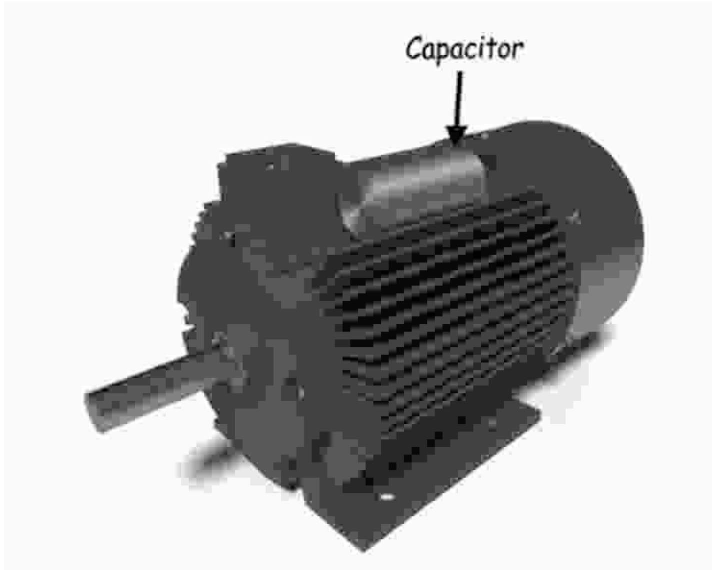
StatorofSinglePhaseInductionMotor
Thestatorofthesingle-phaseinductionmotorhaslaminatedstampingtoreduceeddycurrentlossesonitsperiphery.Theslotsareprovidedonitsstampingtocarrystatorormainwinding.Stampingsaremadeupofsiliconsteeltoreducethehysteresislosses.WhenweapplyasinglephaseACsupplytothestatorwinding,themagneticfieldgetsproduced,andthemotorrotatesatspeedslightlylessthanthesynchronousspeedNs.

$$N_s = \frac{120f}{P}$$

Synchronousspeed Ns is given by
Where,f=supplyvoltagefrequency, P=No.ofpolesofthemotor.
The constructionofthestatorofthesingle-phaseinductionmotorissimilarto thatofthreephaseinductionmotorexcepttherearetwodissimilaritiesinthewindingpartofthesinglephaseinductionmotor.

1. Firstly,thesingle-phaseinductionmotorsaremostlyprovidedwithconcentriccoils.Wecaneasilyadjust thenumberofturnspercoilcanwiththehelpofconcentriccoils.Themmfdistributionisalmostsinusoidal.
2. Exceptforshadedpolemotor,theasynchronousmotorhastwostatorwindingsnamelythemainwinding andtheauxiliarywinding.Thesetwowindingsareplacedinspacequadraturetoeachother.

RotorofSinglePhaseInductionMotor
The construction of the rotor of the single-phase induction motor is similar to the squirrel cage three-phaseinductionmotor.Therotoriscylindricalandhasslotsalloveritsperiphery.Theslotsarenotmadeparalleltoeachotherbutarealittlebitskewedastheskewingpreventsmagneticlockingofstatorandrotorteethandmakestheworkingofinductionmotormoresmoothandquieter(i.e.lessnoisy).
Thesquirrelcagerotorconsistsofaluminum,brassorcopperbars.Thesealuminumorcopperbarsarecalled rotor conductors and placed in the slots on the periphery of the rotor. The copper or aluminum ringspermanentlyshorttherotorconductorscalledtheendrings.
Toprovidemechanicalstrength,theserotorconductorsarebracedtotheendringandhenceformacomplete closed circuit resembling a cage and hence got its name as squirrel cage induction motor. As end ringspermanentlyshortthebars,therotorelectricalresistanceisverysmallanditisnotpossibletoaddexternalresistanceasthebarsgetpermanentlyshorted.Theabsenceofslipringandbrushesmaketheconstructionofsinglephaseinductionmotorverysimpleandrobust.



RESULT:
WehavestudiedaboutDCmachines,Squirrelcageinductionmotor,Synchronousmachines,1-phinductionmotor.

VIVAVOICE:
1. Why 1-ph induction motor is not self-starting ?
2. Whatisthedifferencebetweendcmachineandsynchronousmachine?
3. Whatisslip?
4. Writethetypesofdcmachine?

ExperimentNo. 02

2(a):TRANSIENT RESPONSE OF R-C NETWORK

AIM:

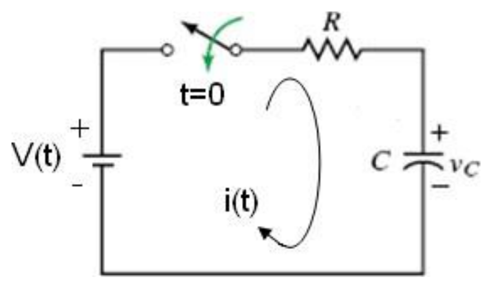
Study and obtain the transient response of a series R-C Network

APPARATUS:

S. No.	Name of the Equipment	Range	Type	Quantity
1	Function Generator			
2	Required resistors			
3	Required Inductors			
4	Required capacitors			
5	Voltmeter			
6	Connecting wires			

CIRCUITDIAGRAM:

THEORY: Let us consider the R-C circuit as shown below



Applying KVL, we obtain

$$v(t) = Ri(t) + \frac{1}{C}\int i(t)dt$$

Taking Laplace transform on both sides of the above equation,

$$V(s) = RI(s) + \frac{1}{C}\left[\frac{I(s)}{s} + \frac{q(0\_)}{s}\right]$$

or, $$V(s) = RI(s) + \frac{I(s)}{sC} + \frac{v_C(0\_)}{s}$$

Now as all initial conditions set equal to zero, i.e. $v_C(0\_) = 0$, so the equation becomes

$$V(s) = RI(s) + \frac{I(s)}{sC}$$

or, $$V(s) = I(s)\left[R + \frac{1}{sC}\right]$$

Example:

To study the transient response of a series R-C circuit where R=200Ω, C=10µF for the following conditions

1) source voltage is 40V DC with all initial conditions set equal to zero.

2) source voltage is a pulse signal with a period of 0s, width of 5ms, rise and fall times of 1µs, amplitude of 20V
and an initial value of 0V and all initial conditions set equal to zero.

For Case - 1:-

$$v(t) = 40u(t) \qquad \therefore V(s) = \frac{40}{s}$$

Therefore,

$$I(s) = \frac{sC}{RC(s + \frac{1}{RC})} \cdot \frac{40}{s} = \frac{40}{R} \cdot \frac{1}{(s + \frac{1}{RC})}$$

Taking Inverse Laplace transform on both sides of the above equation,

$$i(t) = \frac{40}{R} e^{-\frac{1}{RC}.t}$$

Putting $R = 200\Omega$ and $C = 10\mu F$, we get

$$i(t) = \frac{40}{200} e^{-500.t}$$

At $t = 0$, $i(t) = \frac{40}{200} \text{A} = 200\text{mA}$

At $t = \infty$, $i(t) = 0$

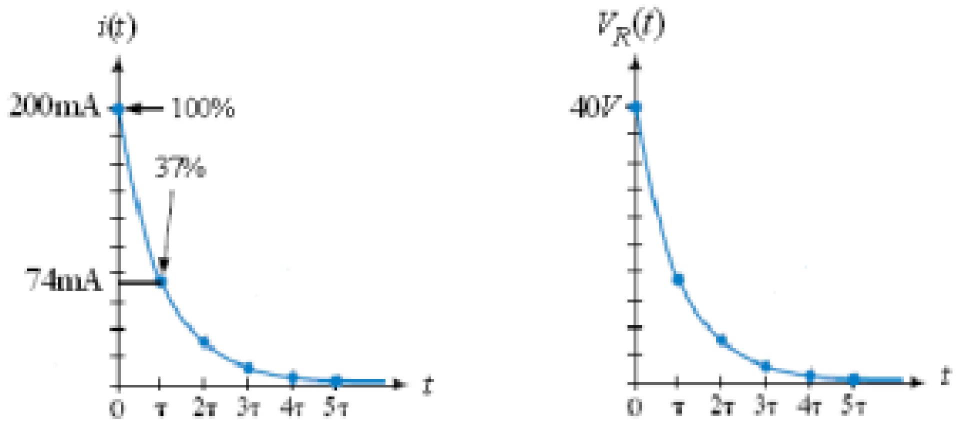
At $t = \tau = RC = 2\text{ms}$, $i(t) = 200 \times (37\%) = 74\text{mA}$

Voltage drop across the resistor R is,

$$V_R(t) = Ri(t) = 200 \times \frac{40}{200} . e^{-500.t} = 40e^{-500.t}$$

At $t = 0$, $V_R(t) = 40\text{V}$

At $t = \infty$, $V_R(t) = 0$



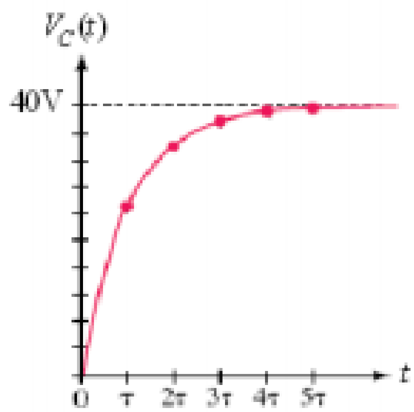
Voltage drop across the capacitor C is,

$$V_C(t) = v(t) - V_R(t) = 40(1 - e^{-500t})$$

At $t = 0$, $V_C(t) = 0$

At $t = \infty$, $V_C(t) = 40\text{V}$

The plot of $V_C(t)$ vs. t is as follows:



For Case - 2:-

$$v(t) = 20[u(t) - u(t-1)]$$

Therefore, $$V(s) = \frac{20}{s}(1 - e^{-s})$$

and, $$I(s)=\frac{20sC(1-e^{-s})}{sRC(s+\frac{1}{RC})}.\frac{1}{s}=\frac{20}{R}.\left[\frac{1}{(s+\frac{1}{RC})}-\frac{e^{-s}}{(s+\frac{1}{RC})}\right]$$

Taking Inverse Laplace transform on both sides of the above equation,

$$i(t)=\frac{20}{R}\left[e^{-\frac{1}{RC}t}u(t)-e^{-\frac{1}{RC}.(t-1)}u(t-1)\right]$$

Putting $R=200\Omega$ and $C=10\mu F$, we get

$$i(t)=\frac{20}{200}\left[e^{-500.t}u(t)-e^{-500.(t-1)}u(t-1)\right]$$

At $t=0$, $i(t)=\frac{20}{200}\text{A}=100\text{mA}$

At $t=\infty$, $i(t)=0$

Voltage drop across the resistor R is,

$$V_R(t)=Ri(t)=200\times\frac{20}{200}\left[e^{-500.t}u(t)-e^{-500.(t-1)}u(t-1)\right]$$

or, $$V_R(t)=20\left[e^{-500.t}u(t)-e^{-500.(t-1)}u(t-1)\right]$$

At $t=0$, $V_R(t)=20\text{V}$

At $t=\infty$, $V_R(t)=0$

Voltage drop across the capacitor C is,

$$V_C(t)=v(t)-V_R(t)=20(1-e^{-500.t})u(t)-20(1-e^{-500.(t-1)})u(t-1)$$

At $t=0$, $V_C(t)=0$

At $t=\infty$, $V_C(t)=0$

At $t=T=5\text{ms}$, $V_C(t)=18.36\text{V}$

PROCEDURE:

1. Connect the circuit as shown in fig.
2. Set the voltage Accordingly Case 1 & Case 2.
3. Vary the frequency of the signal in steps and note down the magnitude of response on CRO respectively.(response wave form is observed across Elements ,RC)
4. Form the observation table between the time and magnitude of response in CRO.
5. Draw a graph between time and magnitude of response on the semi-log sheet.

Observation Table

S. No	t(sec)	Ic (t)	Vc (t)	Vr(t)
1				
2				
3				
4				

RESULT: Transient response of a series R-C and series R-L circuit

EXPERIMENT – 2 (b)

TRANSIENT RESPONSE OF R-L NETWORK

AIM:

Study and obtain the transient response of a series R-L circuit

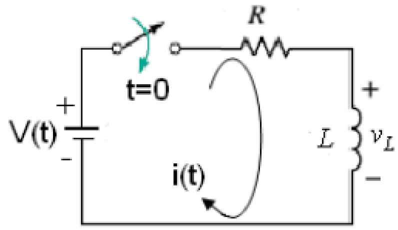
APPARATUS:

S. No.	Name of the Equipment	Range	Type	Quantity
1	Function Generator			
2	Required resistors			
3	Required Inductors			
4	Required capacitors			
5	Voltmeter			
6	Connecting wires			

CIRCUITDIAGRAM:

THEORY: Let us consider the R-L circuit as shown below

Let us consider the R-L circuit as shown below:



Applying KVL, we obtain

$$v(t) = Ri(t) + L\frac{di(t)}{dt}$$

Taking Laplace transform on both sides of the above equation,

$$V(s) = RI(s) + L[sI(s) - i(0\_)]$$

Now as all initial conditions set equal to zero, i.e. $i(0\_) = 0$, so the equation becomes

$$V(s) = I(s)[R + sL]$$

or, $$I(s) = \frac{V(s)}{R + sL} = \frac{1}{L}\cdot\frac{V(s)}{s + \frac{R}{L}}$$

To study the transient response of a series R-L circuit where R=100Ω, L=10mH for the following conditions:

1) Source voltage is 10V DC with all initial conditions set equal to zero.
2) Source voltage is 10V DC with initial condition $i_L(0\_)$= 20mA

For Case - 1:-

$$v(t) = 10u(t) \qquad \therefore V(s) = \frac{10}{s}$$

Therefore, $$I(s) = \frac{1}{L}.\frac{\frac{10}{s}}{s+\frac{R}{L}} = \frac{1}{L}\left[\frac{10}{s(s+\frac{R}{L})}\right] = \frac{10}{R}\left[\frac{1}{s} - \frac{1}{s+\frac{R}{L}}\right]$$

Taking inverse Laplace transform on both sides of the above equation,

$$i(t) = \frac{10}{R}\left[1 - e^{-\frac{R}{L}.t}\right]$$

Putting $R = 100\Omega$ and $L = 10mH$, we get

$$i(t) = \frac{10}{100}\left[1 - e^{-10^4 t}\right]$$

At $t = 0$, $i(t) = 0$

At $t = \infty$, $i(t) = \frac{10}{100}\text{A} = 100\text{mA}$

At $t = \tau = \frac{L}{R} = 100\mu\text{s}$, $i(t) = 100 \times (63\%) = 63\text{mA}$

Voltage drop across the resistor R is,

$$V_R(t) = Ri(t) = 100 \times \frac{10}{100}(1 - e^{-10^4.t}) = 10(1 - e^{-10^4.t})$$

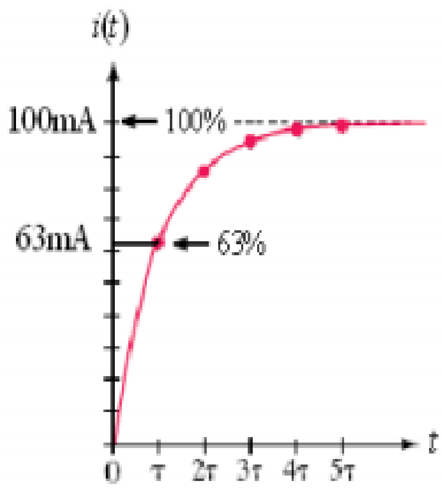
Voltage drop across the inductor L is,

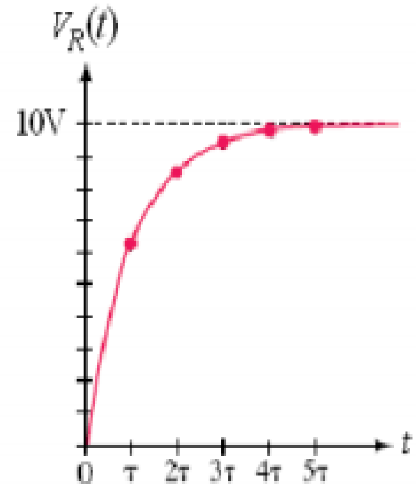
$$V_L(t) = v(t) - V_R(t) = 10e^{-10^4 t}$$

At $t = 0$, $V_L(t) = 10\text{V}$

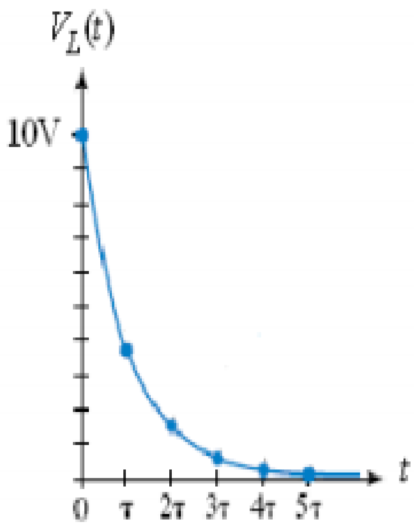
At $t = \infty$, $V_L(t) = 0$

The plot of $i(t)$ vs. t and $V_R(t)$ vs. t are as follows:





The plot of $V_L(t)$ vs. t is as follows:



For Case - 2:-

$$v(t) = 10u(t) \quad \text{and} \quad i_L(0\_) = 20\text{mA}$$

$$\therefore V(s) = \frac{10}{s}$$

$$V(s) = RI(s) + L[sI(s) - 20\times10^{-3}]$$

or,
$$\frac{10}{s} + 20\times10^{-4} = LI(s)\left[s + \frac{R}{L}\right]$$

or,
$$I(s) = \frac{0.02}{s+10^4} + \frac{10^3}{s(s+10^4)}$$

Taking inverse Laplace transform on both sides of the above equation,

$$i(t) = 0.1 - 0.08e^{-10^4.t}$$

At $t = 0$, $i(t) = 20\text{mA}$

At $t = \infty$, $i(t) = 100\text{mA}$

Voltage drop across the resistor R is,

$$V_R(t) = Ri(t) = 100\times i(t) = 100(0.1 - 0.08e^{-10^4.t}) = 10 - 8e^{-10^4.t}$$

At $t = 0$, $V_R(t) = 2\text{V}$

At $t = \infty$, $V_R(t) = 10\text{V}$

Voltage drop across the inductor L is,

$$V_L(t) = v(t) - V_R(t) = 8e^{-10^4.t}$$

At $t = 0$, $V_L(t) = 8\text{V}$

At $t = \infty$, $V_L(t) = 0$

PROCEDURE:

1. Connect the circuit as shown in fig.
2. Set the voltage Accordingly Case 1 & Case 2.
3. Vary the frequency of the signal in steps and note down the magnitude of response on CRO respectively.(response wave form is observed across Elements ,RC)
4. Form the observation table between the time and magnitude of response in CRO.
5. Draw a graph between time and magnitude of response on the semi-log sheet.

RESULT: Transient response of a series R-C and series R-L circuit

ExperimentNo. 2(c)

TRANSIENT RESPONSE OF R-L-C

AIM:

Study and obtain the transient response of a R-L-Ccircuit

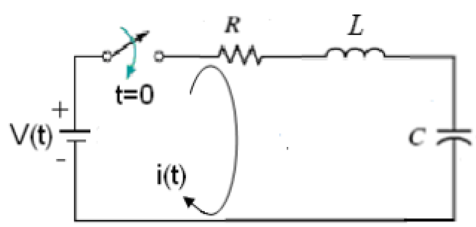
1. Transient response of a R-L-C circuit, excited by a unit step input

APPARATUS:

S. No.	Name of the Equipment	Range	Type	Quantity
1	Signal generator			
2	Required resistors			
3	Required Inductors			
4	Required capacitors			
5	CRO probes			
6	Connecting wires			

CIRCUITDIAGRAM:

THEORY: Let us consider the R-L-C circuit as shown below:



Applying KVL, we obtain

$$v(t) = Ri(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)dt$$

Taking Laplace transform on both sides of the above equation,

$$V(s) = RI(s) + L[sI(s) - i(0\_)] + \frac{I(s)}{sC} + \frac{v_C(0\_)}{s}$$

Now as all initial conditions set equal to zero, i.e. $i(0\_) = 0$ and $v_C(0\_) = 0$, so the equation becomes,

$$V(s) = I(s)\left[R + sL + \frac{1}{sC}\right]$$

Here, $v(t) = u(t)$ $\qquad \therefore V(s) = \frac{1}{s}$

Therefore, $\frac{1}{s} = I(s)\left[R + sL + \frac{1}{sC}\right]$

or,
$$I(s) = \frac{1/L}{s^2 L + \frac{R}{L}s + \frac{1}{LC}}$$

The roots of the denominator polynomial of the above equation are,

$$s^2 L + \frac{R}{L}s + \frac{1}{LC} = 0$$

or, $s_1 = -\frac{R}{2L} + \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$ and

$$s_2 = -\frac{R}{2L} - \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

Let $\omega_0 = \frac{1}{\sqrt{LC}}$ and $\xi\omega_0 = \frac{R}{2L}$

$$\therefore \xi = \frac{R}{2}\sqrt{\frac{C}{L}}$$

Now,

$$I(s) = \frac{1/L}{(s - s_1)(s - s_2)} = \frac{\frac{1}{L(s_1 - s_2)}}{(s - s_1)} + \frac{\frac{1}{L(s_2 - s_1)}}{(s - s_2)}$$

or, $$I(s) = \frac{1}{2\omega_0 L\sqrt{\xi^2 - 1}}\left[\frac{1}{(s - s_1)} - \frac{1}{(s - s_2)}\right]$$

Taking inverse Laplace Transform on both sides,

$$i(t) = \frac{1}{2\omega_0 L\sqrt{\xi^2 - 1}} e^{-\xi\omega_0 t}\left[e^{\omega_0 t\sqrt{\xi^2-1}} - e^{-\omega_0 t\sqrt{\xi^2-1}}\right]$$

Case - 1:-

$$R < 2\sqrt{\frac{L}{C}}$$

i.e. $\xi < 1$

$$i(t) = \frac{1}{\omega_0 L\sqrt{1-\xi^2}} e^{-\xi\omega_0 t}\sin\left(\omega_0 t\sqrt{1-\xi^2}\right)$$

The network is then said to be **Under Damped** or **Oscillatory.**

Case - 2:-

$$R = 2\sqrt{\frac{L}{C}}$$

i.e. $\xi = 1$

$$i(t) = \frac{1}{L} t.e^{-\omega_0 t}$$

The network is then said to be **Critically Damped.**

Case - 3:-

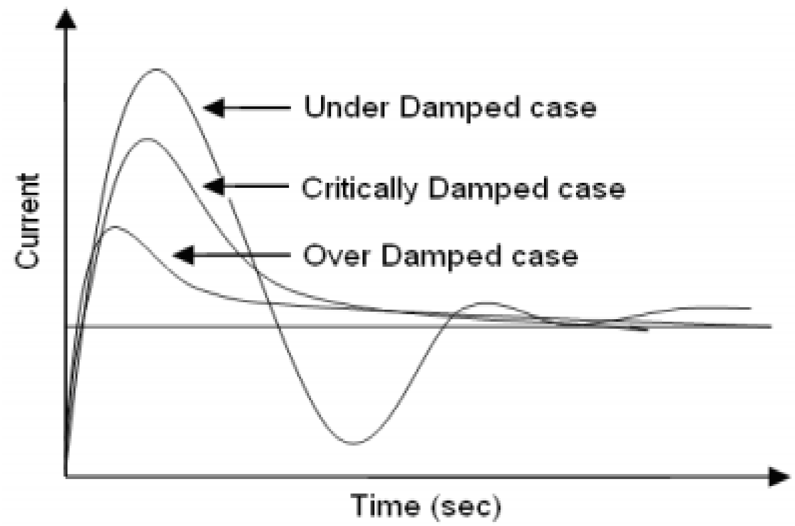
$$R > 2\sqrt{\frac{L}{C}}$$

i.e. $\xi > 1$

$$i(t) = \frac{1}{\omega_0 L\sqrt{\xi^2 - 1}} e^{-\xi\omega_0 t}\sinh\left(\omega_0 t\sqrt{\xi^2 - 1}\right)$$

The network is then said to be **Over Damped.**

The current response for the above three cases is shown in the figure below:



PROCEDURE:

1. Connect the circuit as shown in fig.
2. Set the voltage Accordingly.
3. Vary the frequency of the signal in steps and note down the magnitude of response on CRO respectively.
4. Form the observation table between the time and magnitude of response in CRO.
5. Draw a graph between time and magnitude of response on the semi-log sheet

RESULT: Transient response of a R-L-C circuit is verified

Experiment No-03

VERIFICATION OF SERIESRESONANCE

AIM:

To design the resonant frequency, quality factor and band width of a series resonant circuit.

APPARATUS:

S. No.	Name of the Equipment	Quantity
1.	Series resonance Trainer Kit	**1**
2.	Digital CRO	**1**
3.	CRO probes	As Required
4.	Connecting wires	As Required

CIRCUITDIAGRAM:

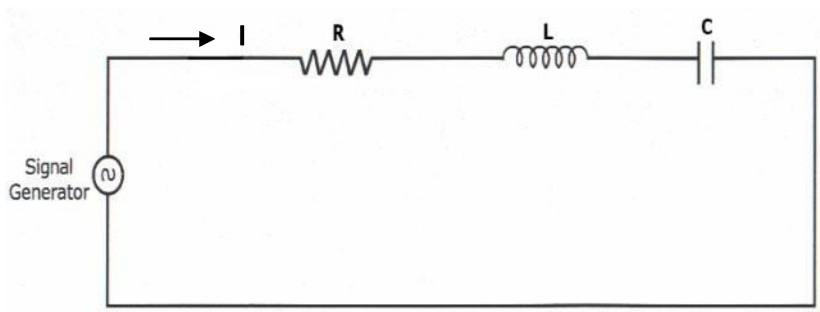


Fig – 12.1 Series Resonance

PROCEDURE:

1. Connect the circuit as shown in fig.12.1 for series resonantcircuit
2. Set the voltage of the signal from function generator to10V.
3. Vary the frequency of the signal in steps and note down the magnitude of response on CRO respectively.(response wave form is observed across elementR)
4. Form the observation table between the frequency and magnitude of response in CRO for series resonance circuit.
5. Draw a graph between frequency and magnitude of response on the semi-log sheet and determine the resonant frequency, quality factor and bandwidth of series RLCcircuit\.

THEORETICAL CALCULATIONS: SeriesResonance

ResonantFrequency (fr) = 1/(2∏√LC) Lower cutofffrequency (f1) =fr-R/4∏L

Upper cut off frequency (f2) = fr+R/4∏L

Quality factor $Q_r = \omega_r L/R = 1/\omega_r RC$

BandWidth $f_2 - f_1$ =R/2∏L

TABULARCOLUMN:

S.No.	Frequency *(kHz)*	Magnitude of response
1	2.701	1.031
2	2.787	1.028
3	3.315	1.019
4	4.167	0.993
5	5.014	0.935
6	6.068	0.885
7	6.682(fr)	0.900
8	7.475	0.940
9	8.250	0.968
10	9.028	0.991

MODELGRAPH:

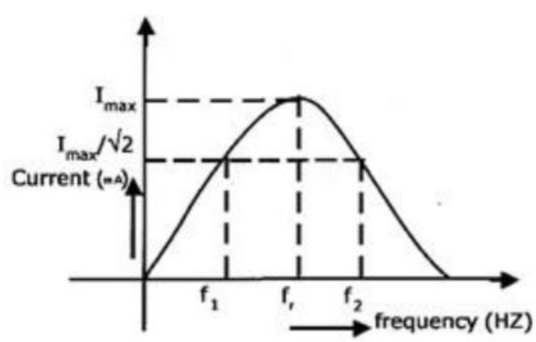


Fig – 12.2 Series Resonance

RESULT: Series Resonance is Verified

ExperimentNo. 04

a) Observationoftheno-loadcurrentwaveformforsinglephasetransformeronCRO.
b) Tomeasurethevoltagesandcurrents,andpowerofaforsinglephasetransformerforresistiveloadandcalculateturnratio.

ApparatusRequired

S. No	Name of apparatus	Type	Specification	Quantity
1.	Single Phase Transformer	Core Type	2 KVA	1
2.	CRO	Dual channel	30 MHz	1
3.	Ammeter	MI	0-5 A	2
4.	Voltmeter	MI	0-300V	2
5.	Wattmeter	Electro Dynamic	0-1500W	2
6.	Load	Resistive	3KW	
7.	Connecting Leads		1.5 sq mm, 9A	

Introduction

Transformersareoneofthemostimportantcomponentsofanypowersystem.Itbasicallychangesthelevelofvoltages from one valueto the other at constant frequency. Being a static machine the efficiency of atransformer could be as high as 99%. The transformer is a static device (means that has no moving parts) thatconsists of one, two or more windings which are magnetically coupled and electrically separated with orwithout a magnetic core. It transfers the electrical energy from one circuit to the other by electromagneticinductionprinciple.ThewindingconnectedtotheACmainsupplyiscalledprimarywindingandthe windingconnectedtotheloadorfromwhichenergyisdrawnoutiscalledassecondarywinding.Thesetwowindingswit hproperinsulationarewoundonalaminatedcorewhichprovidesamagneticpathbetweenwindings.
Whentheprimarywindingisenergizedwithalternatingvoltagesource,analternatingmagneticfluxorfieldwill beproducedinthetransformercore.Thismagneticfluxamplitudedependsontheappliedvoltagemagnitude,frequency ofthesupplyandthenumberofturnsontheprimaryside.Thisfluxcirculatesthroughthecoreandhencelinkswiththeseco ndarywinding.Basedontheprincipleofelectromagneticinduction,thismagneticlinkinginducesavoltageintheseconda rywinding. Thisiscalledasmutualinductionbetweentwocircuits.
Thesecondaryvoltagedependsonthenumberofturnsonthesecondaryaswellasmagneticfluxandfrequency.**Construc tionofsinglephasetransformer**

Generally,thenameassociatedwiththeconstructionofatransformerisdependentuponhowtheprimaryand secondarywindingsarewoundaroundthecentrallaminatedsteelcore.Thetwomostcommonandbasicdesignsoftran sformerconstructionaretheClosed-coreTransformerandtheShell-coreTransformer.
Inthe“closed-core”type(coreform)transformer,theprimaryandsecondarywindingsarewoundoutsideand surroundthecorering.Inthe“shelltype”(shellform)transformer,theprimaryandsecondarywindingspassinsidethest eelmagneticcircuit(core)whichformsashellaroundthewindingsasshownbelow.

In both types of transformer core design, the magnetic flux linking the primary and secondary windings travelsentirelywithinthecorewithnolossofmagneticfluxthroughair.Inthecoretypetransformerconstruction,oneha lf of each winding is wrapped around each leg (or limb) of the transformers magnetic circuit as shown above.Thecoilsarenotarrangedwiththeprimarywindingononelegandthesecondaryontheotherbutinsteadhalfof the primary winding and half of the secondary winding are placed one over the other concentrically on eachleg in order to increase magnetic coupling allowing practically all of the magnetic lines of force go through boththeprimaryandsecondarywindingsatthesametime.However,withthistypeoftransformerconstruction,asmall percentageofthemagneticlinesofforceflowoutsideofthecore,andthisiscalled“leakageflux”.

Shell type transformer cores overcome this leakage flux as both the primary and secondary windings arewound on the same centre leg or limb which has twice the cross-sectional area of the two outer limbs. Theadvantage here is that the magnetic flux has two closed magnetic paths to flow around external to the coils onbothleftandrighthandsidesbeforereturningbacktothecentralcoils.

Thismeansthatthemagneticfluxcirculatingaroundtheouterlimbsofthistypeoftransformerconstructionis equaltoΦ/2.Asthemagneticfluxhasaclosedpatharoundthecoils,thishastheadvantageofdecreasingcorelossesandi ncreasingoverallefficiency.

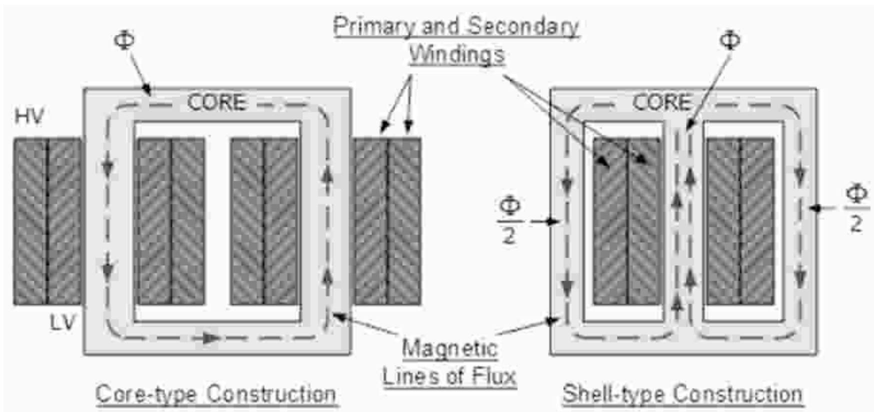


Fig2(a).1 Core type and shell type transformer

LaminatingtheIronCore

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

The laminationsusedinatransformerconstructionareverythinstripsofinsulatedmetal joinedtogetherto produceasolidbutlaminatedcoreaswesawabove.Theselaminationsareinsulatedfromeachotherbyacoatofvarnish orpapertoincreasetheeffectiveresistivityofthecoretherebyincreasingtheoverallresistancetolimittheflowoftheed dycurrents.

Theresultofallthisinsulationisthattheunwantedinducededdycurrentpower-lossinthecoreisgreatly reduced, and it is for this reason why the magnetic iron circuit of every transformer and other electro-magneticmachinesarealllaminated.Usinglaminationsinatransformerconstructionreduceseddycurrentlosses.

Thelossesofenergy,whichappearsasheatduebothtohysteresisandtoeddycurrentsinthemagneticpath, isknowncommonlyas“transformercorelosses”.Sincetheselossesoccurinallmagneticmaterialsasaresult of alternating magnetic fields. Transformer core losses are always present in a transformer whenever theprimary is energized, even if no load is connected to the secondary winding. Also these hysteresis and theeddy current losses are sometimes referred to as “transformer iron losses”, as the magnetic flux causing theselossesisconstantatallloads.

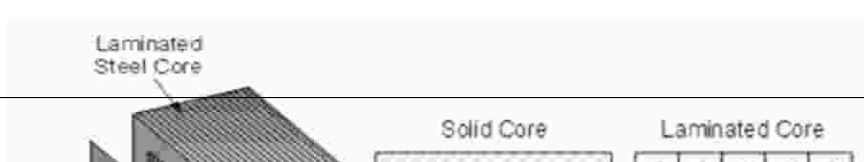


Fig. 2(a).2 Lamination of transformer

corePrincipleofoperationIdealTransformer

A transformer is a device used to change voltages and currents of AC electric power by mutual inductionprinciple. In the simplest version it consists of two windings wrapped around a magnetic core; windings are notelectricallyconnected,buttheyarecoupledbythemagneticfield,asitshowninFigure3.1.Whenonewindingis connected to the AC electric power, the electric current is generated. This winding is called the primarywinding. 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 ifsomeimpedanceisconnectedtotheterminals,anACelectriccurrentissupplied.

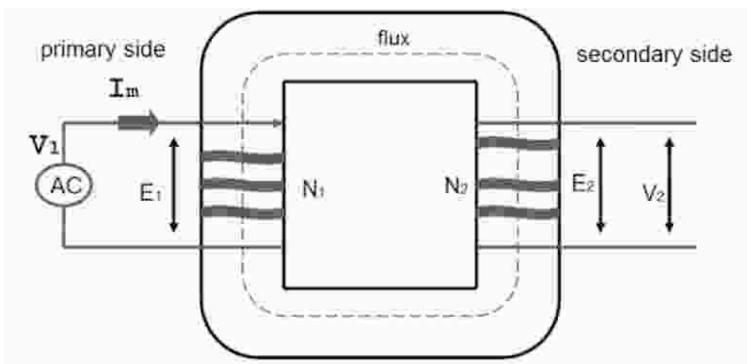


Fig. 2(a).3Ideal Transformer

<u>TransformeronNoLoadCondition</u>

Whenthetransformerisoperatingatnoload,thesecondarywindingisopencircuited,whichmeansthereisnoloadonth esecondarysideofthetransformerand,therefore,currentinthesecondarywillbezero,whileprimarywindingcarriesa smallcurrentI0callednoloadcurrentwhichis2to10%oftheratedcurrent.This

currentisresponsibleforsupplyingtheironlosses(hysteresisandeddycurrentlosses)inthecoreandaverysmall amount of copper losses in the primary winding. The angle of lag depends upon the losses in thetransformer.Thepowerfactorisverylowandvariesfrom0.1to0.15.

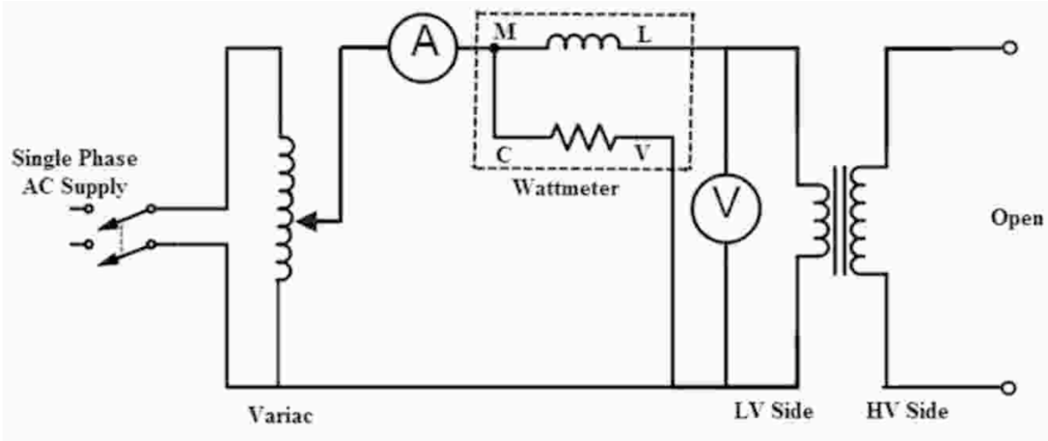


Fig 2(a).4 Single phase transformer on no load condition

Thenoloadcurrentconsistsoftwocomponents

- ReactiveormagnetizingcomponentIm(ItisinquadraturewiththeappliedvoltageV1.Itproducesfluxinthecoreanddo esnotconsumeanypower)
- ActiveorpowercomponentIw,alsoknowasworkingcomponent(Itisinphasewiththeappliedvoltage V1.Itsuppliestheironlossesandasmallamountofprimarycopperloss)Thefollow

ingstepsaregivenbelowtodrawthephasordiagram

1. Thefunctionofthemagnetizingcomponentistoproducethemagnetizingflux,andthus,itwillbeinphasewiththe flux.
2. Inducedemfin theprimary andthesecondary windinglags theflux ϕby90 degrees.
3. Theprimarycopperlossisneglected,andsecondarycurrentlossesarezeroasI2=0.Therefore,thecurrentI0lagsb ehindthevoltagevectorV1byanangleϕ0calledno-loadpowerfactorangleshowninthephasordiagramabove.
4. TheappliedvoltageV1isdrawnequalandoppositetotheinducedemfE1becausethedifference betweenthetwo,atnoload,isnegligible.
5. Active componentIw isdrawn inphase withthe appliedvoltageV1.
6. The phasor sumof magnetizing currentIm and theworking currentIw gives theno load currentI0.

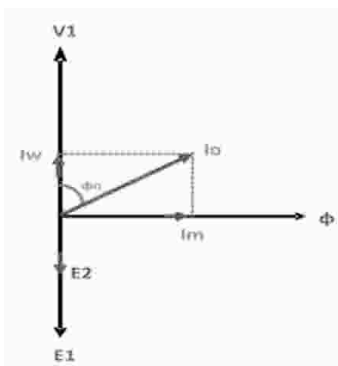


Fig 2(a).5 Phasor diagram of transformer no load condition

Observationofnoloadcurrentintransformer

Method:- Oscilloscope typically doesn't measure current but instead it measures voltage. Thus to observecurrent waveform you could simply use current-to-voltage component like resistor, and probe the voltageacrossthatresistor.ThecurrentinformationcanbeobtainedbyusingOhmLawformula:V=I.RorI=V/Rwhic h means current waveform will match exactly the observed voltage, despite the magnitude may bedifferent.

PROCEDURE:

1. Connect circuit as shown in the circuit diagram. Open circuit the secondaryand apply full load voltage to the primary through a variac. The copper lossis negligible since there is only no load current is flowing. Hence powerconsumedis the corelosses ofthecore.
2. Oscilloscope typically doesn't measure current but instead it measures voltage. Thus to observecurrent waveform you could simply use current-to-voltage component like resistor, and probe the voltageacrossthatresistor.
3. ThecurrentinformationcanbeobtainedbyusingOhmLawformula:V=I.RorI=V/Rwhich means current waveform will match exactly the observed voltage, despite the magnitude may bedifferent.
4. Observe the no-load current waveform on the CRO screen.
5. Note ammeter reading and Currentobserved by CRO(A)reading in observation table.

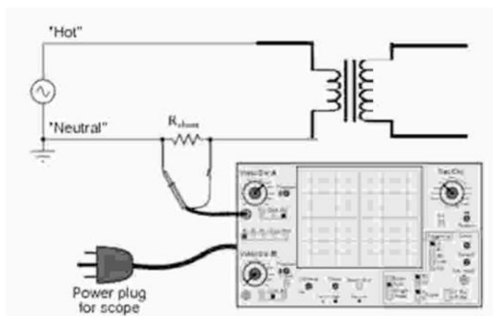


Fig 2(a).6 Observation of no load current in transformer

S.No	Currentobserved byAmmeter(A)	Currentobserved by CRO(A)
1.		
2.		
3.		
4.		

Transformer"On-load"

Whenanelectricalloadisconnectedtothesecondarywindingofatransformerandthetransformerloadingistherefore greater than zero, a current flows in the secondary winding and out to the load. This secondarycurrent is due to the induced secondary voltage, set up by the magnetic flux created in the core from theprimarycurrent.

Thesecondarycurrent,ISwhichisdeterminedbythecharacteristicsoftheload,createsaself-induced secondarymagneticfield,ΦSinthetransformercorewhichflowsintheexactoppositedirectiontothemainprimaryfield,ΦP.Thesetwomagneticfieldsopposeeachotherresultinginacombinedmagneticfieldoflessmagneticstrengththan thesinglefieldproducedbytheprimarywindingalonewhenthesecondarycircuitwasopencircuited.

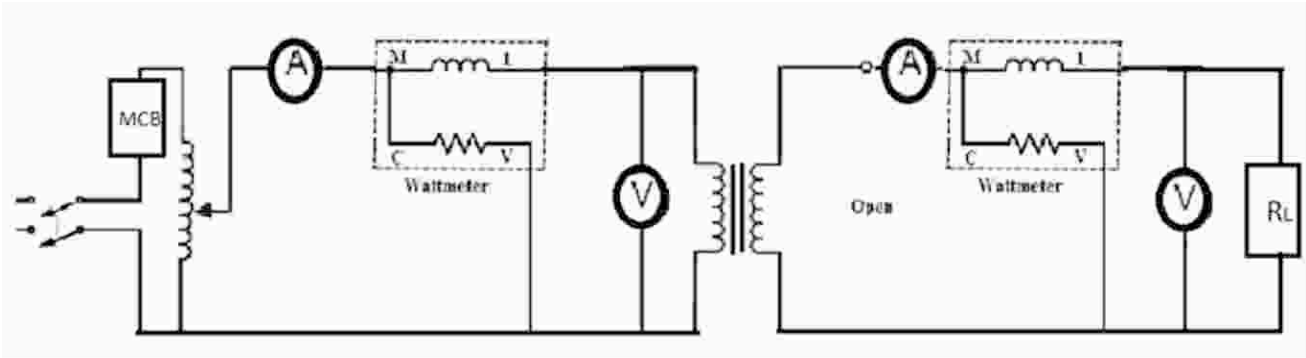


Fig2(b).1TransformerOn-load

We know that the turns ratio of a transformer states that the total induced voltage in each winding isproportional to the number of turns in that winding and also that the power output and power input of atransformerisequaltothevoltstimesamperes,(VxI).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 atransformercanbelinkedtogetherandisthereforegivenas

TransformerRatio(n)

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

Where:

- NP/NS=VP/VS-representsthevoltageratio
- NP/NS=IS/IP-representsthecurrentratio

Note that the current is inversely proportional to both the voltage and the number of turns. This means that witha transformer loading on the secondary winding, in order to maintain a balanced power level across thetransformers windings, if the voltage is stepped up, the current must be stepped down and vice versa. In otherwords,“highervoltage—lowercurrent”or“lowervoltage—highercurrent”.
Asatransformersratioistherelationshipsbetweenthenumberofturnsintheprimaryandsecondary,the voltageacrosseachwinding,andthecurrentthroughthewindings,wecanrearrangetheabovetransformerratioequationtofindthevalueofanyunknownvoltage,(V)current,(I)ornumberofturns,(N)asshown.
Thetotalcurrentdrawnfromthesupplybytheprimarywindingisthevectorsumoftheno-loadcurrent,Ioand

theadditionalsupplycurrent,I1asaresultofthesecondarytransformerloadingandwhichlagsbehindthesupplyvoltagebyanangleofΦ.

Procedure:

1. Connect circuit as shown in the circuit diagram.
2. Apply Load on the transformer step by step.
3. Note down the readings of Primary, secondary side voltmeter, ammeter, wattmeter.
4. Repeat step no 3 for different loads on the transformer.
5. Switch off the supply.

ObservationTable:-

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

Result:-

Observationoftheno-loadcurrentwaveformhasbeendoneonanoscilloscope.

Measurementofprimaryandsecondaryvoltagesandcurrents,andpowerisdoneafterloadingofatransformerwithdifferentresistiveloadcondition.

Efficiencyoftransformeriscalculatefordirectloadingcondition.

VIVAVOICE:

1. WhathappenwhenTransformerisgivenDCsupply?
2. Foratransformerwithprimaryturns100,secondaryturns400,if200Visappliedatprimarywhatvoltagewewillgetinsecondary?
3. Whatisdifferencebetweentransformerandamplifier?
4. Howcaneddycurrentlossbeminimized?
5. Whatisautotransformer?
6. Doesthetransformerdrawanycurrentwhenitssecondaryisopen?
7. Whatiscurrenttransformer?
8. Whattypeoftransformeradistributiontransformeris?step-uporstep-down.
9. Whatistransformerregulation?

<u>ExperimentNo. 05</u>

Open circuit and short circuit test on a single-phase transformer

AIMOFTHEEXPERIMENT:

To perform the open circuit and short circuit test on a single-phase transformer and to draw theequivalentcircuitafter determiningitsconstants.

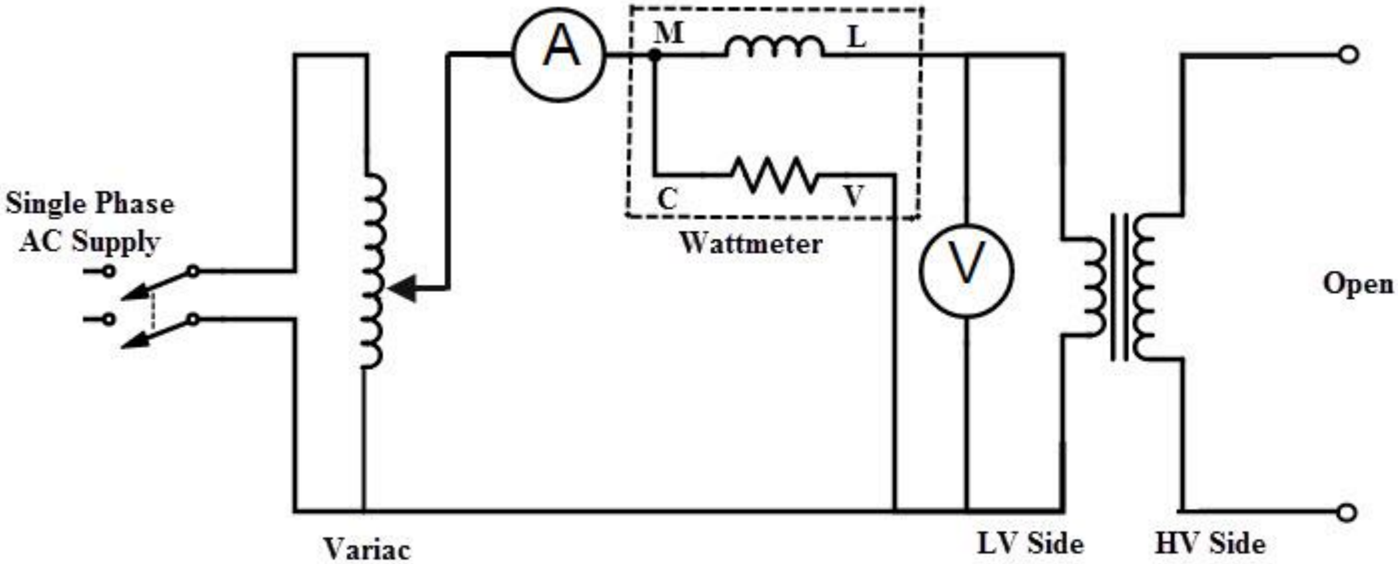
NAMEPLATEDETAILS:

VoltageRatio	220/110V
Full loadCurrent	13.6A
KVARATING	3KVA

EQUIPMENTREQUIRED:

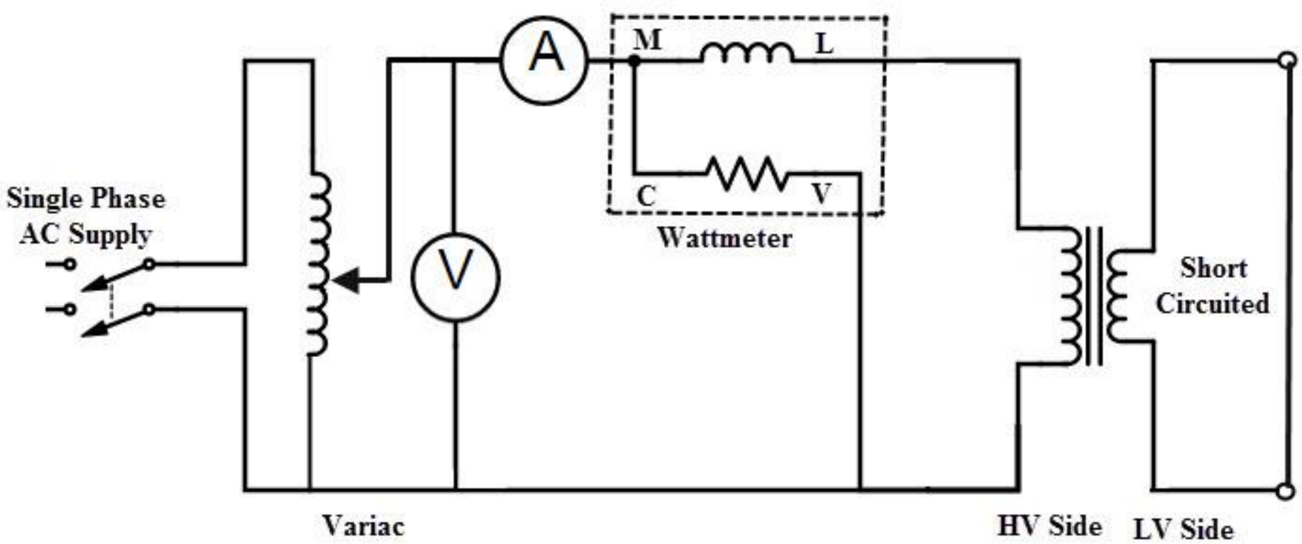
S.NO	NAMEOFTHEEQUIPMENT	RANGE	TYPE	QUANTITY
1	Singlephase transformer	3KVA,230/230V,50HZ		1
2	Wattmeter	2.5/5ALPF	LPF	1
3	Wattmeter	10/20A UPF	UPF	1
4	Ammeter	0-1A		1
5	Ammeter	0-20A		1
6	Voltmeter	0-300V		1
7	Voltmeter	0-30/75V		1
8	1ph Variac	0-300V,15A		1

OPENCIRCUITTEST:



Circuit Diagram: OC Test

SHORTCIRCUITTEST:



Circuit Diagram: SC Test

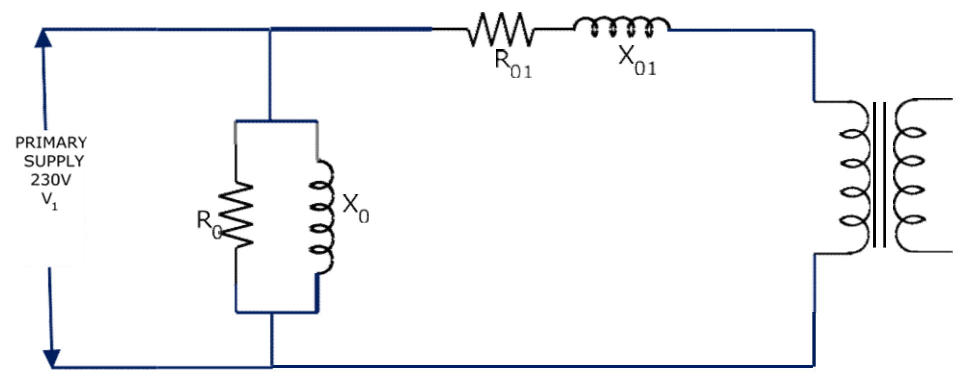
THEORY:

The performance of a transformer can be calculated on the basis of its equivalent circuit whichcontainsfourmainparameters,theequivalentresistanceR_{01}asreferredtoprimary(orsecondary R_{02}), the equivalent leakage reactance X_{01} as referred to primary, the core-lossconductance G_0 and the magnetizing susceptance B_0. These constants or parameters can beeasily determined by two test i.e. Open circuit test and short circuit test. These are veryeconomical and convenient, because they furnish the required information without actuallyloading the transformer. In fact, the testing of very large a.c machinery consists of running twotestsimilartothe openand short circuit test of a transformer.

The purpose of thistestisto determine no loadloss or core loss and no loadI_0which ishelpful in finding X_0 and R_0. One winding of the transformer whichever is convenient butusually high voltage winding is left open and the other is connected to its supply of normalvoltage and frequency. A wattmeter (W), Voltmeter (V) and ammeter (A) are connected in thelow voltage winding i.e. primary winding in the present case. With normal voltage applied tothe primary, normal flux will be setup in the core, hence normal iron losses will occur whichare recorded by the wattmeter. As the primary no load current I_0 is small, Cu loss is negligiblysmall in primary and nil in secondary. Hence, the wattmeter reading represents practically thecoreloss underno loadcondition.

For short circuit test, one winding usually the low voltage winding, is solidly short- circuitedby a thick conductor (or through an ammeter which may serve the additional purpose ofindicatingrated loadcurrent).

A low voltage (usually 5 to 10% of normal primary voltage) at correct frequency (though forCu losses it is not essential) is applied to the primary and is cautiously increased ill full- loadcurrentareflowingbothin primaryandsecondary(asindicatedbythe respectiveammeters).
Since, in this test, the applied voltage is a small percentage of the normal voltage, the mutualflux ø produced is also a small percentage of its normal value. Hence, core losses are verysmall with the result that the wattmeter reading represents the full load Cu loss or i2 R loss forthewholetransformeri.e.bothprimaryCulossandsecondaryCuloss.Theequivalentcircuit of the transformer under short- circuitcondition.If Vsc is the voltage required tocirculateratedload currents, then $Z_{01}=Vsc/I_1$
A two winding transformer can be represented by means of an equivalent circuit as shownbelow



PRECAUTIONS:

1. Don'tswitch on power supplywithoutconcerningrespectedteachers.

2. 1∅Auto transformer must be kept at minimum potential point.
Beforeswitch onthe experiment.

OPEN CIRCUIT TESTPROCEDURE:

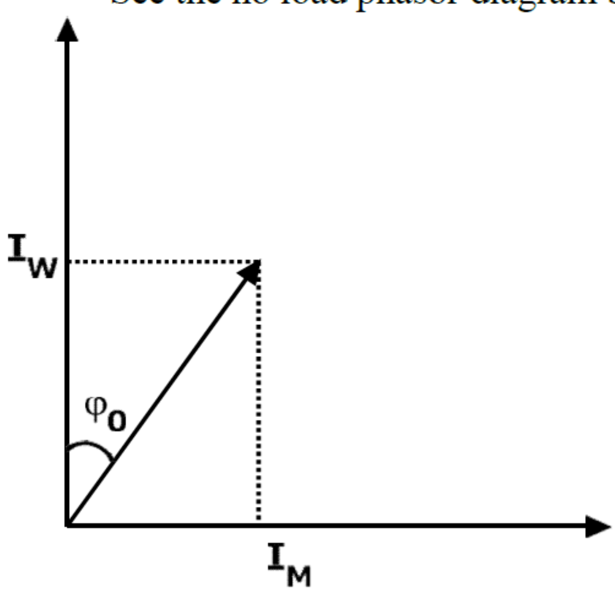
1. Connect circuit as shown in the circuit diagram. open circuit the secondaryand apply full load voltage to the primary through a variac. The cupper lossis negligible since there is only no load current is flowing. Hence powerconsumedis the corelosses ofthecore.
2. Note voltmeterand ammeter and wattmeterreading.

OBSERVATION TABLE:

S.No.	V	I_0	W	I_w=W/V	$I_M=\sqrt{I_0^2-I_w^2}$	COSφ=W/(VI_0)
1	125	0.37	24			

CALCULATION:

See the no load phasor diagram below



$W = VI_0 COS\, Ø_0$

$I_W = \frac{W}{V}$, $I_M = \sqrt{I_0^2 \quad I_W^2}$ $R_0 = \frac{V}{I_W}$, $X_0 = \frac{V}{I_M}$

SHORTCIRCUIT TEST PROCEDURE:

1. Connect as shown in the circuit diagram. Short circuit the secondary and apply a lowvoltage to the primary through aauto transformer. The iron losses are negligiblesince thefluxwillbeverylow on account of the primaryandsecondary.
2. Increase the voltage gradually till full load current flows in the

primary. Notevoltmeterand ammeter and wattmeterreading.

OBSERVATION:

SL.NO.	V	I	W_c
1	15	40.9	52

CALCULATIONS:

LetthetotalequivalentresistanceofprimaryandsecondaryreferredtoprimarysidebeR_1ohms and the total equivalent leakage reactancereferred to primarysidebeX_1ohms.
$W_c=I^2R_1$
Hence$R_1=W_c/I^2$Also $V/I= Z_1$ and X1= $\sqrt{Z_1{}^2 - R_1{}^2}$ohms.

CONCLUSION:

a. Nowdrawtheequivalent circuit.
b. Plotagraphofcopperlossversusloadcurrent(shortcircuitcurrent).Whatistheshapeofthecurve ?
c. Determinetheregulationofthetransformeratvariousloadsforanassumedloadpowerfactorof0 .8 lagging.

Regulationpercentage=$(V_o-V_t)/V_t$ X100 Vt

WhereV_o=secondarynoloadvoltage.

V_t = secondaryfull loadvoltage.

d. Plotacurveor regulation versus load current.

RESULT:

POSTLABQUESTIONS:

1. Why iron is chosen as the material for the core of the transformer? Why not weusealuminium?
2. What isnormallytheefficiencyofatransformertobe?
3. WhyTransformersAreRated In KVA?

ExperimentNo. 06

CharacteristicsofLamps

Aim:

I) Obtaining theV-I characteristicsofthefollowingnonlinear elementsLamp(L1):40W,220VACTungstenLamp

Lamp(L2):18W,220VAC,CompactFluorescent Lamps(CFL).

APPARATUS:

Sl.NO.	Nameoftheequipment	Range	Type	Qty
1	Autotransformer	0-230V		1
2	Ammeter	0-0.2A	MI	2
3	Voltmeter	0-300v	MI	1
4	Incandisentlamp,CFLlamp	40w,18w		1

CircuitDiagram:

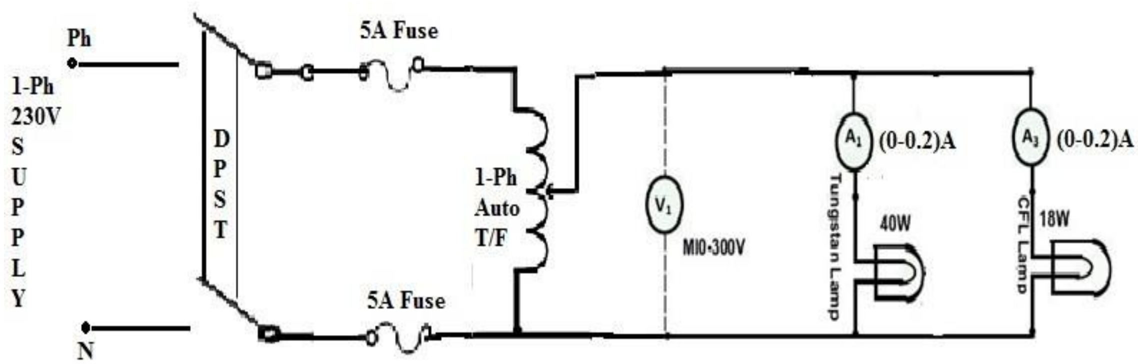


Fig.1V-IcharacteristicsoftheTungstenandCFLLamp

ProcedureforV-I characteristicsoftheTungstenandCFLLamp

a) ChoosetheappropriateratingsoftheAmmeters, Voltmeters andFusewire.
b) SetupthecircuitasshowninFig1withthelampsandinstrumentsasindicated.KeeptheswitchS open.
c) Settheautotransformerforzerooutputvoltage.ClosetheswitchS.
d) Increasetheautotransformeroutputvoltageinstepsof20/30V,untilthefullvoltage(i.e230V) is obtained. At each step, note the readings of V_1, A_1, A_2 and record them in
e) Table1.Repeatstep (d) decreasingoutputvoltageofautotransformerfromfulltozerovolts.

Observation Table:

S.No	V_1(V)	I_1(A)(TungstenLamp)			I_2(A)(CFLLamp)		
		Inc	Dec	Mean	Inc	Dec	Mean
1.	40	0.08	0.076	0.078	0.08	0.076	0.078
2	80	0.086	0.102	0.094	0.09	0.086	0.088
3	120	0.11	0.124	0.117	0.086	0.084	0.085
4	160	0.132	0.144	0.138	0.082	0.08	0.081

Modelgraph

I

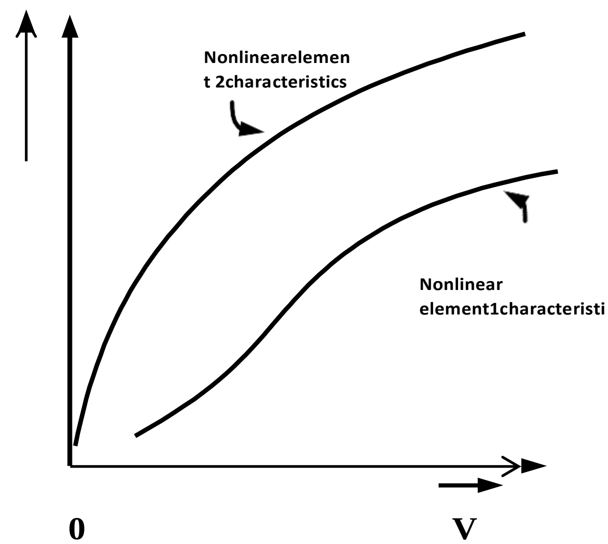


Fig.2Modelgraph forV-Icharacteristics

RESULT:

V-I Characteristicsofdifferentlampshavebeenstudied.

DiscussionQuestions:

1. Howwillyouinterpret thev-icharacteristicsoftwodifferentincandescentlamps?
2. Whydothereadingsdifferforincreasinganddecreasingvaluesofthelampvolta ges? DiscussionQuestions:

1. Accountforthedifferences,ifany,betweenthepredictedandtheobservedsteadystateopera tingpointsofthecircuit.

Whysourcecharacteristicswillbereferredasloadlinecharacteristics?

II.FLUORESCENTLAMP:

Aim: ToobtaintheV-IcharacteristicsofaFluorescentLamp

APPARATUS:

Sl.NO.	Nameoftheequipment	Range	Type	Qty
1	Autotransformer	0-230V		1
2	Ammeter	0-0.2A	MI	2
3	Voltmeter	0-300v,0-150v	MI	2,1
4	Fluorescentlamp	36w		1

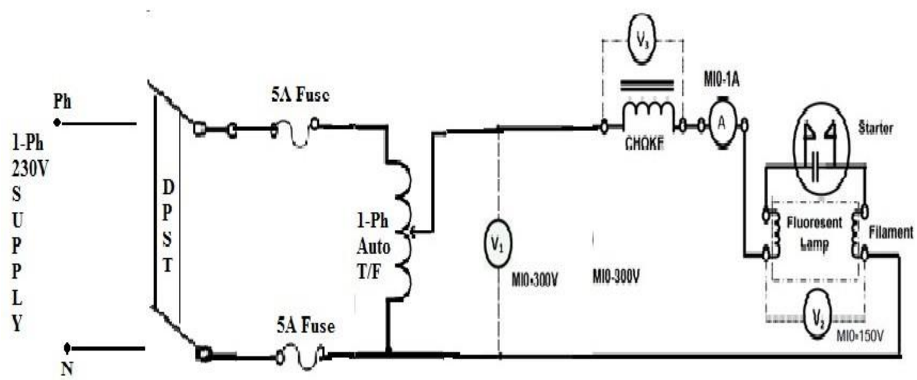


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Fig.7 Circuitdiagramfor testingofaFluorescentLamp

Procedure:

1. SetupthecircuitasshowninFig.7KeeptheswitchSopen.
2. Withtheautotransformer atzerooutputposition,close theswitchS.
3. Increasethe autotransformeroutputgraduallyuntilthelamplightsup.Notethemeterreadingsandenterth emintheproper columninTable3.

Whenthelampstartstoglow,increasetheautotransformeroutputvoltageinstepsuntiltheratedvoltageis obtained.EnterthereadingsofthemetersinTable3.

4. Decreasethesupplyvoltageinstepsuntilthelampextinguishes.Recordthemeterreading s

.

Table3:Fluorescentlamp characteristics.

S.NO.	Vs	V_L	Vc	I_L	Remarks
1	230	106	184	3.6	Fullbright
2	210	114	150	2.4	Lowbright
3	190	128	124	2.2	Dim
4	150	149	20	0	Lightextinguish

V_s = Voltage across the supply = reading of the voltmeter V_1

V_1 = Voltage across the lamp = reading of the voltmeter V_2

V_c = Voltage across the choke = reading of the voltmeter V_3

I_L = Current through the lamp = reading of the ammeter A

RESULT: Thecharacteristicsoffluorescentlampsarestudied.

DiscussionQuestions:

1. Plot V_L versus I_L and V_c versus I_L on the same graph sheet.
2. Comment on the nature of the plots. How are V_L and Vc related?
3. Discuss the function of the choke in the lamp circuit. Can it be replaced by a resistor?
4. What is the necessity of a starter? Can a single- pole switch replace it?
5. The voltage needed for starting the glow of the lamp and the voltage when the lamp extinguishes, are not equal. Explain why?
6. If ac supply is replaced by dc, will the circuit work? If not, what changes are to be made?

ExperimentNo. 07

VERIFICATION OF KVL ANDKCL

AIM:

To verify Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL) in a Passive Resistive Network.

STATEMENT:

KCL: Algebraic Sum of All the Currents Entering and Leaving a node Must be equal to zero

$$I_{(exiting)} + I_{(entering)} = 0$$

KVL: Algebraic sum of all voltages within the loop must be equal to zero

$$V_s = V_1 + V_2 + V_3$$

APPARATUS:

S. No	Apparatus Name	Range	Type	Quantity
1	RPS			
2	Ammeter			
3	Voltmeter			
4	Resistors			
5	Bread Board	-	-	01
6	Connecting Wires	-	-	As required

CIRCUITDIAGRAMS:

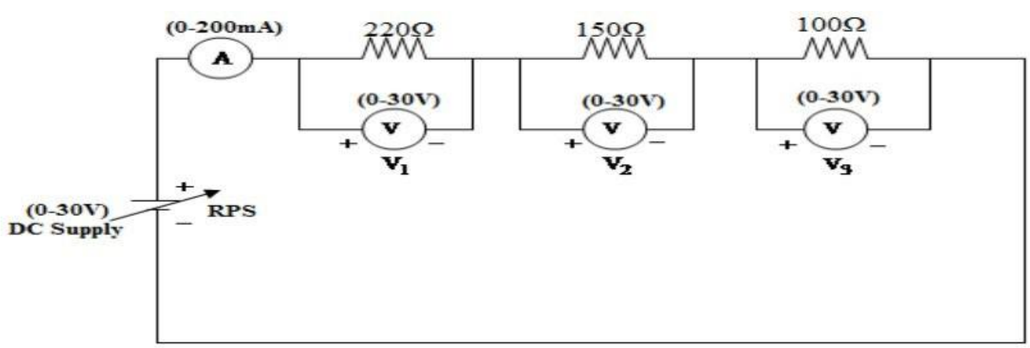


Figure – 1.1 Verification of KVL

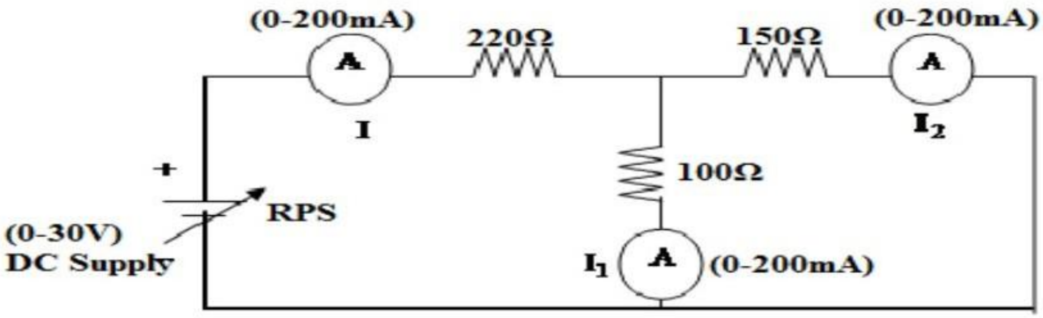


Figure – 1.2 Verification of KCL

PROCEDURE:

To Verify KVL

1. Connect the circuit diagram as shown in Figure1.
2. Switch ON the supply toRPS.
3. Apply the voltage (say 5v) and note the voltmeterreadings.
4. Gradually increase the supply voltage insteps.
5. Note the readings ofvoltmeters.
6. sum up the voltmeter readings (voltage drops) , that should be equal to applied voltage.
7. Thus KVL is Verifiedpractically.

To Verify KCL

1. Connect the circuit diagram as shown in Figure2.
2. Switch ON the supply toRPS.
3. Apply the voltage (say 5v) and note the Ammeterreadings.
4. Gradually increase the supply voltage insteps.
5. Note the readings ofAmmeters.
6. Sum up the Ammeter readings (I_1 and I_2) , that should be equal to total current(I).
7. Thus KCL is Verifiedpractically

OBSERVATIONS:

ForKVL

Applied Voltage V (volts)	V_1 (volts)		V_2 (volts)		V_3 (volts)		$V_1+V_2+V_3$ (volts)	
	Theoritical	Practical	Theoritical	Practical	Theoritical	Practical	Theoritical	Practical

ForKCL

Applied Voltage V (volts)	I (A)		I_1 (A)		I_2 (A)		I_1+I_2 (A)	
	Theoretical	Practical	Theoretical	Practical	Theoretical	Practical	Theoretical	Practical

PRECAUTIONS:

1. Check for proper connections before switching ON thesupply
2. Make sure of proper color coding ofresistors
3. The terminal of the resistance should be properlyconnected.

RESULT: Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL) in a Passive Resistive Network Verified.

ExperimentNo. 08

VerificationofNetworkTheorems

Theobjectiveofthisexperimentistoverifythe

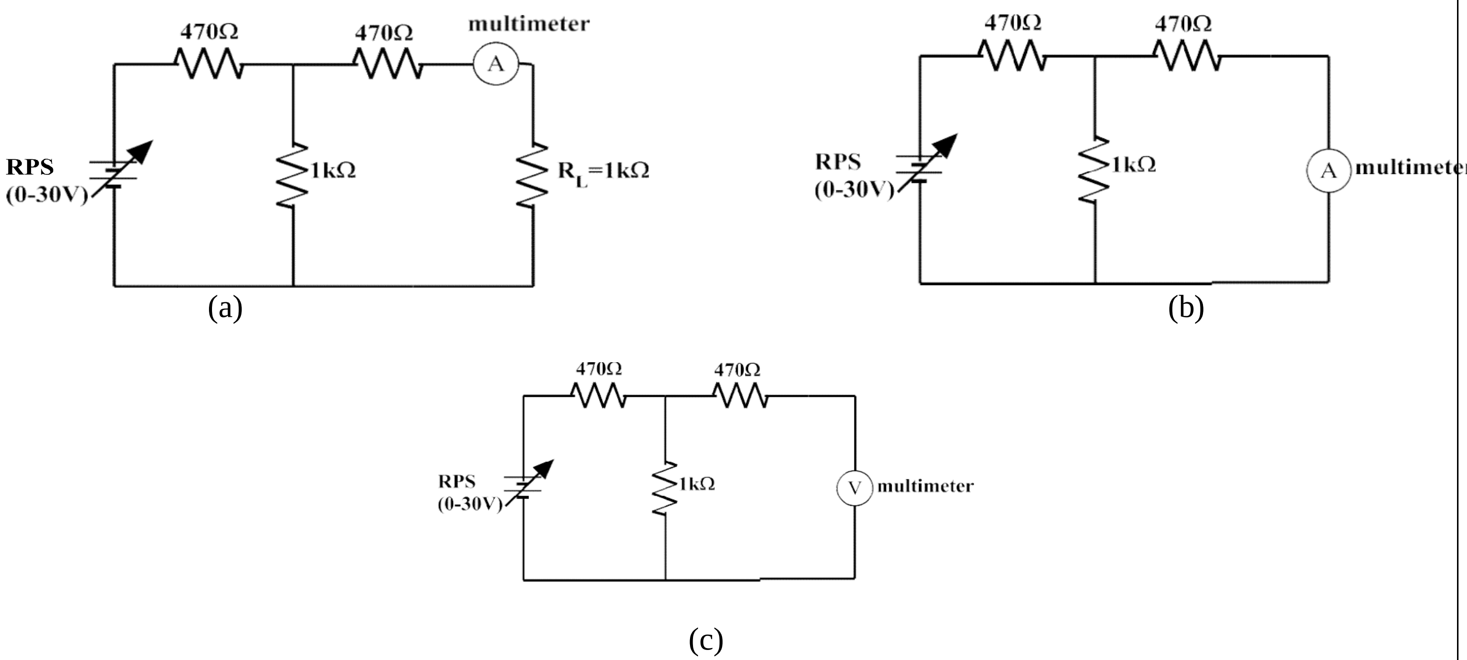
a. Thevenin’sTheorem
b. SuperpositionTheorem

APPARATUS:

Sl.NO.	**Nameoftheequipment**	**Range**	**Type**	**Qty**
1	Resistors	470Ω 470Ω 1kΩ 1kΩ		1 1 1 1
2	Breadboard	-	-	1
3	Regulatedpowersupply	0-30V	-	1
4	Multimeter	-	Digital	1
5	SingleStandWires			AsRequired

a) Thevenin’sTheorem

CircuitDiagrams:



Procedure:

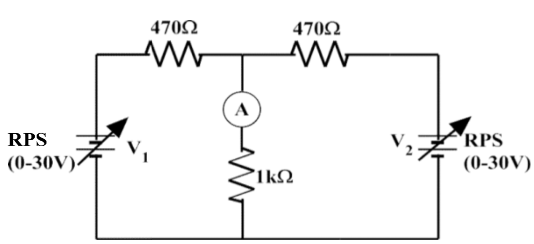
Fig1:CircuitDiagramforverificationofthevenin’stheorem

1. Connectthecircuitasshowninfig1(a)
2. SwitchontheRPSandapplysomeinputvoltage(say30V),observetheloadcurrentI_L.
3. NowreconnectthecircuitasshowninFig1(b)andapplythesameinputvoltageasinst ep 2andobservetheshortcircuitcurrent(I_{SC}).
4. Nowreconnectthecircuitasshowninfig1(c)andapplythesameinputvoltageasin step2andobservethevoltage(V_{Th}).opencircuitvoltagewhichisnothingbutthethevenin’s
5. Nowcomputethethevenin’sequivalentresistance($R_{Th}=V_{Th}/I_{SC}$).
6. Computetheloadcurrentapplyingthevenin’stheoremas$I_L=V_{Th}/(R_{Th}+R_L)$.
7. Comparetheaboveloadcurrentwithitsobservedvalueinstep(2)andverifythet heorem.
8. Adjusttheinputvoltagetoanewvalueandrepeattheprocedurefromstep(2)tost ep(7)(Takeatleastfivesetsofreadings).

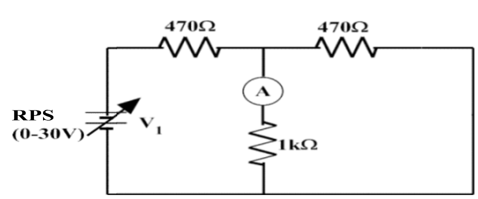
<u>Table-IThevenin’sTheorem:</u>

Sl.No.	**Sourcevoltage V_S**	**Observed loadcurrent(I_L)ma**	**I_{SC}ma**	**V_{Th}**	**$R_{Th}=(V_{Th}/I_{SC})$**	**Computed loadcurrent ($V_{Th}/(R_{Th}+R_L)$)=$I_L$ma**
1	10	3.8	8.3	6.75	0.813	3.72
2.	20	7.4	16.9	13.4	0.792	7.4

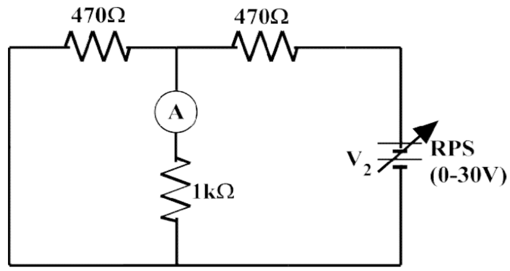
b) SuperpositionTheorem:<u>Circ uit Diagram:</u>



(a)



(b)



(c)

Fig2:CircuitDiagramforSuperpositionTheorem

Procedure:

1. Connectthecircuitas showninthe Fig2(a),applysomeinputvoltageV_1andV_2 andobservethecurrent(I) throughthe1kΩ resistor.
2. Connectthecircuitasshowninfig2(b),andapplythesamevoltageV_1asinstep1andobservethecurrent(I_1)throughthe1kΩresistor.
3. Connectthecircuitasshowninfig2(c),andapplythesamevoltageV_2asinstep1andobservethecurrent(I_2)throughthe1kΩresistor.
4. CompareIwith (I_1+I_2)takingcareofsigns properlyto verifythetheorem.
5. Repeattheprocedurefromstep1tostep4forfivedifferentcombinationsofvoltages V_1andV_2

Table–II SuperpositionTheorem:ForV_S =10,20v

Sl.No.	ITma	I1ma	I2ma	Computed current(I_T=I+I_2) ma	Error	%Error
1.	8.3	4.1	4.2	8.3	0	0
2	16.18	8.16	7.99	16.15	0.03	3

RESULT: HenceTheThevenin'sandsuperpositiontheoremsAreverified.

Discussion:

1) Canyousuggest anyalternativeprocedure forthedetermination ofthevenin'sresistanceR_{Th}?
2) Isthereanyrestrictionforthechoiceofcircuitelements?
   i) Whileconsideringtheeffectofasinglesource,theothersource isshortcircuitedwhy?Howfarisitjustified?

EXPERIMENTNO. 09(a)
V-I CHARACTERISTICS P-NJUNCTIONDIODE

AIM:1.ToobserveanddrawtheForwardandReversebiasV-ICharacteristicsofaP-NJunction diode.

2.Tocalculatestaticanddynamic resistanceinbothforwardandReverse BiasCondition.

EQUIPMENTREQUIRED:

SNO	NAMEOFTHEEQUIPMENT	QUANTITY
1	P-NDiodeIN4007	1No.
2	Regulated Powersupply(0-30V)	1No.
3	Resistor1KΩ	1No.
4	Ammeter(0-20mA)	1No
5	Ammeter(0-200µA)	1No.
6	Voltmeter(0-20V)	2No.
7	Breadboard	1No.
8	Connectingwires	RequiredNo.

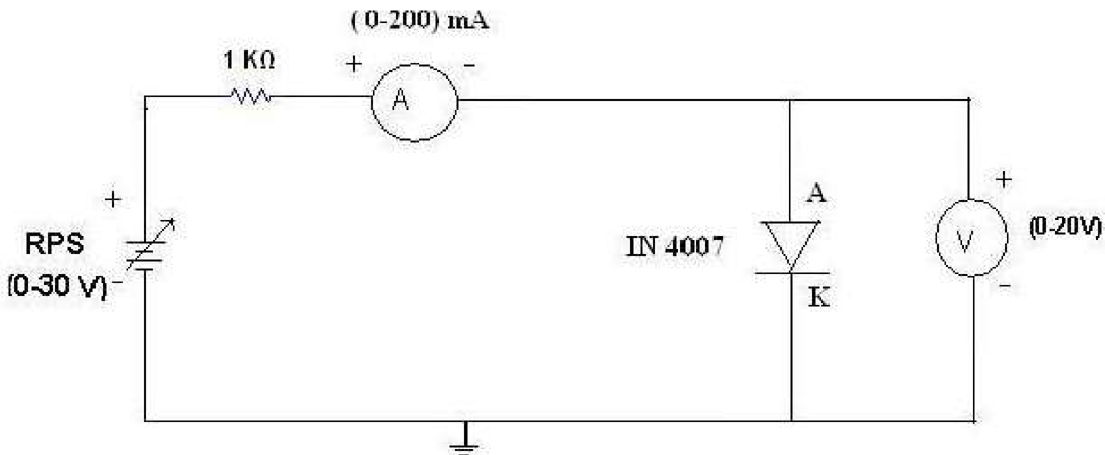
THEORY:

A P-N junction diode conducts only in one direction. The V-I characteristics of thediode are curve between voltage across the diode and current flowing through the diode. Whenexternal voltage is zero, circuit is open and the potential barrier does not allow the current toflow. Therefore, the circuit current is zero. When P-type (Anode) is connected to +ve terminaland n- type (cathode) is connected to –ve terminal of the supply voltage is known as forwardbias. The potential barrier is reduced when diode is in the forward biased condition. At someforward voltage, the potential barrier altogether eliminated and current starts flowing throughthe diode and also in the circuit. Then diode is said to be in ON state. The current increaseswithincreasingforwardvoltage.

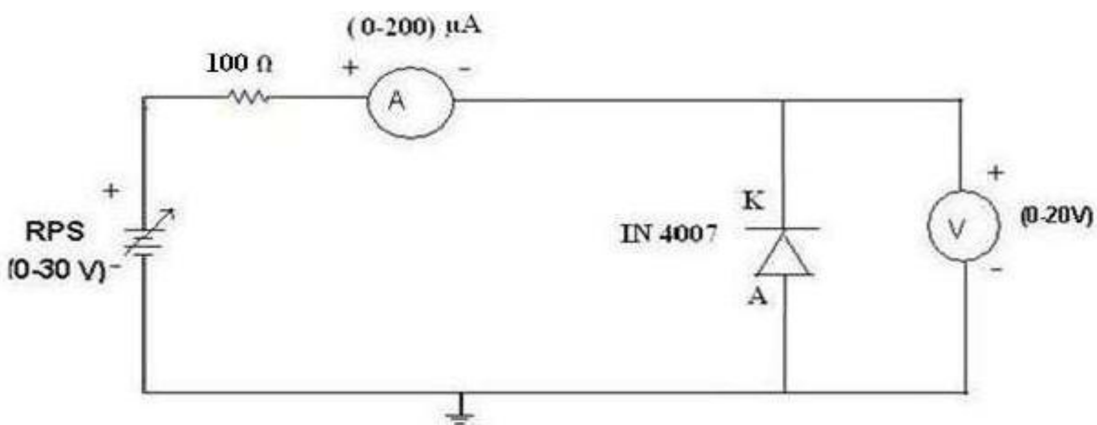
When N-type (cathode) is connected to +ve terminal and P-type (Anode) is connected –veterminal of the supply voltage is known as reverse bias and the potential barrier across thejunction increases. Therefore, the junction resistance becomes very high and a very smallcurrent (reverse saturation current) flows in the circuit. Then diode is said to be in OFF state.Thereversebiascurrent isdue to minoritychargecarriers.

CIRCUITDIAGRAM:

A) Forwardbias:

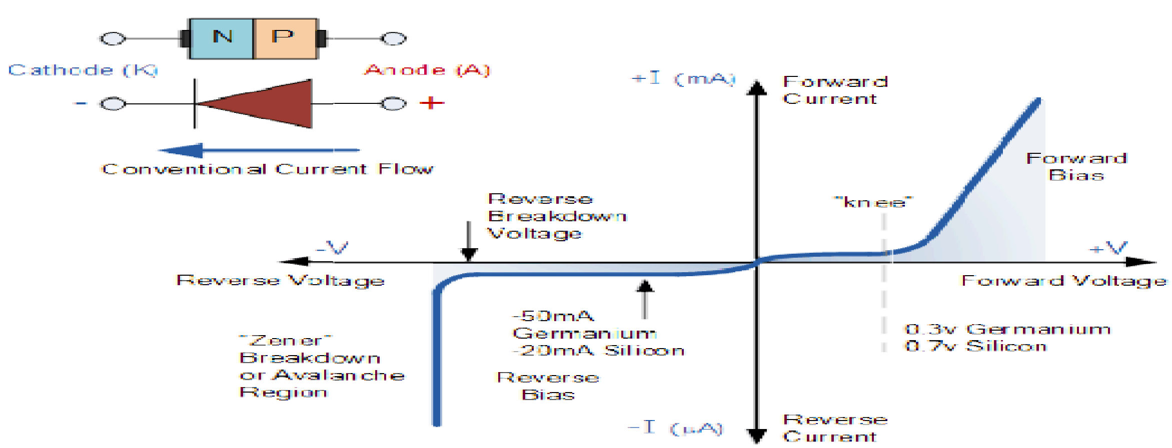


B) ReverseBias:



MODELGRAPH

:



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OBSERVATIONS:

A) FORWARDBIAS:

S.NO	Applied Voltage(V)	ForwardVoltage (V_f)	ForwardCurrent(I_f(mA))
1	0V	0V	0mA
2	0.1V	300mV	0mA
3	0.3V	319.2mV	0.04mA
4	0.5V	450mV	0.08mA
5	0.7V	0.495V	0.22mA
6	1V	0.5V	0.47mA
7	2V	0.596V	1.58mA
8	3V	0.621V	2.56mA
9	4V	0.639V	3.63mA
10	5V	0.651V	4.57mA

B) REVERSEBIAS:

S.NO	Applied Voltage(V)	ReverseVoltage(V_R)	ReverseCurrent(I_R(μA))
1	1V	-1.1V	0
2	2 V	-2V	0.1
3	3 V	-3V	0.2
4	4 V	-4.4V	0.3
5	5 V	-5.17V	0.4
6	6 V	-6.27V	0.7

CALCULATIONS:

CalculationofStaticandDynamicResistanceforagivendiode.

StaticResistance , $R_s = V_f/I_f$ =

DynamicResistance, $R_D = \Delta V_f/\Delta I_f$ =

InReversebiascondition:

StaticResistance,

$R_S = V_R/I_R$ =DynamicResistance,R

$_D = \Delta V_R/\Delta I_R$ =

PROCEDURE:

A) FORWARDBIAS:

1. Connectionsaremadeasperthecircuitdiagram.
2. forforwardbias,theRPS+veisconnectedtotheanodeofthediodeandRPS–veisconnectedtothecathode of thediode
3. Switchonthepowersupplyandincreasestheinputvoltage(supplyvoltage)inStepsof0.1V
4. Notedownthecorrespondingcurrentflowingthroughthediodeandvoltageacrossthediodeforeachand everystepof the inputvoltage.
5. Thereadingofvoltageandcurrentaretabulated.
6. Graphisplottedbetweenvoltage(V_f)onX-axisandcurrent(I_f)onY-axis.

B) REVERSEBIAS:

1. Connectionsaremadeasperthecircuitdiagram
2. Forreversebias,theRPS+veisconnectedtothecathodeofthediodeandRPS–veisconnectedtotheanode of thediode.
3. Switchonthepowersupplyandincreasetheinputvoltage(supplyvoltage)inStepsof1V.
4. Notedownthecorrespondingcurrentflowingthroughthediodevoltageacrossthediodeforeachandevery step oftheinputvoltage.
5. Thereadingsofvoltageandcurrentaretabulated
6. Graphisplottedbetweenvoltage(V_R)onX-axisandcurrent(I_R)onY-axis.

PRECAUTIONS:

1. Alltheconnectionsshouldbecorrect.
2. Parallaxerrorshouldbe avoidedwhiletakingthereadingsfromtheAnalogmeters.

RESULT:V-ICharacteristics of PN junction diode have been observed.

POSTLABQUESTIONS:

1. Definedepletionregionofadiode?
2. Whatismeantbytransition&spacechargecapacitanceofadiode?
3. IstheV-IrelationshipofadiodeLinearorExponential?
4. Definecut-involtageofadiodeandspecifythevaluesforSiandGediodes?
5. Whataretheapplicationsofap-ndiode?
6. DrawtheidealcharacteristicsofP-Njunctiondiode?
7. Whatisthediodeequation?
8. WhatisPIV?
9. Whatisthebreakdownvoltage?
10. WhatistheeffectoftemperatureonPNjunctiondiodes?
11. Specificationsofdiodes

Experiment No-09(b)

INPUTANDOUTPUTCHARACTERISTICSOFTRANSISTOR CBCONFIGURATION

AIM:1.Toobserveanddrawtheinputandoutputcharacteristicsofatransistorconnectedincommonbaseconfiguration.

EQUIPMENTREQUIRED:

SNO.	NAMEOFTHEEQUIPMENT	QUANTITY
1	Transistor,BC107	1No.
2	Regulatedpowersupply(0-30V)	1No.
3	Voltmeter(0-20V)	-2No.
4	Ammeters(0-10mA)	2No.
5	Resistor,1KΩ	2No
6	Breadboard	1No.
7	Connectingwires	Required No.

THEORY:

A transistor is a three terminal active device. The terminals are emitter, base, collector. In CBconfiguration, the base is common to both input (emitter) and output (collector). For normal operation,the E-B junction is forward biased and C-B junction is reverse biased.InCB configuration, $I_E$is +ve,I_C is–ve and$I_B$is–ve.So,

$$V_{EB}=F1(V_{CB},I_E) \text{ and } I_C=F2(V_{EB},I_B)$$

Withanincreasingthereversecollectorvoltage,thespace-chargewidthattheoutputjunctionincreases and the effective base width 'W' decreases. This phenomenon isknown as "Early effect".Then, there will be less chance for recombination within the base region. With increase of chargegradient with in the base region, the current of minority carriers injected across the emitter junctionincreases.

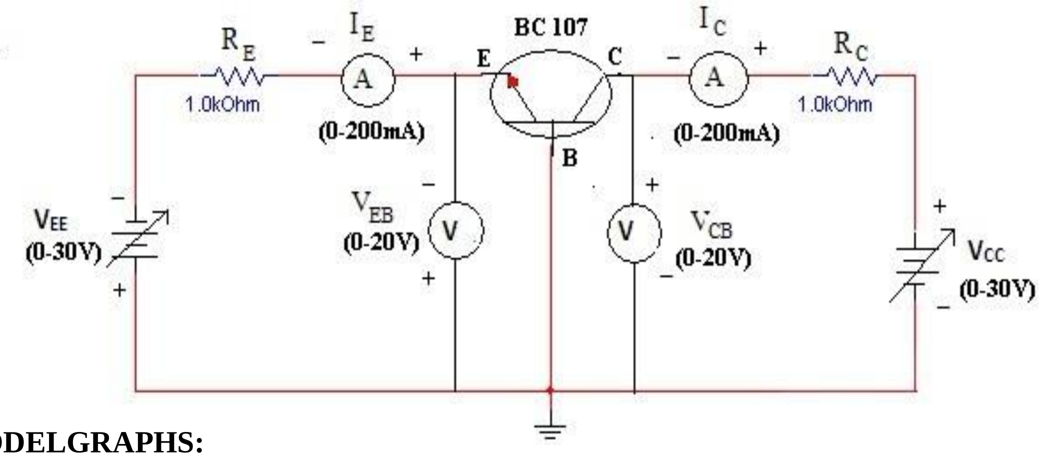
ThecurrentamplificationfactorofCBconfigurationisgivenby,

$$\alpha=\Delta I_C/\Delta I_E$$

InputResistance,$r_i=\Delta V_{BE}/\Delta I_E$ atConstantV_{CB}

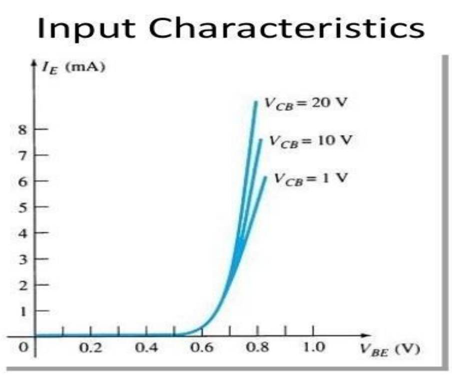
OutputResistance,$r_o=\Delta V_{CB}/\Delta I_C$ atConstantI_E

CIRCUITDIAGRAM:

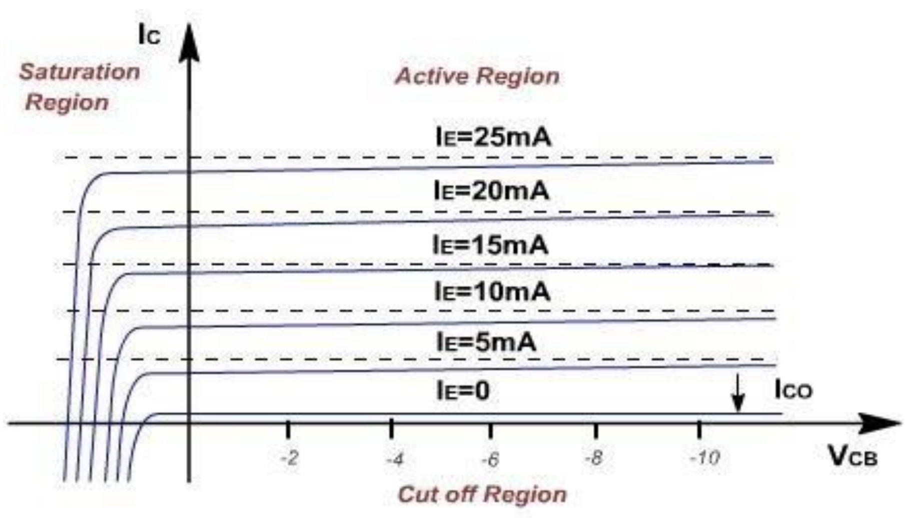


MODELGRAPHS:

A) INPUTCHARACTERISTICS



B) OUTPUTCHARACTERISTICS



OBSERVATIONS:

A) INPUTCHARACTERISTICS:

VEE(V)	V_{CB}=1V		V_{CB}==2V		V_{CB}=4V	
	V_{EB}(V)	I_E(mA)	V_{EB}(V)	I_E(mA)	V_{EB}(V)	I_E(mA)

B) OUTPUTCHARACTERISTICS:

V_{CC}(V)	I_E=10mA		I_E=20mA		I_E=30mA	
	VCB(V)	IC(mA)	VCB(V)	IC(mA)	VCB(V)	IC(mA)

PROCEDURE:

A) INPUTCHARACTERISTICS:

1. Connectionsaremadeasperthecircuitdiagram.
2. Forplottingtheinputcharacteristics,theoutputvoltageV_{CE}iskeptconstantat0Vandfordifferentvalueso fV_{EE}note downthevaluesof$I_E$andV_{BE}.
3. RepeattheabovestepkeepingV_{CB}at2V,4V,and6Vandallthereadingsaretabulated.
4. Agraphisdrawnbetween$V_{EB}$and$I_E$forconstantV_{CB}.

B) OUTPUTCHARACTERISTICS:

1. Connectionsaremadeasperthecircuitdiagram.
2. Forplottingtheoutputcharacteristics,theinput$I_E$iskeptconstantat0.5mAandfordifferentvaluesofV_{CC}, notedown thevaluesof$I_C$andV_{CB}.
3. Repeattheabovestepforthevaluesof$I_E$at1mA,5mAandallthereadingsaretabulated.
4. AgraphisdrawnbetweenV_{CB}andIcforconstantI_E

PRECAUTIONS:

1. Thesupplyvoltagesshouldnotexceedtheratingofthetransistor.

2. Metersshouldbeconnectedproperlyaccordingtotheirpolarities.

RESULT: Inputandoutputcharacteristicsofatransistorconnectedincommonbaseconfiguration.

POSTLABQUESTIONS:

1. Whatistherangeofαforthetransistor?
2. DrawtheinputandoutputcharacteristicsofthetransistorinCBconfiguration?
3. Identifyvariousregionsinoutputcharacteristics?
4. Whatistherelationbetweenαandβ?
5. WhataretheapplicationsofCBconfiguration?
6. WhataretheinputandoutputimpedancesofCBconfiguration?
7. Defineα(alpha)?
8. Whatisearlyeffect?
9. DrawCircuitdiagramofCBconfigurationforPNPtransistor?
10. WhatisthepowergainofCBconfiguration?

EXPERIMENTNO.10(a)

HALF-WAVERECTIFIERWITHANDWITHOUTFILTER

AIM: Toexaminetheinputandoutputwaveformsofhalfwave Rectifierandalso Calculateitsloadregulation and ripplefactor.

1. WithFilter
2. WithoutFilter

EQUIPMENTREQUIRED:

SNO.	NAMEOFTHEEQUIPMENT	QUANTITY
1	DigitalMultimeter	1No.
2	Transformer(6V-0-6V)	1No.
3	Diode,1N4007	1No.
4	Capacitor100µf/470µf	1No.
5	DecadeResistanceBox	1No.
6	Breadboard	1No.
7	CRO	1No.
8	CROprobesConnectingwires	RequiredNo.

THEORY:
InHalfWaveRectification,WhenACsupplyisappliedattheinput,onlyPositiveHalfCycleappearsacrosstheload whereas,thenegativeHalfCycleissuppressed.Howthiscanbeexplainedasfollows:

During positive half-cycle of the input voltage, the diode D1 is in forward bias and conductsthrough the load resistor R_L. Hence the current produces an output voltage across the load resistor R_L,whichhasthesameshapeasthe+vehalfcycleoftheinputvoltage.

During the negative half-cycle of the input voltage, the diode is reverse biased and there is nocurrent through the circuit. i.e., the voltage across R_L is zero. The net result is that only the +ve halfcycle of the input voltage appears across the load. The average value of the half wave rectified o/pvoltageisthe valuemeasuredondcvoltmeter.

Forpracticalcircuits,transformercouplingisusuallyprovidedfortworeasons.

Thevoltagecanbestepped-uporstepped-down,asneeded.
Theacsourceiselectricallyisolatedfromtherectifier.Thus,preventingshockhazardsinthe secondarycircuit.
TheefficiencyoftheHalfWaveRectifieris40.6%

TheoreticalcalculationsforRipplefactor:WithoutFilter*:*

Vrms = Vm/2 Vm = 2Vrms Vdc =

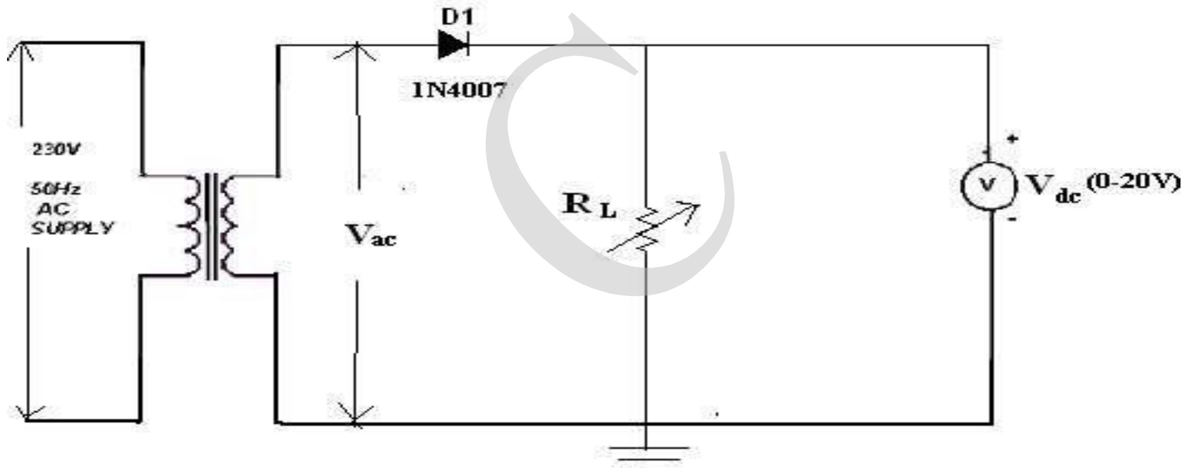
Vm/ΠRipplefactorr=$\sqrt{(Vrms/Vdc)^2-1}$=1.21

WithFilter:

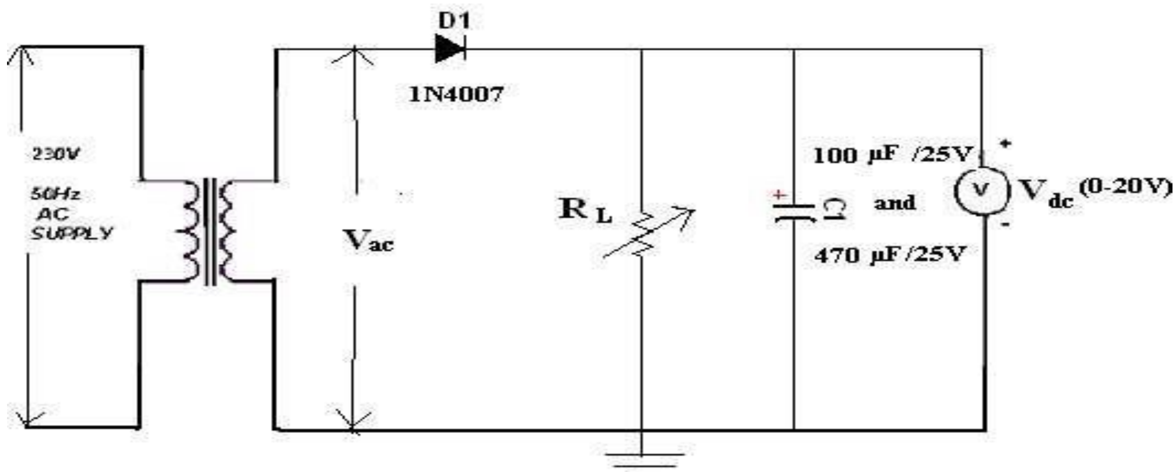
Ripplefactor,r=1/(2√3fCR)

CIRCUITDIAGRAM:

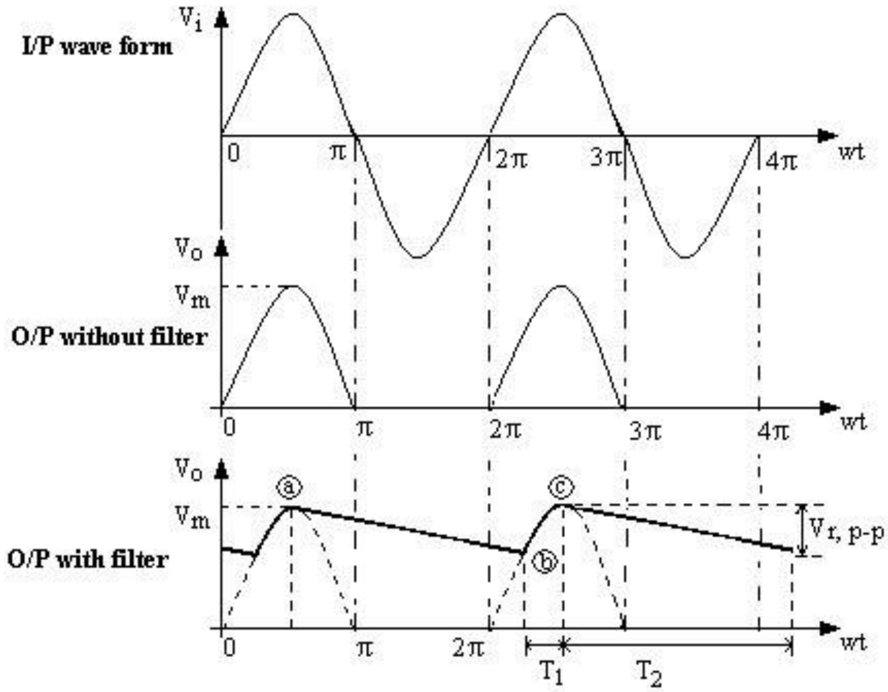
A) HALFWAVERECTIFIERWITHOUTFILTER



B) HALFWAVERECTIFIERWITHFILTER



MODELWAVEFORMS:AWAVEFORMS:



Half-wave Rectifier with capacitor filter wave form

PROCEDURE:

1. Connectionsaremadeasperthecircuitdiagram.
2. Connecttheprimarysideofthetransformertoacmainsandthesecondarysidetotherectifierinput.
3. Bythemultimeter,measuretheacinputvoltageoftherectifierand,acanddcvoltageattheoutputofther ectifier.
4. Findthetheoreticalvalueofdcvoltagebyusingtheformula,Vdc=Vm/Π
a. Where,Vm=2Vrms,(Vrms=outputacvoltage.)
5. 5.TheRipplefactoriscalculatedbyusingtheformula
6. r=acoutputvoltage/dcoutputvoltage.

WITHOUTFILTER:

S.No.	Load Resistance(R_L) in Kilo-ohms	Output voltage			
		V_{AC}(volts)	V_{DC}(volts)		
1	R_1	4.24	3.75		
2	R_2	4.3	3.5		
3	R_3	4.4	3.58		

WITH CAPACITORFILTER:

S.No.	Load Resistance(R_L) in Kilo-ohms	Output voltage			
		V_{AC}(volts)	V_{DC}(volts)		
1	R_1				
2	R_2				
3	R_3				

REGULATIONCHARACTERSTICS:

1. Connectionsaremadeasperthecircuitdiagram.
2. Byincreasingthevalueoftherheostat,thevoltageacrosstheloadandcurrentflowingthroughtheload aremeasured.
3. Thereadingistabulated.
4. Fromthevalueofno-loadvoltages,the%regulationiscalculatedusingtheformula,

%Regulation=[(V_{NL}-V_{FL})/V_{FL}]*100

PRECAUTIONS:

1. Theprimaryandsecondarysideofthetransformershouldbecarefullyidentified
2. Thepolaritiesofallthediodesshouldbecarefullyidentified.
3. Whiledeterminingthe%regulation,firstfullloadshouldbeappliedandthenitshouldbedecrementedinste ps

RESULT:

POSTLABQUESTIONS:

1. WhatisthePIVofHalfwaverectifier?
2. Whatistheefficiencyofhalfwaverectifier?
3. Whatistherectifier?
4. WhatisthedifferencebetweenthehalfwaverectifierandFullWaveRectifier ?
5. Whatistheo/pfrequencyofBridgeRectifier?
6. Whataretheripples?
7. Whatisthefunctionofthefilters?
8. WhatisTUF?
9. Whatis theaveragevalueofo/pvoltageforHWR?

EXPERIMENTNO.10(b)
FULL-WAVERECTIFIERWITHANDWITHOUTFILTER

AIM: ToExaminetheinputandoutputwaveformsofFullWaveRectifierandalsocalculateitsloadregulation andripplefactorwith FilterandwithoutFilter.

EQUIPMENTREQUIRED:

SNO.	NAMEOFTHEEQUIPMENT	QUANTITY
1	DigitalMultimeter	1No.
2	Transformer(6V-0-6V)	1No.
3	Diode,1N4007	2No.
4	Capacitor100µf/470µf	1No.
5	DecadeResistanceBox	1No.
6	Breadboard	1No.
7	CRO	1No.
8	CROprobesConnectingwires	RequiredNo.

THEORY:
Thecircuitofacenter-tappedfullwaverectifierusestwodiodesD1&D2.Duringpositivehalfcycleof secondary voltage (input voltage), the diode D1 is forward biased and D2 is reverse biased. So, thediodeD1conductsandcurrentflowsthroughloadresistorR$_L$.

Duringnegativehalfcycle,diodeD2becomesforwardbiasedandD1reversebiased.Now,D2conductsandcurrentf lowsthroughtheloadresistorR$_L$inthesamedirection.ThereisacontinuouscurrentflowthroughtheloadresistorR_L ,duringboththehalfcyclesandwillgetunidirectional current as show in the model graph. The difference between full wave and half waverectification is that a full wave rectifier allows unidirectional (one way) current to the load during theentire 360 degrees of theinputsignal andhalf-wave rectifierallows this only during one half cycle(180degree).

THEORITICALCALCULATIONS:

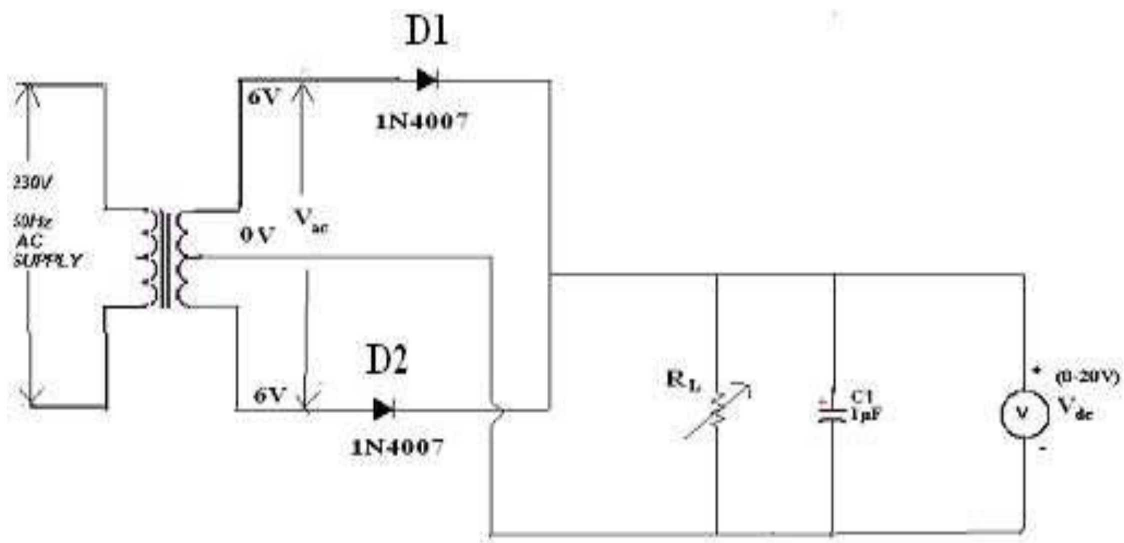
$V_{rms}=V_m/\sqrt{2}$ $V_m=V_{rms}\sqrt{2}$ $V_{dc}=2V_m/\Pi$

Withoutfilter:Ripplefactor,$r=\sqrt{(V_{rms}/V_{dc})^2-1}=0.812$

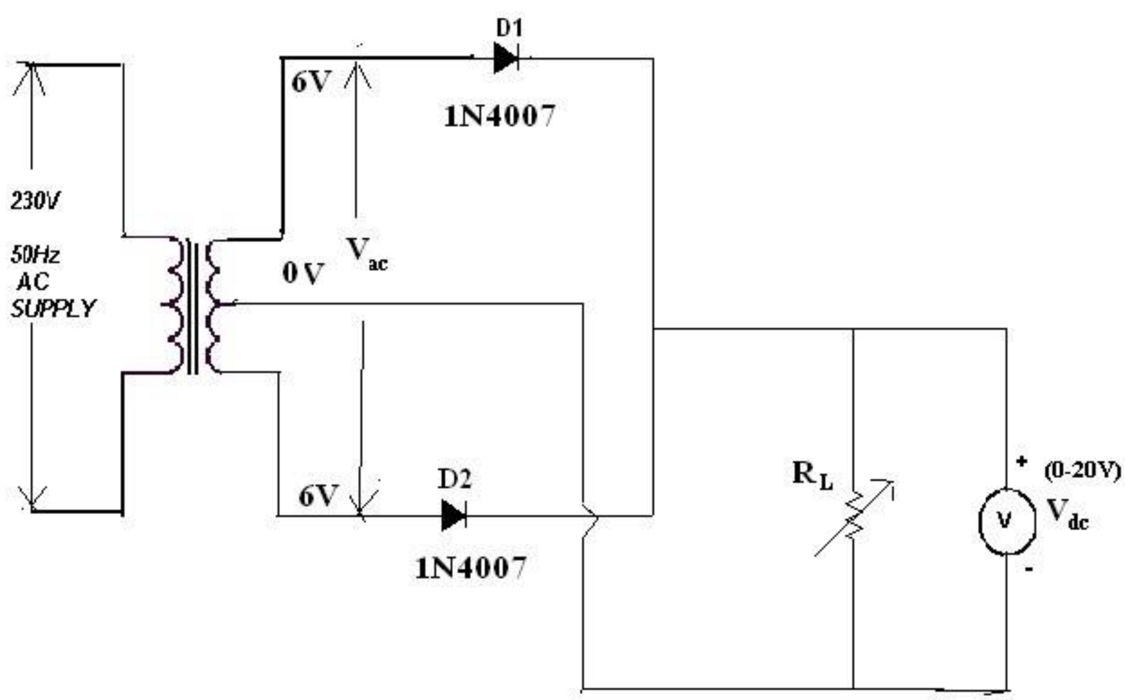
Withfilter: Ripplefactor,$r=1/(4\sqrt{3}fCR_L)$

CIRCUITDIAGRAM:

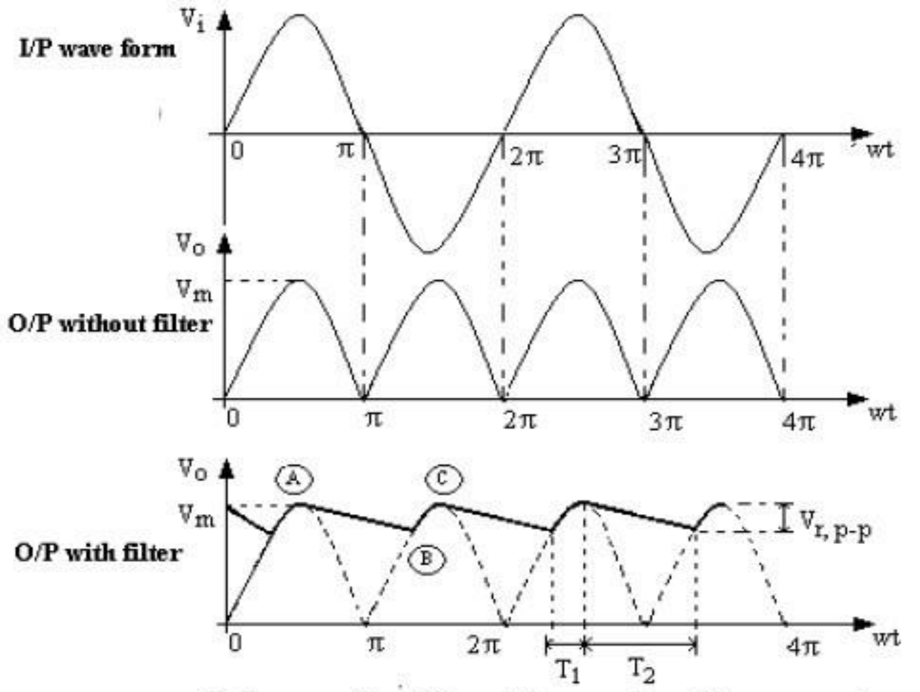
FULLWAVERECTIFIERWITHOUTFILTER:



FULLWAVERECTIFIERWITHFILTER:



MODELWAVEFORMS:



Full-wave Rectifier with capacitor filter wave form

WITHOUTFILTER:

V no load Voltage (Vdc) = V

S.No	Load Resistance R_L kilo-ohms	O/P Voltage (Vo)		Ripple factor $\left(\gamma = \frac{V_{ac}}{V_{dc}}\right)$	% of Regulation $\left(\frac{V_{NL} - V_{FL}}{V_{NL}} * 100\%\right)$
		V_{ac} (V)	V_{dc} (V)		
1	1				
2	2				
3	3				
4	4				
5	5				
6	6				
7	7				
8	8				

WITH CAPACITOR FILTER:

V no load Voltage (Vdc) = V

S.No	Load Resistance R_L kilo-ohms	O/P Voltage (Vo)		Ripple factor $\left(\gamma = \frac{V_{ac}}{V_{dc}}\right)$	% of Regulation $\left(\frac{V_{NL} - V_{FL}}{V_{NL}} * 100\%\right)$
		V_{ac} (V)	V_{dc} (V)		
1	1				
2	2				
3	3				
4	4				
5	5				
6	6				
7	7				
8	8				

PROCEDURE:

1. Connectionsaremadeasper thecircuitdiagram.
2. Connecttheacmainstotheprimarysideofthetransformerandthesecondarysidetotherectifier.
3. Measuretheacvoltageattheinputside oftherectifier.
4. Measurebothacanddcvoltagesattheoutputsidetherectifier.
5. FindthetheoreticalvalueofthedcvoltagebyusingtheformulaVdc=2Vm/Π
6. Connectthe filter capacitoracross theloadresistorandmeasurethe values ofVacandVdcattheoutput.
7. ThetheoreticalvaluesofRipplefactorswithandwithoutcapacitorarecalculated.
8. FromthevaluesofVacandVdcpracticalvaluesofRipplefactorsarecalculated.Thepracticalvaluesar e comparedwith theoreticalvalues.

PRECAUTIONS:

1. Theprimaryandsecondarysideofthetransformershouldbecarefullyidentified.
2. Thepolaritiesofallthediodesshouldbecarefullyidentified.

RESULT:

POSTLABQUESTIONS:

1. Defineregulationofthefullwaverectifier?
2. Definepeakinversevoltage(PIV)?AndwriteitsvalueforFull-waverectifier?
3. Ifoneofthediodesischangedinitspolaritieswhatwaveformwouldyouget?
4. Doestheprocessofrectificationalterthefrequencyofthewaveform?
5. WhatisripplefactoroftheFull-waverectifier?
6. Whatisthenecessityofthetransformerintherectifiercircuit?
7. Whataretheapplicationsofarectifier?
8. WhatismeantbyrippleanddefineRipplefactor?
9. Explainhowcapacitorhelpstoimprovetheripplefactor?
10. CanarectifiermadeinINDIA(V=230v,f=50Hz)beusedinUSA(V=110v,f=60Hz)?

EXPERIMENTNO.11
STUDY OF LOGIC GATES

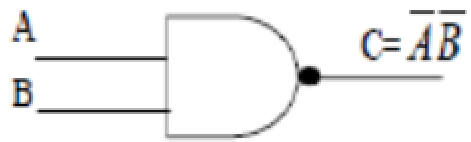
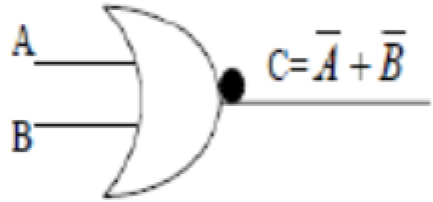
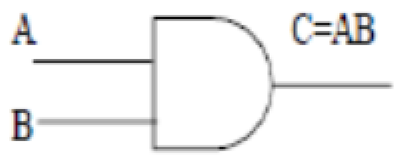
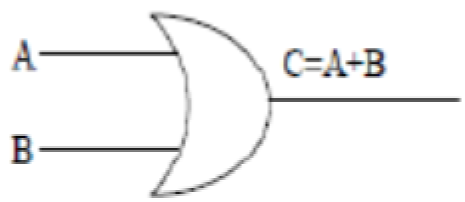
AIM: To study and verify the truth table of logic gates

OBJECTIVE:
Identify various ICs and their specification
a. OR gate
b. AND gate
c. NAND gate
d. NOR gate

COMPONENTS REQUIRED:
• Breadboard.
• Connecting wires.
• IC 7400, IC 7408, IC 7432, IC 7406, IC 7402, IC 7404, IC 7486

THEORY:
The basic logic gates are the building blocks of more complex logic circuits. These logicgates perform the basic Boolean functions, such as AND, OR, NAND, NOR, Inversion, Exclusive-OR, Exclusive-NOR. Fig. below shows the circuit symbol, Boolean function, and truth. It is seen from the Fig that each gate has one or two binary inputs, A and B, andone binary output, C. The small circle on the output of the circuit symbols designates thelogic complement. The AND, OR, NAND, and NOR gates can be extended to have morethan two inputs. A gate can be extended to have multiple inputs if the binary operation itrepresents is commutative and associative. These basic logic gates are implemented as small-scale integrated circuits (SSICs) or aspart of more complex medium scale (MSI) or very large-scale (VLSI) integrated circuits. Digital IC gates are classified not only by their logic operation, but also the specific logiccircuitfamily to which they belong. Each logic family has its own basic electronic circuitupon which more complex digital circuits and functions are developed. The following logicfamilies are the most frequently used.
TTL Transistor-transistor logic
ECL Emitter-coupled logic
MOS Metal-oxide semiconductor
CMOS Complementary metal-oxide semiconductor
TTL and ECL are based upon bipolar transistors. TTL has a popularity among logic families.ECL is used only in systems requiring high-speed operation. MOS and CMOS, are based onfield effect transistors. They are widely used in large scale integrated circuits because of theirhigh component density and relatively low power consumption. CMOS logic consumes far lesspower than MOS logic. There are various commercial integrated circuit chips available. TTLICs are usually distinguished by numerical designation as the 5400 and 7400 series.

PROCEDURE:
1. Check the components for their working.
2. Insert the appropriate IC into the IC base.
3. Make connections as shown in the circuit diagram.
4. Provide the input data via the input switches and observe the output on output LEDs

S.NO	GATE	SYMBOL	INPUTS A	INPUTS B	OUTPUT C
1.	NAND IC 7400		0	0	1
			0	1	1
			1	0	1
			1	1	0
2.	NOR IC 7402		0	0	1
			0	1	0
			1	0	0
			1	1	0
3.	AND IC 7408		0	0	0
			0	1	0
			1	0	0
			1	1	1
4.	OR IC 7432		0	0	0
			0	1	1
			1	0	1
			1	1	1

RESULT: Logic gates have been studied.

QUESTIONS:

1. WhyNAND & NOR gates are called universal gates?
2. Realize the EX – OR gates using minimum number of NAND gates.
3. Give the truth table for EX-NOR and realize using NAND gates?
4. What are the logic low and High levels of TTL IC’s and CMOS IC’s?
5. Compare TTL logic family with CMOS family?
6. Which logic family is fastest and which has low power dissipation?