UNIT-I-INTRODUCTION

CONTENTS

1. Measurement:

- Measurementofagivenquantityisessentiallyanactorresultofcomparisonbetweenthequantity(whosemagnitudeisunknown)andpredeterminedorpredefinedstandards.
- Twoquantities arecomparedtheresultisexpressedinnumericalvalues.

2. Basicrequirementsforameaningfulmeasurement:

- Thestandardusedforcomparisonpurposesmustbeaccuratelydefinedandshouldbecommonlyaccepted.
- Theapparatus usedandthemethodadoptedmustbeprovable(verifiable).

3. SignificanceofMeasurement

- ImportanceofMeasurementissimplyandeloquentlyexpressedinthefollowingstatementoffamousphysicistLordKelvin:”*Ioftensaythatwhenyoucanmeasurewhatyouarespeakingaboutandcanexpressitinnumbers,youknowsomethingaboutit;whenyoucannotexpressinitnumbersyourknowledgeisofmeager andunsatisfactorykind*”

4. MethodsofMeasurement

- DirectMethods
- IndirectMethods

- DIRECTMETHODS:Inthesemethods,theunknownquantity(calledthemeasurand)is directlycomparedagainstastandard.

- INDIRECTMETHOD:Measurementsbydirectmethodsarenotalwayspossible,feasibleandpracticable.Inengineeringapplicationsmeasurementsystemsareusedwhichrequireneed of indirectmethodformeasurementpurposes.

5. InstrumentsandMeasurementSystems

- Measurementinvolves the useofinstrumentsasa physicalmeans ofdeterminingquantitiesorvariables.
- Becauseofmodularnature ofthe elementswithinit,itiscommon to referthemeasuringinstrumentas aMEASUREMENTSYSTEM.

6. EvolutionofInstruments

- Mechanical
- Electrical
- ElectronicInstruments.

- MECHANICAL:Theseinstrumentsareveryreliableforstaticandstableconditions.Buttheirdisadvantageisthattheyareunabletorespondrapidlytomeasurementsofdynamicandtransientconditions.

ELECTRICAL:Itisfasterthanmechanical,indicatingtheoutputarerapidthanmechanicalmethods.Butitdependsonthemechanicalmovementofthemeters.Theresponseis 0.5to24seconds.

ELECTRONIC:Itismorereliablethanothersystem.Itusessemiconductordevicesandweaksignalcanalso bedetected

7. ClassificationofInstruments

- AbsoluteInstruments.
- SecondaryInstruments.

ABSOLUTE:Theseinstrumentsgivethe magnitudeifthe quantity undermeasurementtermsofphysicalconstantsoftheinstrument.

SECONDARY:Theseinstruments arecalibratedbythecomparisonwithabsoluteinstrumentswhichhavealreadybeencalibrated.

Furtheritis classifiedas

- DeflectionTypeInstruments
- NullTypeInstruments.

- Functionsofinstrumentandmeasuringsystemcanbeclassifiedintothree.Theyare:

i) Indicatingfunction.
ii) Recordingfunction.
iii) Controllingfunction.

- Applicationofmeasurementsystemsare:

i) Monitoring ofprocess andoperation.
ii) Controlofprocessesandoperation.
iii) Experimentalengineeringanalysis.

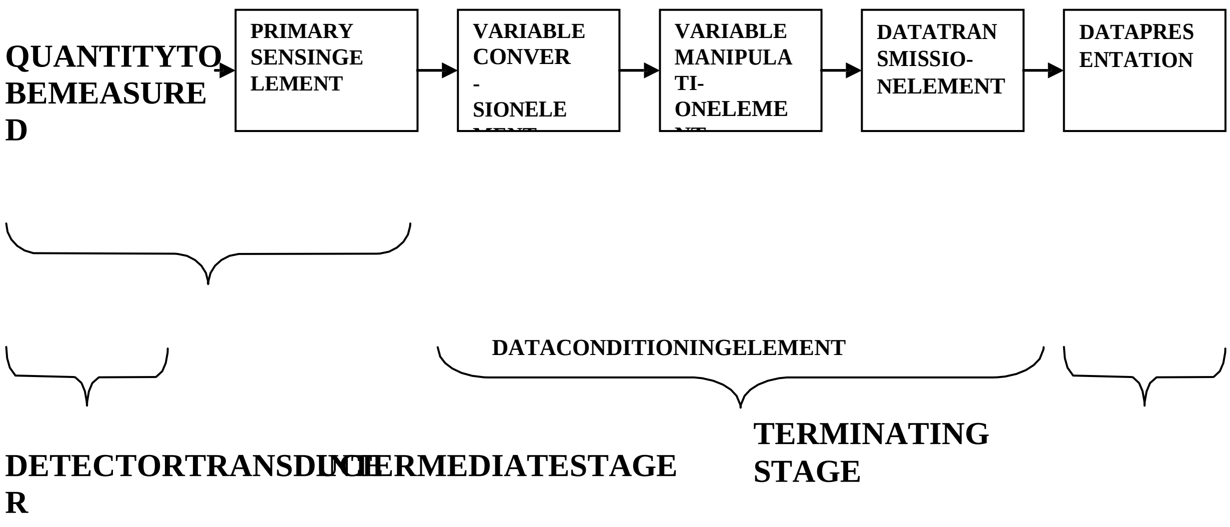
8. TypesofInstrumentationSystem

- IntelligentInstrumentation(datahasbeenrefinedforthepurposeofpresentation)
- DumbInstrumentation(data mustbeprocessedbytheobserver)

9. ElementsofGeneralizedMeasurementSystem

- Primarysensingelement.
- Variableconversionelement.
- Datapresentationelement.
- PRIMARYSENSINGELEMENT:Thequantityundermeasurementmakesitsfirstcontactwiththeprimarysensingelementofameasurementsystem.
- VARIABLECONVERSIONELEMENT:Itconverts theoutputoftheprimarysensingelementintosuitableformto preservetheinformationcontentoftheoriginalsignal.
- DATAPRESENTATIONELEMENT:Theinformationaboutthequantityundermeasurementhastobe conveyedtothepersonnelhandlingtheinstrumentorthesystemformonitoring,controloranalysis purpose.

10. FunctionalElementsofanInstrumentationSystem



11. StaticCharacteristicsofInstrumentsandMeasurementSystems

Applicationinvolvedmeasurement ofquantitythatareeitherconstant orvaries slowlywithtimeis knownasstatic.

- Accuracy
- Drift
- DeadZone
- StaticError
- Sensitivity
- Reproducibility

StaticCharacteristics

- Staticcorrection
- Scalerange
- Scalespan
- Noise
- DeadTime
- Hysteresis.
- Linearity

- **ACCURACY**:Itisthecloseneswithaninstrumentreadingapproachesthetruevalueofthequantitybeingmeasured.
- **TRUEVALUE**:Truevalueofquantitymaybedefinedastheaverageofaninfiniteno. ofmeasuredvalue.
- **SENSITIVITY**isdefinedastheratioofthemagnitudeoftheoutputresponsetothatofinputresponse.
- **STATICERROR**:Itisdefinedasthedifferencebetweenthemeasuredvalueandtruevalueofthequantity.
- **Reproducibility**isspecifiedin terms ofscalereadingsoveragivenperiod oftime.

- **Drift**isanundesirablequalityinindustrialinstrumentsbecauseitisrarelyapparentandcannotbemaintained.

Itisclassifiedas

- Zerodrift
- Spandriftor sensitivitydrift
- Zonaldrift.

Noise

- Aspuriouscurrentorvoltageextraneoustothecurrentorvoltageofinterestinanelectricalorelectroniccircuitiscallednoise.

12. DynamicCharacteristicsofMeasurementSystem

- Speed ofresponse
- Measuringlag
- Fidelity
- Dynamicerror

- **SPEEDOFRESPONSE**:It isdefinedastherapiditywithwhichameasurementsystemrespondstochangesinmeasuredquantity.Itisoneofthedynamiccharacteristicsofameasurementsystem.

- **FIDELITY:**Itisdefinedasthedegreetowhichameasurementsystemindicateschangesin themeasuredquantitywithoutanydynamicerror.

DynamicError

- Itisthedifferencebetweenthetruevalueofthequantitychangingwithtimeandthevalueindicatedbythemeasurementsystemifnostaticerrorisassumed.Itisalsocalledmeasurementerror. Itisonethedynamiccharacteristics.

MeasuringLag

- Itistheretardationdelayintheresponseofameasurementsystemtochangesinthemeasuredquantity.Itis of2types:
- Retardationtype:The responsebeginsimmediatelyaftera changeinmeasuredquantityhas occurred.
- Timedelay:Theresponseofthemeasurementsystembeginsafteradeadzoneaftertheapplicationoftheinput.

13. ErrorsinMeasurement

- LimitingErrors (GuaranteeErrors)
- KnownError

SystematicErrors

- **INSTRUMENTALERROR**:Theseerrors arisedueto3reasons-
- Due toinherentshortcomingsin theinstrument
- Due tomisuseoftheinstrument
- Due toloadingeffectsoftheinstrument
- **ENVIRONMENTALERROR:**Theseerrorsareduetoconditionsexternaltothemeasuring device.Thesemaybeeffectsoftemperature,pressure,humidity,dustorofexternalelectrostaticormagneticfield.
- OBSERVATIONALERROR:Theerroronaccountofparallaxistheobservationalerror.

Residualerror

Thisisalsoknownasresidualerror.Theseerrorsareduetoamultitude

ofsmallfactorswhichchangeorfluctuatefromonemeasurementtoanother.Thehappeningsordisturbancesaboutwhichweareunawarearelumpedtogetherandcalled“Random”or“Residual”.Hencetheerrorscausedbythesearecalledrandomorresidualerrors.

14. Statisticalevaluationofmeasurementdata

ArithmeticMean

- Themostprobablevalueofmeasuredvariableisthearithmeticmeanofthenumberofreadingstaken.

Deviation

- Deviationisdepartureoftheobservedreadingfromthearithmeticmeanofthegroupofreadings.

StandardDeviation

- Thestandarddeviationofaninfinitenumberofdataisdefinedasthesquareroot ofthesumoftheindividualdeviationssquareddividedbythe numberofreadings.

Problem

Question:Thefollowing10observationwererecordedwhenmeasuringavoltage:

41.7,42.0,41.8,42.0,42.1,41.9,42.0,41.9,42.5,41.8volts.CalculateMean,Standard

Deviation,ProbableError andRange.

Answer

- Mean=41.97volt
- S.D=0.22volt
- Probableerror=0.15volt
- Range=0.8volt.

15. Calibration

- Calibrationofallinstrumentsisimportantsinceitaffordstheopportunitytochecktheinstrumentsagainsta knownstandardandsubsequentlytofinderrorsandaccuracy.
- CalibrationProcedureinvolveacomparisonoftheparticularinstrumentwitheither

➢ aPrimarystandard

- asecondarystandardwithahigheraccuracythantheinstrumenttobecalibrated.
- aninstrument ofknownaccuracy.

16. Standards

Astandardisaphysicalrepresentationofaunitofmeasurement.Theterm „standard‟isappliedtoapieceofequipmenthaving aknownmeasureofphysical quantity.

Types of Standards

- InternationalStandards(definedbased on internationalagreement)

- PrimaryStandards(maintainedbynationalstandardslaboratories)

- SecondaryStandards(usedbyindustrialmeasurementlaboratories)

- WorkingStandards(usedin generallaboratory)

TwoMarks

1. Whatis meant bymeasurement?

Measurementisanact ortheresult ofcomparisonbetweenthequantityandaPre-definedstandard.

2. Mention thebasicrequirements of measurement.

- Thestandardusedforcomparisonpurposemustbeaccuratelydefinedandshould becommonlyaccepted.
- Theapparatususedandthemethodadoptedmustbeprovable.

3. Whatarethe2methodsformeasurement?

- Directmethodand
- Indirectmethod.

4. Explainthefunctionofmeasurementsystem.

Themeasurementsystemconsistsofatransducingelementwhichconverts thequantitytobemeasuredin ananalogousform.theanalogoussignal is thenprocessedbysomeintermediatemeansandisthenfedtotheenddevicewhichpresents theresultsofthemeasurement.

5. DefineInstrument.

Instrumentisdefinedas adevicefordeterminingthevalueormagnitudeofaquantityorvariable.

6. List thetypes ofinstruments.

- The3typesof instruments are
- MechanicalInstruments
- ElectricalInstruments and
- ElectronicInstruments.

7. Classifyinstrumentsbasedontheirfunctions.

IndicatinginstrumentsIntegratinginstrumentsRecordinginstruments

8. Givetheapplications of measurementsystems.

- Theinstrumentsandmeasurementsystems aresuedfor
- Monitoring ofprocesses andoperations.

- Controlofprocessesandoperations.
- Experimentalengineeringanalysis.

9. Whycalibrationof instrumentis important?

Thecalibrationofallinstrumentsisimportantsinceitaffords theopportunitytochecktheinstrumentagainstaknownstandardandsubsequentlyto errors inaccuracy.

10. Explainthecalibrationprocedure.

Calibrationprocedureinvolves acomparisonoftheparticularinstrumentwitheither.

- Aprimarystandard
- Asecondarystandardwithahigheraccuracythantheinstrumenttobecalibratedor Aninstrument ofknownaccuracy.

11. DefineCalibration.

Itis theprocess bywhichcomparingtheinstrumentwithastandardtocorrecttheaccuracy.

UNIT-II-ELECTRICALANDELECTRONICINSTRUMENTS

CONTENTS

1. AnalogInstruments

Ananalogdeviceisoneinwhichtheoutputordisplayisacontinuousfunctionof timeandbears aconstantrelationto itsinput.

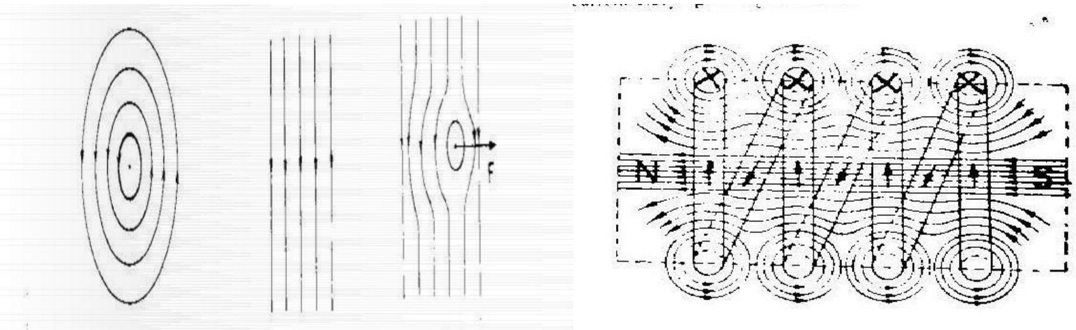
2. Classification

- Classifiedbaseduponthequantitytheymeasure(ammeter,voltmeter)
- Classifiedaccordingtothecurrentthatcanbemeasuredbythem.(DC,AC)
- Classifiedaccordingtotheeffectsusedforworking.
- ClassifiedasIndicating,Recording,AndIntegrating.
- Classifiedonthebasisofmethodusedforcomparingtheunknownquantity.(Direct/ Comparisonmeasurement)

3. Principleofoperation

- MagneticEffect
- ThermalEffect
- ElectrostaticEffect
- InductionEffect
- HallEffect

4. MagneticEffect



ForcebetweenCurrentcarryingMagnet

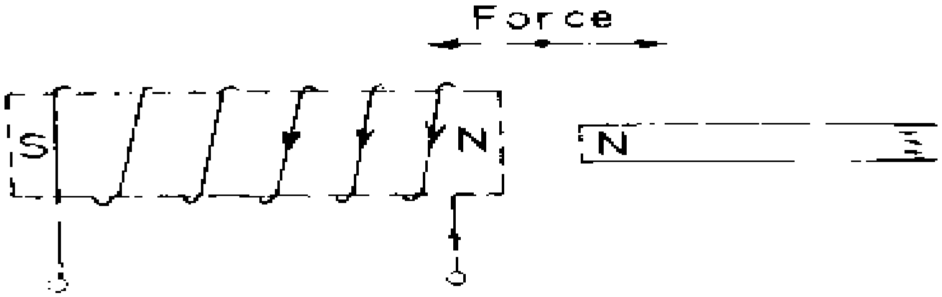


Fig. 7.3. Force between current carrying [illegible] magnet.

ForcebetweenTwoCurrentCarryingCoils

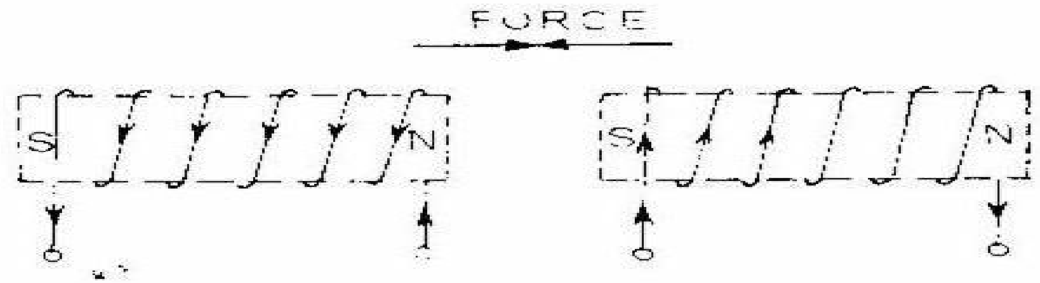
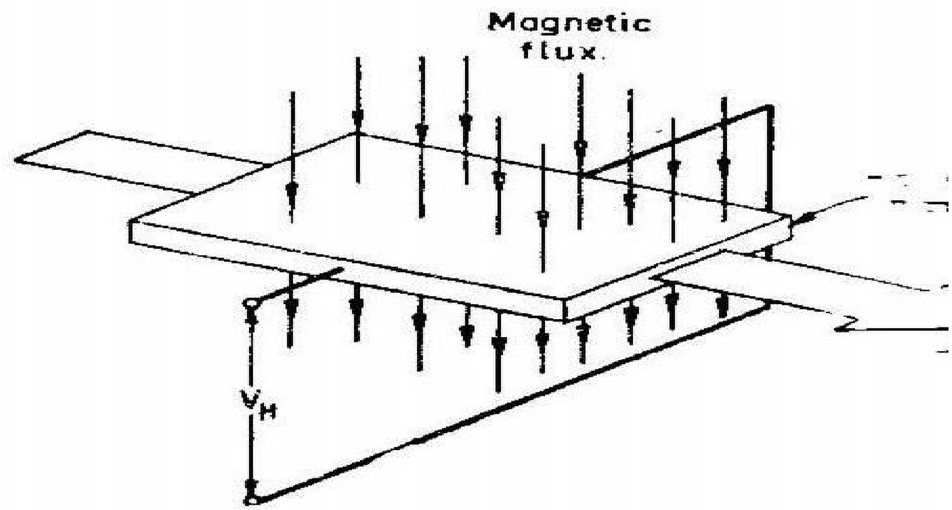


Fig. 7.4. Force between two current carrying coils.

HallEffects



OperatingForces

- DeflectingForce
- ControllingForce
- DampingForce

Supportingthemovingelement

- Suspension
- TautSuspension
- Pivotandjewelbearings

ControlSystems

- GravityControl
- SpringControl

5. AnalogAmmeters

- Ammetersareconnectedinseriesinthecircuitwhosecurrentistobemeasured.ThepowerlossinanammeterisI^2R_a.Thereforeammetersshouldhavealowelectricalresistancesothattheycauseasmallvoltage dropandconsequentlyabsorbsmallpower.

6. AnalogVoltmeters

- Voltmeters areconnectedin parallelinthecircuitwhosevoltageistobemeasured.Thepowerlossinanammeteris$V^{2/}R_V$.Thereforevoltmetersshouldhaveahighelectricalresistancesothattheycauseasmallvoltage dropandconsequentlyabsorbsmallpower.

7.TypesofInstruments

- Permanentmagnetmovingcoil(PMMC).
- MovingIron
- Electro-dynamometer type.
- Hotwiretype.
- Thermocoupletype.
- Inductiontype.
- Electrostatictype.
- Rectifiertype.

PMMC

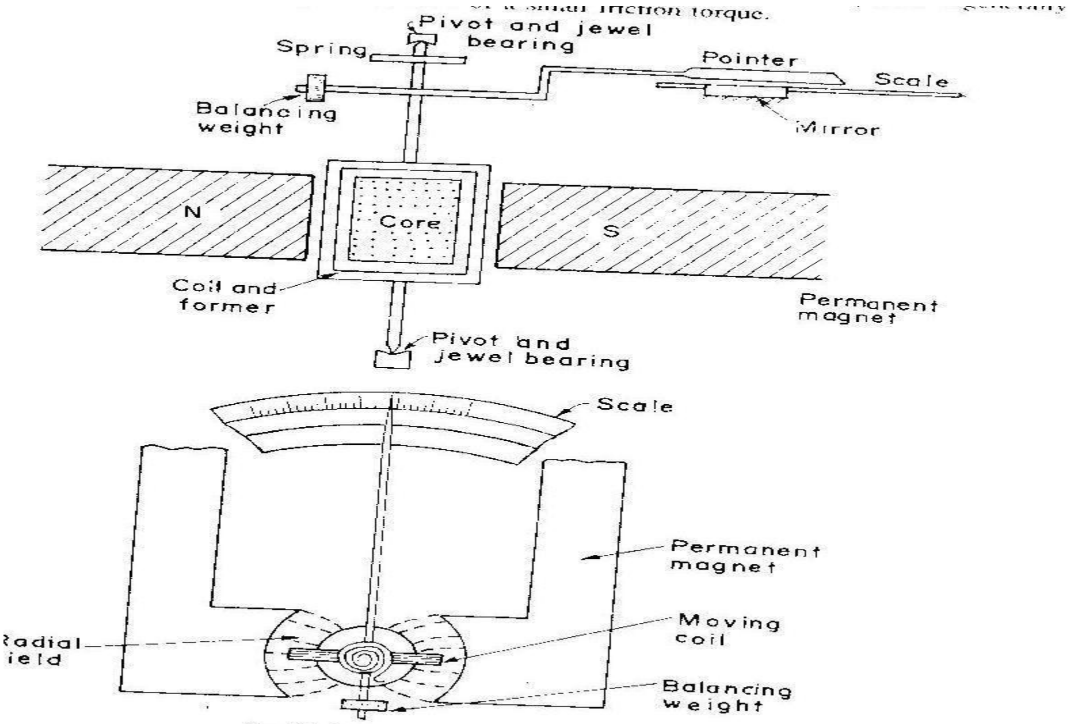


Fig. 9.1. Permanent magnet moving coil instrument.

MovingIronInstruments-AttractionType

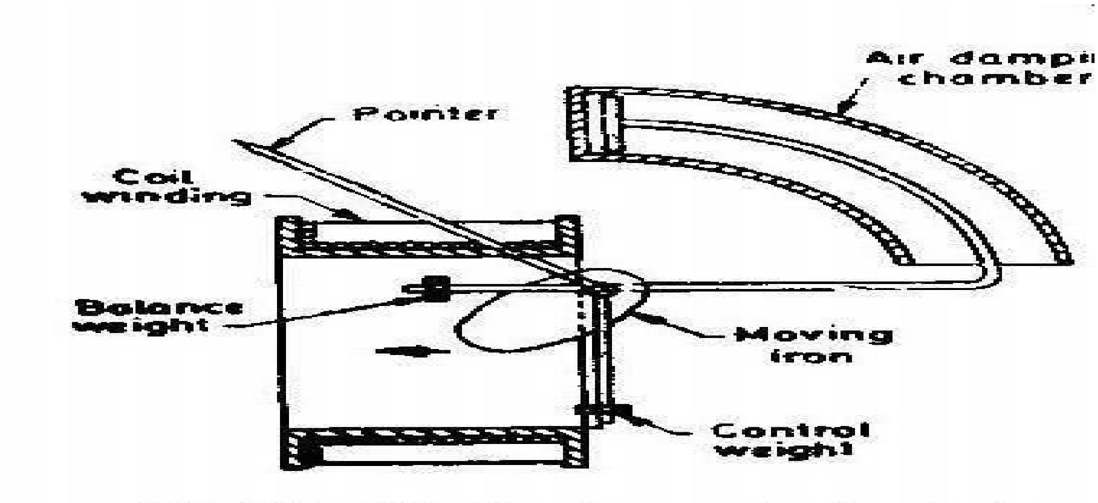
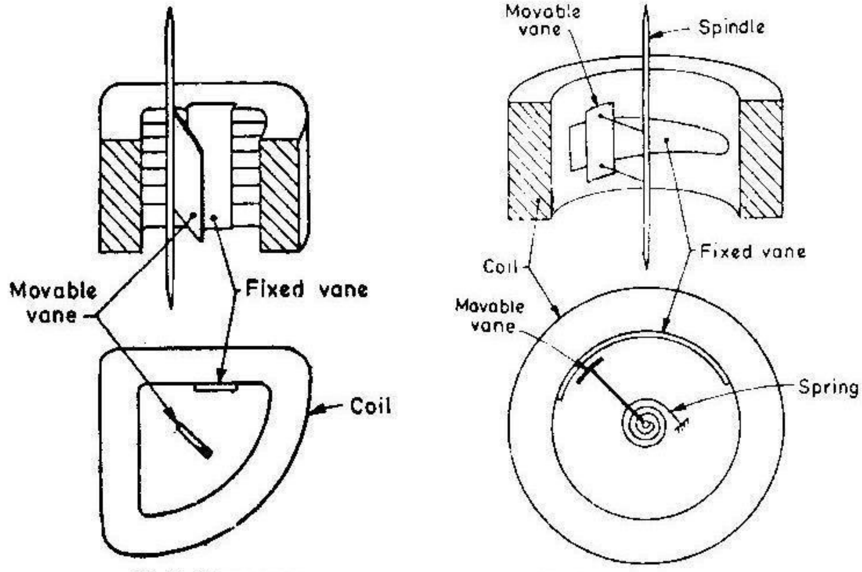


Fig. 9.24. Attraction type moving iron instrum

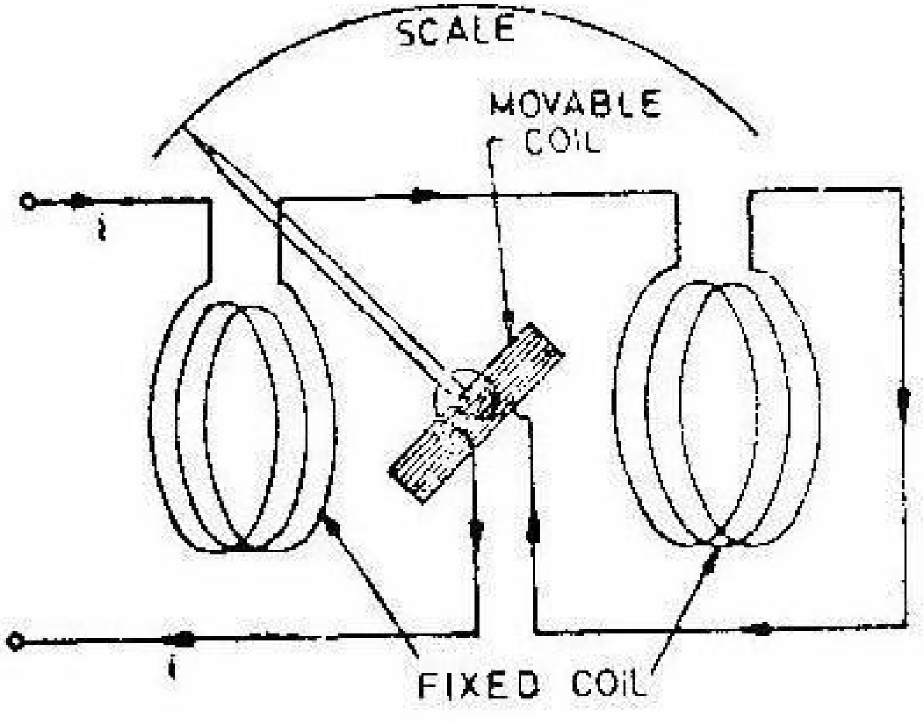
RepulsionTypeMovingIronInstruments



(a) Radial vane type.　(b) Co-axial vane type.

Fig. 9.25. Replusion type moving iron instruments.

ElectrodynamometerType



Wattmeter

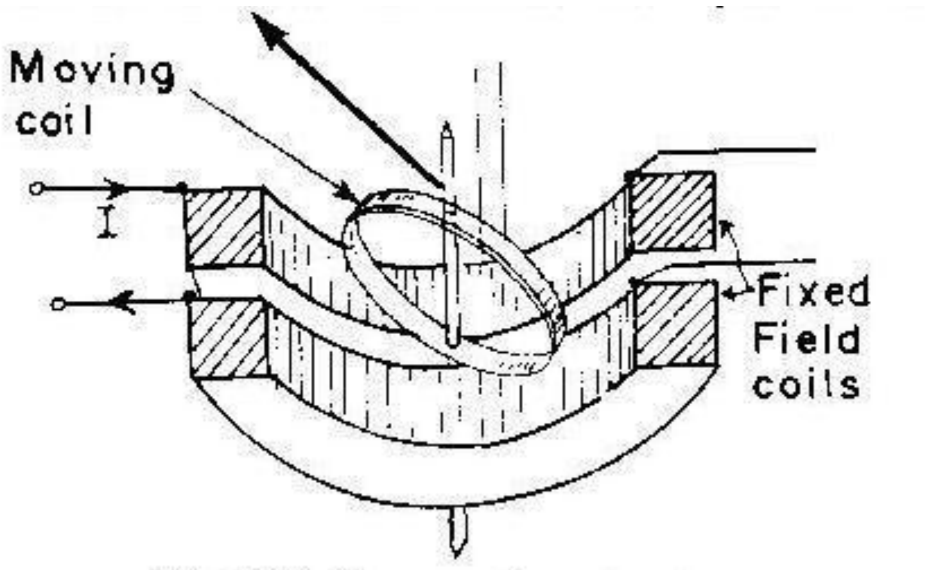


Fig. 11.2. Dynamometer wattmeter.

PowerMeasurementin3phase3wiresystem

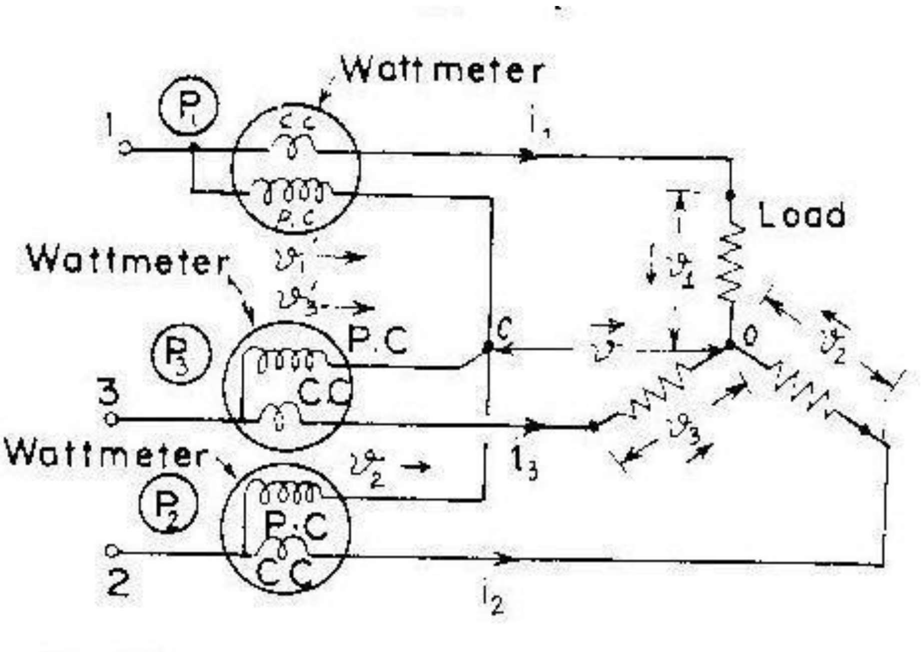


Fig. 11.23. Power measurement in a 3 phase 3 wire system.

Twowattmetermethod

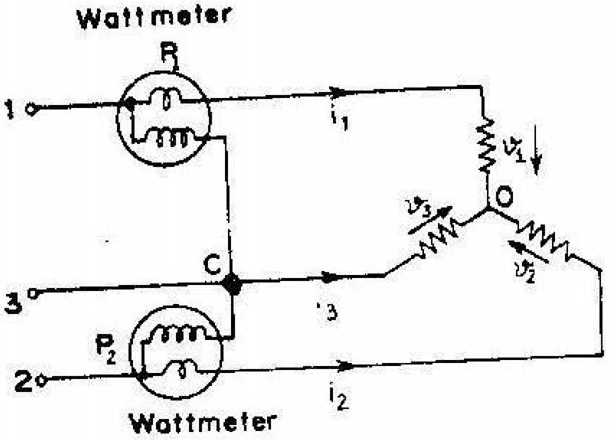


Fig. 11.25. Two wattmeter method (Star connection).

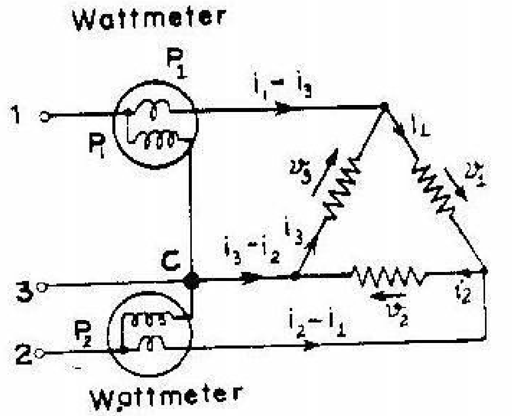


Fig. 11.26. Two wattmeter method (Delta connection

Energymeters

itions.

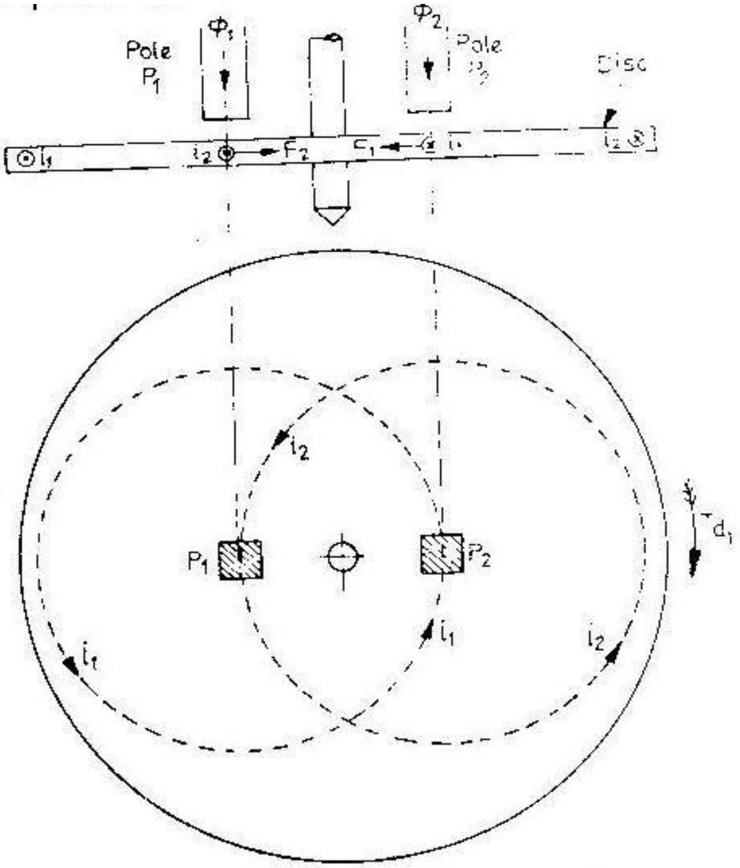


Fig. 12.1 Principle of working of an induction type instrument.

SinglePhaseEnergyMeter

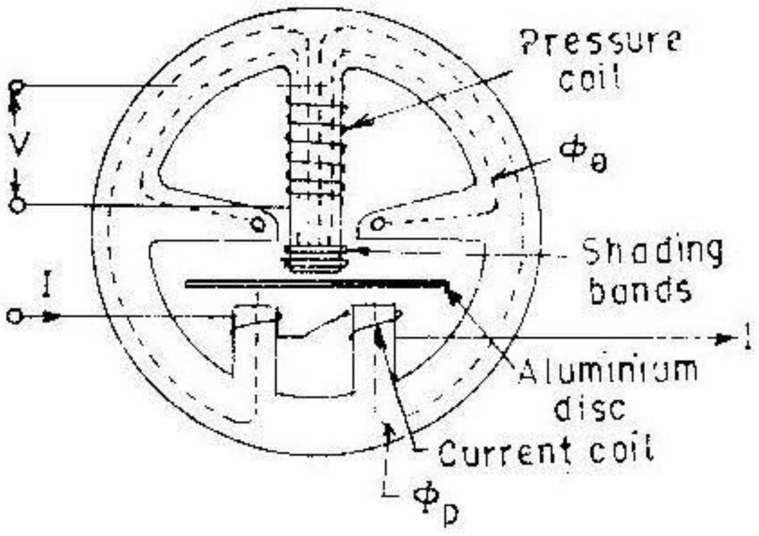


Fig. 12.3 Single phase energy meter.

PolyPhaseEnergyMeter

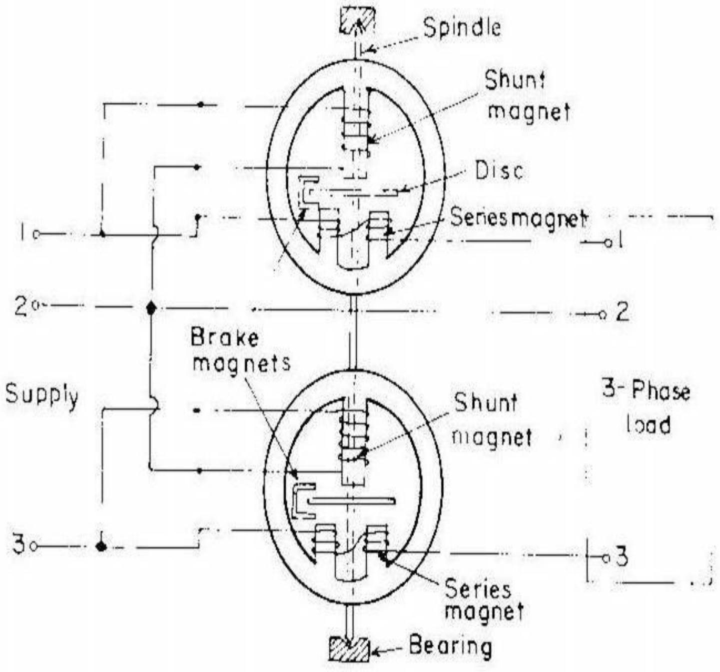


Fig. 12.13. Two element energy meter.

MovingCoilMeters

Thedesignofavoltmeter,ammeterorohmmeterbeginswithacurrent-sensitiveelement.Thoughmostmodernmetershavesolid-statedigitalreadouts,thephysicsismorereadilydemonstratedwithamovingcoilcurrentdetectorcalledagalvanometer.Sincethemodificationsofthecurrentsensorarecompact,itispracticaltohaveallthreefunctionsinasingleinstrumentwithmultiplerangesofsensitivity.Schematically,asinglerange"multimeter"mightbedesignedasillustrated.

Voltmeter

Avoltmetermeasuresthechangeinvoltagebetweentwopointsinanelectriccircuitandthereforemustbeconnectedinparallelwiththeportionofthecircuitonwhichthemeasurementismade.Bycontrast,anammetermustbeconnectedinseries.Inanalogywithawatercircuit,avoltmeterislikeameterdesignedtomeasurepressuredifference.Itisnecessaryforthevoltmetertohaveaveryhighresistancesothatitdoesnothaveanappreciableaffectonthecurrentorvoltageassociatedwiththemeasuredcircuit.Modernsolid-statemetershavedigitalreadouts,buttheprinciplesofoperationcanbebetterappreciatedbyexaminingtheoldermovingcoilmetersbasedongalvanometersensors.

Ammeter

Anammeterisaninstrumentformeasuringtheelectriccurrentinamperesinabranchofanelectriccircuit.Itmustbeplacedinserieswiththemeasuredbranch,andmusthaveverylowresistancetoavoidsignificantalterationofthecurrentitistomeasure.Bycontrast,avoltmetermustbeconnectedinparallel.Theanalogywithanin-lineflowmeterinawatercircuitcanhelpvisualizewhyanammetermusthavealowresistance,andwhyconnectinganammeterinparallelcandamagethemeter.Modernsolid-statemetershavedigitalreadouts,buttheprinciplesofoperationcanbebetterappreciatedbyexaminingtheoldermovingcoilmetersbased ongalvanometersensors.

Ohmmeter

Thestandardwaytomeasureresistanceinohmsistosupplyaconstantvoltagetotheresistanceandmeasurethecurrentthroughit.Thatcurrentisofcourseinverselyproportionaltotheresistanceaccording toOhm'slaw,sothatyouhaveanon-linearscale.Thecurrentregisteredbythecurrentsensingelementisproportionalto1/R,sothatalargecurrent impliesasmallresistance.Modernsolid-statemetershavedigitalreadouts,buttheprinciplesofoperationcanbebetterappreciatedbyexaminingthe oldermovingcoilmetersbased ongalvanometersensors.

Voltmeter/AmmeterMeasurements

Thevalueofelectricalresistanceassociatedwithacircuitelementormeasuringthevoltageacrossitandthecurrentthroughitandthendividingthemeasuredvoltagebythecurrentcandetermineappliance.Thismethodworksevenfornon-ohmicresistanceswheretheresistancemightdependuponthecurrent.

D'ArsonvalGalvanometer

ThetwoFrenchinventorsofthisformofgalvanometerintheearly1880scamefromquitedifferentbackgrounds.JacquesD'Arsonval(1851-1940)wasadirectorofalaboratoryof biologicalphysicsandaprofessorof experimentalmedicine,andoneofthefoundersofdiathermytreatments.MarcelDeprez(1843-1918)wasanengineerandanearlypromoterofhigh-voltageelectricalpower transmission.

IntheD'Arsonval-Deprezdesignthecoilhasmanyturnsoffinewire,andissuspendedbyflatribbonofwirewhichservesasonelead-inwire.Theconnectiontothelowerendofthecoilisprovidedbyalight,helicalspringthatprovidestherestoringtorque.Theelectro-magnetictorqueisgreatestwhenthemagneticfieldlinesareperpendiculartotheplaneofthecoil;thisconditionismetforawiderangeofcoilpositionsbyplacingthecylindricalcoreofsoftironinthemiddleofthemagneticgap,andgivingthemagnetpolefacesaconcavecontour.Sincetheelectro-magnetictorqueisproportionaltothecurrentinthecoilandtherestoringtoqueisproportionaltotheangleoftwistofthesuspensionfiber,atequilibriumthecurrentthroughthecoilislinearlyproportional toits angulardeflection.Thismeansthatthegalvanometerscalescanalwaysbelinear,agreatboontotheuser.

Moving Ironmeters

AC voltmeters andammeters

ACelectromechanicalmetermovementscomeintwobasicarrangements:thosebasedonDCmovementdesigns,andthoseengineeredspecificallyforACuse.Permanent-magnetmovingcoil(PMMC)metermovementswillnotworkcorrectlyifdirectlyconnectedtoalternatingcurrent,becausethedirectionofneedlemovementwillchangewitheachhalf-cycleoftheAC.(Figurebelow)Permanent-magnetmetermovements,likepermanent-magnetmotors,aredeviceswhosemotiondependsonthepolarityoftheappliedvoltage(or,youcanthinkofitintermsofthedirectionofthecurrent).

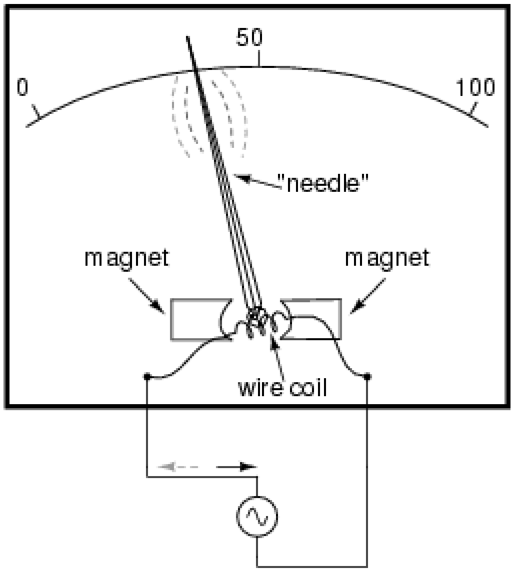


Fig:PassingACthroughthisD'Arsonvalmeter movementcauses uselessflutter oftheneedle

InordertouseaDC-stylemetermovementsuchastheD'Arsonvaldesign,thealternatingcurrentmustbe*rectified*intoDC.Thisis mosteasilyaccomplishedthrough theuseofdevices called*diodes*.Wesawdiodes usedin anexamplecircuitdemonstratingthecreationofharmonicfrequenciesfromadistorted(orrectified)sinewave.Withoutgoingintoelaboratedetailoverhowandwhydiodesworkas theydo,justrememberthattheyeachactlikeaone-wayvalveforelectronstoflow:actingasaconductorforonepolarityandaninsulatorforanother.Oddlyenough,thearrowheadineachdiodesymbolpoints*against*thepermitteddirectionofelectronflowratherthanwithitasonemightexpect.Arrangedinabridge,fourdiodeswillserveto steerACthroughthemetermovementin aconstantdirectionthroughoutallportionsoftheAC cycle:(Figurebelow)

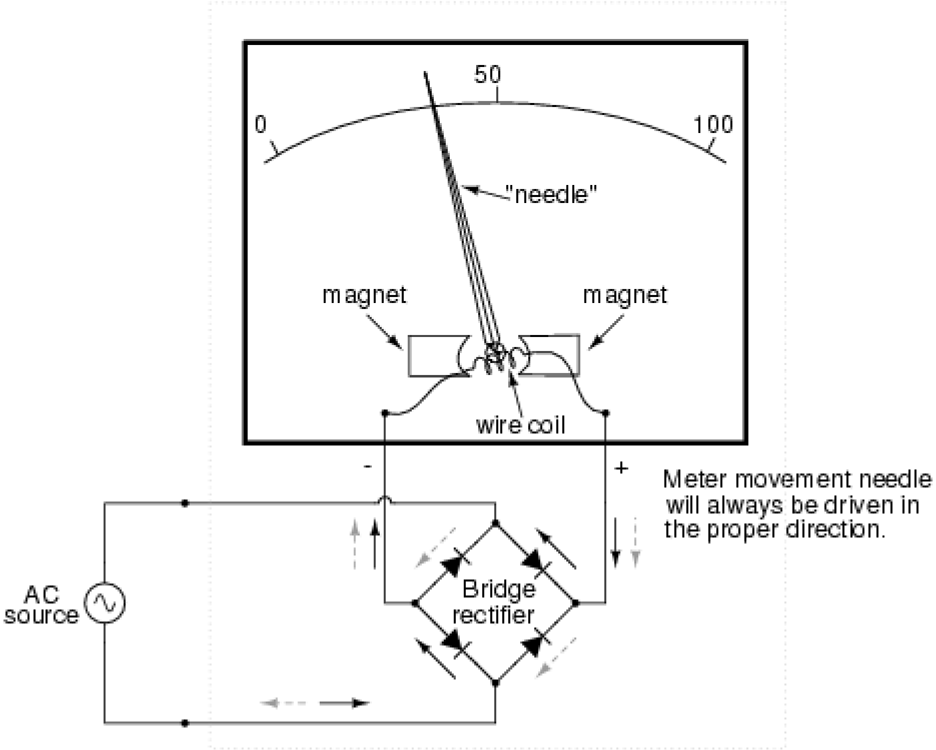


Fig:PassingACthroughthisRectifiedACmetermovementwilldriveitinonedirection.

AnotherstrategyforapracticalACmetermovementistoredesignthemovementwithouttheinherentpolaritysensitivityoftheDCtypes.Thismeansavoidingtheuseofpermanentmagnets.Probablythesimplestdesignistouseanomagnetizedironvanetomovetheneedleagainstspringtension,thevanebeingattractedtowardastationarycoilofwireenergizedbytheAC quantitytobemeasuredasin Figurebelow.

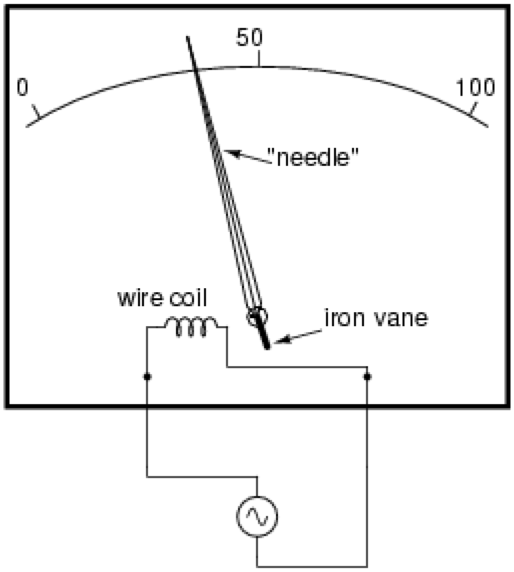


Fig:Iron-vaneelectromechanicalmetermovement

Electrostaticattractionbetweentwometalplatesseparatedbyanairgapisanalternativemechanismforgeneratinganeedle-movingforceproportional toappliedvoltage.ThisworksjustaswellforACasitdoesforDC,orshouldIsay,justaspoorly!Theforcesinvolvedareverysmall,muchsmallerthanthemagneticattractionbetweenanenergizedcoilandanironvane,andassuchthese“electrostatic”metermovementstendtobefragileandeasilydisturbedbyphysicalmovement.But,forsomehigh-voltageACapplications,theelectrostaticmovementisaneleganttechnology.Ifnothingelse,thistechnologypossessestheadvantageofextremelyhighinputimpedance,meaningthatnocurrentneedbedrawnfromthecircuitundertest.Also,electrostaticmetermovementsarecapableofmeasuringveryhighvoltageswithoutneedforrangeresistorsorother,externalapparatus.

Whenasensitivemetermovementneedstobere-rangedtofunctionasanACvoltmeter,series-connected“multiplier”resistorsand/orresistivevoltagedividersmaybeemployedjustasin DCmeterdesign:(Figurebelow)

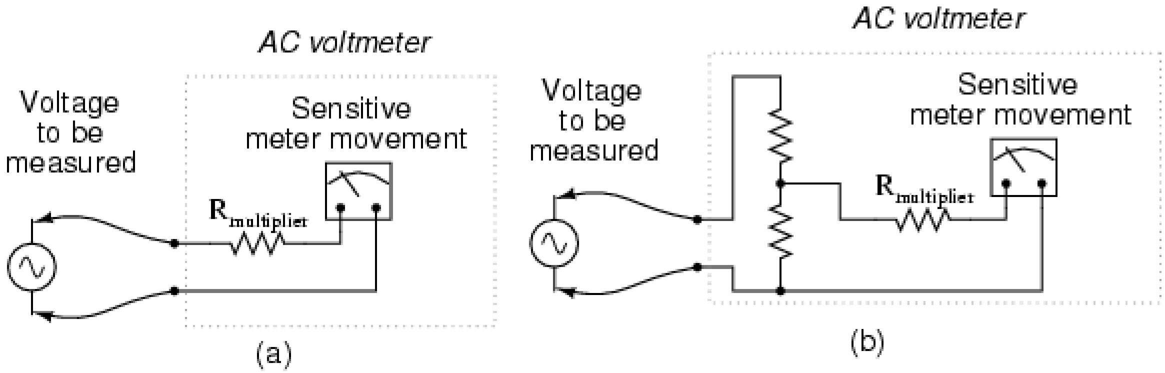


Fig:Multiplier resistor (a)or resistivedivider (b) scales therangeofthebasicmetermovement

Capacitorsmaybeusedinsteadofresistors,though,tomakevoltmeterdividercircuits.This strategyhas theadvantageofbeingnon-dissipative(notruepowerconsumedandnoheatproduced): (Figurebelow)

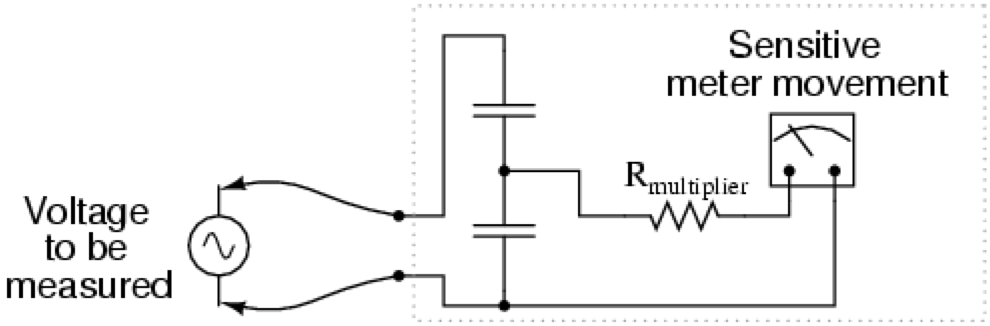


Fig:ACvoltmeterwithcapacitivedivider

Ifthemetermovementiselectrostatic,andthusinherentlycapacitiveinnature,asingle“multiplier”capacitormaybeconnectedinseriestogiveit agreatervoltagemeasuringrange,justasaseries-connectedmultiplierresistorgivesamoving-coil(inherentlyresistive)metermovementagreater voltagerange:(Figurebelow)

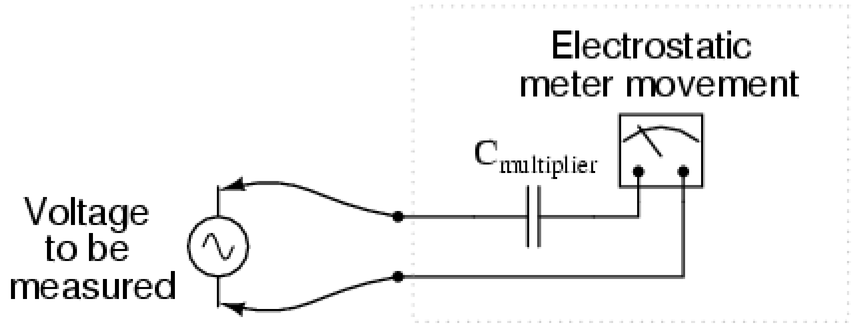
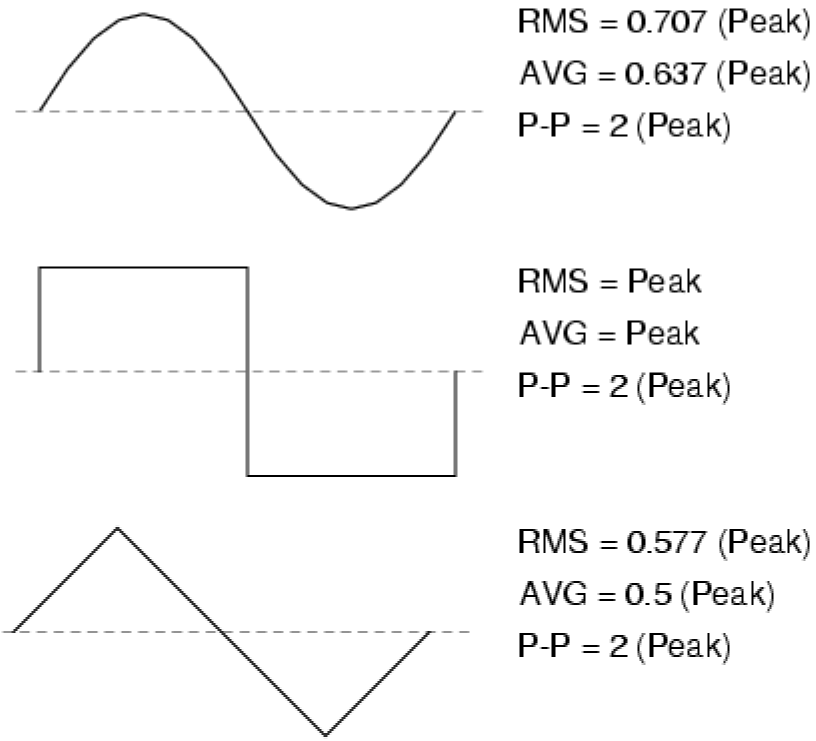


Fig:Anelectrostaticmetermovementmayuseacapacitive multipliertomultiplythescaleofthebasicmetermovement..

TheCathodeRayTube(CRT)mentionedintheDCmeteringchapterisideallysuitedformeasuringACvoltages,especiallyiftheelectronbeamissweptside-to-sideacrossthescreenofthetubewhilethemeasuredACvoltagedrivesthebeamupanddown.AgraphicalrepresentationoftheACwaveshapeandnotjustameasurementofmagnitudecaneasilybehadwithsuchadevice.However,CRT'shavethedisadvantagesofweight,size,significantpowerconsumption,andfragility(beingmadeofevacuatedglass)workingagainstthem.Forthesereasons,electromechanicalACmetermovementsstillhaveaplacein practicalusage.

Withsomeoftheadvantagesanddisadvantagesofthesemetermovementtechnologieshavingbeendiscussedalready,thereisanotherfactorcruciallyimportantforthedesignerandusersofACmeteringinstrumentstobeawareof.ThisistheissueofRMSmeasurement.Aswealreadyknow,ACmeasurementsareoftencastinascaleofDCpowerequivalence,called*RMS*(**R**oot-**M**ean-**S**quare)forthesakeofmeaningfulcomparisons withDC andwithotherAC waveformsofvaryingshape.NoneofthemetermovementtechnologiessofardiscussedinherentlymeasuretheRMSvalueofanACquantity.Metermovementsrelyingonthemotionofamechanicalneedle(“rectified”D'Arsonval,iron-vane,andelectrostatic)alltendtomechanicallyaveragetheinstantaneousvaluesintoanoverallaveragevalueforthewaveform.ThisaveragevalueisnotnecessarilythesameasRMS,althoughmanytimesitismistakenassuch.AverageandRMSvaluesrateagainsteachotherassuchforthesethreecommonwaveformshapes: (Figurebelow)



RMS, Average,andPeak-to-Peakvalues forsine, square,andtrianglewaves.

SinceRMSseemstobethekindofmeasurementmostpeopleareinterestedinobtainingwithaninstrument,andelectromechanicalmetermovementsnaturallydeliver*average*measurementsratherthanRMS,whatareACmeterdesignerstodo?Cheat,ofcourse!Typicallytheassumptionismadethatthewaveformshapetobe measuredisgoingtobesine(byfarthemostcommon,especiallyforpowersystems),andthenthemetermovementscaleisalteredbytheappropriatemultiplicationfactor.ForsinewavesweseethatRMSisequal to0.707timesthepeakvaluewhileAverageis0.637timesthepeak,sowecandivideonefigurebytheotherto obtainanaverage-to-RMSconversionfactorof1.109:

$$\frac{0.707}{0.637} = 1.1099$$

Inotherwords,themetermovementwillbecalibratedtoindicateapproximately

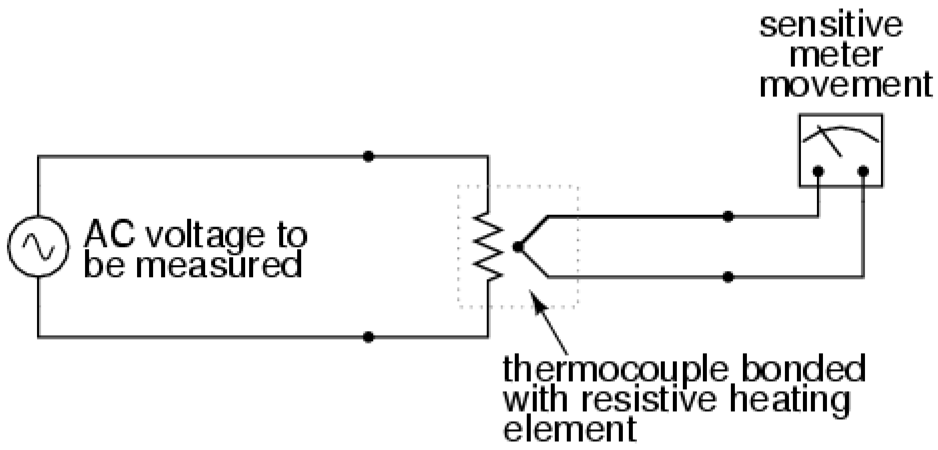
1.11 timeshigherthan itwouldordinarily (naturally)indicatewithnospecial accommodations. It must be stressed that this “cheat” only works well when the meter is used to measure pure sine wave sources. Note that for triangle waves, the ratio between RMS and Average is not the same as for sine waves:

$$\frac{0.577}{0.5} = 1.154$$

With square waves, the RMS and Average values are identical! An AC meter calibrated to accurately read RMS voltage or current on a pure sine wave will *not* give the proper value while indicating the magnitude of anything other than a perfect sine wave. This includes triangle waves, square waves, or any kind of distorted sine wave. With harmonics becoming an ever-present phenomenon in large AC power systems, this matter of accurate RMS measurement is no small matter.

The astute reader will note that I have omitted the CRT “movement” from the RMS/Average discussion. This is because a CRT with its practically weightless electron beam “movement” displays the Peak (or Peak-to-Peak if you wish) of an AC waveform rather than Average or RMS. Still, a similar problem arises: how do you determine the RMS value of a waveform from it? Conversion factors between Peak and RMS only hold so long as the waveform falls neatly into a known category of shape (sine, triangle, and square are the only examples with Peak/RMS/Average conversion factors given here!).

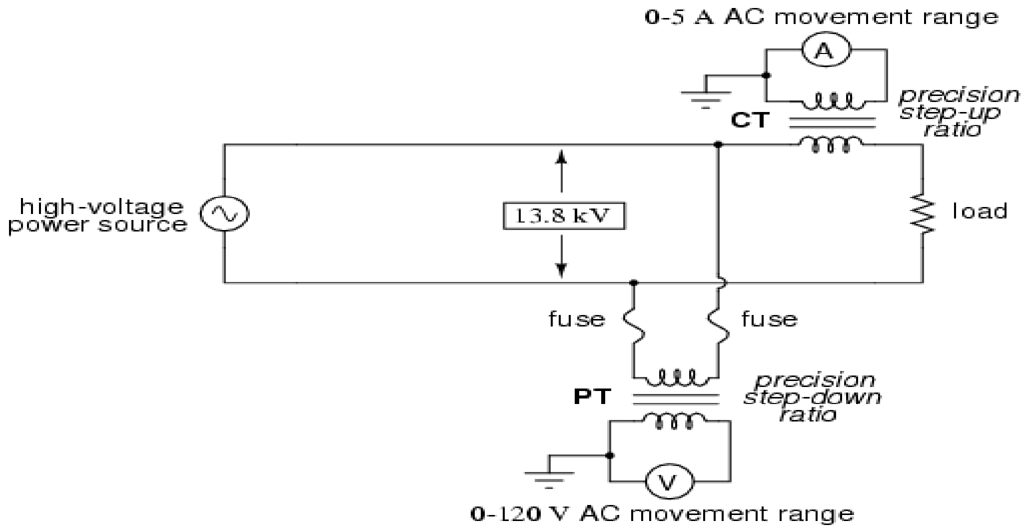
One answer is to design the meter movement around the very definition of RMS: the effective heating value of an AC voltage/current as it powers a resistive load. Suppose that the AC source to be measured is connected across a resistor of known value, and the heat output of that resistor is measured with a device like a thermocouple. This would provide a far more direct measurement means of RMS than any conversion factor could, for it will work with ANY waveform shape whatsoever: (Figure below)



DirectreadingthermalRMSvoltmeter accommodates anywaveshape.

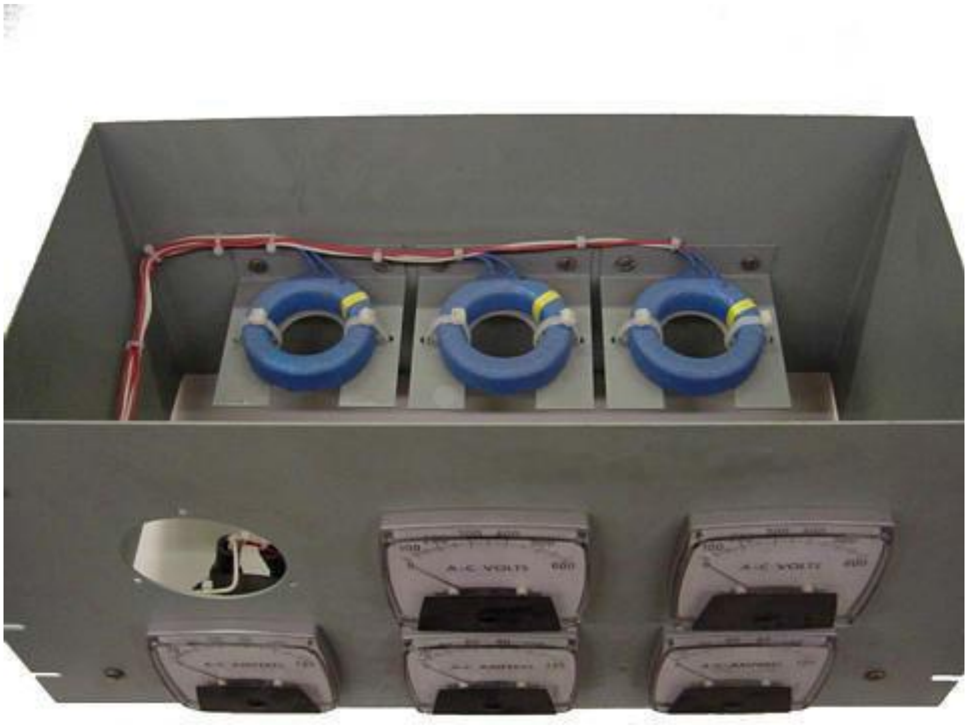
Whilethedeviceshownaboveissomewhatcrudeandwouldsufferfromuniqueengineeringproblemsofits own,theconceptillustratedisverysound.TheresistorconvertstheACvoltageorcurrentquantityintoathermal(heat)quantity,effectivelysquaringthevaluesinreal-time.Thesystem'smassworkstoaveragethesevaluesbytheprincipleofthermalinertia,andthenthemeterscaleitselfiscalibratedtogiveanindicationbasedonthesquare-rootofthethermalmeasurement:perfectRoot-Mean-Squareindicationallinonedevice!Infact,onemajorinstrumentmanufacturerhasimplementedthistechniqueintoitshigh-endlineofhandheldelectronicmultimetersfor“true-RMS”capability.

CalibratingACvoltmetersandammetersfordifferentfull-scalerangesofoperationismuchthesameaswithDCinstruments:series“multiplier”resistorsareusedtogivevoltmetermovementshigherrange,andparallel“shunt”resistorsareusedtoallowammetermovementstomeasurecurrentsbeyondtheirnaturalrange.However,wearenotlimitedtothesetechniquesaswewerewithDC:becausewecanusetransformerswithAC,meterrangescanbeelectromagneticallyratherthanresistively“steppedup”or“steppeddown,”sometimesfarbeyondwhatresistorswouldhavepracticallyallowedfor.PotentialTransformers(PT's)andCurrentTransformers(CT's)areprecisioninstrumentdevicesmanufacturedtoproduceverypreciseratiosoftransformationbetweenprimaryandsecondarywindings.TheycanallowsmallsimpleACmetermovementstoindicateextremelyhighvoltagesandcurrentsinpowersystemswithaccuracyandcomplete electricalisolation(somethingmultiplierandshuntresistorscouldneverdo):(Figurebelow)



(CT)Currenttransformerscales currentdown.(PT)Potentialtransformerscales voltagedown.

Shownhereisavoltageandcurrentmeterpanelfromathree-phaseACsystem.Thethree“donut”currenttransformers(CT's)canbeseenintherearofthepanel.ThreeAC ammeters(rated5ampsfull-scaledeflectioneach)onthefrontofthepanelindicatecurrentthrougheachconductorgoingthroughaCT.Asthispanelhasbeenremovedfromservice,therearenocurrent-carryingconductorsthreadedthroughthecenteroftheCT“donuts”anymore:(Figurebelow)



Toroidal current transformers scale high current levels down for application to 5A full-scale AC ammeters.

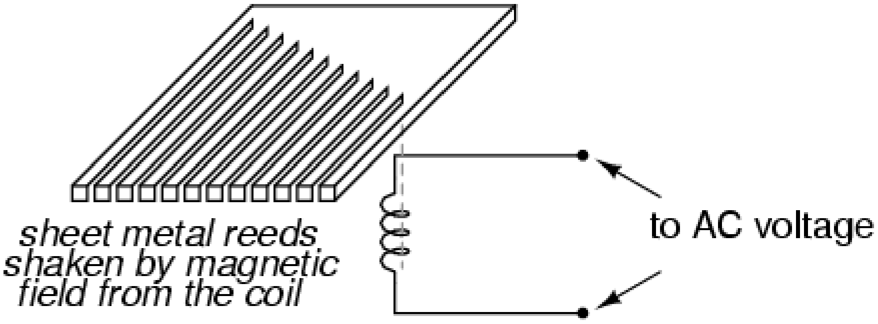
Because of the expense (and often large size) of instrument transformers, they are not used to scale AC meters for any applications other than high voltage and high current. For scaling a milliamp or microamp movement to a range of 120 volts or 5 amps, normal precision resistors (multipliers and shunts) are used, just as with DC.

Frequency and phase measurement

An important electrical quantity with no equivalent in DC circuits is *frequency*. Frequency measurement is very important in many applications of alternating current, especially in AC power systems designed to run efficiently at one frequency and one frequency only. If an electromechanical alternator is generating the AC, the frequency will be directly proportional to the shaft speed of the machine, and frequency could be measured simply by measuring the speed of the shaft. If frequency needs to be measured at some distance from the alternator, though, other means of measurement will be necessary.

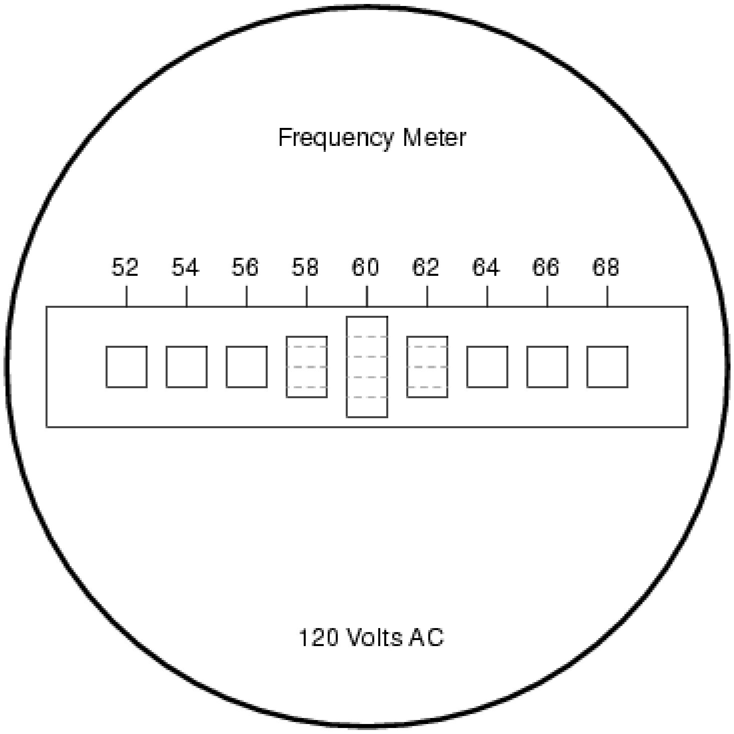
Onesimplebutcrudemethodoffrequencymeasurementinpowersystemsutilizestheprincipleofmechanicalresonance.Everyphysicalobjectpossessingthepropertyofelasticity(springiness)hasaninherentfrequencyatwhichitwillprefertovibrate.Thetuningforkisagreatexampleofthis:strikeitonceanditwillcontinuetovibrateatatonespecifictoitslength.Longertuningforkshavelowerresonantfrequencies:theirtoneswillbeloweronthemusicalscalethanshorterforks.

Imaginearow ofprogressivelysizedtuningforksarrangedside-by-side.TheyareallmountedonacommonbaseandthatbaseisvibratedatthefrequencyofthemeasuredACvoltage(orcurrent)bymeansofanelectromagnet.Whichevertuningforkisclosestin resonantfrequencytothefrequencyofthatvibrationwilltendtoshakethemost(ortheloudest).Iftheforks'tineswereflimsyenough,wecouldseetherelativemotionofeachbythelengthoftheblurwewouldseeasweinspectedeachonefromanend-viewperspective.Well,makeacollectionof“tuningforks”outofastripofsheetmetalcutinapatternakintoarake,andyouhavethe*vibratingreed*frequencymeter:(Figurebelow)



Vibratingreedfrequencymeter diagram.

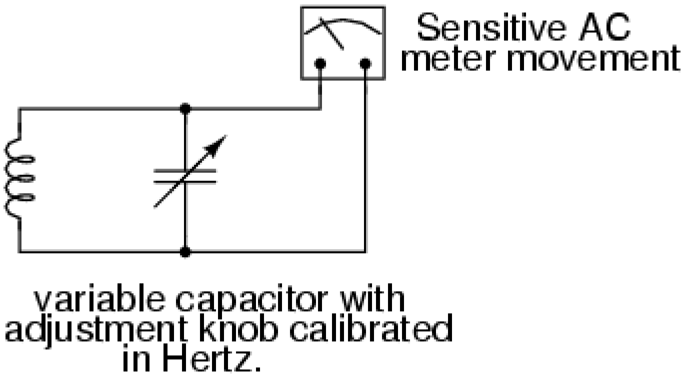
TheuserofthismeterviewstheendsofallthoseunequallengthreedsastheyarecollectivelyshakenatthefrequencyoftheappliedACvoltagetothecoil.TheoneclosestinresonantfrequencytotheappliedACwillvibratethemost,lookingsomethinglikeFigurebelow.



Vibratingreedfrequencymeter frontpanel.

Vibratingreedmeters,obviously,arenotprecisioninstruments,buttheyareverysimpleandthereforeeasytomanufacturetoberugged.Theyareoftenfoundonsmallengine-drivengeneratorsetsforthepurpose of settingenginespeedsothatthefrequencyissomewhatcloseto60(50 in Europe) Hertz.

Whilereed-typemetersareimprecise,theiroperationalprincipleisnot.Inlieuofmechanicalresonance,wemaysubstituteelectricalresonanceanddesignafrequencymeterusinganinductorandcapacitorintheformofatankcircuit(parallelinductorandcapacitor).SeeFigurebelow.Oneorbothcomponentsaremadeadjustable,andameterisplacedinthecircuittoindicatemaximumamplitudeofvoltageacrossthetwocomponents.Theadjustmentknob(s)arecalibratedtoshowresonantfrequencyforanygivensetting,andthefrequencyisreadfromthemafterthedevicehasbeenadjustedformaximumindicationonthemeter.Essentially,thisisatunablefiltercircuit,whichisadjustedandthenreadinamannersimilartoabridgecircuit(whichmustbebalancedfora“null” conditionandthenread).



Resonantfrequencymeter “peaks”as L-Cresonantfrequencyis tunedtotestfrequency.

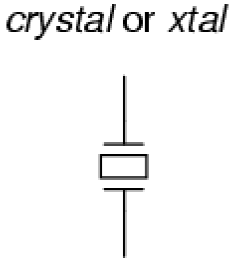
Thistechniqueisapopularoneforamateurradiooperators(oratleastitwasbeforetheadventofinexpensive digitalfrequencyinstrumentscalled*counters*),especiallybecauseitdoesn'trequiredirectconnectiontothe circuit.Solongastheinductorand/orcapacitorcaninterceptenoughstrayfield(magneticorelectric,respectively)fromthecircuitundertesttocausethemetertoindicate,itwillwork.

Infrequencyasinothertypesof electricalmeasurement,themostaccuratemeansofmeasurementareusuallythosewhereanunknownquantityiscomparedagainstaknown*standard*,thebasicinstrumentdoingnothingmorethanindicatingwhenthetwoquantitiesareequaltoeachother.ThisisthebasicprinciplebehindtheDC(Wheatstone)bridgecircuit anditisasoundmetrologicalprincipleappliedthroughoutthesciences.Ifwehaveaccesstoanaccuratefrequencystandard(asourceofACvoltageholdingverypreciselytoasinglefrequency),thenmeasurementofanyunknownfrequencybycomparisonshouldberelativelyeasy.

Forthatfrequencystandard,weturnourattentionbacktothetuningfork,oratleastamoremodernvariationofitcalledthe*quartzcrystal*.Quartzisanaturallyoccurringmineralpossessingaveryinterestingpropertycalled*piezoelectricity*.Piezoelectricmaterialsproduceavoltageacrosstheirlengthwhenphysicallystressed, andwillphysicallydeformwhenanexternalvoltageisappliedacrosstheirlengths.Thisdeformationisvery, veryslightinmostcases,butitdoesexist.

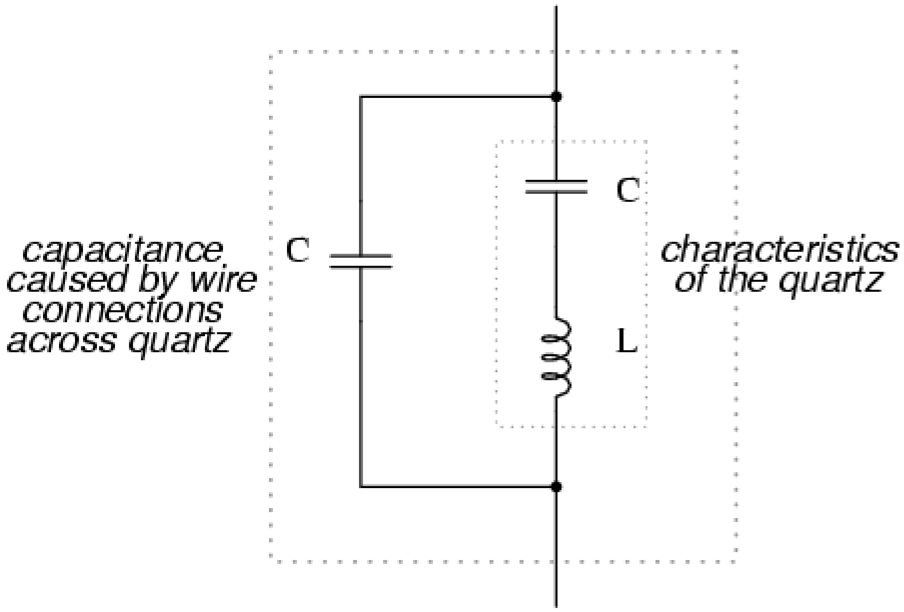
Quartzrockiselastic(springy)withinthat smallrangeofbendingwhichanexternalvoltagewouldproduce,whichmeansthatitwillhaveamechanical resonant frequencyofitsowncapableofbeingmanifestedasanelectricalvoltagesignal.Inotherwords,ifachipofquartzisstruck,itwill“ring”withitsownuniquefrequencydeterminedbythelengthofthechip,andthatresonantoscillationwillproduceanequivalentvoltageacrossmultiplepointsofthequartzchipwhichcanbetappedintobywiresfixedtothesurfaceofthechip.Inreciprocalmanner,thequartzchipwilltendtovibratemostwhenitis“excited”byanappliedACvoltageatprecisely therightfrequency,justlikethereedsonavibrating-reedfrequencymeter.

Chipsofquartzrockcanbepreciselycutfordesiredresonantfrequencies,andthatchipmountedsecurelyinsideaprotectiveshellwithwiresextendingforconnectiontoanexternalelectriccircuit.Whenpackagedassuch,theresultingdeviceissimplycalleda*crystal*(orsometimes “*xtal*”).Theschematicsymbol isshownin Figurebelow.



Crystal(frequencydetermingelement)schematicsymbol.

Electrically,thatquartzchipisequivalenttoaseriesLCresonantcircuit.(Figurebelow)Thedielectricpropertiesofquartzcontributeanadditionalcapacitiveelementtotheequivalentcircuit.



Quartzcrystalequivalentcircuit.

\

The“capacitance”and“inductance”showninseriesaremerelyelectricalequivalentsofthequartz'smechanicalresonanceproperties:theydonotexistasdiscretecomponentswithinthecrystal.Thecapacitanceshowninparallelduetothewireconnectionsacrossthedielectric(insulating)quartzbodyisreal,andithasaneffectontheresonantresponseofthewholesystem.Afulldiscussiononcrystaldynamicsisnotnecessaryhere, butwhatneedstobeunderstoodaboutcrystalsisthisresonantcircuitequivalenceandhowitcanbeexploited withinanoscillatorcircuittoachieveanoutputvoltagewithastable,knownfrequency.

Crystals,asresonantelements,typicallyhavemuchhigher“Q”(*quality*)values thantankcircuitsbuiltfrominductorsandcapacitors,principallyduetotherelativeabsenceofstrayresistance,makingtheirresonantfrequenciesverydefiniteandprecise.Becausetheresonantfrequencyissolelydependenton thephysicalpropertiesofquartz(averystablesubstance,mechanically),theresonantfrequencyvariationovertimewithaquartzcrystalisvery,verylow.Thisishow*quartzmovement*watchesobtaintheirhighaccuracy:bymeansofanelectronicoscillator stabilizedbytheresonantactionofaquartzcrystal.

Forlaboratoryapplications,though,evengreaterfrequencystabilitymaybedesired.Toachievethis,thecrystalinquestionmaybeplacedinatemperaturestabilized environment(usuallyanoven),thus eliminatingfrequencyerrorsdue to thermalexpansionandcontractionofthequartz. Fortheultimateinafrequencystandardthough,nothingdiscoveredthusfarsurpassestheaccuracyofasingleresonatingatom.Thisistheprincipleoftheso-called*atomicclock*,whichuses anatomofmercury(orcesium)suspendedinavacuum,excitedbyoutsideenergytoresonateatitsownuniquefrequency.Theresultingfrequencyisdetectedasaradio-wavesignalandthatformsthebasisforthemostaccurateclocksknowntohumanity.Nationalstandardslaboratoriesaroundtheworldmaintainafewofthesehyper-accurateclocks,andbroadcastfrequencysignalsbasedonthoseatoms'vibrationsforscientistsandtechnicianstotuneinanduseforfrequencycalibrationpurposes.

TwoMarks

1. Namethedifferentessentialtorques inindicatinginstruments.

DeflectingtorqueControllingtorqueDampingtorque

2. Namethetypes of instrumentsusedformakingvoltmeterandammeter.PMMCtype MovingirontypeDynamometer typeHotwiretypeElectrostatictypeInductiontype.

3. Statetheadvantages of PMMCinstruments

Uniformscale.NohysterisislossVeryaccurateHigheffuiciency.

4. Statethedisadvantages of PMMCinstruments

Cannotbeusedforacm/s

Some errorsarecausedbytemperaturevariations.

5. Statetheapplications of PMMCinstruments

m/sofdcvoltageandcurrentusedin dcgalvanometer.

6. HowtherangeofinstrumentcanbeextendedinPMMCinstruments.

InammeterbyconnectingashuntresisterInvoltmeterbyconnectingaseriesresister.

7. Statetheadvantages of Dynamometertypeinstruments

Can beusedforbothdcandacm/s.

Freefromhysterisisandeddycurrenterrors.

8. Statetheadvantages of Movingirontypeinstruments

Lessexpensive

Can beusedforbothdcandacReasonablyaccurate.

9. Statetheadvantages ofHotwiretypeinstruments

Can beusedforbothdcandacUnaffectedbystraymagneticfields

Readings areindependent of frequencyandwaveform.

10. Whataretheconstructionalparts ofdynamometertypewattmeter?

FixedcoilMovingCoil
CurrentlimitingresisterHelicalspring
SpindleattachedwithpointerGraduatedscale

11. Writedownthedeflectingtorqueequationindynamometertypewattmeter.

TdáVICosÖ

12. Statethedisadvantages of Dynamometertype wattmeter.

Readingsmay beaffectedbystraymagneticfields.Atlowpower factor itcauses error.

13. NametheerrorscausedinDynamometertypewattmeter.

ErrorduetopressurecoilinductanceErrorduetopressurecoilcapacitanceErrorduetomethodsofconnectionErrorduetostraymagneticfieldsErrorduetoeddycurrent.

14. Howtheerrorscausedbypcinductanceis compensated.

Byconnectingacapacitorin paralleltotheresister.

15. Howtheerrorscausedbymethods of connectionis compensated

Byusingcompensatingcoil.

16. Namethemethodsusedforpowermeasurementinthreephasecircuits.

(i) Singlewattmetermethod

(ii) Twowattmetermethod

(iii) Threewattmetermethod.

17. Whatarethespecialfeatures tobeincorporatedforLPF wattmeter?

Pressurecoilcircuit

CompensationforPressurecoilcurrentCompensationforPressurecoilinductance.

18. DefinePhantom loading.

Methodbywhichenergizingthepressurecoilcircuitandcurrentcoilcircuitsseparately iscalledphantomloading.

19. Statetheuseof phantom loading.Powerlossisminimized.

20. NamethemethodsusedinWattmetercalibration.

Bycomparingwithstdwattmeter.Byusingvoltmeterammetermethod.ByusingPotentiometer.

21. Whatarethetypes ofenergymeters?

ElectrolyticmetersMotor meters.
Clockmeters

22. Nametheconstructionalparts ofinductiontypeenergymeter.

CurrentcoilwithseriesmagnetVoltagecoilwithshuntmagnetAldisc
BrakingmagnetRegisteringmechanism.

23. Howvoltagecoilis connectedininductiontypeenergymeter.

Itis connectedin parallelto supplyandload.

24. Howcurrentcoilis connectedininductiontypeenergymeter.

Itis connectedin seriestotheload.

25. WhyAldiscis usedininductiontypeenergymeter.Aluminum is anonmagneticmetal.

26. Whatisthepurposeof registeringmechanism.

Itgives avaluablenumberproportionalto therotations.

27. Whatisthepurposeof brakingmechanism.

Itprovidesnecessarybrakingtorque.

28. Definecreeping.

Slowbutcontinuousrotationofdiscwhenpcisenergizedandccisnotenergized.

29. StatethereasonwhyholesareprovidedinAldisc.

Toavoidcreepingholes areprovided onbothsidesofAldisc.

UNIT-III-COMPARISONMETHODOFMEASUREMENTS

CONTENTS

- **D.C&A.Cpotentiometers**
- **D.C&A.Cbridges**

1.Potentiometers

APotentiometerisaninstrumentdesignedtomeasureanunknownvoltagebycomparingitwithaknownvoltage

2. D.C&A.Cbridges

Resistance

- Low Resistance(<1□)
- MediumResistance(1□□to0.1M□)
- HighResistance(> 0.1M□)

LowResistance(<1□)

- Ammetervoltmetermethod
- Kelvin‟sdoublebridgemethod
- Potentiometermethod
- Kelvin‟sdoublebridge

MediumResistance(1□□to0.1M□)

- Ammeter-voltmetermethod
- Substitutionmethod
- Wheatstonebridgemethod
- Ohmmetermethod
- WheatstoneBridge

HighResistance(>0.1M□)

- Directdeflectionmethod
- Lossofchargemethod
- Megohmbridge
- Megger

Inductance

- MeasurementofselfInductance
- Maxwell‟sInductancebridge
- Maxwell‟sInductance-capacitancebridge
- Hay‟sbridge
- Owen‟sbridge
- Anderson‟sbridge
- Measurementof mutualInductance
- HeavisidemutualInductancebridge
- CareyfosterbridgeHeydweillerbridge
- Campbell‟sbridge

Capacitance

- Desauty‟sbridge
- Scheringbridge
- ScheringBridge

Frequency

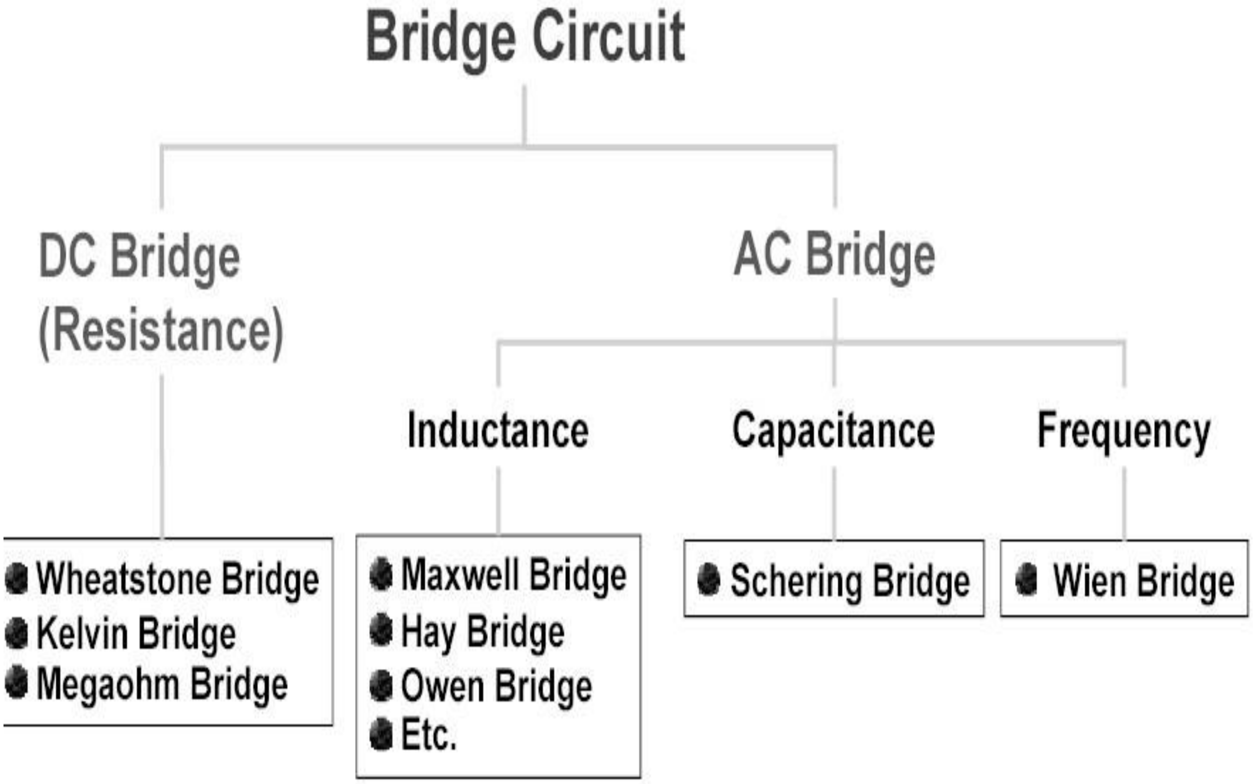
- Wien‟sBridge.

TransformerRatioBridge

- TheyarereplacingtheconventionalACbridge

Bridge Circuit

Bridge Circuit is a null method, operates on the principle of comparison. That is a known (standard) value is adjusted until it is equal to the unknown value.

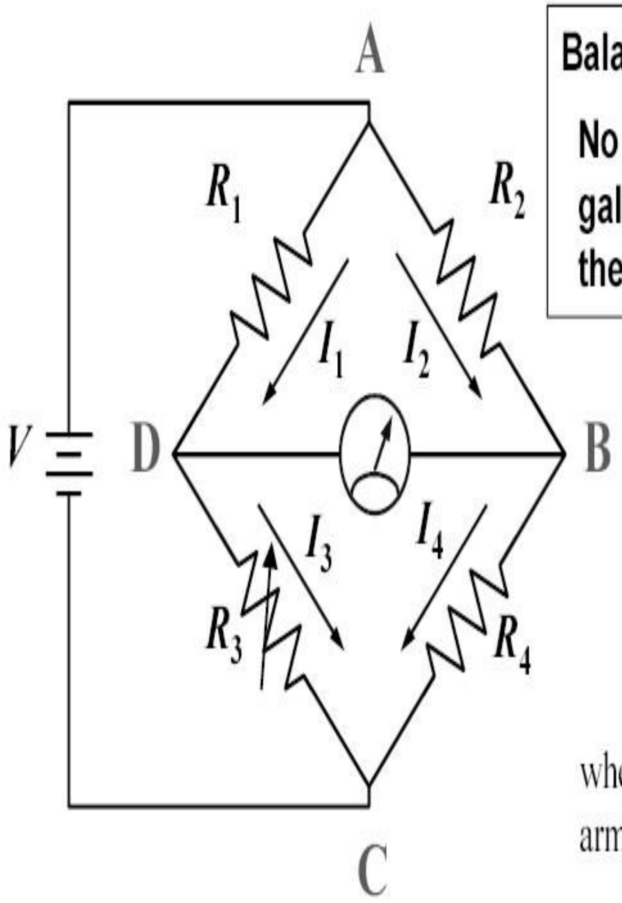


Bridge Circuit

- DC Bridge (Resistance)
  - Wheatstone Bridge
  - Kelvin Bridge
  - Megaohm Bridge
- AC Bridge
  - Inductance
    - Maxwell Bridge
    - Hay Bridge
    - Owen Bridge
    - Etc.
  - Capacitance
    - Schering Bridge
  - Frequency
    - Wien Bridge

Wheatstone Bridge and Balance Condition

Suitable for moderate resistance values: 1 Ω to 10 MΩ



Balance condition:

No potential difference across the galvanometer (there is no current through the galvanometer)

Under this condition: $V_{AD} = V_{AB}$

$$I_1R_1 = I_2R_2$$

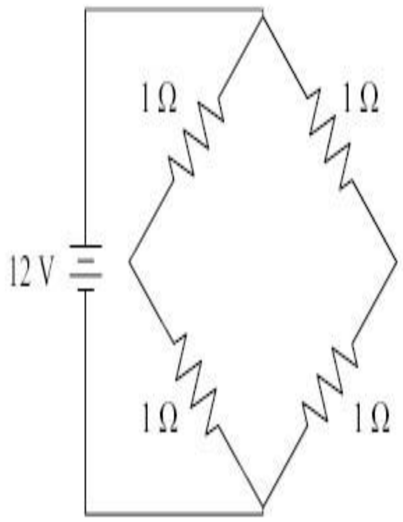
And also $V_{DC} = V_{BC}$

$$I_3R_3 = I_4R_4$$

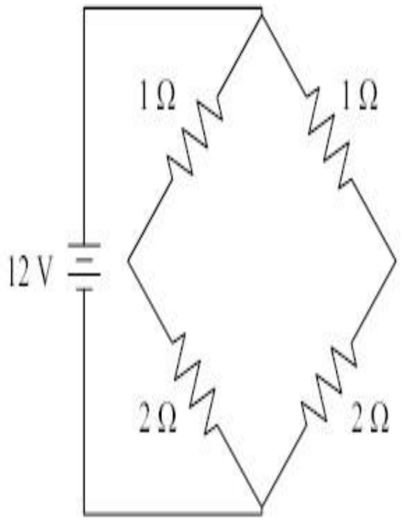
where I_1, I_2, I_3, and I_4 are current in resistance arms respectively, since $I_1 = I_3$ and $I_2 = I_4$

$$\frac{R_1}{R_3} = \frac{R_2}{R_4} \quad \text{or} \quad \boxed{R_x = R_4 = R_3\frac{R_2}{R_1}}$$

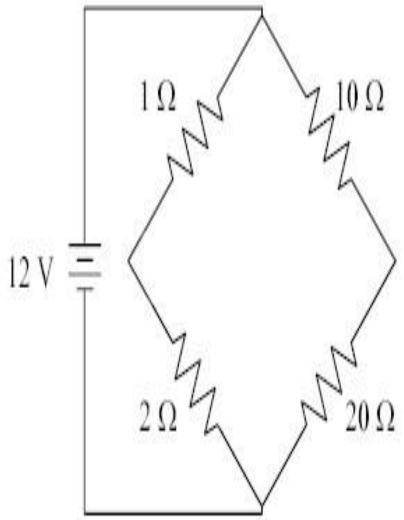
Example



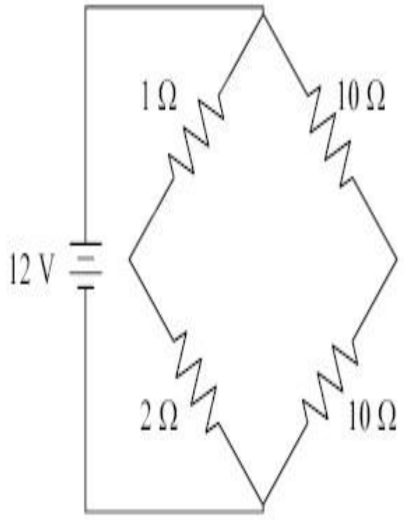
(a) Equal resistance



(b) Proportional resistance



(c) Proportional resistance

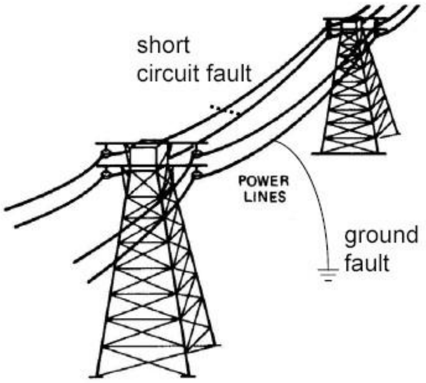


(d) 2-Volt unbalance

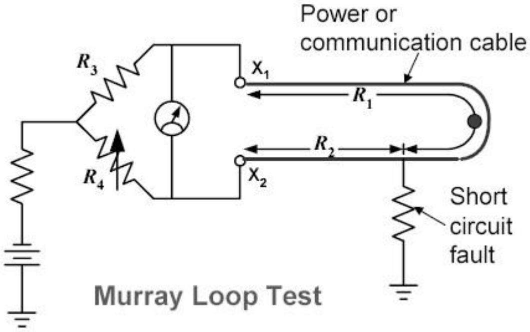
Application of Wheatstone Bridge

Murray/Varrley Loop Short Circuit Fault (Loop Test)

- **Loop test can be carried out for the location of either a ground or a short circuit fault.**



Assume: earth is a good conductor



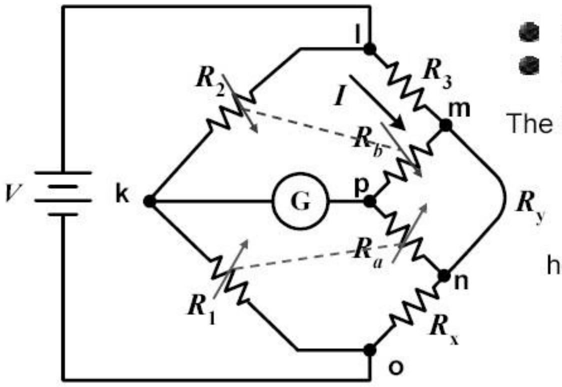
Murray Loop Test

Let $R = R_1+R_2$

At balance condition: $\frac{R_3}{R_4}=\frac{R_1}{R_2}$

$$\boxed{R_1 = R\left(\frac{R_3}{R_3+R_4}\right)} \qquad \boxed{R_2 = R\left(\frac{R_4}{R_3+R_4}\right)}$$

Kelvin Double Bridge: 1 to 0.00001 Ω



- 2 ratio arms: R_1-R_2 and R_a-R_b
- the connecting lead between m and n: yoke

The balance conditions: $V_{lk}=V_{lmp}$ or $V_{ok}=V_{onp}$

$$V_{lk}=\frac{R_2}{R_1+R_2}V \text{ ———— } (1)$$

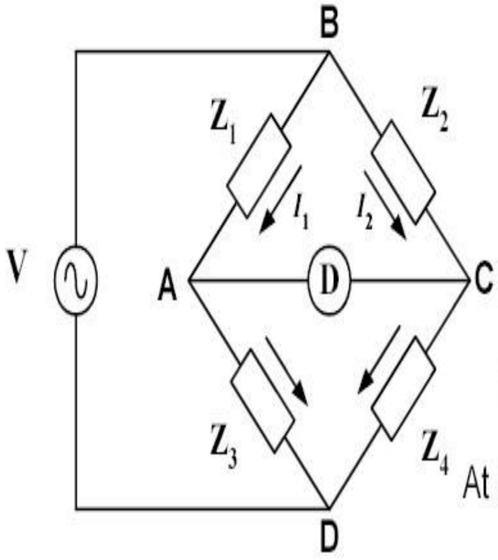
here $V = IR_{lo} = I[R_3+R_x+(R_a+R_b)//R_y]$

$$V_{lmp} = I\left[R_3+\frac{R_y}{R_a+R_b+R_y}R_b\right] \text{ —— } (2)$$

Eq. (1) = (2) and rearrange: $R_x = R_3\frac{R_1}{R_2}+\frac{R_bR_y}{R_a+R_b+R_y}\left(\frac{R_1}{R_2}-\frac{R_a}{R_b}\right) \Longrightarrow \boxed{R_x = R_3\frac{R_1}{R_2}}$

If we set $R_1/R_2 = R_a/R_b$, the second term of the right hand side will be zero, the relation reduce to the well known relation. In summary, The resistance of the yoke has no effect on the measurement, if the two sets of ratio arms have equal resistance ratios.

AC Bridge: Balance Condition



General Form of the ac Bridge

- all four arms are considered as impedance (frequency dependent components)
- The detector is an ac responding device: headphone, ac meter
- Source: an ac voltage at desired frequency

Z_1, Z_2, Z_3 and Z_4 are the impedance of bridge arms

At balance point: $E_{BA} = E_{BC}$ or $I_1 Z_1 = I_2 Z_2$

$$I_1 = \frac{V}{Z_1 + Z_3} \text{ and } I_2 = \frac{V}{Z_2 + Z_4}$$

Complex Form: $\boxed{Z_1 Z_4 = Z_2 Z_3}$

Polar Form:

$$\boxed{Z_1 Z_4 (\angle\theta_1 + \angle\theta_4) = Z_2 Z_3 (\angle\theta_2 + \angle\theta_3)}$$

Magnitude balance: $\boxed{Z_1 Z_4 = Z_2 Z_3}$

Phase balance: $\boxed{\angle\theta_1 + \angle\theta_4 = \angle\theta_2 + \angle\theta_3}$

Comparison Bridge: Capacitance

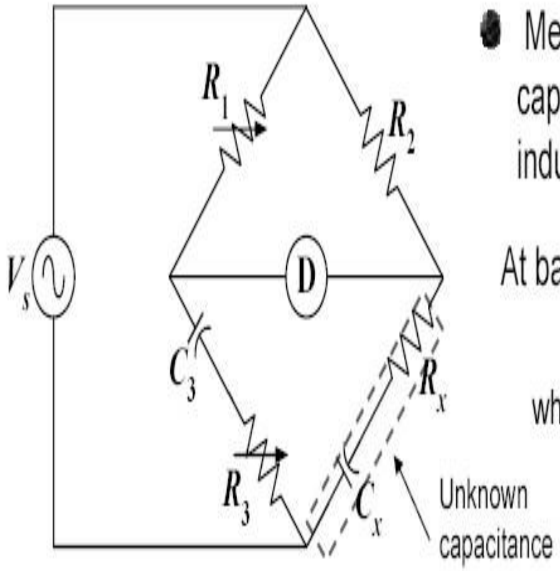


Diagram of Capacitance Comparison Bridge

- Measure an unknown inductance or capacitance by comparing with it with a known inductance or capacitance.

At balance point: $\mathbf{Z}_1\mathbf{Z}_x = \mathbf{Z}_2\mathbf{Z}_3$

where $\mathbf{Z}_1 = R_1; \mathbf{Z}_2 = R_2;$ and $\mathbf{Z}_3 = R_3 + \frac{1}{j\omega C_3}$

$$R_1\left(R_x + \frac{1}{j\omega C_x}\right) = R_2\left(R_3 + \frac{1}{j\omega C_3}\right)$$

Separation of the real and imaginary terms yields: $\boxed{R_x = \frac{R_2 R_3}{R_1}}$ and $\boxed{C_x = C_3 \frac{R_1}{R_2}}$

- Frequency independent
- To satisfy both balance conditions, the bridge must contain two variable elements in its configuration.

Comparison Bridge: Inductance

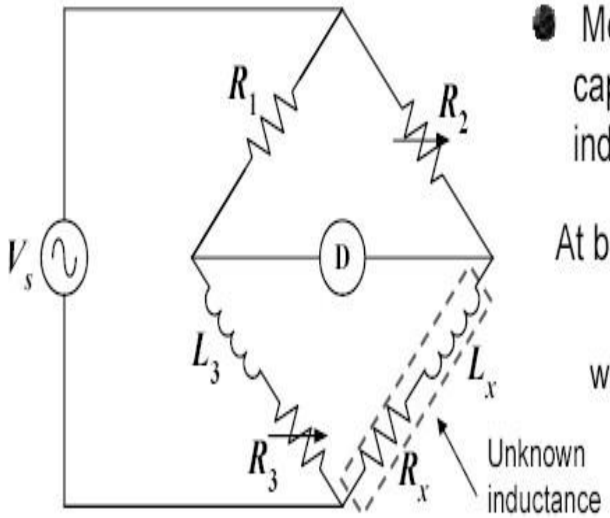


Diagram of Inductance Comparison Bridge

- Measure an unknown inductance or capacitance by comparing with it with a known inductance or capacitance.

At balance point: $\mathbf{Z}_1\mathbf{Z}_x = \mathbf{Z}_2\mathbf{Z}_3$

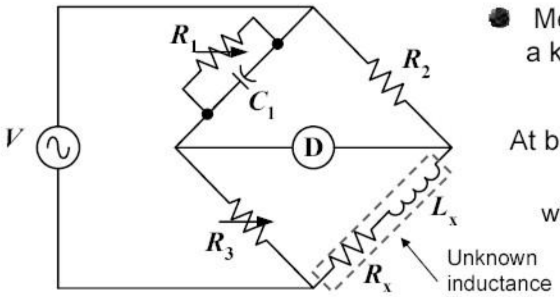
where $\mathbf{Z}_1 = R_1; \mathbf{Z}_2 = R_2;$ and $\mathbf{Z}_3 = R_3 + j\omega L_3$

$$R_1\left(R_x + j\omega L_x\right) = R_2\left(R_S + j\omega L_S\right)$$

Separation of the real and imaginary terms yields: $\boxed{R_x = \frac{R_2 R_3}{R_1}}$ and $\boxed{L_x = L_3 \frac{R_2}{R_1}}$

- Frequency independent
- To satisfy both balance conditions, the bridge must contain two variable elements in its configuration.

Maxwell Bridge



- Measure an unknown inductance in terms of a known capacitance

At balance point: $\mathbf{Z}_x = \mathbf{Z}_2\mathbf{Z}_3\mathbf{Y}_1$

where $\mathbf{Z}_2 = R_2$; $\mathbf{Z}_3 = R_3$; and $\mathbf{Y}_1 = \frac{1}{R_1} + j\omega C_1$

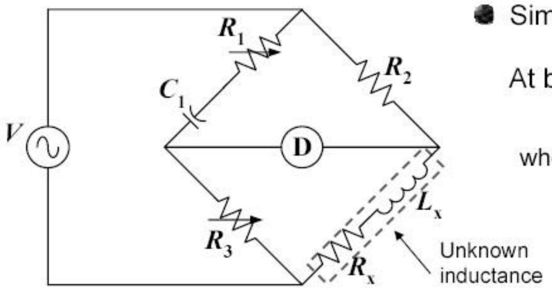
$$\mathbf{Z}_x = R_x + j\omega L_x = R_2 R_3 \left(\frac{1}{R_1} + j\omega C_1 \right)$$

Diagram of Maxwell Bridge

Separation of the real and imaginary terms yields: $\boxed{R_x = \frac{R_2 R_3}{R_1}}$ and $\boxed{L_x = R_2 R_3 C_1}$

- Frequency independent
- Suitable for Medium Q coil (1-10), impractical for high Q coil: since R_1 will be very large.

Hay Bridge



- Similar to Maxwell bridge: but R_1 series with C_1

At balance point: $\mathbf{Z}_1\mathbf{Z}_x = \mathbf{Z}_2\mathbf{Z}_3$

where $\mathbf{Z}_1 = R_1 - \frac{j}{\omega C_1}$; $\mathbf{Z}_2 = R_2$; and $\mathbf{Z}_3 = R_3$

$$\left(R_1 + \frac{1}{j\omega C_1} \right)\left(R_x + j\omega L_x \right) = R_2 R_3$$

Diagram of Hay Bridge

which expands to $R_1 R_x + \frac{L_x}{C_1} - \frac{jR_x}{\omega C_1} + j\omega L_x R_1 = R_2 R_3$

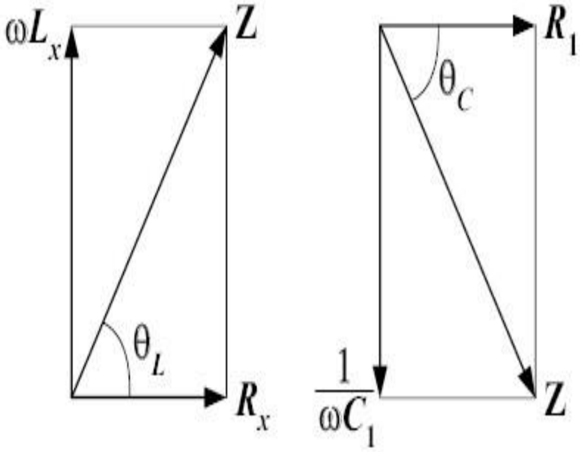
$$R_1 R_x + \frac{L_x}{C_1} = R_2 R_3 \text{.........(1)}$$

$$\frac{R_x}{\omega C_1} = \omega L_x R_1 \text{.........(2)}$$

Solve the above equations simultaneously

Hay Bridge: continues

$$\boxed{R_x = \frac{\omega^2 C_1^2 R_1 R_2 R_3}{1 + \omega^2 C_1^2 R_1^2}} \quad \text{and} \quad \boxed{L_x = \frac{R_2 R_3 C_1}{1 + \omega^2 C_1^2 R_1^2}}$$



Phasor diagram of arm 4 and 1

$$\tan\theta_L = \frac{X_L}{R} = \frac{\omega L_x}{R_x} = Q$$

$$\tan\theta_C = \frac{X_C}{R} = \frac{1}{\omega C_1 R_1}$$

$$\boxed{\tan\theta_L = \tan\theta_C \text{ or } Q = \frac{1}{\omega C_1 R_1}}$$

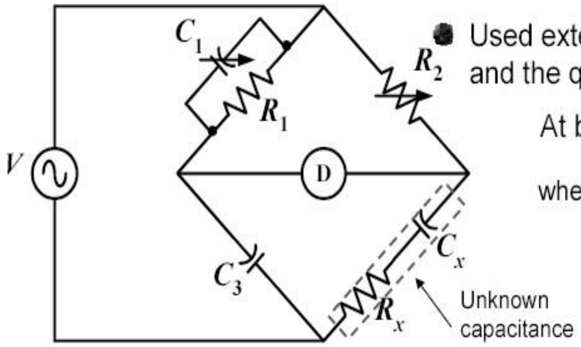
Thus, L_x can be rewritten as

$$L_x = \frac{R_2 R_3 C_1}{1 + (1/Q^2)}$$

For high Q coil (> 10), the term $(1/Q)^2$ can be neglected

$$\boxed{L_x \approx R_2 R_3 C_1}$$

Schering Bridge



- Used extensively for the measurement of capacitance and the quality of capacitor in term of D

At balance point: $\mathbf{Z}_x = \mathbf{Z}_2\mathbf{Z}_3\mathbf{Y}_1$

where $\mathbf{Z}_2 = R_2$; $\mathbf{Z}_3 = \dfrac{1}{j\omega C_3}$; and $\mathbf{Y}_1 = \dfrac{1}{R_1} + j\omega C$

$$R_x - \frac{j}{\omega C_x} = R_2\left(\frac{-j}{\omega C_x}\right)\left(\frac{1}{R_1} + j\omega C_1\right)$$

Diagram of Schering Bridge

which expands to $R_x - \dfrac{j}{\omega C_x} = \dfrac{R_2 C_1}{C_3} - \dfrac{jR_2}{\omega C_3 R_1}$

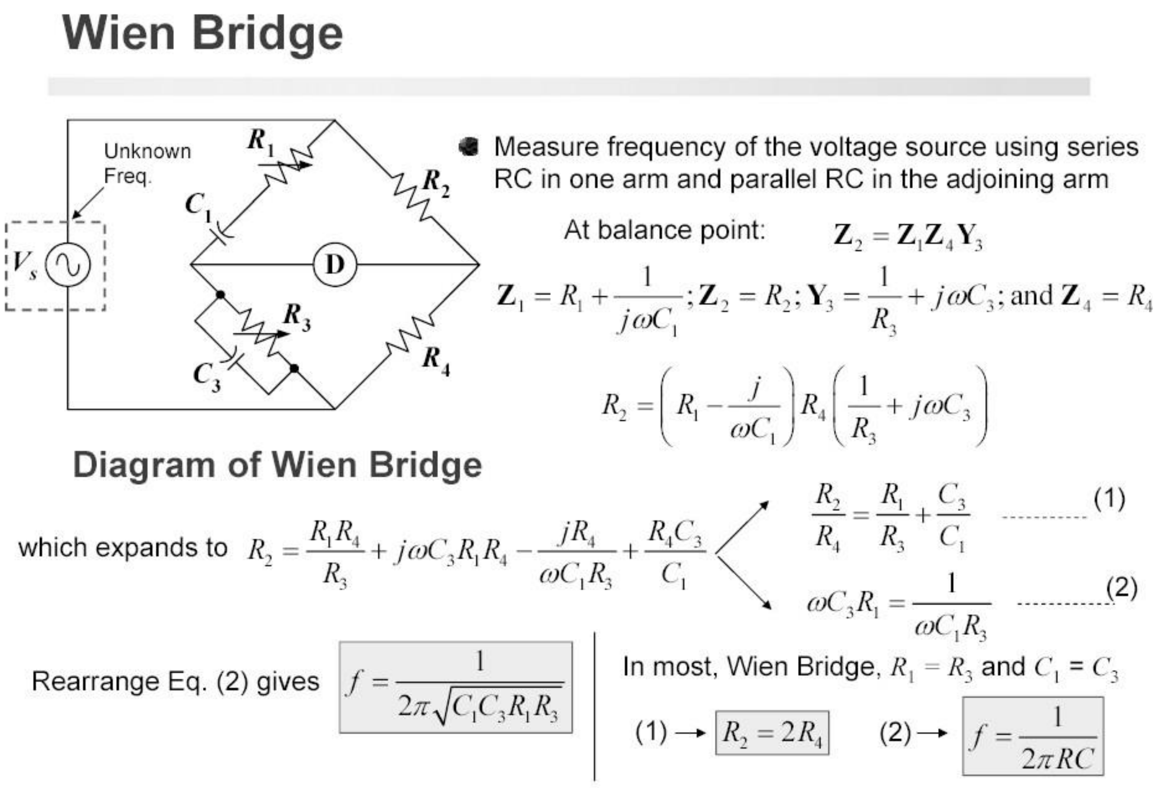
Separation of the real and imaginary terms yields: $\boxed{R_x = R_2 \frac{C_1}{C_3}}$ and $\boxed{C_x = C_3 \frac{R_1}{R_2}}$

Dissipation factor of a series RC circuit: $D = \dfrac{R_x}{X_x} = \omega R_x C_x$

Dissipation factor tells us about the quality of a capacitor, how close the phase angle of the capacitor is to the ideal value of 90°

For Schering Bridge: $\boxed{D = \omega R_x C_x = \omega R_1 C_1}$

For Schering Bridge, R_1 is a fixed value, the dial of C_1 can be calibrated directly in D at one particular frequency



Wien Bridge

Diagram of Wien Bridge

- Measure frequency of the voltage source using series RC in one arm and parallel RC in the adjoining arm

At balance point: $\mathbf{Z}_2 = \mathbf{Z}_1\mathbf{Z}_4\mathbf{Y}_3$

$$\mathbf{Z}_1 = R_1 + \frac{1}{j\omega C_1}; \mathbf{Z}_2 = R_2; \mathbf{Y}_3 = \frac{1}{R_3} + j\omega C_3; \text{and } \mathbf{Z}_4 = R_4$$

$$R_2 = \left(R_1 - \frac{j}{\omega C_1}\right) R_4 \left(\frac{1}{R_3} + j\omega C_3\right)$$

which expands to $R_2 = \frac{R_1R_4}{R_3} + j\omega C_3R_1R_4 - \frac{jR_4}{\omega C_1R_3} + \frac{R_4C_3}{C_1}$

$$\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1} \quad \text{..........} (1)$$

$$\omega C_3R_1 = \frac{1}{\omega C_1R_3} \quad \text{..........} (2)$$

Rearrange Eq. (2) gives $\boxed{f = \frac{1}{2\pi\sqrt{C_1C_3R_1R_3}}}$

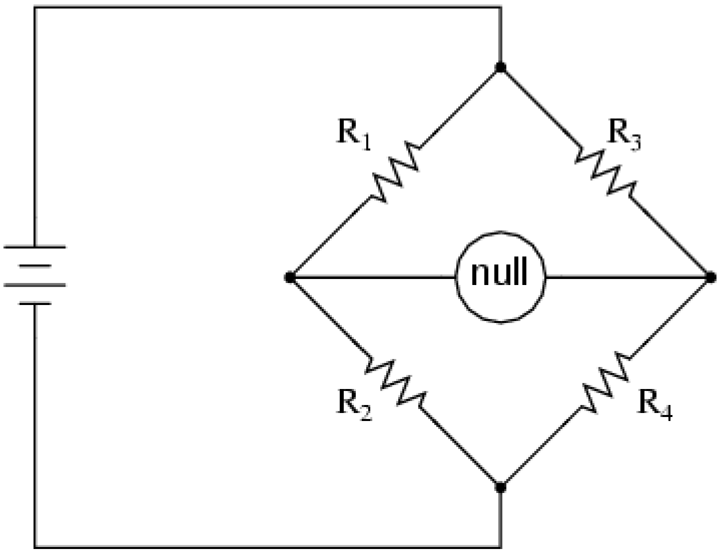
In most, Wien Bridge, $R_1 = R_3$ and $C_1 = C_3$

(1) → $\boxed{R_2 = 2R_4}$ (2) → $\boxed{f = \frac{1}{2\pi RC}}$

AC bridge circuits

As we saw with DC measurement circuits, the circuit configuration known as a *bridge* can be a very useful way to measure unknown values of resistance. This is true with AC as well, and we can apply the very same principle to the accurate measurement of unknown impedances.

To review, the bridge circuit works as a pair of two-component voltage dividers connected across the same source voltage, with a *null-detector* meter movement connected between them to indicate a condition of "balance" at zero volts: (Figure below)



Abalancedbridgeshows a“null”,or minimumreading,ontheindicator.

Anyoneofthefourresistorsintheabovebridgecanbetheresistorofunknownvalue,anditsvaluecanbedeterminedbyaratiooftheotherthree,whichare“calibrated,”orwhoseresistancesareknown toaprecisedegree.Whenthebridgeisinabalancedcondition(zerovoltageasindicatedbythenulldetector), theratioworksouttobethis:

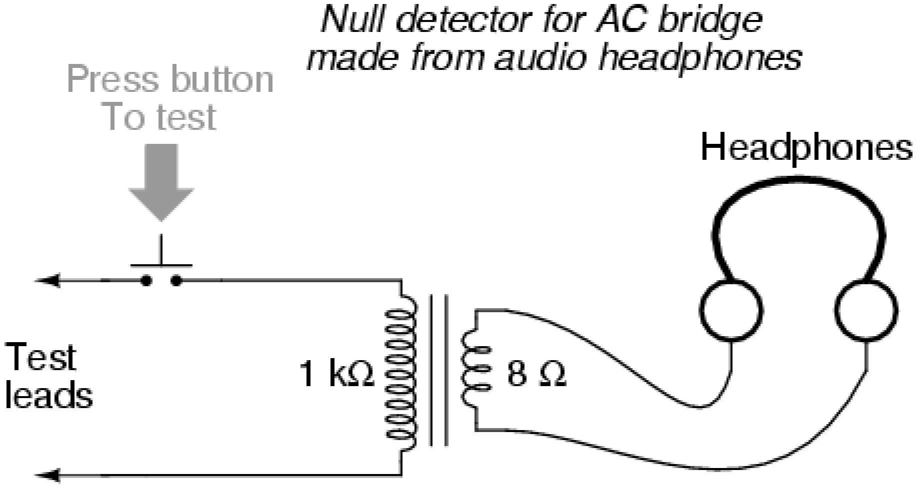
*In a condition of **balance**:*

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Oneoftheadvantagesofusingabridgecircuittomeasureresistanceisthatthevoltageofthepowersourceisirrelevant.Practicallyspeaking,thehigherthesupplyvoltage,theeasieritistodetectaconditionofimbalance betweenthefourresistorswiththenulldetector,andthusthemoresensitiveitwillbe.Agreatersupplyvoltageleadstothepossibilityofincreasedmeasurementprecision.However,therewillbenofundamentalerror introducedas aresult ofalesserorgreaterpowersupplyvoltageunlikeother typesofresistancemeasurementschemes.

Impedancebridgesworkthesame,onlythebalanceequationiswith*complex*quantities,asbothmagnitudeandphaseacrossthecomponentsofthetwodividersmustbeequalinorderforthenulldetectortoindicate“zero.”Thenulldetector,ofcourse, mustbeadevicecapableofdetectingverysmallACvoltages.Anoscilloscopeisoftenusedforthis,althoughverysensitiveelectromechanicalmetermovementsandevenheadphones(smallspeakers)maybeusedifthesourcefrequencyiswithinaudiorange.

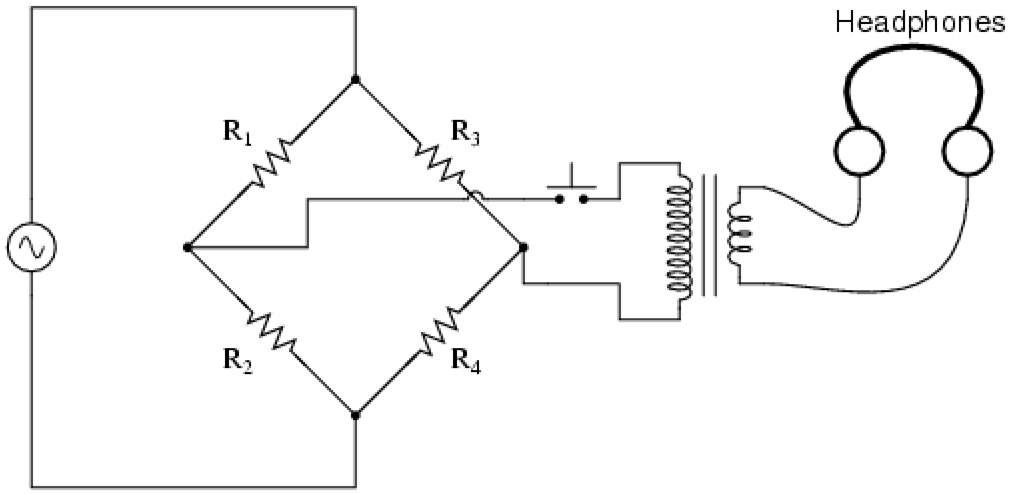
Onewaytomaximizetheeffectivenessofaudioheadphonesasanulldetectoristoconnectthemtothesignalsourcethroughanimpedance-matchingtransformer.Headphonespeakersaretypicallylow-impedanceunits(8Ω),requiringsubstantialcurrenttodrive,andsoastep-downtransformerhelps“match”low-currentsignalstotheimpedanceoftheheadphonespeakers.Anaudiooutputtransformerworkswellforthis purpose: (Figurebelow)



“Modern”low-Ohmheadphonesrequireanimpedancematchingtransformerforuseasasensitive nulldetector.

Usingapairofheadphonesthatcompletelysurroundtheears(the“closed-cup”type),I'vebeenabletodetectcurrentsoflessthan0.1µAwiththissimpledetectorcircuit.Roughlyequalperformancewasobtainedusingtwodifferentstep-downtransformers:asmallpowertransformer(120/6voltratio),andanaudiooutputtransformer(1000:8ohmimpedanceratio).Withthepushbuttonswitchinplacetointerruptcurrent,thiscircuitisusablefordetectingsignalsfromDC tooover2MHz:evenifthefrequencyisfaraboveorbelowtheaudiorange,a“click”willbeheardfromtheheadphones eachtimetheswitchispressedandreleased.

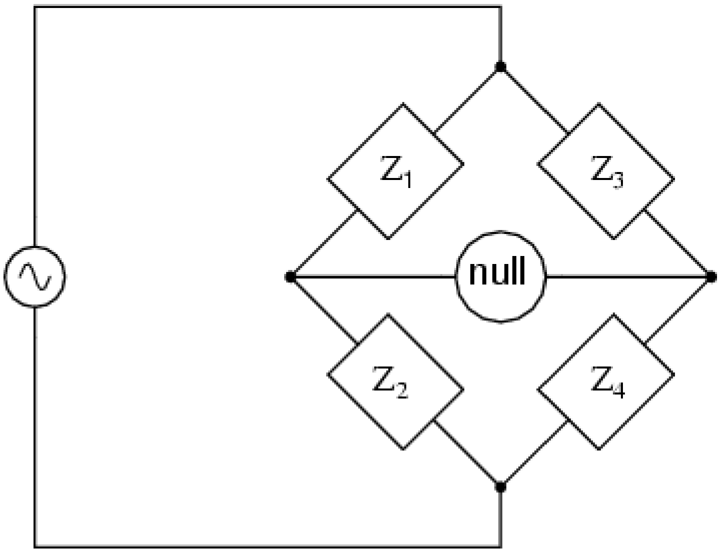
ConnectedtoaresistivebridgethewholecircuitlookslikeFigurebelow.



Bridge with sensitive AC null detector.

Listening to the headphones as one or more of the resistor “arms” of the bridge is adjusted, a condition of balance will be realized when the headphones fail to produce “clicks” (or tones, if the bridge's power source frequency is within audio range) as the switch is actuated.

When describing general AC bridges, where *impedances* and not just resistances must be in proper ratio for balance, it is sometimes helpful to draw the respective bridge legs in the form of box-shaped components, each one with a certain impedance: (Figure below)



Generalized AC impedance bridge: Z = nonspecific complex impedance.

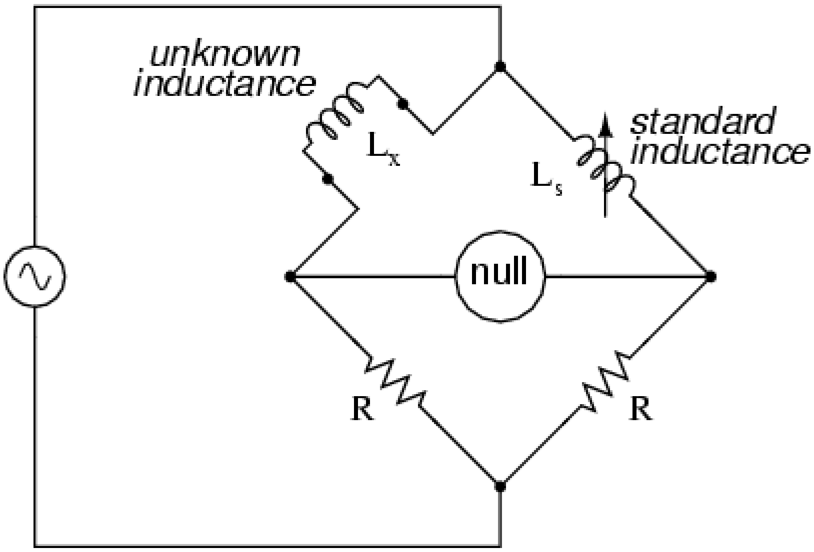
For this general form of AC bridge to balance, the impedance ratios of each branch must be equal:

$$\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$$

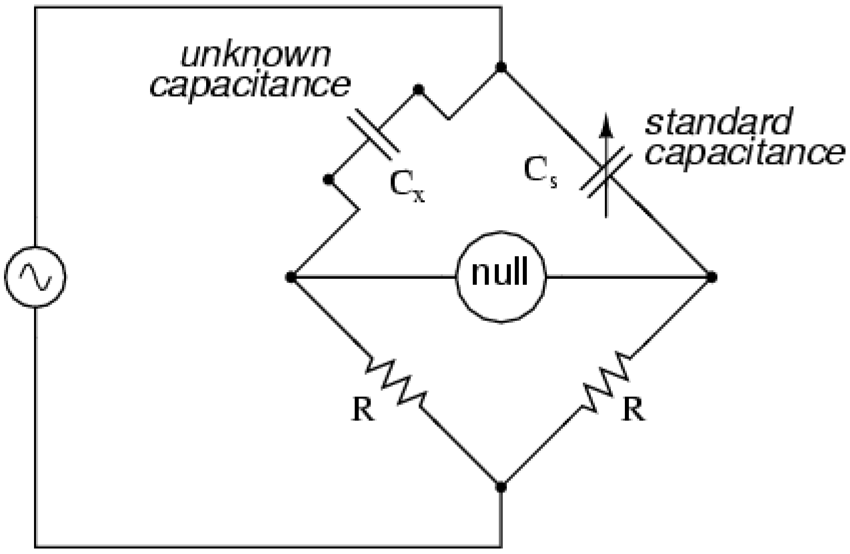
Again, it must be stressed that the impedance quantities in the above equation *must* be complex, accounting for both magnitude and phase angle. It is insufficient that the impedance magnitudes alone be balanced; without phase angles in balance as well, there will still be voltage across the terminals of the null detector and the bridge will not be balanced.

Bridge circuits can be constructed to measure just about any device value desired, be it capacitance, inductance, resistance, or even “Q.” As always in bridge measurement circuits, the unknown quantity is always “balanced” against a known standard, obtained from a high-quality, calibrated component that can be adjusted in value until the null detector device indicates a condition of balance. Depending on how the bridge is set up, the unknown component's value may be determined directly from the setting of the calibrated standard, or derived from that standard through a mathematical formula.

A couple of simple bridge circuits are shown below, one for inductance (Figure below) and one for capacitance: (Figure below)

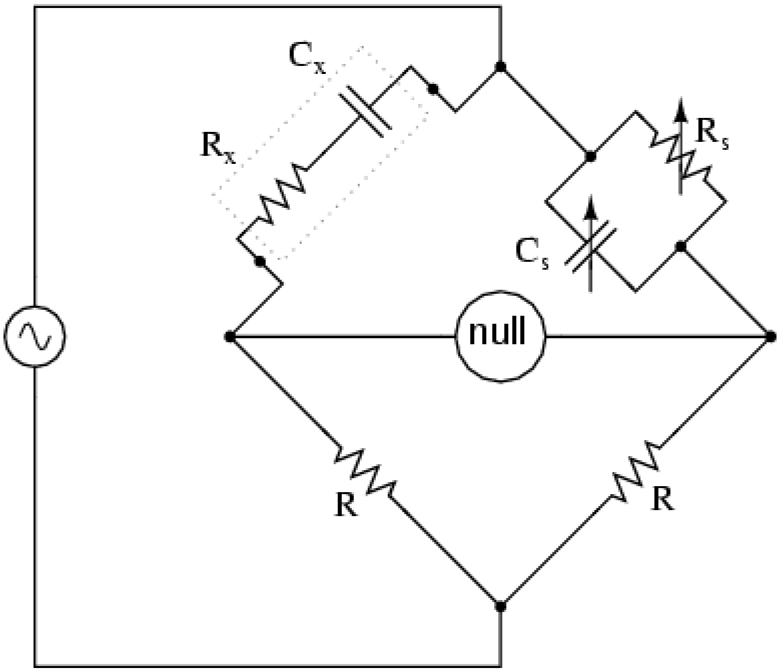


Symmetrical bridge measures unknown inductor by comparison to a standard inductor.



Symmetricalbridgemeasuresunknowncapacitorbycomparisontoastandardcapacitor.Simple“symmetrical”bridgessuchasthesearesonamedbecausetheyexhibitsymmetry(mirror-imagesimilarity)fromlefttoright.Thetwobridgecircuitsshownabovearebalancedbyadjustingthecalibratedreactivecomponent($L_s$orC_s).Theyareabitsimplifiedfromtheirreal-lifecounterparts,aspracticalsymmetricalbridgecircuitsoftenhaveacalibrated,variableresistorinseriesorparallelwiththereactivecomponenttobalanceoutstrayresistanceintheunknowncomponent.But,inthehypotheticalworldofperfectcomponents,thesesimplebridgecircuitsdojustfinetoillustratethebasic concept.

Anexampleofalittleextracomplexityaddedtocompensateforreal-worldeffectscanbefoundintheso-called*Wienbridge*,whichusesaparallelcapacitor-resistorstandardimpedancetobalanceoutanunknownseriescapacitor-resistorcombination.(Figurebelow)Allcapacitorshavesomeamountofinternalresistance,beitliteralorequivalent(intheformofdielectricheatinglosses)whichtendtospoiltheirotherwiseperfectlyreactivenatures.Thisinternalresistancemaybeofinteresttomeasure,andsotheWienbridgeattemptstodosobyprovidingabalancingimpedancethatisn't“pure”either:

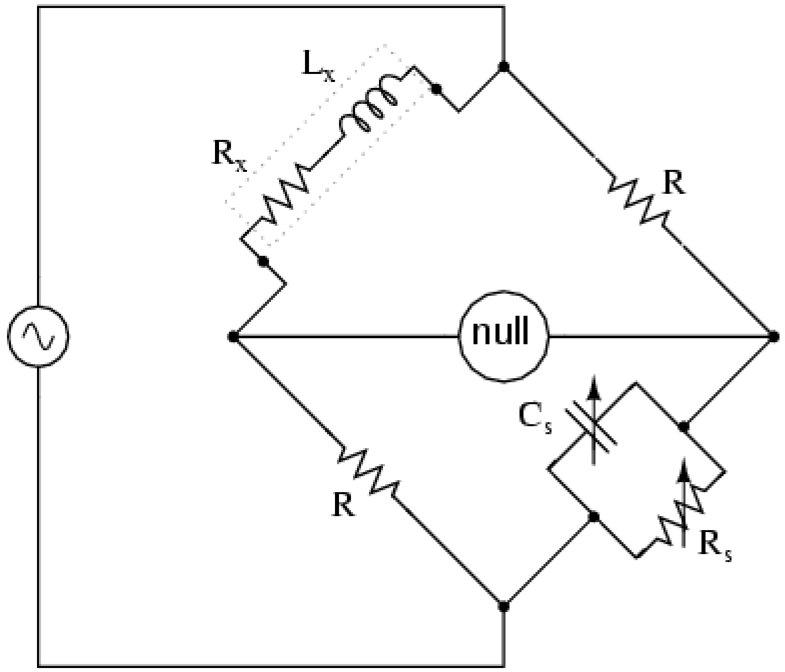


WeinBridgemeasuresboth capacitive $C_x$and resistive$R_x$componentsof “real” capacitor.

Beingthattherearetwostandardcomponentstobeadjusted(aresistorandacapacitor)thisbridgewilltakealittlemoretimetobalancethantheotherswe'veseensofar.Thecombinedeffectof $R_s$and$C_s$istoalterthemagnitudeandphaseangleuntilthebridgeachievesaconditionofbalance.Oncethatbalanceisachieved,thesettingsof$R_s$and$C_s$canbereadfromtheircalibratedknobs,theparallel impedanceofthetwodeterminedmathematically,andtheunknowncapacitanceandresistancedeterminedmathematicallyfromthe balanceequation($Z_1/Z_2= Z_3/Z_4$).

Itisassumedintheoperationofthe Wienbridgethatthestandardcapacitorhasnegligibleinternalresistance, oratleastthatresistanceisalreadyknownsothatitcanbefactoredintothebalanceequation.Wienbridgesare usefulfordeterminingthevaluesof“lossy”capacitordesignslikeelectrolytics,wheretheinternalresistanceisrelativelyhigh.Theyarealsousedasfrequencymeters,becausethebalanceofthebridgeisfrequency-dependent.Whenusedinthisfashion,thecapacitorsaremadefixed(andusuallyofequalvalue)andthetoptworesistorsaremadevariableandareadjustedbymeansofthesameknob.

Aninterestingvariationonthisthemeisfoundinthenextbridgecircuit,usedtopreciselymeasureinductances.



Maxwell-Weinbridgemeasures aninductor intermsofacapacitorstandard.

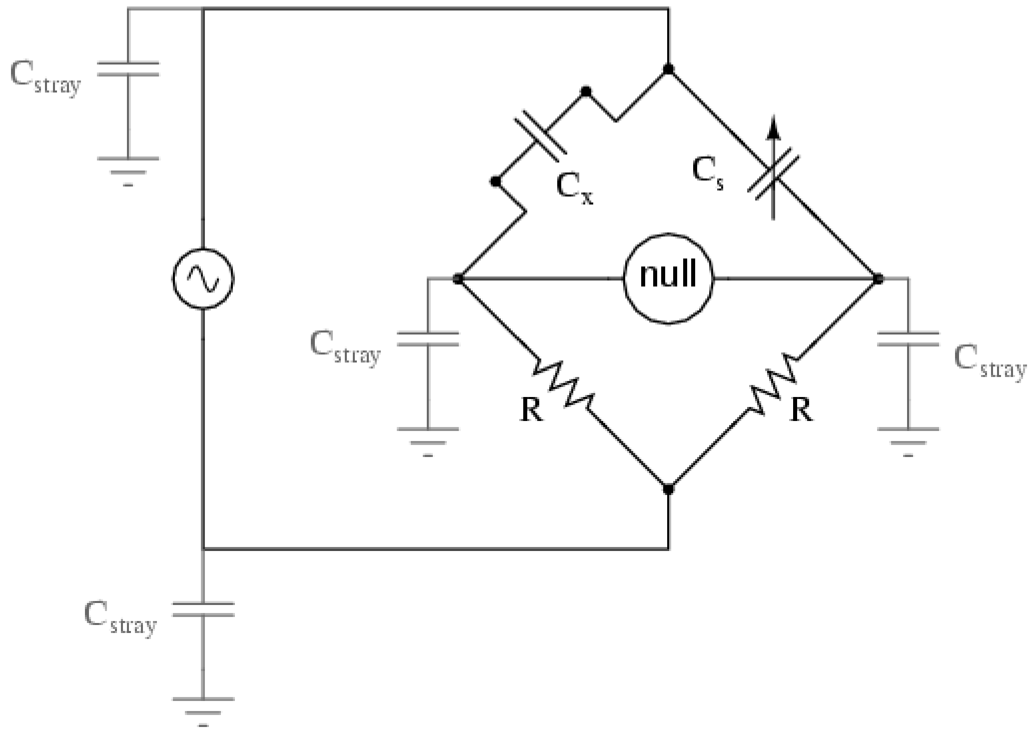
Thisingeniousbridgecircuitisknownasthe*Maxwell-Wienbridge*(sometimesknownplainlyasthe*Maxwellbridge*),andisusedtomeasureunknowninductancesintermsofcalibratedresistanceandcapacitance.(Figureabove)Calibration-gradeinductorsaremoredifficulttomanufacturethancapacitorsof similarprecision,andsotheuseofasimple“symmetrical”inductancebridgeisnotalwayspractical.Becausethephaseshiftsofinductorsandcapacitorsareexactlyoppositeeachother,acapacitiveimpedancecanbalanceoutaninductiveimpedanceiftheyarelocatedinoppositelegsofabridge,astheyarehere. AnotheradvantageofusingaMaxwellbridgeto measureinductanceratherthanasymmetricalinductancebridgeistheeliminationofmeasurementerrorduetomutualinductancebetweentwoinductors.Magneticfieldscanbedifficulttoshield,andevenasmallamountofcouplingbetweencoilsinabridgecanintroducesubstantialerrorsincertainconditions.WithnosecondinductortoreactwithintheMaxwellbridge,thisproblem is eliminated.

For easiest operation, the standard capacitor (C_S) and the resistor in parallel with it (R_S) are made variable, and both must be adjusted to achieve balance. However, the bridge can be made to work if the capacitor is fixed (non-variable) and more than one resistor made variable (at least the resistor in parallel with the capacitor, and one of the other two). However, in the latter configuration it takes more trial-and-error adjustment to achieve balance, as the different variable resistors interact in balancing magnitude and phase.

Unlike the plain Wien bridge, the balance of the Maxwell-Wien bridge is independent of source frequency, and in some cases this bridge can be made to balance in the presence of mixed frequencies from the AC voltage source, the limiting factor being the inductor's stability over a wide frequency range.

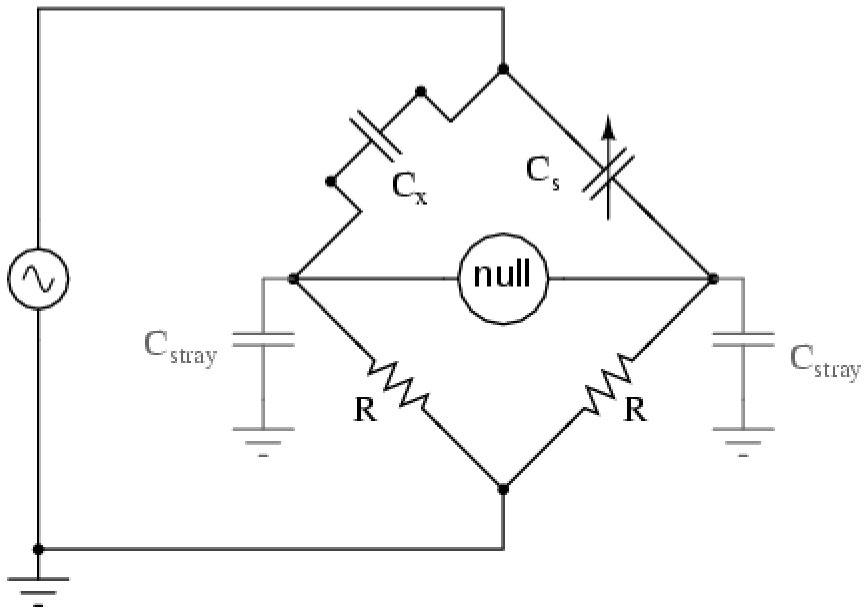
There are more variations beyond these designs, but a full discussion is not warranted here. General-purpose impedance bridge circuits are manufactured which can be switched into more than one configuration for maximum flexibility of use.

A potential problem in sensitive AC bridge circuits is that of stray capacitance between either end of the null detector unit and ground (earth) potential. Because capacitances can “conduct” alternating current by charging and discharging, they form stray current paths to the AC voltage source which may affect bridge balance: (Figure below)



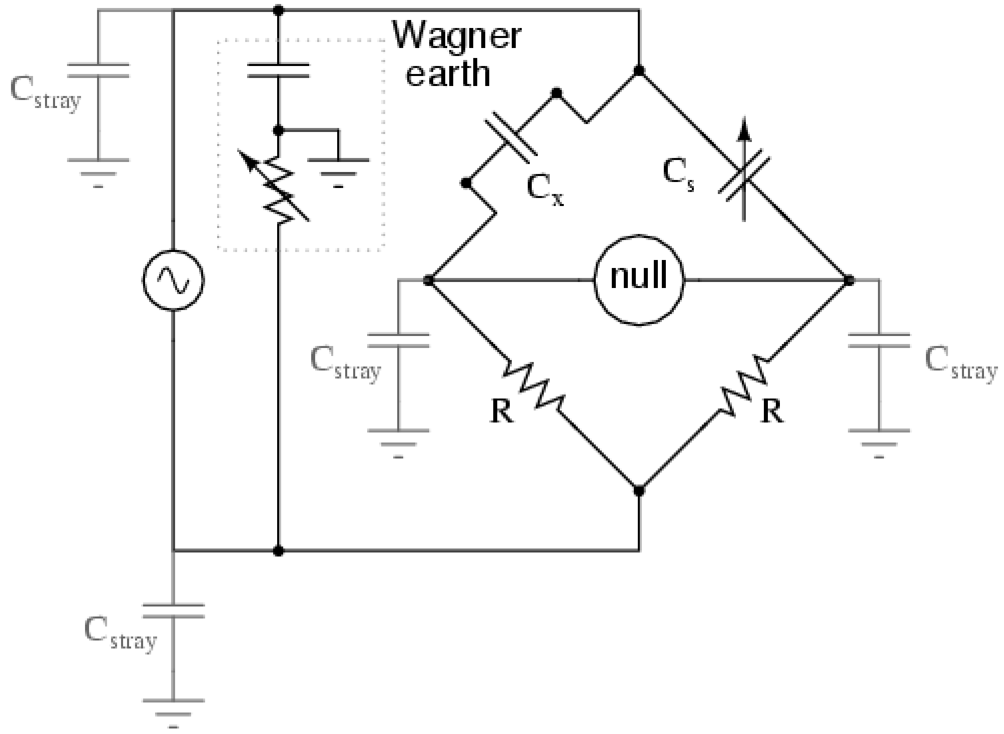
Straycapacitancetogroundmay introduceerrorsintothebridge.

Whilereed-typemetersareimprecise,theiroperationalprincipleisnot.Inlieuofmechanicalresonance,wemaysubstituteelectricalresonanceanddesignafrequencymeterusinganinductorandcapacitorintheformofatankcircuit(parallelinductorandcapacitor).Oneorbothcomponentsaremadeadjustable,andameterisplacedinthecircuittoindicatemaximumamplitudeofvoltageacrossthetwocomponents.Theadjustmentknob(s)arecalibratedtoshowresonantfrequencyforanygivensetting,andthefrequencyisreadfrom themafterthedevicehasbeenadjustedformaximumindicationonthemeter.Essentially,thisisatunablefiltercircuitwhichisadjustedandthenreadinamannersimilartoabridgecircuit(whichmustbebalancedfora“null”conditionandthenread).TheproblemisworsenediftheACvoltagesourceisfirmlygroundedatoneend, the totalstrayimpedanceforleakage currentsmadefarlessand anyleakagecurrents throughthesestraycapacitancesmadegreateras aresult:(Figurebelow)
]



StraycapacitanceerrorsaremoresevereifonesideoftheAC supplyis grounded.

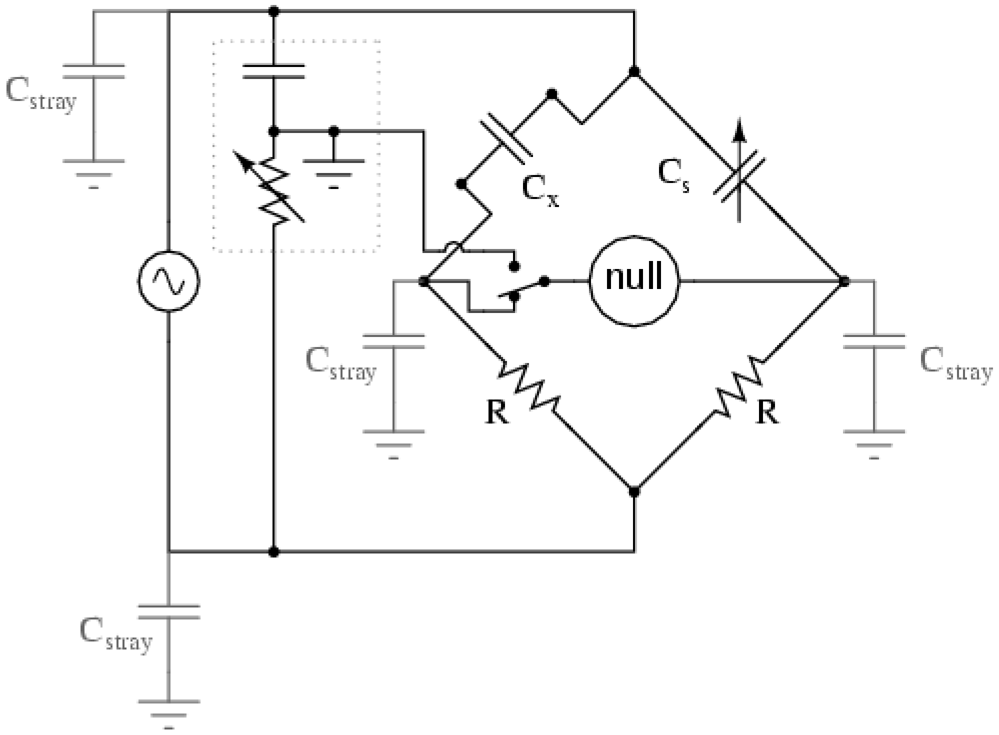
Onewayofgreatlyreducingthiseffectistokeepthenulldetectoratgroundpotential,sotherewillbenoACvoltagebetweenitandtheground,andthusnocurrentthroughstraycapacitances.However,directlyconnectingthenulldetectortogroundisnotanoption,asitwouldcreatea*direct*currentpathforstraycurrents,whichwouldbeworsethananycapacitivepath.Instead,aspecialvoltagedividercircuitcalleda*Wagnerground*or*Wagnerearth*maybeusedtomaintainthenulldetectoratgroundpotentialwithouttheneedforadirectconnectiontothenulldetector.(Figurebelow)



Wagner ground for AC supply minimizes the effects of stray capacitance to ground on the bridge.

The Wagner earth circuit is nothing more than a voltage divider, designed to have the voltage ratio and phase shift as each side of the bridge. Because the midpoint of the Wagner divider is directly grounded, any other divider circuit (including either side of the bridge) having the same voltage proportions and phases as the Wagner divider, and powered by the same AC voltage source, will be at ground potential as well. Thus, the Wagner earth divider forces the null detector to be at ground potential, without a direct connection between the detector and ground.

There is often a provision made in the null detector connection to confirm proper setting of the Wagner earth divider circuit: a two-position switch, (Figure below) so that one end of the null detector may be connected to either the bridge or the Wagner earth. When the null detector registers zero signal in both switch positions, the bridge is not only guaranteed to be balanced, but the null detector is also guaranteed to be at zero potential with respect to ground, thus eliminating any errors due to leakage currents through stray detector-to-ground capacitances:



Switch-up position allows adjustment of the Wagner ground.

REVIEW:

- AC bridge circuits work on the same basic principle as DC bridge circuits: that a balanced ratio of impedances (rather than resistances) will result in a “balanced” condition as indicated by the null-detector device.
- Null detectors for AC bridges may be sensitive electromechanical meter movements, oscilloscopes (CRT's), headphones (amplified or unamplified), or any other device capable of registering very small AC voltage levels. Like DC null detectors, its only required point of calibration accuracy is at zero.
- AC bridge circuits can be of the “symmetrical” type where an unknown impedance is balanced by a standard impedance of similar type on the same side (top or bottom) of the bridge. Or, they can be “nonsymmetrical,” using parallel impedances to balance series impedances, or even capacitances balancing out inductances.
- AC bridge circuits often have more than one adjustment, since both impedance magnitude *and* phase angle must be properly matched to balance.

- Someimpedancebridgecircuitsarefrequency-sensitivewhileothersarenot.Thefrequency-sensitivetypesmaybeusedasfrequencymeasurementdevicesifallcomponentvalues areaccuratelyknown.
- A *Wagnerearth* or *Wagnerground* isavoltagedividercircuitaddedtoACbridgestohelpreduceerrors duetostraycapacitancecouplingthenulldetectortoground.

TwoMarks

1. Whatisthebasicprincipleusedinpotentiometer.

Inpotentiometer theunknownemfismeasuredbycomparingitwithastdknownemf.

2. Namethepotentiometermaterialused.

GermansilverManganinwire

3. Definestandardization.

Itis theprocess bywhichadjustingthecurrentflows throughthepotentiometercoiltomakethevoltageacrossthestdcell is equal.

4. Statetheapplications of potentiometer.

Usedform/sofunknownemfUsedforammetercalibrationUsedforVoltmetercalibrationUsedforwattmetercalibration

5. Statetheadvantages ofcromptonpotentiometer.

MoreaccurateEasyto adjust

6. Whatarethepracticaldifficulties inacpotentiometers.Morecomplicated
Accuracy isseriouslyaffected

Difficultyisexperiencedin standardization.

7. Classifyacpotentiometers.

Polarpotentiometer

Coordinatepotentiometer.

8. Howthephaseangleis measuredinpolartypepotentiometers.

Itismeasuredfromthepositionofphase shifter.

9. Namesomeacpotentiometers. Drysd
aleTinsleypotentiometerGallTinsleypotentiome
ter

10. Statetheadvantages ofacpotentiometers.

Can beusedform/sofbothmagnitudeandphaseangleCan beusedform/sof
inductanceofthecoil.
Itis usedinm/soferrors in CTS

11. Statetheapplications ofacpotentiometers.

M/sofself
inductance.AmmetercalibrationVoltmetercalib
rationWattmetercalibration.

12. Statetheadvantages ofinstrumenttransformers.

UsedforextensionofrangePowerlossisminimum
Highvoltageandcurrents can bemeasured.

13. Statethedisadvantageofinstrumenttransformers.

Cannotbeusedfordcmeasurements.

14. Whataretheconstructionalparts ofcurrenttransformer?

PrimarywindingSecondarywindingMa
gneticcore.

15. Nametheerrorscausedincurrenttransformer.

Ratioerror

Phaseangle error

16. Defineratioerror.

Theratio ofenergycomponentcurrentandsecondarycurrentisknownas theratioerror.

17. Howthephaseangleerroris created.

Itismainlydueto magnetizingcomponentofexcitationcurrent.

18. Statetheuseof potential transformer.

Usedform/sof highvoltage

Usedforenergizingrelaysandprotectivecircuits.

19. Nametheerrorscausedinpotential transformer.

Ratioerror

Phaseangle error.

20. HowtheCT andPTareconnectedinthecircuits.

CTis connectedin series andPTis connectedin parallel.

21. Classifyresistance.

LowresistanceMediumresistanceHighresistance

22. Whatistherangeof medium resistance?

Resistanceofabout1ohmto 100kiloohms arecalledmediumresistance.

23. Namethemethodsusedforlowresistancemeasurement.

Ammeter–voltmetermethodPotentiometermethod KelvindoublebridgemethodOhmmetermethod.

24. Namethemethodsusedformedium resistancemeasurement

Ammeter–voltmetermethodSubstitutionmethodWheatstonebridgemethodCareyfosterbridgemethod.

25. Wherehighresistancem/s isrequired?

InsulationresistanceofcablesHighresistancecircuitelementsVolumeresistivityofamaterial

Surfaceresistivity.

26. Statetheadvantages of Wheatstonebridgemethod.

Freefromerrors

Thebalanceisquitindependent ofsourceemf

27. Statetheadvantages ofKelvindoublebridgemethod.

Errorsowing to contactresistance,resistanceof leads can beeliminatedbyusingthisKelvindoublebridge.

28. Whataretheconstructionalfeatures ofdoctorohmmeter?

PermanentmagnetCurrentcoilPressu
recoilBattery
Pointerwithgraduatedscale.

29. Definemegger.

Themeggerisaninstrumentusedforthemeasurementofhighresistanceandinsulationresistance.

30. Nametheparts ofmegger.

Itconsistsofahanddrivendcgeneratorandadirectreadingtrueohmmeter.

31. Whatistherangeoflowresistance?

Resistanceofabout1ohmandunderareincludedin this class.

32. Whatistherangeof medium resistance?

Resistanceof100kiloohmsandaboveareusuallytermedashighresistance.

33. Whatranges of resistancecanbemeasuredbyusingdoctorohmmeter.

0to500microohms

0to5milliohms

0to50milliohms

0to500milliohms

0to5ohms.

34. Howresistanceis measuredindirectdeflectionmethod.

Thedeflectionofgalvanometerconnectedin serieswiththeresistancetobemeasuredgives ameasureoftheinsulationresistance.

35. Classifythecables accordingtotheirsheathing.

ArmouredcablesUnarmouredcables.

36. Nametheleadspresentinmegger.

EarthleadLineleadGuardlead.

37. Howresistanceis measuredbyusingohm metermethod.

SeriesohmmetermethodShuntohmmetermethod.

38. Howresistanceismeasuredinloss of chargemethod.

Inthismethodacapacitorischargedanddischargedforaspecifictimeperiodandfromthis resistanceismeasured.

39. Statethebalanceequationusedinbridgemethods.

Theproductofoppositebranchresistances areequal.

40.Statetheadvantages of price’sguardwiremethod.

Inthismethodleakagecurrentdoes notflowsthroughthemeterandthereforeitgives accuratereading.

41. Howtheearthresistanceis measured.

Byusingearthmeggerthevalueofsurfaceearthresistancecanbemeasured.

42. Statetheuseofacbridges.

ACbridges areusedforthem/sofselfandmutualinductanceandcapacitance.

43. Statethebalanceequationusedinacbridges.

Theproductofoppositebranchimpedances areequal.

44. Name thebridgecircuitsusedforthem/s ofself inductance.

Maxwell‟sbridgeMaxwell-WeinBridgeAndersonbridgeHay‟sbridge.

45. Namethebridgecircuitsusedforthem/s ofcapacitance.

DeSauty‟sbridgeScheringBridgeWeinbridge

46. Namethebridgecircuitsusedforthem/s ofmutualinductance.

TheHeavisideCampbellbridgeTheCampbellbridge.

47. Whichtypeof detectoris usedinacbridges?

Vibrationgalvanometers areused.

48. Nametheacsourcesusedinacbridges.AC supplywithstep-downtransformerMotor drivenalternator
Audiofrequencyandradiofrequencyoscillator.

49. Inwhichcases audiofrequencyoscillatorsareusedas acsource.

Forhighfrequencyacrequirementaudiofrequencyoscillatorsareused.

50. Namethesources of errors inacbridgem/s. Errors duetostraymagneticfieldsLeakage errors
EddycurrenterrorsResidualerrors
Frequencyandwaveformerrors.

51. Statetheadvantages of Maxwell-weinbridge.

Thebalanceequationisindependentoffrequencyandthereforemoreaccurate.

52. StatethedisadvantageofMaxwell-weinbridge.

Thismethodneeds astdvariablecapacitor.VariableCapacitoriscostliest.

53.Statethedisadvantages ofHay’s bridge.

Thebalanceequationisdependentof frequencyandthereforeanychangesinfrequencywillaffectthem/s.

54. StatetheuseofWeinbridge.

Itis usedforthem/sofunknowncapacitanceandfrequency.

55. WhatistheuseofCampbellbridge?

Thisisusedforthem/sof mutualinductance.

56. Whatis meant byinductometer?

Thestdvariablemutualinductancemeteriscalledasinductometer.

57. DefineQ-factorofthecoil.

Itis theratiobetweenpowerstoredin thecoilto thepower dissipatedin thecoil.

58. Namethecomponents ofironloss.

EddycurrentlossHysterisisloss.
**59. Namethefaults thatoccurs
incables.**BreakdownofcableinsulationShortcircuitfault
Openconductorfault.

60. Namethelloop testmethodsusedinlocationoffault.

MurraylooptestVarleylooptest.
61. Howleakageerrorsareminimizedinacbridgecircuits.

Byusinghighgradeinsulation.

Unit 4
As we know a word "meter" associated with the measurement. Meter is an instrument which can measure a particular quantity. we know, the unit of **current** is Ampere. **Ammeter** means Ampere-meter which measures ampere value. Ampere is the unit of current so an ammeter is a meter or an instrument which measures current. The main **principle of ammeter** is that it must have a very low resistance and also inductive reactance. Now, why do we need this? Can't we connect an ammeter in parallel? The answer to this question is it has very low impedance because it must have very low amount of voltage drop across it and must be connected in series connection because current is same in the series circuit. Also due to very low impedence the power loss will be low and if it is connected in parallel it becomes almost a short circuited path and all the current will flow through ammeter as a result of high current the instrument may burn. So due to this reason it must be connected in series. For an ideal ammeter, it must have zero impedance so that it has zero voltage drop across it so the power loss in the instrument is zero. But the ideal is not achievable practically.

Classification or Types of Ammeter

Depending on the constructing principle, there are many types of ammeter we get, they are mainly -

1. **Permanent Magnet Moving Coil(PMMC) ammeter**.
2. **Moving Iron(MI) Ammeter**.
3. **Electrodynamometer type Ammeter**.
4. **Rectifier type Ammeter**.

Depending on this types of measurement we do, we have-

1. **DC Ammeter**.
2. **AC Ammeter**.

DC Ammeter are mainly PMMC instruments, MI can measure both AC and DC currents, also Electrodynamometer type thermal instrument can measure DC and AC, induction meters are not generally used for ammeter construction due to their higher cost, inaccuracy in measurement.

Description of Different Types of Ammeters

PMMC Ammeter

Principle PMMC Ammeter:

When current carrying conductor placed in a magnetic field, a mechanical force acts on the conductor, if it is attached to a moving system, with the coil movement, the pointer moves over the scale.

Explanation: As the name suggests it has permanent magnets which are employed in this kind of measuring instruments. It is particularly suited for DC measurement because here deflection is proportional to the current and hence if current direction is reversed, deflection of the pointer will also be reversed so it is used only for DC measurement. This type of instrument is called D Arnsonval type instrument. It has major advantage of having linear scale, low power consumption, high accuracy. Major disadvantage of being measured only DC quantity, higher cost etc.

Deflecting torque, $T = BiNlbNm$ Where,

B = Flux density in Wb/m^2.

i = Current flowing through the coil in Amp.

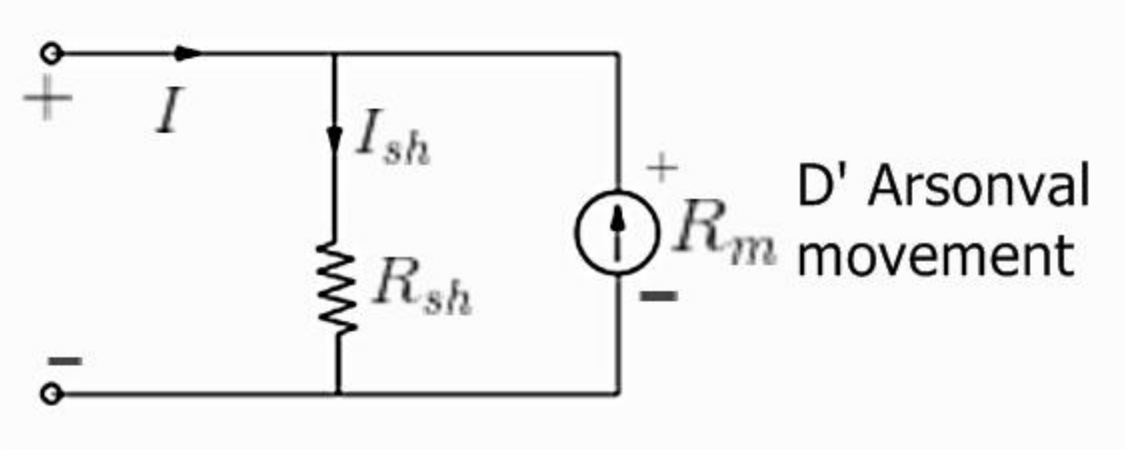
l = Length of the coil in m.

b = Breadth of the coil in m.

N = No of turns in the coil.

Extension of Range in a PMMC Ammeter:

Now it looks quite extraordinary that we can extend the range of measurement in this type of instrument. Many of us will think that we must buy a new ammeter to measure higher amount of current and also many of us may think we have to change the constructional feature so that we can measure higher currents, but there is nothing like that, we just have to connect a shunt resistance in parallel and the range of that instrument can be extended, this is a simple solution provided by the instrument.



In the figure I = total current flowing in the circuit in Amp. I_{sh} is the current through the shunt resistor in Amp.

$$Then,\ R_{sh} = \frac{R_m}{\frac{I}{I-I_{sh}} - 1}$$

R_m is the ammeter resistance in Ohm.

MI Ammeter

It is a moving iron instrument, used for both AC and DC, It can be used for both because the deflection θ propotional square of the current so what ever is the direction of current, it shows directional deflection, further they are classified in two more ways-

1. **Attraction type**.
2. **Repulsion type**.

Its torque equation is: $T = \frac{1}{2} I^2 \frac{dL}{d\theta}$ Where,

I is the total current flowing in the circuit in Amp.
L is the self inductance of the coil in Henry.
θ is the deflection in Radian.

1. **Attraction Type MI Instrument Principle:** When an unmagnetised soft iron is placed in the magnetic field, it is attracted towards the coil, if a moving system attached and current is passed through a coil, it creates a magnetic field which attracts iron piece and creates deflecting torque as a result of which pointer moves over the scale.
2. **Repulsion Type MI Instrument Principle:** When two iron pieces are magnetized with same polarity by passing a current than repulsion between them occurs and that repulsion produces a deflecting torque due to which the pointer moves.

The advantages of MI instruments are they can measure both AC and DC, cheap, low friction errors, robustness etc. It is mainly used in AC measurement because in DC measurement error will be more due to hysteresis.

Electrodynamometer Type Ammeter

This can be used to measure both i.e. AC and DC currents. Now we see that we have PMMC and MI instrument for the measurement of AC and DC currents, a question may arise - "why do we need

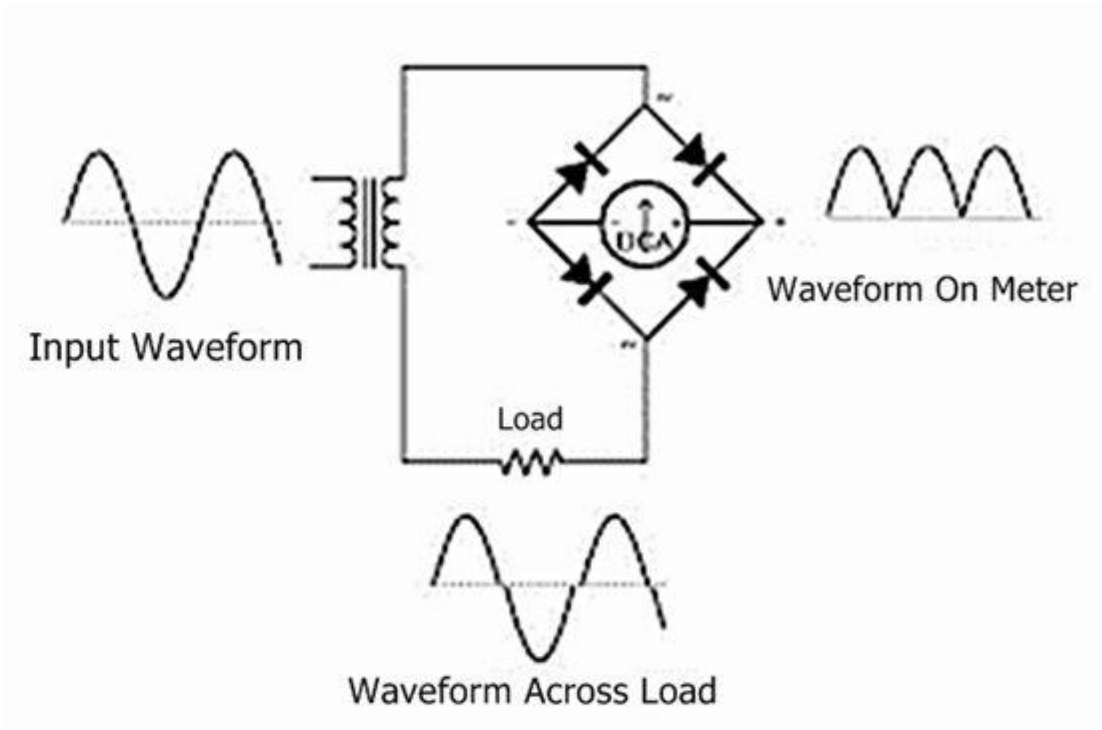
Electrodynamometer Ammeter? if we can measure current accurately by other instrument also?". The answer is Electrodynamometer instruments have the same calibration for both AC and DC i.e. if it is calibrated with DC, then also without calibrating we can measure AC.

Principle Electrodynamometer Type Ammeter:
There we have two coils, namely fixed and moving coils. If a current is passed through two coils it will stay in the zero position due to the development of equal and opposite torque. If somehow, the direction of one torque is reversed as the current in the coil reverses, an unidirectional torque is produced.
For ammeter, the connection is a series one and φ = 0

$$T = I^2 \frac{dM}{d\theta}$$

Where, φ is the phase angle. Where,
I is the amount of current flowing in the circuit in Amp.
M = Mutual inductance of the coil.
They have no hysteresis error, used for both AC and DC measurement, the main disadvantages are they have low torque/weight ratio, high friction loss, expensive than other measuring instruments etc.

Rectifier Ammeter



Principle of Rectifier Ammeter:
They are used for AC measurement which is connected to secondary of a current transformer, the secondary current is much less than primary and connected with a bridge rectifier to moving coil ammeter.

Advantages:
1. It can be used in high frequency also.
2. Uniform scale for most of the ranges.

Disadvantages being error due to temperature decrease in sensitivity in AC operation.

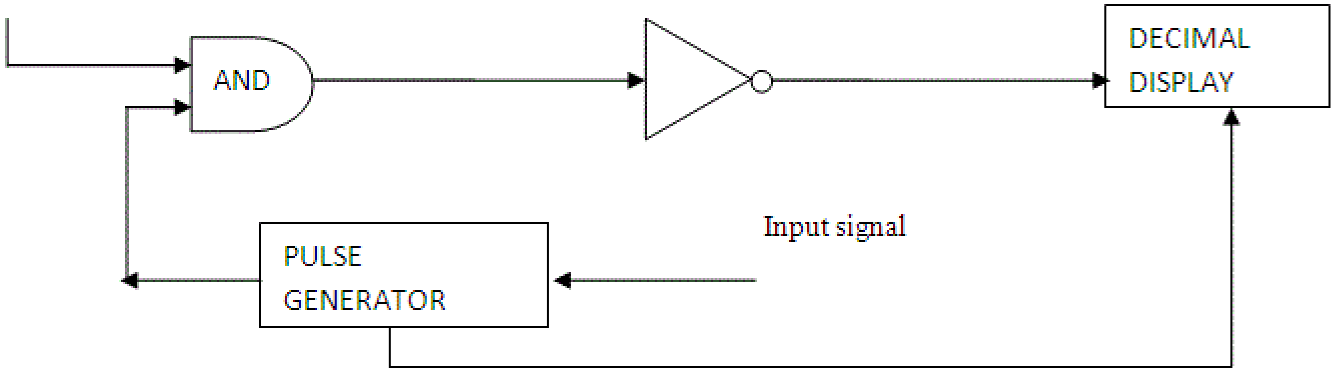
Voltmeter is an electrical measuring instrument which is used to measure potential differencebetween two points. The voltage to be measured may be AC or DC. Two types of voltmetersare available for the

purpose of voltage measurement i.e. analog and digital. Analog voltmeters generally contain a dial with a needle moving over it according to the measur and hence displaying the value of the same.
With the passage of time analog voltmeters are replaced by **digital voltmeters** due to the same advantages associated with digital systems. Although analog voltmeters are not fully replaced by **digital voltmeters**, still there are many places where analog voltmeters are preferred over digital voltmeters.
Digital voltmeters display the value of AC or DC voltage being measured directly as discrete numerical instead of a pointer deflection on a continuous scale as in analog instruments.

Advantages Associated with Digital Voltmeters

- Read out of **DVMs** is easy as it eliminates observational errors in measurement committed by operators.
- Error on account of parallax and approximation is entirely eliminated.
- Reading can be taken very fast.
- Output can be fed to memory devices for storage and future computations.
- Versatile and accurate
- Compact and cheap
- Low power requirements
- Portability increased

Working Principle of Digital Voltmeter



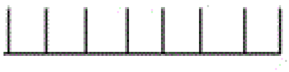
The **block diagram of a simple digital voltmeter** is shown in the figure.

Explanation of various blocks

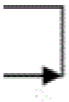
Input signal: It is basically the signal i.e. voltage to be measured.

Pulse generator: Actually it is a voltage source. It uses digital, analog or both techniques to generate a rectangular pulse. The width and frequency of the rectangular pulse is controlled by the digital circuitry inside the generator while amplitude and rise & fall time is controlled by analog circuitry.

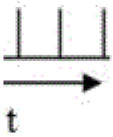
AND gate: It gives high output only when both the inputs are high. When a train pulse is fed to it along with rectangular pulse, it provides us an output having train pulses with duration as same as the rectangular pulse from the pulse generator.



ulse

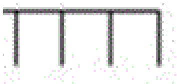


gular pulse



of AND gate

NOT gate: It inverts the output of AND gate.



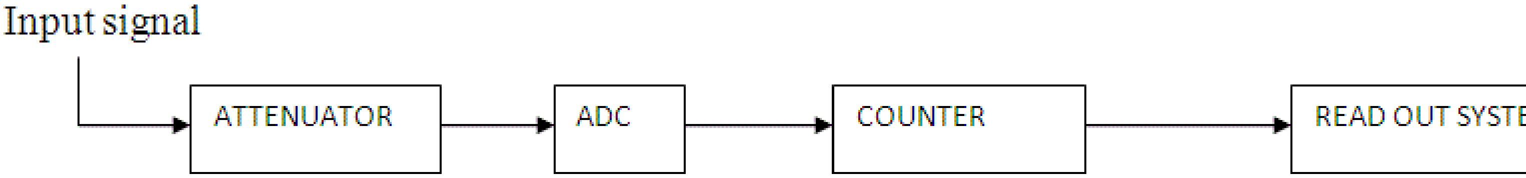
of NOT gate

Decimal Display: It counts the numbers of impulses and hence the duration and display the value of voltage on LED or LCD display after calibrating it.

Now we are in situation to understand the **working of a digital voltmeter** as follows:

- Unknown voltage signal is fed to the pulse generator which generates a pulse whose width is proportional to the input signal.
- Output of pulse generator is fed to one leg of the AND gate.
- The input signal to the other leg of the AND gate is a train of pulses.
- Output of AND gate is positive triggered train of duration same as the width of the pulse generated by the pulse generator.
- This positive triggered train is fed to the inverter which converts it into a negative triggered train.
- Output of the inverter is fed to a counter which counts the number of triggers in the duration which is proportional to the input signal i.e. voltage under measurement.
- Thus, counter can be calibrated to indicate voltage in volts directly.

We can see the working of digital voltmeter that it is nothing but an analog to digital converter which converts an analog signal into a train of pulses, the number of which is proportional to the input signal. So a **digital voltmeter** can be made by using any one of the A/D conversion methods.



On the basis of A/D conversion method used digital voltmeters can be classified as:

- Ramp type digital voltmeter
- Integrating type voltmeter
- Potentiometric type digital voltmeters
- Successive approximation type digital voltmeter
- Continuous balance type digital voltmeter

Now-a-days **digital voltmeters** are also replaced by digital millimeters due to its multitasking feature i.e. it can be used for measuring current, voltage and resistance. But still there are some fields where separated digital voltmeters are being used.

Watt hour meter or energy meter is an instrument which measures amount of electrical energy used by the consumers. Utilities install these instruments at every place like homes, industries, organizations to charge the electricity consumption by loads such as lights, fans and other appliances. Most interesting type are used as prepaid electricity meters.

Basic unit of power is watts. One thousand watts is one kilowatt. If we use one kilowatt in one hour, it is considered as one unit of energy consumed. These meters measure the instantaneous voltage and currents, calculate its product and gives instantaneous power. This power is integrated over a period which gives the energy utilized over that time period.

Types of energy Meter

These may be single or three phase meters depending on the supply utilized by domestic or commercial installations. For small service measurements like domestic customers, these can be directly connected between line and load. But for larger loads, step down current transformers must be placed to isolate energy meters from higher currents.

3 Basic types of Energy meters

Energy meter or watt hour meter is classified in accordance with several factors such as:

- Type of display like analog or digital electric meter.
- Type of metering point like grid, secondary transmission, primary and local distribution.
- End applications like domestic, commercial and industrial.
- Technical like three phases, single phase, HT, LT and accuracy class meters.

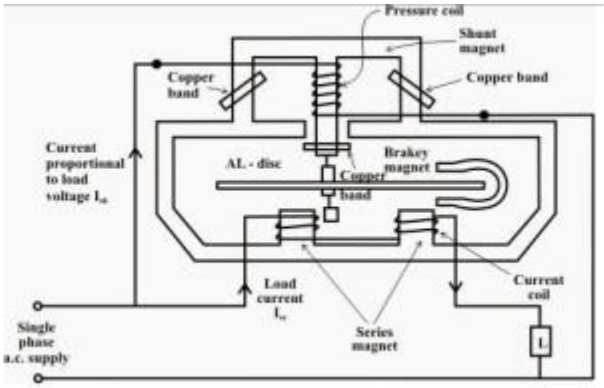
1. Electromechanical induction type Energy meter

Induction type Energy meter

It is the popularly known and most common type of age old watt hour meter. It consists of rotating aluminum disc mounted on a spindle between two electro magnets. Speed of rotation of disc is proportional to the power and this power is integrated by the use of counter mechanism and gear trains. It comprises of two silicon steel laminated electromagnets i.e., series and shunt magnets.

Series magnet carries a coil which is of few turns of thick wire connected in series with line whereas shunt magnet carries coil with many turns of thin wire connected across the supply.

Breaking magnet is a permanent magnet which applies the force opposite to normal disc rotation to move that disc at balanced position and to stop the disc while power is off.



Working of induction type energy meter

Series magnet produces the flux which is proportional to the current flowing and shunt magnet produces the flux proportional to the voltage. These two fluxes lag by 90 degrees due to inductive nature. The interaction of these two fields produces eddy current in the disk, exerting a force, which is proportional to product of instantaneous voltage, current and phase angle between them.

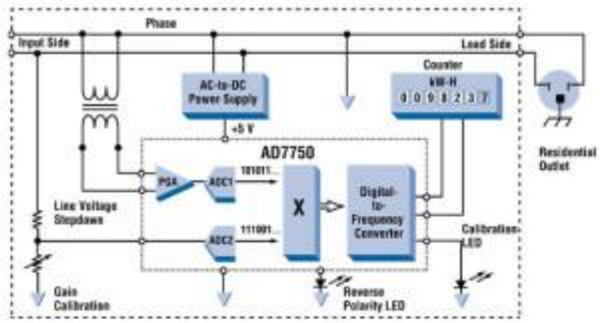
Vertical spindle or shaft of the aluminum disc is connected to gear arrangement which records a number, proportional to the number of revolutions of the disc. This gear arrangement sets the number in a series of dials and indicates energy consumed over a time. This type of meter is simple in construction and accuracy is somewhat less due to creeping and other external fields. A major problem with these types of meters is their easy prone to tampering, leading to a requirement of an electrical energy monitoring system. These are very commonly used in domestic and industrial applications.

2. Electronic Energy meters

These are of accurate, high procession and reliable types of measuring instruments as compared to conventional mechanical meters. It consumes less power and starts measuring instantaneously when connected to load. These meters might be analog or digital. In analog meters, power is converted to proportional frequency or pulse rate and it is integrated by counters placed inside it. In digital electric meter power is directly measured by high end processor. The power is integrated by logic circuits to get the energy and also for testing and calibration purpose. It is then converted to frequency or pulse rate.

Analog Electronic Energy Meters

In analog type meters, voltage and current values of each phase are obtained by voltage divider and current transformers respectively which are directly connected to the load as shown in figure.

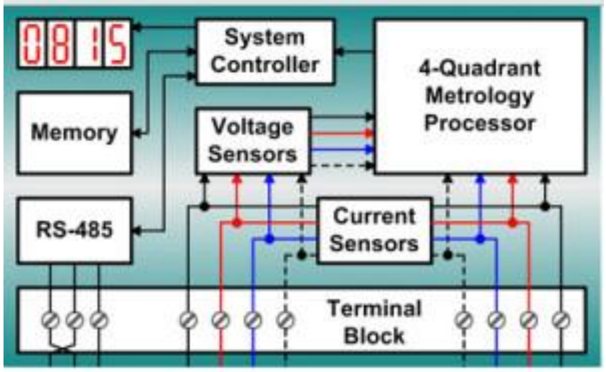


Analog Electronic Meters

Analog to digital converter converts these analog values to digitized samples and it is then converted to corresponding frequency signals by frequency converter. These frequency pulses then drive a counter mechanism where these samples are integrated over a time to produce the electricity consumption.

Digital Electronic Energy Meters

Digital signal processor or high performance microprocessors are used in digital electric meters. Similar to the analog meters, voltage and current transducers are connected to a high resolution ADC. Once it converts analog signals to digital samples, voltage and current samples are multiplied and integrated by digital circuits to measure the energy consumed.



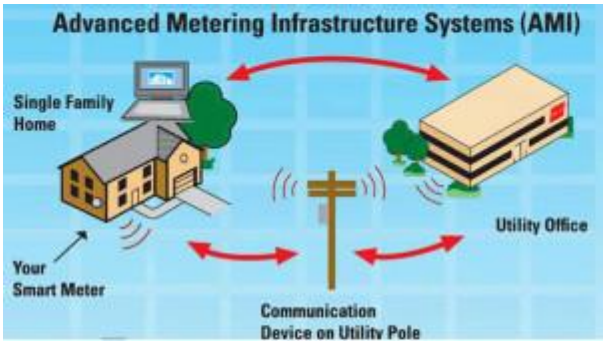
Digital Electronic Energy Meters

Microprocessor also calculates phase angle between voltage and current, so that it also measures and indicates reactive power. It is programmed in such a way that it calculates energy according to the tariff and other parameters like power factor, maximum demand, etc and stores all these values in a non volatile memory EEPROM.

It contains real time clock (RTC) for calculating time for power integration, maximum demand calculations and also date and time stamps for particular parameters. Furthermore it interacts with liquid crystal display (LCD), communication devices and other meter outputs. Battery is provided for RTC and other significant peripherals for backup power.

3. Smart Energy Meters

It is an advanced metering technology involving placing intelligent meters to read, process and feedback the data to customers. It measures energy consumption, remotely switches the supply to customers and remotely controls the maximum electricity consumption. Smart metering system uses the advanced metering infrastructure system technology for better performance.



Smart Energy Meters

These are capable of communicating in both directions. They can transmit the data to the utilities like energy consumption, parameter values, alarms, etc and also can receive information from utilities such as automatic meter reading system, reconnect/disconnect instructions, upgrading of meter software's and other important messages. These meters reduce the need to visit while taking or reading monthly bill. Modems are used in these smart meters to facilitate communication systems such as telephone, wireless, fiber cable, power line communications. Another advantage of smart metering is complete avoidance of tampering of energy meter where there is scope of using power in an illegal way.

This is all about types of energy meter and their working. Hope you are satisfied with this article. We express our gratitude to all the readers. Please share your comments and suggestions on the comment section given below.

The **wattmeter** is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic wattmeters are used for measurement of utility frequency and audio frequency power; other types are required for radio frequency measurements. The traditional analog wattmeter is an electrodynamic instrument. The device consists of a pair of fixed coils, known as *current coils*, and a movable coil known as the *potential coil*.

The current coils are connected in series with the circuit, while the potential coil is connected in parallel. Also, on analog wattmeters, the potential coil carries a needle that moves over a scale to indicate the measurement. A current flowing through the current coil generates an electromagnetic field around the coil. The strength of this field is proportional to the line current and in phase with it. The potential coil has, as a general rule, a high-value resistor connected in series with it to reduce the current that flows through it.

The result of this arrangement is that on a dc circuit, the deflection of the needle is proportional to *both* the current (I) *and* the voltage (V), thus conforming to the equation $P=VI$.

For AC power, current and voltage may not be in phase, owing to the delaying effects of circuit inductance or capacitance. On an ac circuit the deflection is proportional to the average instantaneous product of voltage and current, thus measuring true power, $P=VI \cos \varphi$. Here, $\cos\varphi$ represents the power factor which shows that the power transmitted may be less than the apparent power obtained by multiplying the readings of a voltmeter and ammeter in the same circuit.

The two circuits of a wattmeter can be damaged by excessive current. The ammeter and voltmeter are both vulnerable to overheating — in case of an overload, their pointers will be driven off scale — but in the wattmeter, either or even both the current and potential circuits can overheat *without* the pointer approaching the end of the scale. This is because the position of the pointer depends on the power factor, voltage and current. Thus, a circuit with a low power factor will give a low reading on the wattmeter, even when both of its circuits are loaded to the maximum safety limit. Therefore, a wattmeter is rated not only in watts, but also in volts and amperes.

A typical wattmeter in educational labs has two voltage coils (pressure coils) and a current coil. We can connect the two pressure coils in series or parallel to each other to change the ranges of the wattmeter. Another feature is that the pressure coil can also be tapped to change the meter's range. If the pressure coil has range of 300 volts, the half of it can be used so that the range becomes 150 volts.

An **electric current** is a flow of electric charge. In electric circuits this charge is often carried by moving electrons in a wire. It can also be carried by ions in an electrolyte, or by both ions and electrons such as in an ionised gas (plasma).[1]

The SI unit for measuring an electric current is the ampere, which is the flow of electric charge across a surface at the rate of one coulomb per second. Electric current is measured using a device called an ammeter.[2]

Electric currents cause Joule heating, which creates light in incandescent light bulbs. They also create magnetic fields, which are used in motors, inductors and generators.

The moving charged particles in an electric current are called charge carriers. In metals, one or more electrons from each atom are loosely bound to the atom, and can move freely about within the metal. These conduction electrons are the charge carriers in metal conductors.

Unit 5


7-segment Display

Light emitting diodes have many advantages over traditional bulbs and lamps, with the main ones being their small size, long life, various colours, cheapness and are readily available, as well as being easy to interface with various other electronic components and digital circuits.

But the main advantage of light emitting diodes is that because of their small die size, several of them can be connected together within one small and compact package producing what is generally called a **7-segment Display**.

The *7-segment display*, also written as "seven segment display", consists of seven LEDs (hence its name) arranged in a rectangular fashion as shown. Each of the seven LEDs is called a segment because when illuminated the segment forms part of a numerical digit (both Decimal and Hex) to be displayed. An additional 8th LED is sometimes used within the same package thus allowing the indication of a decimal point, (DP) when two or more 7-segment displays are connected together to display numbers greater than ten.

Related Products: **Displays**

Each one of the seven LEDs in the display is given a positional segment with one of its connection pins being brought straight out of the rectangular plastic package. These individually LED pins are labelled from a through to g representing each individual LED. The other LED pins are connected together and wired to form a common pin.

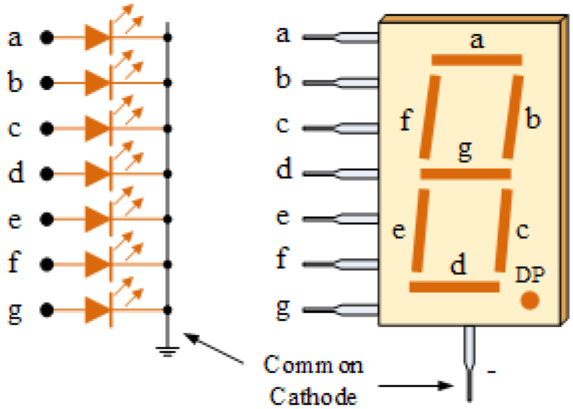
So by forward biasing the appropriate pins of the LED segments in a particular order, some segments will be light and others will be dark allowing the desired character pattern of the number to be generated on the display. This then allows us to display each of the ten decimal digits 0 through to 9 on the same 7-segment display.

The displays common pin is generally used to identify which type of 7-segment display it is. As each LED has two connecting pins, one called the "Anode" and the other called the "Cathode", there are therefore two types of LED 7-segment display called: **Common Cathode** (CC) and **Common Anode** (CA).

The difference between the two displays, as their name suggests, is that the common cathode has all the cathodes of the 7-segments connected directly together and the common anode has all the anodes of the 7-segments connected together and is illuminated as follows.

1. The Common Cathode (CC) – In the common cathode display, all the cathode connections of the LED segments are joined together to logic "0" or ground. The individual segments are illuminated by application of a "HIGH", or logic "1" signal via a current limiting resistor to forward bias the individual Anode terminals (a-g).

Common Cathode 7-segment Display

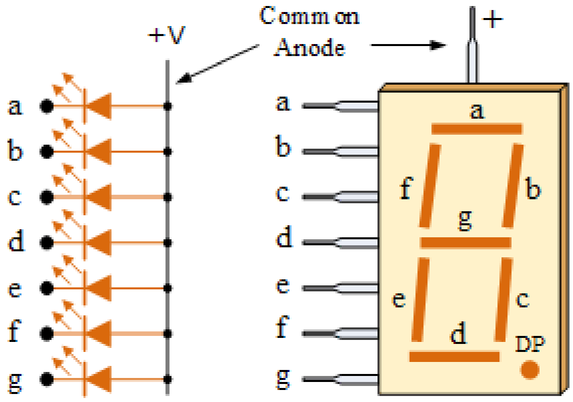


2. The Common Anode (CA) – In the common anode display, all the anode connections of the LED segments are joined together to logic "1". The individual segments are illuminated by applying a ground, logic "0" or "LOW" signal via a suitable current limiting resistor to the Cathode of the particular segment (a-g).

Related Products: **Display Misc**

Unit 5

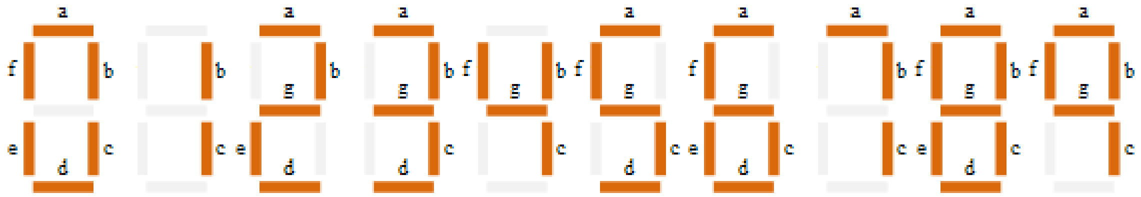
Common Anode 7-segment Display



In general, common anode displays are more popular as many logic circuits can sink more current than they can source. Also note that a common cathode display is not a direct replacement in a circuit for a common anode display and vice versa, as it is the same as connecting the LEDs in reverse, and hence light emission will not take place.

Depending upon the decimal digit to be displayed, the particular set of LEDs is forward biased. For instance, to display the numerical digit 0, we will need to light up six of the LED segments corresponding to a, b, c, d, e and f. Then the various digits from 0through 9 can be displayed using a 7-segment display as shown.

7-Segment Display Segments for all Numbers.



Then for a 7-segment display, we can produce a truth table giving the individual segments that need to be illuminated in order to produce the required decimal digit from 0 through 9 as shown below.

7-segment Display Truth Table

ecimal Digit	Individual Segments Illuminated						
	a	b	c	d	e	f	g
0	×	×	×	×	×	×	
1		×	×				
2	×	×		×	×		×

3	×	×	×	×			×
4		×	×			×	×
5	×		×	×		×	×
6	×		×	×	×	×	×
7	×	×	×				
8	×	×	×	×	×	×	×
9	×	×	×			×	×

Driving a 7-segment Display

Although a 7-segment display can be thought of as a single display, it is still seven individual LEDs within a single package and as such these LEDs need protection from over current. LEDs produce light only when it is forward biased with the amount of light emitted being proportional to the forward current.

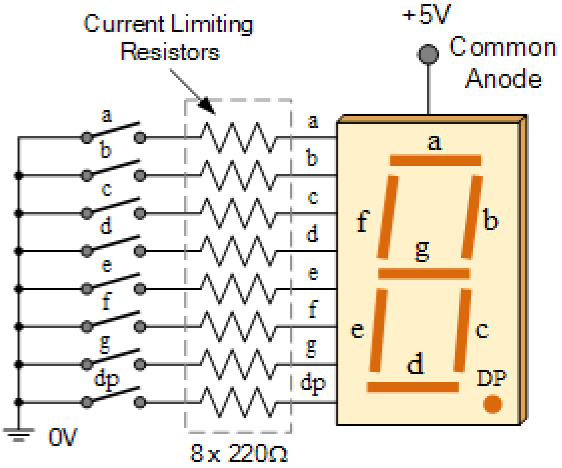
This means then that an LEDs light intensity increases in an approximately linear manner with an increasing current. So this forward current must be controlled and limited to a safe value by an external resistor to prevent damage to the LED segments.

The forward voltage drop across a red LED segment is very low at about 2-to-2.2 volts, (blue and white LEDs can be as high as 3.6 volts) so to illuminate correctly, the LED segments should be connected to a voltage source in excess of this forward voltage value with a series resistance used to limit the forward current to a desirable value.

Typically for a standard red coloured 7-segment display, each LED segment can draw about 15 mA to illuminated correctly, so on a 5 volt digital logic circuit, the value of the current limiting resistor would be about 200Ω (5v – 2v)/15mA, or 220Ω to the nearest higher preferred value.

So to understand how the segments of the display are connected to a 220Ω current limiting resistor consider the circuit below.

Driving a 7-segment Display



In this example, the segments of a common anode display are illuminated using the switches. If switch a is closed, current will flow through the "a" segment of the LED to the current limiting resistor connected to pin a and to 0 volts, making the circuit. Then only segment a will be illuminated. So a LOW condition (switch to ground) is required to activate the LED segments on this common anode display.

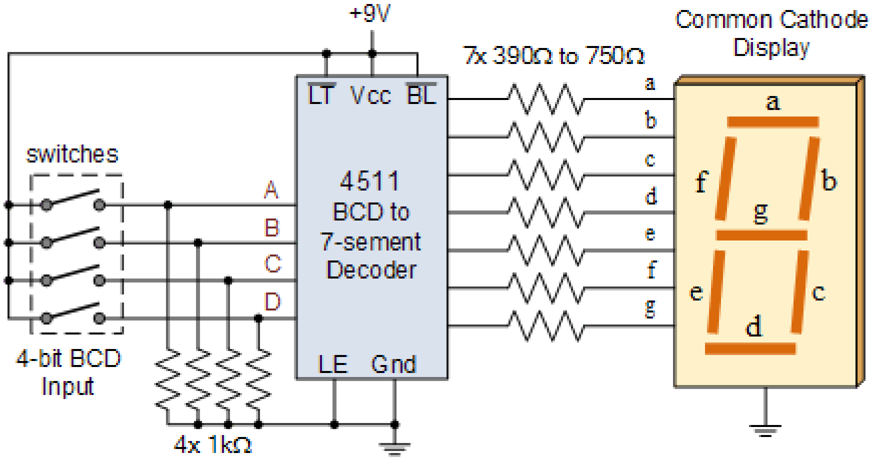
But suppose we want the decimal number "4" to illuminate on the display. Then switches b, c, f and g would be closed to light the corresponding LED segments. Likewise for a decimal number "7", switches a, b, c would be closed. But illuminating 7-segment displays using individual switches is not very practical.

7-segment Displays are usually driven by a special type of integrated circuit (IC) commonly known as a 7-segment decoder/driver, such as the CMOS 4511. This 7-segment display driver which is known as a Binary Coded Decimal or BCD to 7-segment display decoder and driver, is able to illuminate both common anode or common cathode displays. But there are many other single and dual display drivers available such as the very popular TTL 7447.

This BCD-to-7 segment decoder/driver takes a four-bit BCD input labelled A, B, C and Dfor the digits of the binary weighting of 1, 2, 4 and 8 respectively, has seven outputs that will pass current through the appropriate segments to display the decimal digit of the numeric LED display.

The digital outputs of the CD4511 are different from the usual CMOS outputs because they can provide up to 25mA of current each to drive the LED segments directly allowing different coloured LED displays to be used and driven.

Driving a 7-segment Display using a 4511



In this simple circuit, each LED segment of the common cathode display has its own anode terminal connected directly to the 4511 driver with its cathodes connected to ground. The current from each output passes through a 1kΩ resistor that limits it to a safe amount. The binary input to the 4511 is via the four switches. Then we can see that using a BCD to 7-segment display driver such as the CMOS 4511, we can control the LED display using just four switches (instead of the previous 8) or a 4-bit binary signal allowing up to 16 different combinations.

Most digital equipment use **7-segment Displays** for converting digital signals into a form that can be displayed and understood by the user. This information is often numerical data in the form of numbers, characters and symbols. Common anode and common cathode seven-segment displays produce the required number by illuminating the individual segments in various combinations.

LED based 7-segment displays are very popular amongst Electronics hobbyists as they are easy to use and easy to understand. In most practical applications, 7-segment displays are driven by a suitable decoder/driver IC such as the CMOS 4511 or TTL 7447 from a 4-bit BCD input. Today, LED based 7-segment displays have been largely replaced by *liquid crystal displays* (LCDs) which consume less current.

Light emitting diodes (**LEDs**) are semiconductor light sources. The light emitted from **LED**s varies from visible to infrared and ultraviolet regions. They operate on low voltage and power. LEDs are one of the most common electronic components and are mostly used as indicators in circuits. They are also used for luminance and optoelectronic applications.

Based on semiconductor diode, **LED**s emit photons when electrons recombine with holes on forward biasing. The two terminals of LEDs are anode (+) and cathode (-) and can be identified by their size. The longer leg is the positive terminal or anode and shorter one is negative terminal.

The forward voltage of **LED** (1.7V-2.2V) is lower than the voltage supplied (5V) to drive it in a circuit.

Using an LED as such would burn it because a high current would destroy its p-n gate. Therefore a current limiting resistor is used in series with LED. Without this resistor, either low input voltage (equal to forward voltage) or PWM (pulse width modulation) is used to drive the LED. Get details about internal structure of a LED.

A **liquid-crystal display** (**LCD**) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in colour or monochrome.[1] LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and 7-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and indoor and outdoor signage. Small LCD screens are common in portable consumer devices such as digital cameras, watches, calculators, and mobile telephones, including smartphones. LCD screens are also used on consumer electronics products such as DVD players, video game devices and clocks. LCD screens have replaced heavy, bulky cathode ray tube (CRT) displays in nearly all applications. LCD screens are available in a wider range of screen sizes than CRT and plasma displays, with LCD screens available in sizes ranging from tiny digital watches to huge, big-screen television sets.

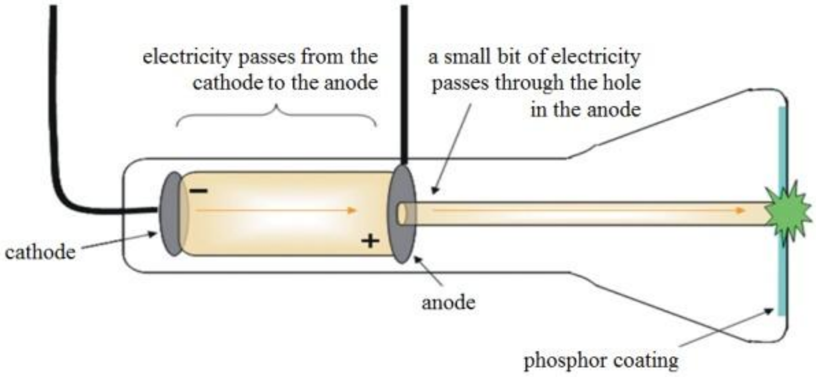
Since LCD screens do not use phosphors, they do not suffer image burn-in when a static image is displayed on a screen for a long time (e.g., the table frame for an aircraft schedule on an indoor sign). LCDs are, however, susceptible to image persistence.[2] The LCD screen is more energy-efficient and can be disposed of more safely than a CRT can. Its low electrical power consumption enables it to be used in battery-powered electronic equipment more efficiently than CRTs can be. By 2008, annual sales of televisions with LCD screens exceeded sales of CRT units worldwide, and the CRT became obsolete for most purposes.

The **cathode ray tube** (**CRT**) is a vacuum tube that contains one or more electron guns and a phosphorescent screen, and is used to display images.[1] It modulates, accelerates, and deflects electron beam(s) onto the screen to create the images. The images may represent electrical waveforms (oscilloscope), pictures (television, computer monitor), radar targets, or others. CRTs have also been used as memory devices, in which case the visible light emitted from the fluorescent material (if any) is not intended to have significant meaning to a visual observer (though the visible pattern on the tube face may cryptically represent the stored data).

In television sets and computer monitors, the entire front area of the tube is scanned repetitively and systematically in a fixed pattern called a raster. An image is produced by controlling the intensity of each of the three electron beams, one for each additive primary colour (red, green, and blue) with a video signal as a reference. In all modern CRT monitors and televisions, the beams are bent by *magnetic deflection*, a varying magnetic field generated by coils and driven by electronic circuits around the neck of the tube, although electrostatic deflection is commonly used in oscilloscopes, a type of electronic test instrument.

A CRT is constructed from a glass envelope which is large, deep (i.e., long from front screen face to rear end), fairly heavy, and relatively fragile. The interior of a CRT is evacuated to approximately 0.01 Pa to 133 nPa.,evacuation being necessary to facilitate the free flight of electrons from the gun(s) to the tube's face. That it is evacuated makes handling an intact CRT potentially dangerous due to the risk of breaking the tube and causing a violent implosion that can hurl shards of glass at great velocity. As a matter of safety, the face is typically made of thick lead glass so as to be highly shatter-resistant and to block most X-ray emissions, particularly if the CRT is used in a consumer product.

Since the late 2000s, CRTs have been largely superseded by newer "flat panel" display technologies such as LCD, plasma display, and OLED displays, which in the case of LCD and OLED displays have lower manufacturing costs and power consumption, as well as significantly less weight and bulk. Flat panel displays can also be made in very large sizes; whereas 38" to 40" was about the largest size of a CRT television, flat panels are available in 60" and larger sizes.



Cathode-Ray Oscilloscope

OBJECTIVE: To learn how to operate a cathode-ray oscilloscope.

APPARATUS: Cathode-ray oscilloscope, multimeter, and oscillator.

INTRODUCTION: The cathode-ray oscilloscope (CRO) is a common laboratory instrument that provides accurate time and aplitude measurements of voltage signals over a wide range of frequencies. Its reliability, stability, and ease of operation make it suitable as a general purpose laboratory instrument. The heart of the CRO is a cathode-ray tube shown schematically in Fig. 1.

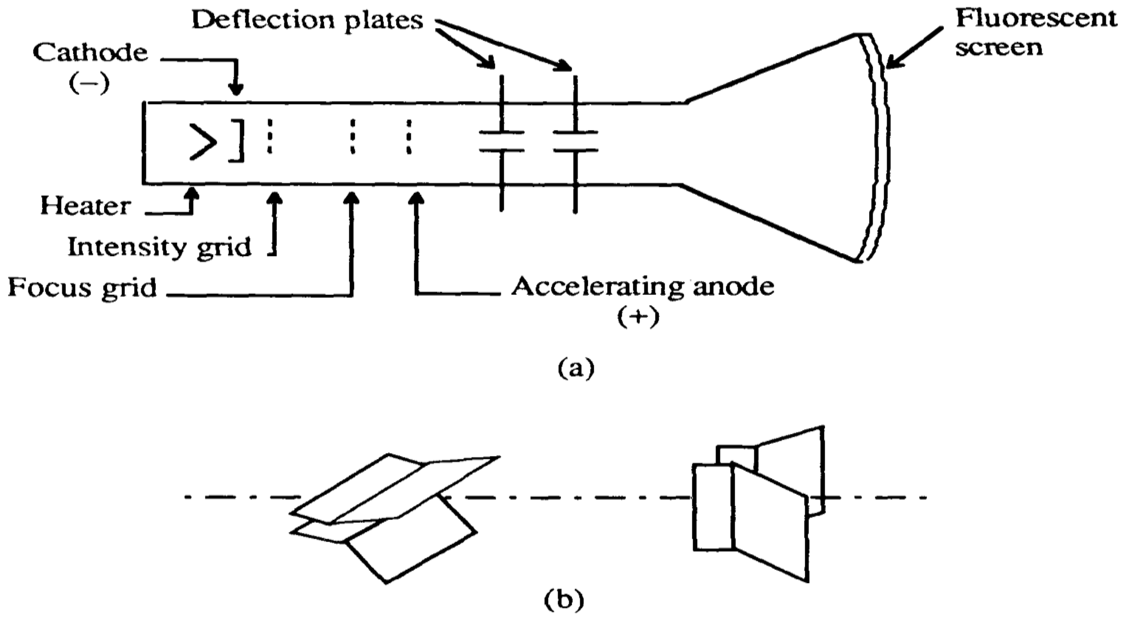


Figure 1. Cathode-ray tube: (a) schematic, (b) detail of the deflection plates.

The cathode ray is a beam of electrons which are emitted by the heated cathode (negative electrode) and accelerated toward the fluorescent screen. The assembly of the cathode, intensity grid, focus grid, and accelerating anode (positive electrode) is called an *electron gun*. Its purpose is to generate the electron beam and control its intensity and focus. Between the electron gun and the fluorescent screen are two pair of metal plates - one oriented to provide horizontal deflection of the beam and one pair oriented ot give vertical deflection to the beam. These plates are thus referred to as the *horizontal* and *vertical deflection plates*. The combination of these two deflections allows the beam to reach any portion of the fluorescent screen. Wherever the electron beam hits the screen, the phosphor is excited and light is emitted from that point. This coversion of electron energy into light allows us to write with points or lines of light on an otherwise darkened screen.

In the most common use of the oscilloscope the signal to be studied is first amplified and then applied to the vertical (deflection) plates to deflect the beam vertically and at the same time a voltage that increases linearly with time is applied to the horizontal (deflection) plates thus causing the beam to be deflected horizontally at a uniform (constant> rate. The signal applied to the verical plates is thus displayed on the screen as a function of time. The horizontal axis serves as a uniform time scale.

The linear deflection or sweep of the beam horizontally is accomplished by use of a *sweep generator* that is incorporated in the oscilloscope circuitry. The voltage output of such a generator is that of a sawtooth wave as shown in Fig. 2. Application of one cycle of this voltage difference, which increases linearly with time, to the horizontal plates causes the beam to be deflected linearly with time across the tube face. When the voltage suddenly falls to zero, as at points (a) (b) (c), etc...., the end of each sweep - the beam flies back to its initial position. The horizontal deflection of the beam is repeated periodically, the frequency of this periodicity is adjustable by external controls.

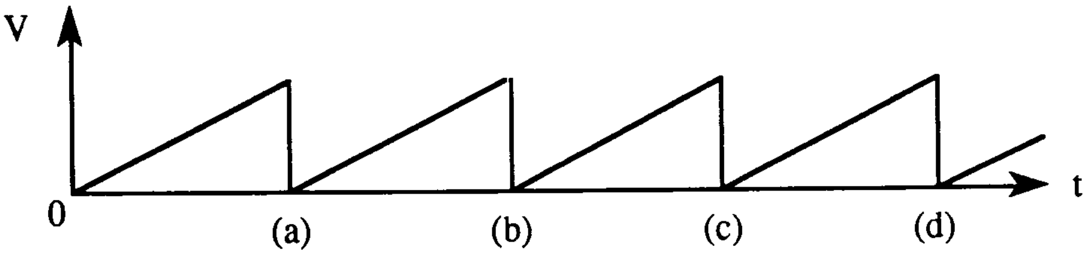


Figure. 2. Voltage difference V between horizontal plates as a function of time t.

To obtain steady traces on the tube face, an internal number of cycles of the unknown signal that is applied to the vertical plates must be associated with each cycle of the sweep generator. Thus, with such a matching of synchronization of the two deflections, the pattern on the tube face repeats itself and hence appears to remain stationary. The persistance of vision in the human eye and of the glow of the fluorescent screen aids in producing a stationary pattern. In addition, the electron beam is cut off (blanked) during flyback so that the retrace sweep is not observed.

CRO Operation: A simplified block diagram of a typical oscilloscope is shown in Fig. 3. In general, the instrument is operated in the following manner. The signal to be displayed is amplified by the vertical amplifier and applied to the verical deflection plates of the CRT. A portion of the signal in the vertical amplifier is applied to the **sweep trigger** as a triggering signal. The sweep trigger then generates a pulse coincident with a selected point in the cycle of the triggering signal. This pulse turns on the sweep generator, initiating the sawtooth wave form. The sawtooth wave is amplified by the horizontal amplifier and applied to the horizontal deflection plates. Usually, additional provisions signal are made for appliying an external triggering signal or utilizing the 60 Hz line for triggering. Also the sweep generator may be bypassed and an external signal applied directly to the horizontal amplifier.

CRO Controls

The controls available on most oscilloscopes provide a wide range of operating conditions and thus make the instrument especially versatile. Since many of these controls are common to most oscilloscopes a brief description of them follows.

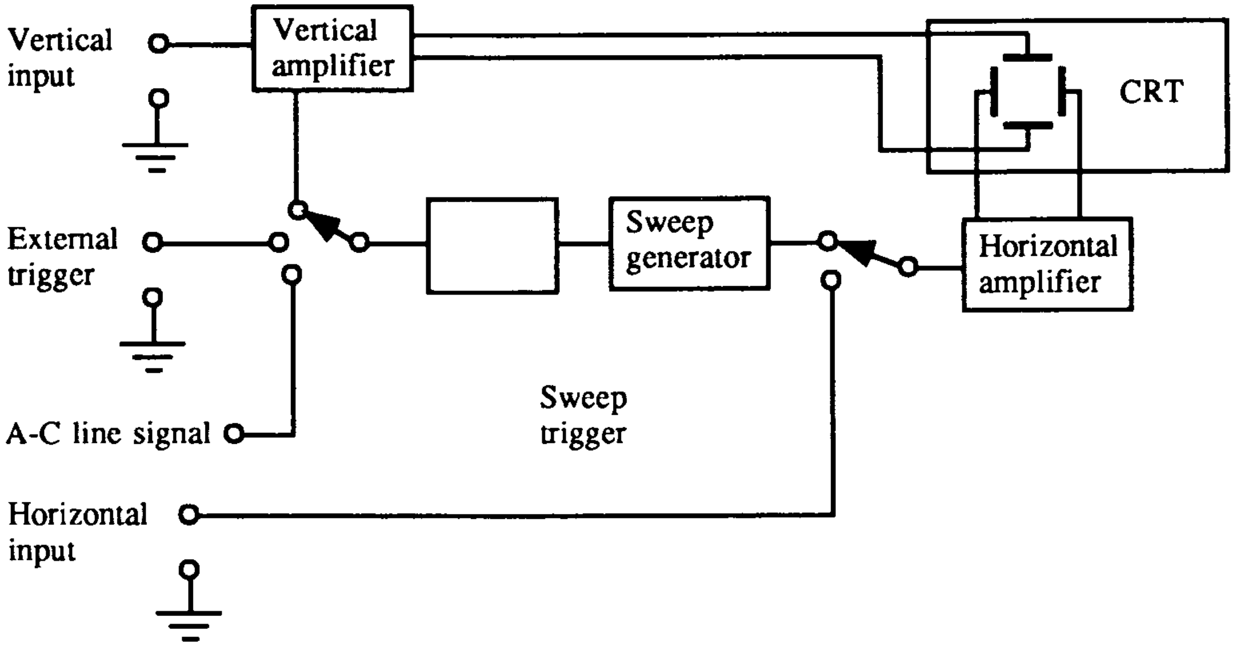


Figure 3. Block diagram of a typical oscilloscope.

CATHODE-RAY TUBE

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

Focus: Focus the spot or trace on the screen.

Intensity: Regulates the brightness of the spot or trace.

VERTICAL AMPLIFIER SECTION

Position: Controls vertical positioning of oscilloscope display.

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

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

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

HORIZONTAL-SWEEP SECTION

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

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

Position: Controls horizontal position of trace on screen.

Horizontal Variable: Controls the attenuation (reduction) of signal applied to horizontal aplifier through Ext. Horiz. connector.

TRIGGER

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

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

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

Source: Selects the source of the triggering signal.

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

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

CONNECTIONS FOR THE OSCILLOSCOPE

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

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

External Tigger Input: Input connector for external trigger signal.

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

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

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

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

(a) Power switch at off
(b) Intensity fully counter clockwise
(c) Vertical centering in the center of range
(d) Horizontal centering in the center of range
(e) Vertical at 0.2
(f) Sweep times 1

Plug line cord into a standard ac wall recepticle (nominally 118 V). Turn power on. Do not advance the Intensity Control.

Allow the scope to warm up for approximately two minutes, then turn the Intensity Control until the beam is visible on the screen.

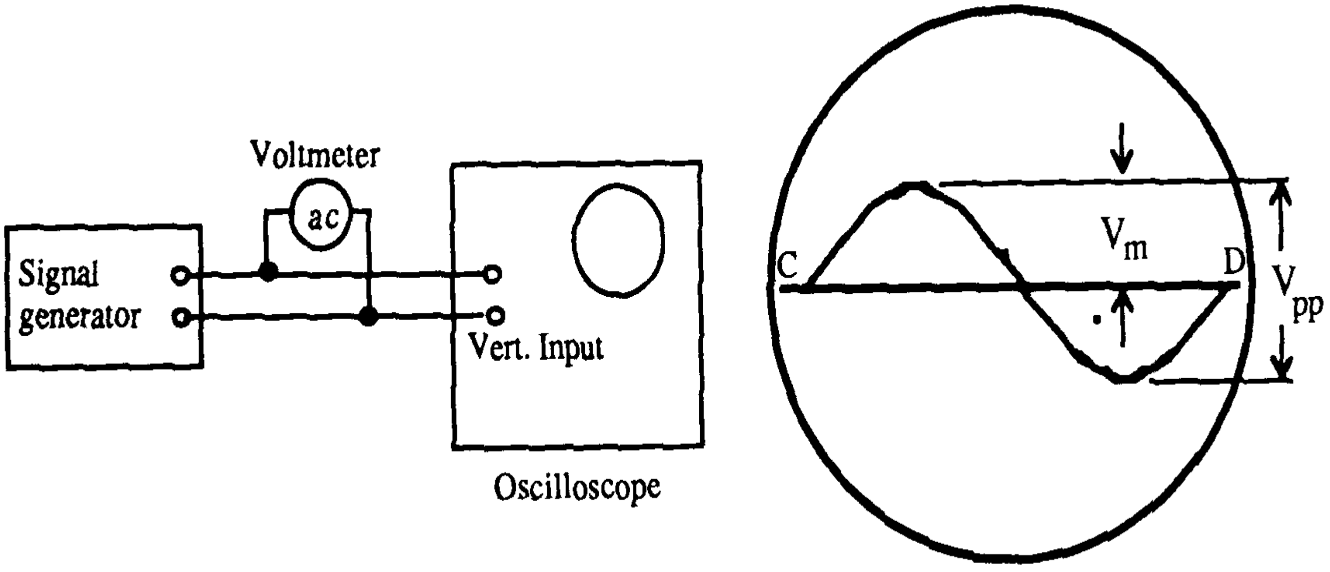
WARNING: Never advance the Intensity Control so far that an excessively bright spot appears. Bright spots imply burning of the screen. A sharp focused spot of high intensity (great brightness) should never be allowed to remain fixed in one position on the screen for any length of time as damage to the screen may occur.

Adjust Horizontal and Vertical Centering Controls. Adjust the focus to give a sharp trace. Set trigger to internal, level to auto.

PROCEDURE:

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

II. <u>Measurements of Voltage:</u> Consider the circuit in Fig. 4(a). The signal generator is used to produce a 1000 hertz sine wave. The AC voltmeter and the leads to the verticle input of the oscilloscope are connected across the generator's output. By adjusting the Horizontal Sweep time/cm and trigger, a steady trace of the sine wave may be displayed on the screen. The trace represents a plot of voltage vs. time, where the vertical deflection of the trace about the line of symmetry CD is proportional to the magnitude of the voltage at any instant of time.



(a) (b)

Figure 4 (a) Circuit for procedure II. (b) Trace seen on scope.

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

The peak or maximum voltage seen on the scope face (Fig. 4b) is V_m volts and is represented by the distance from the symmetry line CD to the maximum deflection. The relationship between the magnitude of the peak voltage displayed on the scope and the effective or RMS voltage (V_{RMS}) read on the AC voltmeter is

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

Thus

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

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

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

Caution: The mathematical prescription given for RMS signals is valid only for sinusoidal signals. <u>The meter will not indicate the correct voltage when used to measure non-sinusoidal signals.</u>

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

Set the oscillator to 1000 Hz. Display the signal on the CRO and measure the period of the oscillations. Use the horizontal distance between two points such as C to D in Fig. 4b.

Set the horizontal gain so that only one complete wave form is displayed.

Then reset the horizontal until 5 waves are seen. Keep the time base control in a calibrated position. Measure the distance (and hence time) for 5 complete cycles and calculate the frequency from this measurement. Compare you result with the value determined above.

Repeat your measurements for other frequencies of 150 Hz, 5 kHz, 50 kHz as set on the signal generator.

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

Use two oscillators to generate some simple Lissajous figures like those shown in Fig. 5. You will find it difficult to maintain the Lissajous figures in a fixed configuration because the two oscillators are not phase and frequency locked. Their frequencies and phase drift slowly causing the two different signals to change slightly with respect to each other.

V. <u>Testing what you have learned:</u> Your instructor will provide you with a small oscillator circuit. Examine the input to the circuit and output of the circuit using your oscilloscope. Measure such quantities as the voltage and frequence of the signals. Specify if they are sinusoidal or of some other wave character. If square wave, measure the frequency of the wave. Also, for square waves, measure the on time (when the voltage is high) and off time (when it is low).

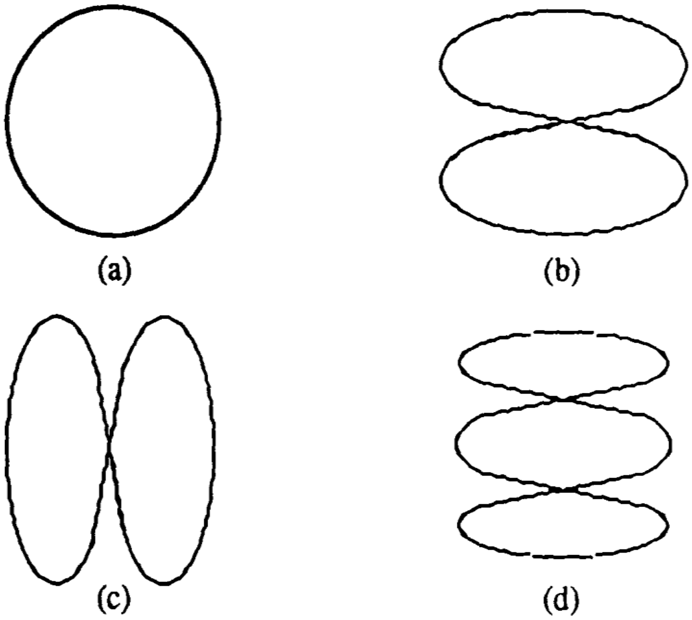


Figure 5. Lissajous figures for horizontal-to-vertical frequency ratios of: (a) 1:1, (b) 2:1, (c) 1:2, and (d) 3:1.

What is a Magnetic Tape Recorders

Before explaining about magnetic tape recorders, I will tell you what a recorder is and what the uses of the recorder are?

A recorder is used to produce a permanent record of the signal that is measured.

A record is used to analyse how one variable varies with respect to another and how the signal saries with time.

The objective of a recording system is to record and preserve information pertaining to measurement at a particular time and also to get an idea of the performance of the unit and to provide the results of the steps taken by the operator.

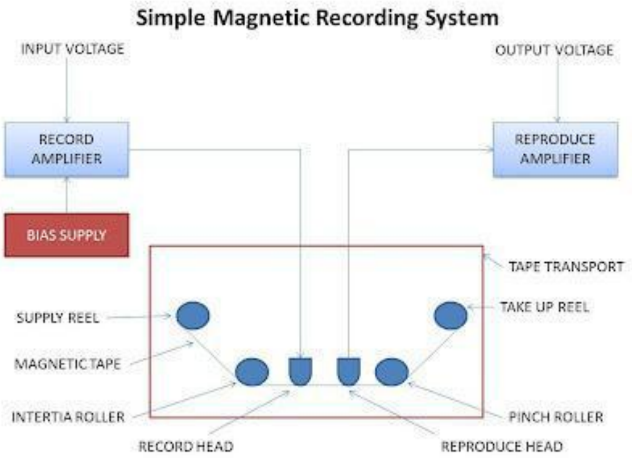
The basic components of a general recorder are an operating mechanism to position the pen or writer on the paper and a paper mechanism for paper movement and a printing mechanism.

Okay, now you know what is a recorder, why it is used and where it is used. Now I will explain about magnetic tape recorder.

A magnetic tape recorder is used to record data which can be retrieved and reproduced in electrical form again. This recorder can record signals of high frequency.

Description of Magnetic Tape Recorders:

The magnetic tape is made of a thin sheet of tough plastic material; one side of it is coated with a magnetic material (iron oxide). The plastic base is usually polyvinyl chloride (PVC) or polyethylene terephthalate. Recording head, reproducing head and tape transport mechanism are also present.



Operation of Magnetic Tape Recorders:

- The recording head consists of core, coil and a fine air gap of about 10 micrometer. The coil current creates a flux, which passes through the air gap to the magnetic tape and magnetizes the iron oxide particles as they pass the air gap. So the actual recording takes place at the trailing edge of the gap.

- The reproducing head is similar to that of a recording head in appearance. The magnetic tape is passes over a reproducing head, thereby resulting in an output voltage proportional to the magnetic flux in the tape, across the coil of the reproducing head. Thus the magnetic pattern in the tape is detected and converted back into original electrical signal.

- The tape transport mechanism moves the tape below the head at constant speed without any strain, distrortion or wear. The mechanism much be such as to guide the tape passed by the magnetic heads with great precision, maintain propoer tension and have sufficient tape to magnetic head contact.

Advantages of Magnetic Tape Recorders:

1. Wide frequency range.

2. Low distortion.

3. Immediate availability of the signal in its initial electrical form as no time is lost in processing.

4. The possibility of erase and reuse of the tape.

5. Possibility of playing back or reproducing of the recorded signal as many times as required without loss if signal.

Applications of Magnetic Tape Recorders:

(a) Data recording and analysis on missiles, aircraft and satelites.

(b) Communications and spying.

(c) Recording of stress, vibration and analysis of noise.