UNIT – 1

SYLLABUS

Basic of Measurement: Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Multimeter**:** Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance.

INSTRUMENTS ACCURACY:

Accuracy can be defined as the amount of uncertainty in a measurement with respect to an absolute standard. Accuracy specifications usually contain the effect of errors due to gain and offset parameters. Offset errors can be given as a unit of measurement such as volts or ohms and are independent of the magnitude of the input signal being measured. An example might be given as ±1.0 millivolt (mV) offset error, regardless of the range or gain settings. In contrast, gain errors do depend on the magnitude of the input signal and are expressed as a percentage of the reading, such as ±0.1%. Total accuracy is therefore equal to the sum of the two: ±(0.1% of input +1.0 mV). An example of this is illustrated in Table 1.

Table 1. Readings as a function of accuracy

Input Voltage	Range of Readings within the Accuracy Specification
0V	-1 mV to +1 mV
5V	4.994V to 5.006V (±6 mV)
10V	9.989V to 10.011V (±11 mV)

conditions: input 0-10V, Accuracy = ±(0.1% of input + 1mV)

PRECISION:

Precision is defined as the closeness between two or more measured values to each other. Precision is also called as repeatability. Suppose if we weigh the same box five times and get close results like 3.1, 3.2, 3.22, 3.4, and 3.0 then your measurements are precise.

SENSITIVITY:

Sensitivity for a typical transducer is the relationship indicating how much output you get for unit input. In other words, it is the ratio between the small change in electrical output to a small change in physical input signal.

It can be defined as the ratio of the incremental output and the incremental input. While defining the sensitivity, we assume that the input-output characteristic of the instrument is approximately linear in that range. Thus if the sensitivity of a thermocouple is denoted as 10 0 μV C/ , it indicates the sensitivity in the linear range of the thermocouple voltage vs. temperature characteristics. Similarly sensitivity of a spring balance can be expressed as 25 mm/kg (say), indicating additional load of 1 kg will cause additional displacement of the spring by 25mm.

Again sensitivity of an instrument may also vary with temperature or other external factors. This is known as sensitivity drift. Suppose the sensitivity of the spring balance mentioned above is 25 mm/kg at 20 o C and 27 mm/kg at 30o C. Then the sensitivity drift/o C is 0.2 (mm/kg)/o C. In order to avoid such sensitivity drift, sophisticated instruments are either kept at controlled temperature, or suitable in-built temperature compensation schemes are provided inside the instrument.

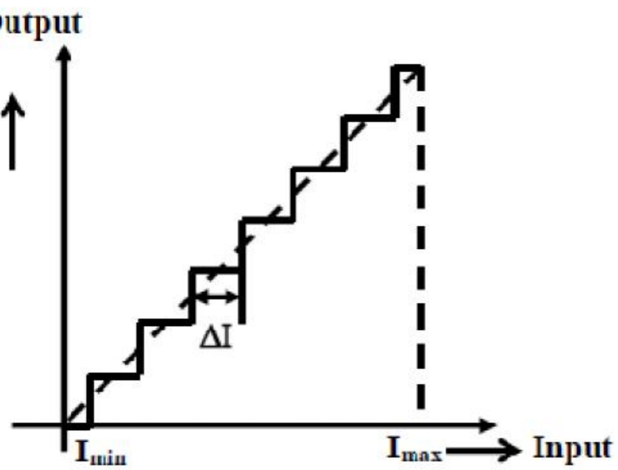
RESOLUTION RANGE:

In some instruments, the output increases in discrete steps, for continuous increase in the input, as shown in Fig. It may be because of the finite graduations in the meter scale; or the instrument has a digital display, as a result the output indication changes discretely. A 3 $\frac{1}{2}$-digit voltmeter, operating in 0-2V range, can have maximum reading of 1.999V, and it cannot measure any change in voltage below 0.001V. Resolution indicates the minimum change in input variable that is detectable. For example, an eight-bit A/D converter with +5V input can measure the minimum voltage of 19.6 mv.

The quotient between the measuring range and resolution is often expressed as *dynamic range* and is defined as:

Dynamic range = $\frac{Measurement\ range}{resolution}$

And is expressed in terms of dB. The dynamic range of an *n*-bit ADC, comes out to be approximately 6*n* dB.



ERRORS IN MEASUREMENT:

Measurement is the basic requirement of almost every science experiment and theory. We need measurement in everything to understand the basic concepts behind it. Every measurement involves some form of uncertainty in the experiment. Suppose you are measuring a building's height in order to calculate the velocity of an object when it is thrown vertically upwards at a certain moment, and the instrument you're using to measure the building is broken or defected, then your answer will definitely be wrong. The reason behind the wrong measurement is uncertainty in the instrument.

- If the instrument is not properly designed and is not accurate
- The calibration of the instrument is incorrect
- If the scale is worn off at edges or broken from somewhere
- If an instrument is giving a wrong reading instead of actual one
- If the markings of a thermometer are improperly calibrated, let's say it's 108°C instead of 100°C, then it is calledan instrumental error.

Personal Errors:

These errors occur due to improper setting of apparatus, lack of observation skills in an experiment and are based on the carelessness of individual only. Personal errors depend on the user or student performing the experiment and have nothing to do with instrument settings.

<u>Example:</u>

For measuring height of an object, if the student don't place his head in a proper way, it may lead to parallax and readings won't be correct

Random Errors:

Random Errors are not fixed on general perimeters and depend on measurements to measurements. That's why they are named Random errors as they are random in nature. Random errors are also defined as fluctuations in statistical readings due to limitations of precisions in the instrument. Random errors occur due to:

Sudden and unexpected shifts in experimental conditions of the environment

A spring balance will give different readings if the temperature of the environment is not constant

Least Count Error:

The smallest value that can be measured in an instrument is called **Least Count of the Instrument**. Least count defines the main part of a measurement and occurs in both random as well as systematic Errors. Least Count Error depends on the resolution of the instrument. The Least Count Error can be calculated if we know the observations and least count of instruments. The table given below shows least count of some instruments.

Instrument	Least count
Vernier Caliper	0.01 cm
Spherometer	0.001 cm
Micrometer	0.0001 cm

To reduce least count error, we perform the experiment several times and take arithmetic mean of all the observations. The mean value is always almost close to the actual value of the measurement.

Absolute Error:

Absolute Error is defined as the difference between exact value and approximate value ofrespective readings. It tells how far a measurement from its true value is. As an example, suppose we perform an experiment in which readings are a_1, a_2, a_3, a_4, a_5 …. up to a_n and total number of observations is ‘n’,

Then mean value of measurement can be calculated as:

$\mathbf{a_{mean} = a_1+a_2+a_3+\ldots\ldots\ldots\ldots+a_n/n}$

Absolute error is denoted by the notation $|\Delta a|$ and errors in individual measurements can be calculated as:

$\mathbf{\Delta a_1 = a_{mean} - a_1}$

$\mathbf{\Delta a_2 = a_{mean} - a_2}$

$\mathbf{\Delta a_3 = a_{mean} - a_3}$

……. ……….. …

$\mathbf{\Delta a_n = a_{mean} - a_n}$

Remember that **Δa** may be a positive or negative sign, but will always focus on the magnitude of it. Also, the arithmetic mean of all absolute error is the final mean of absolute error of experiment.

$\mathbf{\Delta a_{mean} = \Delta a_1 + \Delta a_2 + \Delta a_3 + \ldots\ldots\ldots\ldots + \Delta a_n/n}$

Secondly, note that value of an always lies between a_{mean} - Δa_{mean} anda_{mean} + $\Delta a_{mean.}$Mathematically the range of a measured value ‘a’ is

$\mathbf{a_{mean} - \Delta a_{mean} < a < a_{mean} + \Delta a_{mean}}$

In simple words Absolute Error = Actual Value – Approximate value

Relative Error:

Relative Error is defined as the ratio of the mean absolute error Δa_{mean} to the mean value a_{mean} of the quantity measured in an experiment. Instead of absolute error, we use relative error as it becomes easy to calculate errors and make necessary approximations.

Relative error = $\Delta a_{mean}/ a_{mean}$

Example

If the actual value of a quantity is 50 and its measured value is 49.8. Then calculate the absolute error and relative error in it.

We have a_{mean} = 50 (a_{mean} and actual value are same thing)

Measured value = 49.8

Absolute error = Actual Value – Measured Value

= 50 – 49.8

= 0.2

Relative Error = 0.2/50 = 0.4%

Combination of Errors:

When we perform a physics experiment we have to deal with a number of errors involved. The errors can be in addition or subtraction form or may be in division or multiplication form. Forexample pressure is defined as force per unit area, and then if there is some error in force and area, there are chances that there will be an error in pressure too. There are two ways to calculate combined errors, they are:

- Error of a sum or difference
- Error in product or quotient
- Error in case of a measured quantity raised to a power

Error of a sum or difference:

Let's say two physical quantities A and B have actual values as A ± ΔA and B ± ΔB, then the error in their sum C can be calculated as

C = A + B, then maximum error in C will be

ΔC = ΔA + ΔB, for difference also follow the same formula. Remember that when two quantities are added or subtracted, the absolute error in the final answer will always be the sum of individual absolute errors.

Error of a product or quotient:

When two quantities are divided or multiplied, the relative error in the final answer is given as sum of relative error of each quantity

Suppose A and B are two quantities, with absolute error ΔA and ΔB and C is the product of A and B, that is, C = AB, then the relative error in C can be calculated as:

$\Delta C/C = \Delta A/A + \Delta B/B$

Error in case of a measured quantity rose to some power

The relative error in physical quantity raised to a power's' can be calculated by multiplying 's' with a relative error of the physical quantity.

Suppose, there exist a quantity $S = A^2$, where A is any measured quantity, then relative error in S will be given as:

$\Delta S/S = 2\Delta A/A$

The general formula to find relative error in such cases can be written as:

Suppose $S = A^x B^y C^{z,}$, then

$\Delta S/S = x\,\Delta A/A + y\,\Delta B/B + z\,\Delta C/C$

LOADING EFFECT:

The output of a sensor device may deviate from the correct value due to loading effect. We can categorize two types of loading effect:

•Inter element loading

•Process loading

Inter element loading:-

A given element in the system may modify the characteristics of the previous element.

Process loading:-

The introduction of the sensing element into the process or system being measured causes the value of the measured variable to change.

Loading effects of circuits:-

Loading refers to the phenomena that occurs when a load circuit having low effective impedance is connected to a supply circuit having higher effective impedance this happens because the net parallel resistance is lower than any individual resistors making up the parallel combination.

Loading effect of measuring instrument:-

It is the most common type of error which is caused by the instrument in measurement work. For example, when the voltmeter is connected to the high resistance circuit it gives a misleading reading, and when it is connected to the low resistance circuit, it gives the dependable reading. This means the voltmeter has a loading effect on the circuit. The error caused by the loading effect can be overcome by using the meters intelligently. For example, when measuring a low resistance by the ammeter-voltmeter method, a voltmeter having a very high value of resistance should be used.

Loading effect instrument:-

Potentiometer, Multimeter, Transistor, Rc coupled amplifier, Voltmeter, Transformer, Resistance, etc...

MULTIMETER:

Multimeter is an electronic instrument, which is used to measure voltage, current and resistance. This is called as AVO meter (ampere,Voltage, ohm).

Multimeter can be divided into two types:

- Analog multimeter
- Digital multimeter.

PRINCIPLES OF MEASUREMENT OF DC CURRENT AND DC VOLTAGE:

dc voltage:

Direct voltage (DC VOLTAGE) is the unidirectional flow of electric charge. A battery is a good example of a DC power supply.

dc current:

Electric current can be direct current (DC) or alternating current (AC). Direct current such as the power from dry cells is characterized by a uniform direction of flow and amount (voltage) of electricity.

PRINCIPLES OF MEASUREMENTS OF DC VOLTAGE AND DC CURRENT:

Here, LED when connected to power supply, connecting LED Directly to the power supply will damage it , hence a resistance of suitable value must be connected in series for its proper operation. Where, red wire serves as the positive connection lead while black one is the common or negative lead. In this tutorial we will be measuring DC voltage and current in the circuit.

<u>MEASUREMENT OF VOLTAGE USING MULTIMETER:</u>

9V DC supply is used to power the circuit. The LED will glow as soon as we connect the wires to the power source. Make sure that all the connections are tight. If the LED doesn't glow after connecting the supply then check the connections and the LED.

STEP 1: Connect the testing leads to the multimeter.

STEP 2: Turn the knob to the DC voltage segment in the multimeter at 40DCV.

STEP 3: Connect the probes in the circuit according to the polarity.

STEP 4: Power on the multimeter.

STEP 5: Note down the reading.

HOW TO MEASURE CURRENT USING MULTIMETER:

Multimeter has different procedure for measuring current. Current can be measured in the range of multimeter (400ma - 10A).

Multimeter works like an ammeter.

STEP 1: Turn the knob on the DCA section

STEP 2: Choose the current rating. The meter will display current in both rating.

STEP 3: Connect the testing leads to the current measurement setting.

STEP 4: Turn on the multimeter.

STEP 5: The multimeter will display the current in the circuit.

PRINCIPLE OF MEASUREMENT OF A.C CURRENT:

It is often necessary to measure AC current. Although the same basic steps are used for taking the AC current measurement as when a normal DC measurement is taken, there are a few additional points to note.

The differences in the measurement result from the fact that the multimeter has to rectify the alternating waveform to enable it to measure AC current. For a digital multimeter the main difference is that the measurement type switch must be set to measure AC current rather than DC current.

For an analogue multimeter the situation is a little different. As an analogue multimeter does not contain any active electronics, the diode rectifier used to rectify the alternating waveform has a certain turn on voltage and this will affect the low voltage end of some scales. Some meters may not be able to measure AC current, or they will have very restricted ranges.

Although it is not as common to measure electrical current as it is to measure voltage, it is nevertheless and important ability to be able to measure current. Also knowing how to measure current to gain the best of the multimeter is also important.

PRINCIPLE OF MEASUREMENT OF A.C VOLTAGE:

Step 1 : choose any active alternating current socket.

Step 2 : Turn the multimeter knob to the ACV or AC voltage section.

To ensure safe operation make sure that the knob is pointing to 400 V before c connecting probe to the plug .

Also make sure that the red probe is connected to the 'v' and the black probe to the COM.

Step 3:Insert the testing probes into the socket.

Step 4: Turn on the power supply.

Step 5 :Power on the Multimeter.

Step 6: Turn on the AC supply.

The multimeter will display the AC voltage which is in the specified range of 220-240V, indicating the AC supply to be working normally.

PRINCIPLE OF MEASUREMENT OF RESISTANCE:

1. Turn off all power to the circuit being measured
2. Disconnect one end of the resistance from the circuit. This may involve pulling off spade leads or disordering a component. This is important as there may be other resistances in parallel with the resistance being measured
3. The probes are connected to the meter in the same way as for measuring voltage
4. Turn the dial to the lowest Ohm or Ω range. This is likely to be the 200 ohm range or similar
5. Place a probe tip at each end of the resistance being measured
6. If the display indicates "I", this means that resistance is greater than can be displayed on the range setting you have selected, so you must turn the dial to the next highest range. Repeat this until a value is displayed on the LCD

SPECIFICATIONS OF A MULTIMETER AND THEIR SIGNIFICANCE:

Digital multimeter will only be able to meet its specifications when it is within a certain environment. Conditions such as temperature, humidity and the like will have impact on the performance. Also conditions such as line voltage can affect the performance. In order to ensure that the digital multimeter is able to operate within its uncertainty specification, it is necessary to ensure that the external conditions are met. Outside this range the errors will increase and the readings can no longer be guaranteed.

A further element to be considered is the calibration period of the digital multimeter. As all circuits will drift with time, the DMM will need to be periodically re-calibrated to ensure that it is operating within its specification. The calibration period will form part of the specification for the DMM. The most usual calibration period is a year, but some digital multimeter specifications may state a 90 day calibration period. The 90 day period will enable a tighter specification to be applied to the digital multimeter, allowing it to be used in more demanding applications.

When looking at the calibration period of the digital multimeter, it should be remembered that calibration will form a significant element of the cost of ownership and after some years will be significantly above that of any depreciation. A long calibration period for the digital multimeter is normally to be advised, except when particularly demanding testing is required.

Analogue multimeter or VOA meter ranges:

VOA meters or analogue Multimeters, like digital ones have a variety of ranges. They are described in terms of Full Scale Deflection or FSD. This is the maximum that the range can read. In order to get the best reading, it is necessary to have the scale reading somewhere between about a 25 and 100% of FSD. In this way the optimum accuracy and significant number of figures can be read. As a result of this meters have a variety of ranges, that may appear to be reasonably close to each other - often there are two ranges per decade: 1, 3, 10,etc.

A typical meter may have the following ranges (note that the figures indicate the FSD):

METER RANGE NAME	TYPICAL FSD RANGES
DC Voltage	3.0V, 10V, 30V, 100V, 300V, 1000V
AC Voltage	10V, 30V, 100V, 300V, 1000V
DC Current	50uA, 1mA 10mA, 100mA , 1A
AC Current	100mA, 1A
Resistance	R, 100R, 10 000R

There are several points to note from these typical analogue multimeter or VOA meter ranges:

The low voltage AC voltage, and in this example the 10V AC range may have a different scale to the others. The reason for this is that at low voltages a bridge rectifier is non-linear and this needs to be taken into consideration. Often as in the above example no 3 volt AC range may be included.

High voltage ranges such as the 1000V or 1kV ranges will often use a different input connection to enable the reading to be taken through a different shunt and kept away from the rotary switch that may not be able to handle a voltage this high.

AC current is often not included in the lower end meters because of the difficulties of undertaking the measurement without a transformer to step up any voltage across a series sensing resistor for rectification.

Batteries inside the multimeter are used to provide a current for the resistance measurements. No other readings require the use of battery power - the meter is passive from that viewpoint.

In this example, the three resistance ranges of varying sensitivity multiply the meter reading by 1, 100, or 10 000 dependent upon the range. This allows for low resistance measurements to be made as well as very high ones. Typically the higher resistance ranges may use a higher voltage battery than the one used for the low resistance ranges.

Possible 2 marks

1. Define the term “accuracy”.
2. What is meant precision ?
3. What are the three types of systematic errors ?
4. Write a short notes about resolution range
5. Define sensitivity
6. What is meant by multimeter ?
7. What are called errors ?
8. Write the principle of multimeter.

Possible 6 marks

1. Explain in detail about loading effect and resolution range.
2. Write a short notes about the following terms with suitable example.
   (i) Instrumental Errors (ii) Environmental Errors (iii) Observational Errors
3. Explain the voltage and current measurement in a multimeter.
4. Comment upon the following terms.
   (i) Accuracy (ii) Precision (ii) Sensitivity
5. Explain briefly about Residual Errors and Gross Errors.
6. Describe the specifications and significance of a multimter
7. Explain the various types of systematic errors.

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II B.Sc Physics
Basic Instumenation Skills [17PHU404A]

Unit -1

What is the smallest change in applied stimulus that will indicate a detectable change in deflection in a indicating i
Errors introduced by the observer or user.
_______ is the difference between the true value of quantity and the value indicated by instrument.
The deviation of a reading from the expected value
Errors due to frictions of the meter movement, incorrect spring tension, improper calibration or faulty instruments :
The error of an instrument is normally given as a percentage of
If the instrument is to have a wide range, the instrument should have
Which of the following are considerations for selecting a digital multimeter?
The ratio of maximum displacement deviation to the full scale deviation of the instrumentis called
A 150 V moving iron voltmeter of accuracy class 1.0 reads 75 V when used in a circuit under a standard conditions
The relative error is the
Measurement of quantities are of
Systematic error occurred due to poor calibration of instrument that can be corrected by
Error that occurs due to equally affected measurements is called
Error that occurs during measurement of quantities is
Which of the following is caused by careless handling?
Which of the following is not a fundamental quantity?
Which of the following error is caused by poor calibration of instrument?
A voltmeter connected across an unknown resistance has scale of 0 to 150 V reads 50 V when the current flowing i
How systematic errors are eliminated?
Starting position of an object is represented as x=5.1±0.2m and finishing position as y=6.9±0.3m. What will be the
The systematic errors of an instrument can be reduced by making
If the instrument is used in wrong manner while application, then it will results in
Random errors in a measurement system are due to
If the quantity to be measured remains constant during the process of taking the repeated measurements then the ra
The error between mean of finite data set and mean of infinite data set is known as
In a measurement system,
When a 100 V moving iron voltmeter is of accuracy class 1-0 is used in a circuit, it reads 50 V. Then the maximum
If the two voltage measurements are V1 = 150 ± 2% and V2 = 100 ± 4% respectively. Then the maximum percenta
The errors mainly caused by human mistakes are
Resolution of an instruments is
The measured value of a resistance is 10.25 ohm, whereas its value of 10.22 ohm. What is absolute error of the mea
In measurement system, the function of the signal manipulating elements is to
In AC circuits, the connection of measuring instruments cause loading effect errors which may effect
Systematic errors in a measurement system are caused by
The error in the use of any instrument is normally taken to be half of the smallest division on the scale of the instru
In the case of a metre scale, this error is about _____ mm.
If the error in the measured value is expressed in fraction, it is called

The same error repeated every time in a series of observations is known as
Example of Systematic error is
Errors have no sentence pattern is called as
The length of a rod is measured as 25.0 cm using a scale having an accuracy of 0.1 cm,the percentage error in lengt
The difference between the measured value and the true value is known as
The _________ of a recording system is the magnitude of input voltage required to produce a standard deflection ir
Systematic errors occur due to
Measurement which is close to true value is
Systematic errors can be removed by
A measurement which on repetition gives same or nearly same result is called
The degree of closeness of the measured value of a certain quantity with its true value is known as
Error of measurement =
The ability by which a measuring device can detect small differences in the quantity being measured by it, is called
The following term associated with measuring devices
To compare an unknown with a standard through a calibrated system is called
The following is an internationally recognized and accepted unit system
One yard = _____ inch
The following is a line standard of measurement
1 Angstrom (Å) = _____
An ammeter of 0-25 A range has a guaranteed accuracy of 1% of full scale reading. The current measured is 5 A. T
Accuracy of an measuring instrument indicates the
In an instrument torque/weight ratio is known as
The process of measurement
In the systematic errors, the errors in the output of the measurement system are

Sensitivity	Accuracy	Resolution	Precision	**Resolution**
Observational errors	Environme	Instrument	Gross errors	**Observational errors**
Dynamic error	Fidelity	Measureme	Speed of response	**Dynamic error**
accuracy	precision	error	difference	**error**
Observational errors	Environme	Gross error	Instrument errors	**Instrument errors**
measured value	full-scale v	mean value	rms value	**full-scale value**
Logarithmic scale	Linear scal	Square-law	Exponential scale	**Logarithmic scale**
auto-ranging function	overload pı	accuracy aı	all of these	**all of these**
Static sensitivity	Linearity	Precision	Accuracy	**Linearity**
0.5	1	2	4	**2**
Difference of the measured value and	Ratio of ab	Ratio of the	Ratio of the probable e	**Ratio of the absolute**
2 types	3 types	4 types	5 types	**2 types**
taking several readings	replacing ii	taking mea	taking median of value	**replacing instruments**
random error	systematic	frequent er	precision	**systematic error**
random error	systematic	frequent er	precision	**both a and b**
Systematic error	Gross error	Random er	None of the mentioned	**Gross error**
Length	Angle	Time	Luminous intensity	**Angle**
Random error	Gross error	Systematic	Precision error	**Systematic error**
± 1.5%	± 2.12%	± 2.22%	± 2.5%	**± 2.22%**
Frequent measurement	Replaceme	Finding me	Finding variance of rea	**Replacement of instru**
Displacement= 1m Error= 0.5m	Displaceme	Displaceme	Displacement= 1.5m E	**Displacement=1.8m E**
The sensitivity of instrument to envir	The sensiti	Systematic	None of these	**The sensitivity of inst**
Systematic error	Instrument	Random er	Environmental error	**Instrument error**
Environmental changes	Use of unca	Poor cablin	Unpredictable effects	**Unpredictable effects**
Calculating the mean of the number o	Calculating	Calculating	Either (a) or (b)	**Either (a) or (b)**
True error of the mean	Standard er	Finite error	Infinite error	**Standard error of the**
A single measurement components m	A measurer	Both the sta	Neither statement (a) n	**Both the statement (a**
1%	2%	2.50%	3%	**2%**
± 2.4 %	± 2.6 %	± 2.8 %	± 3.4 %	**± 2.8 %**
gross error.	instrument	observatio	systematic error.	**gross error.**
the maximum non linearity.	the maxim	the minimu	ability to distinguish p	**the minimum quantit**
0.01 ohm.	0.03 ohm.	15.36 ohm	10.26 ohm.	**0.03 ohm.**
to perform linear operation like addit	to perform	change the	change the quantity ur	**change the magnituc**
only the magnitude of the quantity be	only phase	both of abc	magnitude, phase and	**magnitude, phase an**
System disturbance during measurem	Effect of er	Use of unca	All of these	**All of these**
Systematic error	Instrumenta	Random er	Environmental error	**Instrumental error**
0.5	0.6	0.7	0.3	**0.5**
Random error	Environme	Frictional e	Systematic error	**Frictional error**

Constant error	Gross error	Random er	Systematic error		**Constant error**
Instrumental errors	personal er	errors due t	All the above		**All the above**
Gross error	Systematic	Random er	Constant error		**Random error**
0.50%	0.80%	0.30%	0.40%		**0.40%**
Relative error	Random er	Absolute er	Systematic error		**Absolute error**
Accuracy	Linearity	Sensitivity	Resolution		**Sensitivity**
overuse of instruments	careless us	both A and	human sight		**both A and B**
accurate	average	precise	error		**accurate**
buying new instrument	breaking in	dusting ins	recalibrating instrumer		**recalibrating instrum**
accurate measurement	average me	precise mea	estimated measuremen		**precise measurement**
Accuracy	Precision	Standard	Sensitivity		**Accuracy**
True value – Measured value	Precision –	Measured v	None of the above		**True value – Measure**
Damping	Sensitivity	Accuracy	error		**Sensitivity**
Sensitivity	Damping		None of the above		**both ‘a’ and ‘b’**
Direct comparison	Indirect co	both ‘a’ an	None of the above		**Indirect comparison**
MKS	FPS	SI	Standard		**SI**
36	38	40	42		**36**
Measuring tape	Slip gauge	Micromete	End bars		**Measuring tape**
10^-6m	10^-8m	10^-10m	10^-12m		**10^-10m**
2%	2.50%	4%	5%		**5%**
Closeness of the output reading to the	Ratio of ou	Change in o	Degree of freedom fro		**Closeness of the outpu**
Sensitivity	Accuracy	Linearity	Fidelity		**Sensitivity**
Always disturbs the system being mea	It may or m	Never distu	None of these		**Always disturbs the sy**
All the errors will be positive	All the erro	Either all th	None of these		**Either all the errors w**

error to the true value of the quantity under measurement

s

ıment
:rror= 0.36m
rument to environmental input as low as possible

mean
) & (b) are true

y it can measure.

le of the input signal while retaining its identity
d waveform of the quantity being measured

ent

ed value

ıt reading to the true value

ystem being measured
vill be positive or all the errors will be negative

UNIT – 2

SYLLABUS

Electronic Voltmeter: Advantage over conventional multimeter for voltage measurement with respect to input impedance and sensitivity. Principles of voltage, measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance. **AC millivoltmeter:** Type of AC millivoltmeters: Amplifier- rectifier, and rectifier- amplifier. Block diagram ac millivoltmeter**,** specifications and their significance.

ADVANTAGE OVER CONVENTONAL MULTIMETER FOR VOLTAGE MEASUREMENT WITH RESPECT TO INPUT IMPEDANCE AND SENSITIVITY:

INVENTION:

An Italian scientist named Galvani was dissecting a dead frog and noticed twitching of muscle when touched with metal scalpel and he informed that to the next Italian scientist Volta .He started investigation on that and that lead him to the invention of electric cell and electric battery

First digital voltmeter was invented and produced by Andrew Kay.

VOLTAGE:

An electromotive force or potential difference is expressed in volts.

VOLMETER:

An instrument used to measure the potential difference between two points.

IMPEDANCE:

Any obstruction or the measure of the opposition of an electric current to the energy flow when the voltage is applied. Impedance is based on sensitivity.

SENSITIVITY:

The capacity to respond to changes in the environment.

So generally when used for measuring voltage the input impedance of multimeter must be very high compared to the impedance of the circuit being measured otherwise circuit operation may be changed and the reading will be inaccurate .Multimeters will electronic amplifiers have a fixed input impedance that is enough not to disturb most of the circuits . This is often either one or ten mega ohms .input resistance allows the use of external high resistance probes which divides the input voltage and extend the voltage range up to tens to few thousand of volts.

Advantages:

* They are more accurate than analogmultimeters.

* They reduce reading and interpolation errors

* They 'auto –replay' function can prevent problems from connecting the meter to a test circuit with the wrong polarity

* The reading speed is increased as it is easier to read.

* Accuracy is increased due to digital read out

* They have very high input impedance.

* Some advanced digital multimeters have microprocessor and can store the reading for further processing.

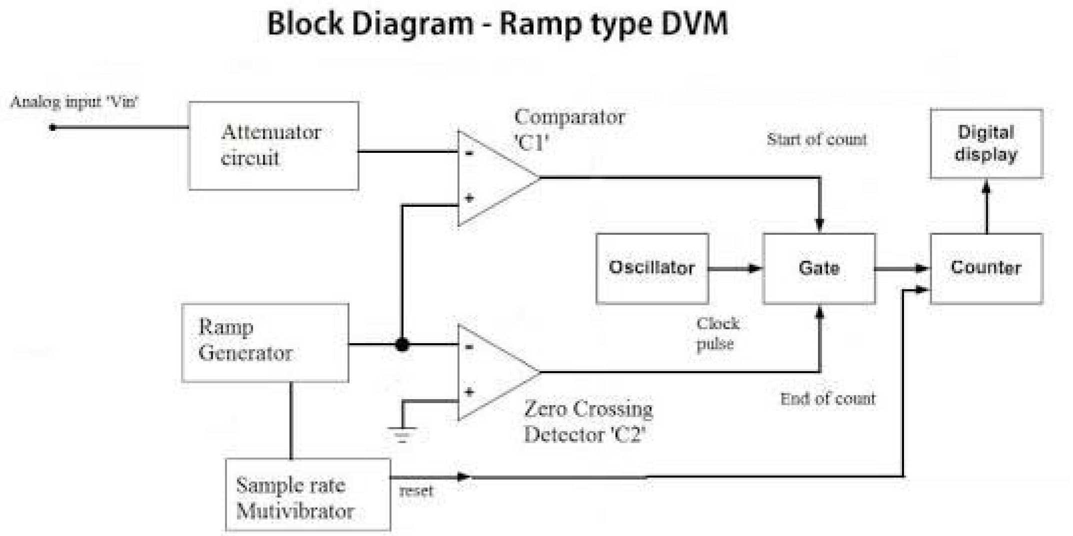
* Unlike analogmultimeters, zero adjustment is not required.

Difference between analog and digital voltmeter:

ANALOG VOLTMETER	DIGITAL VOLTMETER
output will be done using potentiometric deflection	output will be in digital form
this cannot be programmed	this can be programmed
sensitivity is less	sensitivity is more
speed of operation is less	speed of operation is more

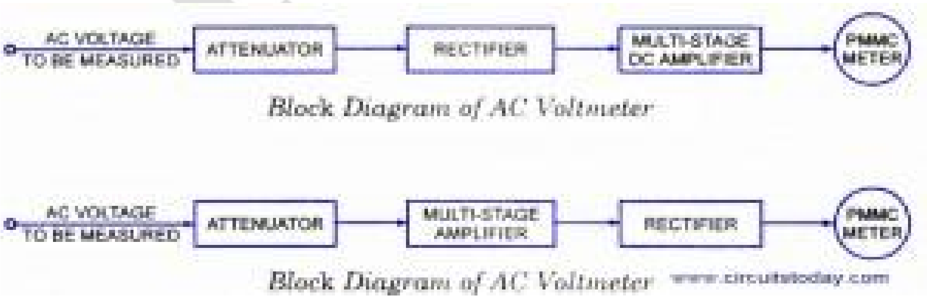
number of measurement range is less	number of measurement range is high
it has poor resolution	it is better resolution

Block diagram of digital multimeter:



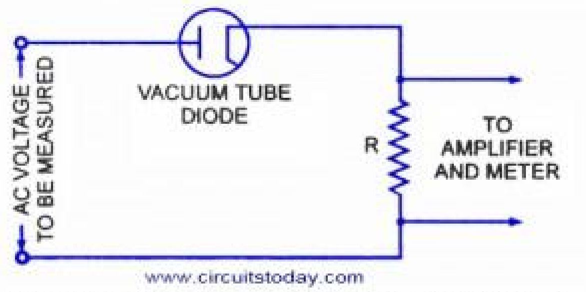
AC MILLIVOLTMETER:

In electronic ac voltmeters input signal is firstly rectified and then sup- plied to the dc amplifier, as shown in figure. Sometimes signal is firstly amplified by ac amplifier and then recti- fied before supplying it to dc meter, as shown in figure. In the former case the advantage is of economical amplifiers and the arrangement is usually used in low priced voltmeters.



Block Diagram of AC Voltmeter
Block Diagram of AC Voltmeter

1. Average Reading AC Voltmeters.



Average Reading AC Voltmeter Using Vacuum Tube Diode

Normally ac voltmeters are average responding type and the meter is calibrated in terms of the rms values for a sine wave. Since most of the voltage measurements involve sinusoidal waveform so this method of measuring rms value of ac voltages works satisfactorily and is less expensive than true rms respond- ing voltmeters. However, in case of measurement of non-sinusoidal waveform voltage, this meter will give high or low reading depending on the form factor of the waveform of the voltage to be measured.

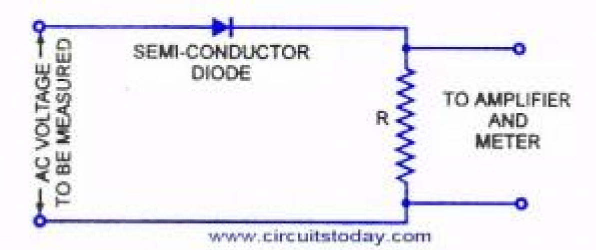
The circuit diagram for an average reading voltme- ter using a vacuum tube diode is shown in figure. The arrangement requires a vacuum tube diode, an high resistance (of the order of 105 Q.) R and PMMC instru- ment, all connected in series, as shown in fig. Resist- ance R is used to limit the current and make the plate voltage-current characteristics linear. The linear plate characteristics are essential in order to make the current directly proportional to voltage. Also because of high series resistance R, plate resist- ance of vacuum tube diode becomes negligible and therefore variations in plate resistance do not cause non-linearity in voltage-current characteristics. In this way we get the scale of PMMC instrument uniform and independent of variations of tube plate resistance. Voltage across the high resistance is fed to dc amplifier and output of the amplifier is fed to PMMC instrument. Circuit diagram of an average reading ac voltmeter using semi-conductor diode is shown in figure. The diode conducts during the positive half cycle and does not conduct during the -ve half cycle, as shown in figure.

The average current through the meter will be given by the expression

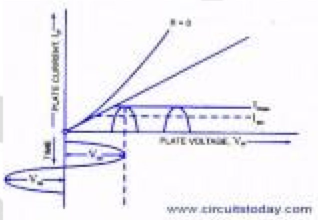
Iav - = Vav / 2R = 0.45 * [Vrms/R]

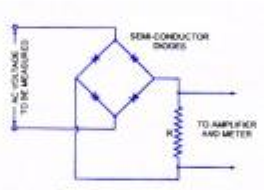
Vrms is the effective or rms value of applied voltage and 1.11 is the form factor of sinusoidal wave. R is multiplied by 2 because the voltmeter operates on half-wave recti- fication. It is to be worthnoting that this instrument can be used to indicate dc voltages but in such a case the instrument readings will have to be multiplied by 2 x 1.11, that is, as the diode conducts all the time. Circuit diagram of an average reading ac voltmeter using semi-conductor diodes as a full-wave rectifier is shown in figure. In this case average current through the meter will be Vrms/ 1.11R. Main advantages associated with these voltmeters are that they are simple in construc- tion, have high input impedance, low power consumption and uniform scale. Main disadvantage of these voltmeters is that these operate in audio-frequency range. In radio-frequency range, distributed capacitance of the high resistance R introduces error in the readings.

Another disadvantage of such a voltmeter is that due to non-linear volt-ampere char- acteristic for lower voltage the readings of the voltmeter at lower voltage are not correct.



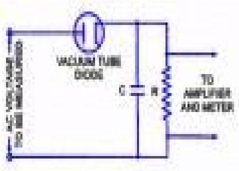
Average Reading AC Voltmeter Using Semi-Conductor Diode As Half-Wave Rectifier



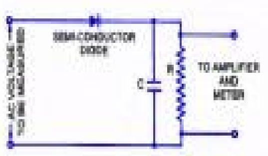


Average Reading AC Voltmeter Using Semi-conductor Diodes As Full-Wave Rectifier

2. Peak Reading AC Voltmeters:

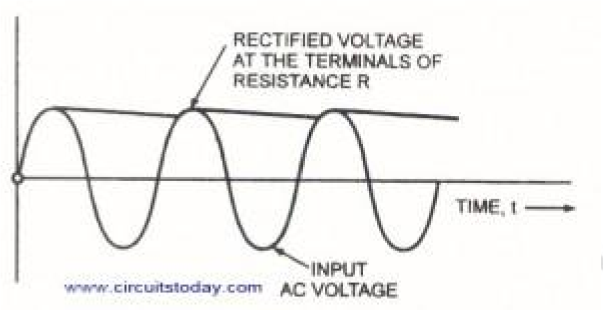


Peak Reading AC Voltmeter Using Vacuum Tube Diode



Peak Reading AC Voltmeter Using Semi-conductor Diode

The circuit diagrams for peak reading voltmeter using vacuum tube and semi-conductor diode are shown in figures respec- tively.



In this type of voltmeters capacitor C is charged to the peak value of .the applied voltage and capaci- tor-is discharged through the high resistance R between two peaks of the wave which results in a small fall in capacitor voltage. But this voltage is again built up during next peak of the wave, as shown in figure. So voltage across capacitor C and resistance R remains almost constant and equal to the peak value of the applied voltage.

Either the average voltage across R or the average current through R, can be used to indicate the peak value of applied voltage. In case the vacuum tube diode (or semi-conductor diode), series resistance R shunted by capacitance C and PMMC are connected in series across the source of unknown voltage, the current through the PMMC will indicate the peak value of applied voltage.

In case, the circuit shown in figure making use of rectifying diode, series resistance R, dc amplifier and PMMC is employed, the average voltage across R will indicate the peak value of applied voltage. This alternative is preferred, as explained earlier, the power consumption can be reduced by making series resistance R high. By making series resistance R high a less sensitive type of PMMC instrument can also be used. The high value input resistance also gives more linear relationship between peak applied voltage and the instrument indication. Also the performance of the diode with inputs consisting of pulses and modulated waves is improved.

The dc amplifier associated with the diode rectifier should be provided with stabilizing means in order to prevent drift in the indication of the output meter. Usually a voltage regulated supply combined with a compensating circuit is used.

The use of high series resistance R, associated with dc amplifier, no doubt results in a high input resistance but at the same time it implies that an applied voltage of sufficient amplitude is required so that the system acts as a peak voltage device. The main disadvantage of this system is with regards to measurement of low voltage. If the applied voltage is too small, then there is a flow of some current throughout the cycle of the voltage because of high velocity of emission of electrons, and the input resistance may be a few hundred ohms and it defeats the very purpose with which elec-tronic instruments are used.

Principles of voltage measurement

It is measured across an electrical circuit element or branch of a circuit. The device that measures the voltage is the voltmeter. ... The ratio of the voltage to the current is the impedance. The current is measured by an ammeter (also called an ampermeter).
Voltmeter is a voltage meter which measures the voltage between the two nodes. The unit of potential difference is volts. So it is a measuring instrument which measures the potential difference between the two points.

TYPES OF VOLTMETER:

Voltmeter:

Voltmeter is a voltage meter. Which measures the voltage between the two nodes. We know the unit of potential difference is volts. So it is a measuring instrument which measures the potential difference between the two points.

Working Principle of Voltmeter:

The main principle of voltmeter is that it must be connected in parallel in which we want to measure the voltage. Parallel connection is used because a voltmeter is constructed in such a way that it has a very high value of resistance. So if that high resistance is connected in series than the current flow will be almost zero which means the circuit has become open.

If it is connected in parallel, than the load impedance comes parallel with the high resistance of the voltmeter and hence the combination will give almost the same the impedance that the load had. Also in parallel circuit we know that the voltage is same so the voltage between the voltmeter and the load is almost same and hence voltmeter measures the voltage.

For an ideal voltmeter, we have the resistance is to be infinity and hence the current drawn to be zero so there will be no power loss in the instrument. But this is not achievable practically as we cannot have a material which has infinite resistance.

Classification or Types of Voltmeter:

According to the construction principle, we have different types of voltmeters, they are mainly -

1. Permanent Magnet Moving coil (PMMC) Voltmeter.
2. Moving Iron (MI) Voltmeter.
3. Electro Dynamometer Type Voltmeter.
4. Rectifier Type Voltmeter
5. Induction Type Voltmeter.
6. Electrostatic Type Voltmeter.
7. Digital Voltmeter (DVM).

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

1. DC Voltmeter.
2. AC Voltmeter.

For DC voltmeters PMMC instruments are used, MI instrument can measure both AC and DC voltages, electrodynamometer type, thermal instrument can measure DC and AC voltages as well. Induction meters are not used because of their high cost, inaccuracy in measurement. Rectifier type voltmeter, electrostatic type and also digital voltmeter (DVM) can measure both AC and DC voltages.

1. PMMC Voltmeter:

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.

PMMC instruments have parmanent magnets. It is suited for DC measurement because here deflection is proportional to the voltage because resistance is constant for a material of the meter and hence if voltage polarity 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 advantages of having linear scale, power consumption is low, high accuracy.

Major disadvantages are -

It only measures DC quantity, higher cost etc.

Deflection torque, T = BiNlb Nm

Where,

B = Flux density in Wb/m².

i = V/R where V is the voltage to be measured and R is the resistance of the load.

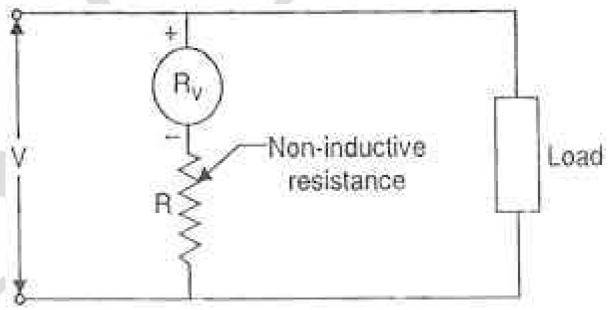
l = Length of the coil in m.

b = Breadth of the coil in m.

N = No of turns in the coil.

Extension of Range in a PMMC Voltmeter:

In the PMMC voltmeters we have the facility of extending the range of measurement of voltage also. Just connecting a resistance in series with the meter we can extend the range of measurement.



Let,

V is the supply voltage in volts.

Rv is the voltmeter resistance in Ohm.

R is the external resistance connected in series in ohm.

V1 is the voltage across the voltmeter.

Then the external resistance to be connected in series is given by

$$R = \frac{V - V_1}{V_1} \times R_v$$

2. MI Voltmeter:

MI instruments mean moving iron instrument. It is used for both AC and DC measurements, because the deflection θ proportional square of the voltage assuming impedance of the meter to be constant, so what ever is polarity of the voltage, it shows directional deflection, further they are classified in two more ways,

1. Attraction type.
2. Repulsion type.

It's torque equation is : $T = \frac{1}{2} \times I^2 \frac{dL}{d\theta}$

Where, I is the total current flowing in the circuit in Amp. I = V/Z

Where, V is the voltage to be measured and Z is the impedance of the load.

L is the self inductance of the coil in Henry.

θ is the deflection in Radian.

Attraction type MI Instrument Principle:

If an un magnetised soft iron is placed in the magnetic field, it is attracted towards the coil, if a pointer is attached to the systems and current is passed through a coil as a result of the applied voltage, it creates a magnetic field which attracts iron piece and creates deflecting torque as a result of which pointer moves over the scale.

Repulsion type MI Instrument Principle:

When two iron pieces are magnetized with the same polarity by passing a current which done by applying a voltage across the voltmeter than repulsion between them occurs and that repulsion produces a deflecting torque due to which the pointer moves.

The advantages are it measure both AC and DC, it is cheap, low friction errors, Robust etc. It is mainly used in AC measurement because in DC measurement error will be more due to hysteresis.

3. Electrodynamometer Type Voltmeter:

Electrodynamometer instruments are used because they 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.

Electrodynamometer Type Voltmeter Principle:

We have two coils, fixed and moving coils. If a voltage is applied at the two coils as a result of which current flows two coils it will stay in the zero position due to the development of equal and opposite torque. If the direction of one torque is reversed as the current in the coil reverses, an undirectional torque is produced.

For voltmeter, the connection is a parallel one and both fixed and moving coils are connected in series with non-inductive resistance.

$\varphi = 0$ where φ is the phase angle.

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

Where, I is the amount of current flowing in the circuit in Amp = V/Z

V and Z are the applied voltages and impedance of the coil respectively.

M = Mutual inductance of the coil.

They have no hysteresis error, can be used for both AC and DC measurement, the main disadvantages are having low torque/weight ratio, high friction loss, expensive than other instruments etc.

4. Rectifier Voltmeter:

Rectifier Voltmeter Principle:

They are used for AC or DC measurements. For DC measurement we have to connect a PMMC meter which measures pulsating DC voltage which measures rectified voltage which is connected across the bridge rectifier.

Advantages of Rectifier Voltmeter:

- Can be used in high frequency.
- It has uniform scale for most of the ranges.

Disadvantages of having an error due to temperature decrease in sensitivity in AC operation.

5. Digital Voltmeters (DVM):

Digital Voltmeters (DVM) Principle:

The digital voltmeter is an instrument which can give the output voltage not by deflection but directly indicating the value. It is a very good instrument to measure the voltage as it eliminates completely the error due to parallax, approximation in measurement, high-speed reading can be done and it can also be stored in memory for further analysis. The main principle is that the value is measured by the same circuit arrangement but that value is not used to deflect the pointer, but it is fed to the analog to digital converter and displayed as the digital value.

6. Electrostatic Instruments:

Electrostatic Instruments Principle:

When electric field created by the charged particles are allowed to act on the conductors which is charged by the current, a deflecting torque is produced. This can be done by using-

1. Two electrodes which are oppositely charged in which one of them is fixed and the other is movable.
2. Force between two electrodes which causes rotary motion of the moving electrode.

Torque equation is $T_D = \frac{1}{2}\ x\ V^2\frac{dC}{d\theta}$

Where, V is the voltage to be measured in volts, C is the value of capacitance in farad and θ is the deflection in radians.

Advantages of the electrostatic meter having low power consumption, can be used for both AC and DC quantities, no hysteresis loss, no stray magnetic field error. Disadvantages are it has non uniform scale, low operating force, it has expansive and the size is large also its construction is not robust.

ELECTRONIC VOLTMETER:

Definition:

The **voltmeter which uses the amplifier for increases their sensitivity** is known as the electronic voltmeter. It is used for measuring the voltages of both the AC and DC devices. The electronic voltmeter gives **the accurate reading because of high input resistance.**

The moving coil voltmeter is not able to detect the low voltages. The electronic voltmeter overcomes this problem. The **electronic voltmeter has high input impedance because of which it detects the signals of very weak strength**, hence gives the accurate reading. The high impedance means the circuit opposes the input supply. The electronic voltmeter uses the transistor or vacuum tube. The transistor type voltmeter (TVM) has resistance because of which it cannot measure the current. And the vacuum voltmeter (VVM) has low resistance. Hence it is used for measuring the current.

Working of Electronic Voltmeter :

The magnitude of the measure and voltage is directly proportional to the deflection of the pointer. The pointer is fixed on the calibrated scale. The point at which the pointer deflects indicates the magnitude of the input voltage.

In moving coil voltmeter the large power is drawn from the measure and circuit because of which the error occurs in their reading. This problem is overcome in the electronic voltmeter.

The moving coil voltmeter is not able to detect the low voltages. The electronic voltmeter overcomes this problem. The **electronic voltmeter has high input impedance because of which it detects the signals of very weak strength**, hence gives the accurate reading. The high impedance means the circuit opposes the input supply.

The electronic voltmeter uses the transistor or vacuum tube. The transistor type voltmeter (TVM) has resistance because of which it cannot measure the current. And the vacuum voltmeter (VVM) has low resistance. Hence it is used for measuring the current

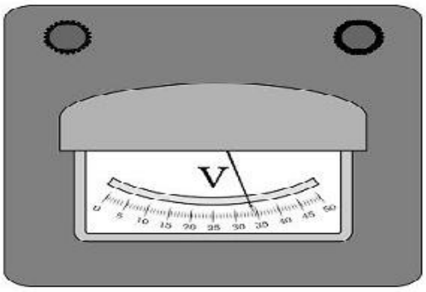
In electronic voltmeter, the pointer is deflected by taking the supply from the auxiliary amplifier circuit. The output voltages of the amplifier circuit are similar to the voltage of the test circuit. The extra power is not passing through the deflector because of which the meter gives the accurate reading.

Types of Electronic Voltmeter:

The electronic voltmeter is categorized into two types. They are

- Analog Electronic Voltmeter
- Digital Electronic Voltmeter

Analog Electronic Voltmeter – The meter whose output is obtained by the deflection of the pointer on the calibrated scale is known as the analogue electronic measurement. It is a voltage measuring instrument which has high circuit impedance. The meter uses the electronic amplifier for controlling the input signals. The analogue electronic voltmeter is further classified into AC and DC analogue electronic voltmeter.



Electronic Voltmeter

Circuit Globe

Digital Electronic Voltmeter – The voltmeter which gives the **digital output reading of the measures voltage** is known as the electronic voltmeter. The output of the digital electronic voltmeter is in the form of the numerical value. The digital electronic instruments reduce the human and the parallax error because the reading is directly shown in the numeric form.

Possible 2 marks

1. Write any three uses of multimeter.
2. . Describe about voltmeter.
3. How you construct a multimeter ?
4. What is meant by sensitivity of a multimeter ?
5. Define amplifier and rectifier.
6. What is a multimeter ?
7. What are the types of electronic voltmeter ?
8. What are the various types of AC millivoltmetetrs ?

Possible 6 marks

1. Draw and explain the block diagram of a AC millivoltmeter.
2. What is a multimeter ? How does it work ?
3. Briefly explain the specifications and significance of an electronic voltmeter.
4. What type of measurement can be made with a multimeter ? Explain with suitable diagrams.
5. Explain the principle of voltage measurement in a multimeter.
6. Write a short notes about Amplifier -Rectifier and Rectifier-Amplifier.
7. Briefly explain the applications, advantage and disadvantage of a multimeter.

Karpagam Academy Of Higher Education
Coimbatore -21
Department of Physics
II B.Sc Physics
Basic Instumenation Skills [17PHU404A]

Unit -2

A voltmeter is connected in a ______ with the circuit component across which potential difference is to be measure
The resistance of an ideal voltmeter is ______ .
Electrostatic instruments are exclusively used as
A voltmeter should have ______ resistance.
If a voltmeter is connected, like an ammeter in series to the load
Which of the voltmeter is used for measuring high direct voltage (say 10kV)?
Sensitivity of a voltmeter is expressed in
A galvanometer in series with a high resistance is called ……………
To increase the current sensitivity below 10 mV, electronic instrument uses
Electronic voltmeters can be designed to measure
An rms reading voltmeter can accurately measure voltages of
In electronic voltmeter, the range of input voltages can be extended by using
The measurement range of digital voltmeter is
Which among the following is not the type of digital voltmeters?
In a ramp type DVM, the multivibrator determines the rate at which the
A multimeter consists of an ordinary pivoted type of moving coil ______.
When electric current is passed through the coil, _____ force acts and the pointer moves over the scale.
When a high resistance is connected in series with a galvanometer, it becomes a ______.
When low resistance is connected in a parallel with a galvanometer, it becomes an ______.
A multimeter has full scale deflection current of 1 mA. Determine its sensitivity
An ammeter is connected in _______with the circuit element whose current we wish to measure.
A voltmeter is connected in _____ with the circuit component across which potential difference is to be measured.
The sensitivity of a multimeter is given in _______.
If the full-scale deflection current of a multimeter is 50 μA, its sensitivity is
If a multimeter has a sensitivity of 1000 □□per volt and reads 50 V full scale, its internal□resistance is
A VTVM has .... input resistance than that of a multimeter.
Which of the following is likely to have the largest resistance ?
The input resistance of a VTVM is about
A VTVM is never used to measure
Multimeters can be useful for _____________________.
If the full-scale deflection current of a multimeter is 100 μA, its sensitivity is _______.
A multimeter is connected in parallel (across) a fuse and measures a voltage of 125 VAC. This indicates ________
If a multimeter has a sensitivity of 1000 Ω per volt and reads 50 V full scale, its internal resistance is ________.
Two multimeters A and B have sensitivities of 10 kΩ/V and 30 kΩ/V respectively. Then _____
Multimeter typically provides measurements of __________ values (for a sinusoidal waveform).
Multimeter is also called as _____ meter.

. In a voltmeter a resistance in series with PMMC movement is used to

The resistance of a voltmeter in 0-100 V range is 1000 Ohm. Its sensitivity is

The series resistance of the multiplier is ____ than the coil resistance

Electrostatic type instruments are primarily used as

A d'Arsonval basic meter movement is converted into a ______ by cone ting a series resistance with it.

______ is a measuring instrument which measures the potential difference between two points.

A __________ in series with a high resistance is called a voltmeter.

A ______ consists of an ordinary pivoted type of moving coil galvanometer.

A ______ is used to convert ac to dc.

______ are used depending upon the range of the input voltage.

Shunts are chosen depending upon the range of the _____.

______ is used to construct a peak reading voltmeter.

The word multimeter comes from

Multimeter is a package of

Most multimeter use a _______ movement.

In a multimeter _____ built for ac measurements.

The lower portion of the meter contains

_____ is used to select the type and range of the measurement.

The ac voltage scale leads the rms voltage for the _______ input.

For resistance measurements generally _____ multiplication ranges used.

For high values of resistance measurements, the internal battery voltage should be ______.

Most of the multimeter use a ___ V battery.

Separate jacks are provided for

________ type instruments are primarily used as voltmeters.

Multimeter often provide a ____ m scale.

Parallel	Series	Series or pa	None of the above	**Parallel**
low	infinite	zero	high	**infinite**
Voltmeters	Ohmmeters	Ammeters	Wattmeters	**Voltmeters**
zero	very high	very low	none of these	**very high**
The measu	Almost no	The meter	An instantaneously hig	**Almost no current will flow in the circuit**
Permanent-	Hot-wire	Electrostati	Moving iron	**Electrostatic**
W/V	W/A	V/W	V/A	**W/A**
An ammete	A voltmete	A wattmete	None of the above	**A voltmeter**
Amplifiers	Modulator	Transducer	Oscillator	**Amplifiers**
Only very s	Only very l	Both very s	None of these	**Both very small and very high voltages**
Sine wavef	Square wav	Saw tooth	All of these	**All of these**
Functional	Input atten	Rectifier	Balanced bridge dc am	**Input attenuator**
1V to 1MV	1V to 1kV	1kV to 1M	100 kV to 100MV	**1V to 1MV**
Ramp type	Integrating	Potentiome	None of these	**None of these**
Clock puls	Measureme	It oscillates	Its amplitude varies	**Measurement cycles are initiated**
Galvanome	Galvanome	Ammeter	Potentiometer	**Galvanometer**
Electrical	mechanical	Opposite	Magnetic	**mechanical**
Galvanome	Voltmeter	Ammeter	Potentiometer	**Voltmeter**
Galvanome	Voltmeter	Ammeter	Potentiometer	**Ammeter**
100 W / V	500 W / V	1000 W / V	750 W / V	**1000 W / V**
series	parallel	series or pa	None of the above	**series**
series	parallel	series or pa	None of the above	**parallel**
W	KW/V	Amperes	none of the above	**KW/V**
10 KW/V	100 KW/V	50 KW/V	20 KW/V	**20 KW/V**
10kW	50 KW	100 KW	40kW	**50 KW**
More	Less	Same	None of these	**More**
voltmeter c	moving coi	ammeter of	a copper wire of length	**voltmeter of range 10 V**
10 MW	1000 MW	100 MW	500 MW	**10 MW**
voltage	current	frequency	time period	**voltage**
checking b	troubleshoo	checking fo	all of these	**all of these**
10kW	40kW	100 KW	70 KW	**40kW**
the fuse is	the fuse is l	a short circ	the test leads are plugg	**the fuse is blown**
40kW	50kW	10kW	70 KW	**50 KW**
Multimeter	Multimeter	Both are eq	None of the above	**Multimeter B is more sensitive**
Peak	rms	Average	Instantaneous	**rms**
AVC	AVO	CRO	CTR	**AVO**

Increase th	Decrease t	Decrease t	Increase the current ra	**Increase the voltage range**
0.1 Ohm/V	1 Ohm/V	10 Ohm/V	100 Ohm/V	**10 Ohm/V**
Less	More	Very much	Lower	**Very much greater**
Galvanome	Voltmeter	Ammeter	Potentiometer	**Voltmeter**
Galvanome	Voltmeter	Ammeter	Potentiometer	**Voltmeter**
Galvanome	Voltmeter	Ammeter	Potentiometer	**Voltmeter**
Galvanome	Voltmeter	Ammeter	Potentiometer	**Galvanometer**
Multimeter	Galvanome	Ammeter	Potentiometer	**Multimeter**
Galvanome	Ammeter	Rectifier	Amplifier	**Rectifier**
Multiplier	Multiplier	Rectifier	Amplifier	**Multiplier resistor**
Input volta	Output volt	Input curre	Output current	**Input current**
Digital volt	Peak detect	Voltage co	Amplifier	**Peak detector**
Multiple m	Multiplex	Multiuse m	None of these	**Multiple meter**
Dc voltmet	An voltmet	Ohmmeter	All the above	**All the above**
Owen	Hay’s	D’Arsonva	De Sauty	**D’Arsonval**
Multiplier	Rectifier	Amplifier	Capacitor	**Rectifier**
Function s	Jacks	Both (A) a	None of these	**Both (A) and (B)**
Function s	Input signa	Probes	Jacks	**Function switch**
Sinusoidal	Cosine	sawtooth	triangle	**Sinusoidal**
4	5	7	3	**3**
Decreased	Increased	Remains sa	Low	**Increased**
12	5	9	15	**9**
high voltag	high curren	Both (A) a	None of these	**Both (A) and (B)**
Electrostati	Electrodyn	Electroche	Electromechanical	**Electrostatic**
Centi	Decibel	Kilo	Ohm	**Decibel**

UNIT-3

SYLLABUS

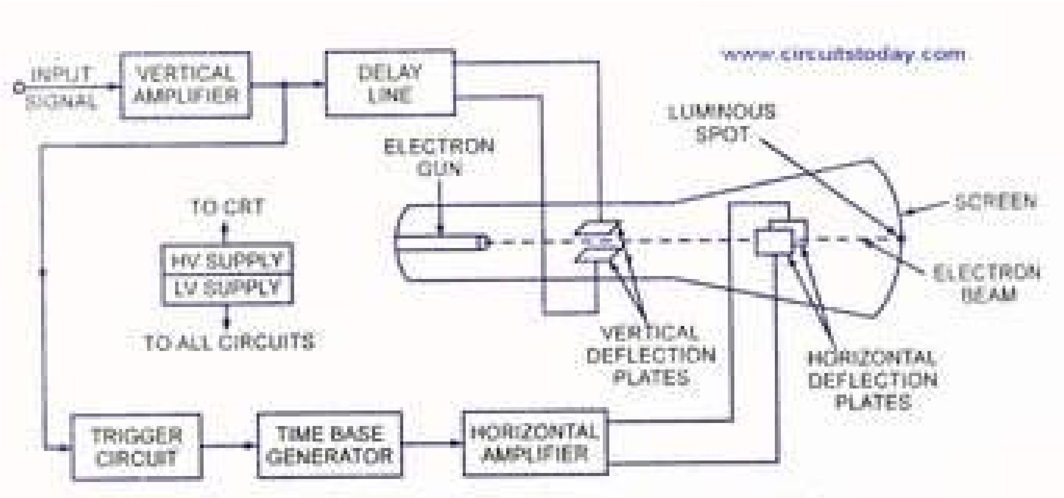
Cathode Ray Oscilloscope: Block diagram of basic CRO. Construction of CRT, Electron gun, electrostatic focusing and acceleration (Explanation only– no mathematical treatment), brief discussion on screen phosphor, visual persistence & chemical composition. Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance.

CATHODE RAY OSCILLOSCOPES (CRO):

Cathode Ray Oscilloscopes (CRO) as one of the pre-requisites of any electronics laboratory, are known to be amongst one of the most flexible and adaptable instruments. A basic CRO is a test instrument that allows an individual to “plot” and “view” two-dimensional (2 – D) graphs of electronic signals during real-time measurements just like a ‘visual’ voltmeter would do so. CRO can therefore be compared to an electronic X – Y plotter which plots electronic signals including voltage, current, phase difference etc. mainly as a function of time and sometimes as a function of voltage. Typically any existing CRO in a contemporary electronics laboratory would have two input channels (vertical Y channels: Y1 and Y2) along with an in-built X channel (horizontal) with a knob to vary the time quotient. The signal that needs to be analysed or studied is directly fed to any of the Y - channel (vertical) whereas the time function is available on the X - axis (horizontal) by default. The two Y channels of the CRO allow measurement of two separate signals at any given point of time and their attributes including amplitude, time-period (frequency) studied or phase difference compared. This type (most common) of CRO is popularly referred to as dual-trace CRO.

Over the last couple of decades the CROs have evolved from CRT (Cathode Ray Tube) based power hungry bulky contraptions to LCD panel based with small form factor and high power efficiency. Some of the modern ones are even battery operated, can be held in hand and operate via touch screen interface enabled with wi-fi / bluetooth data transfer capability and GPS connectivity. The images below show the evolution of the CROs to DSOs to handheld ones.

BLOCK DIAGRAM OF BASIC CRO:



Block Diagram of a General Purpose CRO

A CRO in use in any laboratory worldwide consists of the following components as a standard:

a) Cathode Ray Tube (CRT)

b) Trigger Circuit

c) Time- Base Generator

d) Horizontal Amplifier

e) Vertical Amplifier

f) Delay Line

In conventional CROs the main constituent has been the Cathode Ray Tube (CRT) and rest of the test equipment consists of electronic circuitry used to operate the CRT reproducibly and efficiently. All CROs typically have two in-built power supplies - a High Voltage supply (HV supply from -1000 V to -1500 volts) and a Low Voltage supply (LV supply from + 300 V to +400 V). The negative HV supply drives the CRT whereas the positive LV supply takes care of the associated electronics.

Cathode Ray Oscilloscope broadly, the conventional CRO consists of the following:

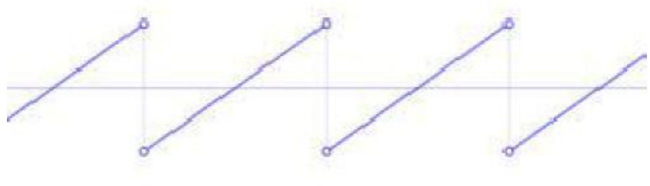
a) Electron Gun - Generates a fine beam of electrons (cathode ray) by means of cathode and a set of three anodes

b) Deflection assembly - Set of pairs of vertical plates (Y1 and Y2) and horizontal plates (time base)

c) Phosphor coated Screen – Coated with visible light emitting 'Phosphors' of specific colours, the 'processed' cathode ray impinges on it and creates light based on secondary emission principle.

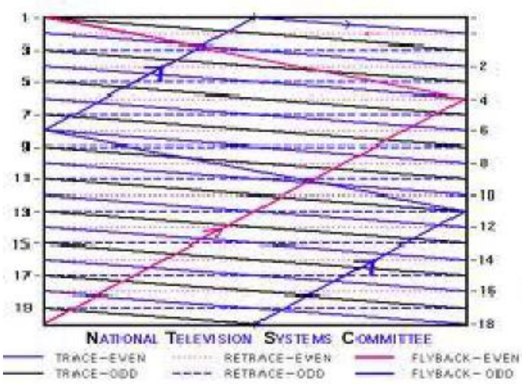
The working principle how the signal to be measured / tested gets displayed onto the CRO screen is described briefly as follows. Initially, as shown in Figure 1, the input signal (signal to be viewed or under test) is fed directly to the Y - input channels of the CRO. This is done by coupling the input signal through a male BNC (Bayonet Neil Concelmann) cable to the female BNC connector on the CRO. The shielded cable allows signal to be fed into the CRO with minimal loss (especially high frequency signals). The Y – input channels consist of a pair of deflection plates that induces the electron beam (cathode ray) generated from the electron gun of the CRO to move vertically in positive or negative direction. The amount of vertical movement of the electron beam from the centre of the screen is directly proportional to the strength (amplitude) of the input signal and this phenomenon happens after it has been duly processed by the vertical amplifier. The processed vertical signal is thereafter momentarily stopped from reaching the phosphor screen because there is no signal on the X – axis (generally time) to balance the input vertical signal on the Y – axis. This momentary stopping is typically in the range of 80 – 200 nanoseconds (10-9 seconds) and is achieved with a circuit known as Delay Line.

With vertical signal stopped at the Delay Line the associated electronics in the CRO tries to generate the balancing signal on the X – axis such that the processed input signal on Y – axis can be faithfully displayed on the CRO screen. For this all conventional CROs have a time-base circuits and their function is to generate sawtooth signals. Typical sawtooth signals are shown as follows (**Figure**).



N = 0

Comparing the sawtooth wave to some of the typical signals encountered in a regular electronics laboratory (**Figure**), it is observed that they are be modified triangular wave signals



Specifically, sawtooth signals can be realized from triangular waves by making the fly-back time of the triangular signal negligible (ideally zero). Fly-back time is defined to be the time taken by the triangular or the sawtooth signal to fall from its maximum value to its minimum value. The obtained sawtooth wave is seen to possess a linear rise in its characteristics from a minimum to a maximum value as a function of time followed by a sudden drop to its minimum from the attained maximum value. This characteristic of the sawtooth signal is observed when it is plotted as a function of time along the Y-axis. However when the electron beam in the CRO is subjected to the influence of a sawtooth signal along the horizontal X-axis then, the beam is seen to move from left of the phosphor screen to the right gradually with time. Once it reaches the end of the screen it resets back to left almost instantly just like the raster patter in a conventional television. The raster pattern is shown is shown in **Figure**

Hence the sawtooth signal applied horizontally within the CRO moves the electron beam along the X – axis from origin to the right corner and resets it back almost instantaneously, however there still remains the problem of synchronization between the vertical (input / test) signal and horizontal time-base signals (sawtooth wave). This problem is overcome using the synchronization circuit within the CRO mainly consisting of the Trigger mechanism. As seen in the **Figure** as soon as a test signal is input on the Y plates of the CRO, some portion of it is taken as a feedback to the Trigger mechanism that initiates generation of the Time-Base signal. Feedback of the original signal onto the X – plate portion electronics not only helps in synchronized plotting of the X and Y signals but also helps in obtaining a stable waveform on the CRO screen. As soon as the intelligent processing is completed on the X – plate electronics, the horizontal signal is amplified and intentional delay on the Y signal is removed. Thereafter one gets a faithful and stable visual signal on the CRO screen.

CONSTRCTION OF CRT:

Cathode Ray Tube (CRT) is a vacuum sealed glass envelope that has a source of electrons (electron gun) which emits electrons (cathode ray), that are accelerated to pass through two-sets (pairs) of plates (one set each of vertical and horizontal plates) before striking a phosphor coated screen internally so as to provide a visual display of signal. CRTs therefore are constituted of three basic systems

a) Electron gun assembly

b) Electrical deflection system consisting of X – X (horizontal) and Y – Y (vertical) plates

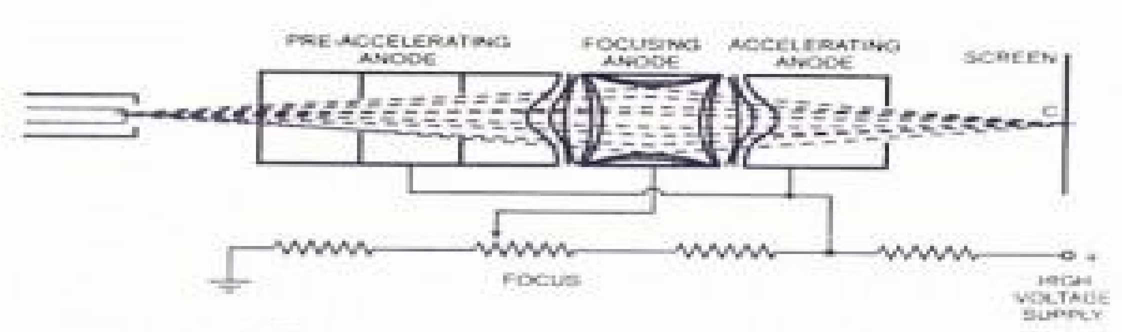
c) Phosphor coated screen to visually depict the electrical waveform.

The block diagram of the CRT is shown in Figure 2.

ELECTRON GUN:

The electron gun assembly consists of an indirectly heated cathode, a control grid surrounding the cathode, a focusing anode and an accelerating anode. The sole function of the electron gun assembly is to provide a focused electron beam which is accelerated towards the phosphor screen. The cathode is a nickel cylinder coated with an oxide coating and emits plenty of electrons, when heated. The emitting surface of the cathode should be as small as possible, theoretically a point. Rate of emission of electrons or say the intensity of electron beam depends on the cathode current, which can be controlled by the control grid |n a manner similar to a conventional vacuum tube. The control grid is a metal cylinder covered at one end but with a small hole in the cover. The grid is kept at negative potential (variable) with respect to cathode and its function is to vary the electron emission and so the brilliancy of the spot on the phosphor screen. The hole in the grid is provided to allow passage for electrons through it and concentrate the beam of electrons along the axis of tube. Electron beam comes out from the control grid through a small hole in it and enters a pre-accelerating anode, which is a hollow cylinder in shape and is at a potential of few hundred volts more positive than the cathode so as to accelerate the electron beam in the electric field. This accelerated beam would be scattered now because of variations in energy and would produce a broad ill-defined spot on the screen. This electron beam is focused on the screen by an electrostatic lens consisting of two more cylindrical anodes called the focusing anode and accelerating anode apart from the pre-accelerating anode. The focusing and accelerating anodes may be open or close at both ends and if covered, holes must be provided in the anode cover for the passage of electrons. The function of these anodes is to concentrate and focus the beam on the screen and also to accelerate the speed of electrons.

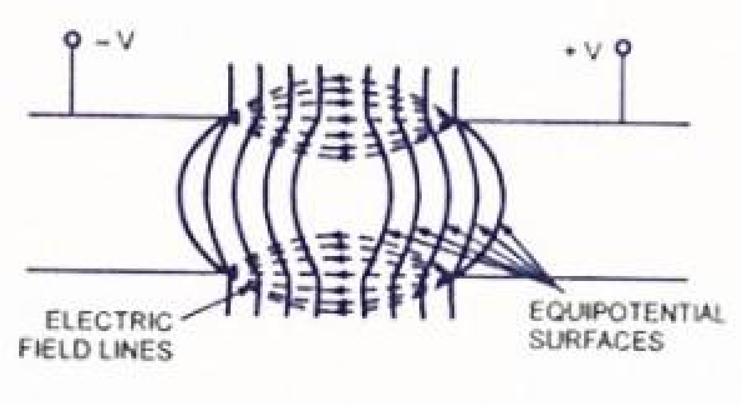
ELECTROSTATIC FOCUSING SYSYTEM:



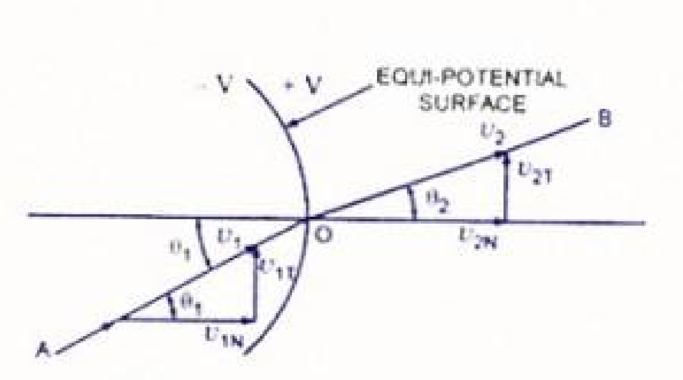
Electrostatic Focusing System of a CRT

An electrostatic focusing system is shown in figure. Electrostatic lens consists of three anodes, with the middle anode at a lower potential than the other two electrodes.

In figure two anodes and its electrostatic lines and equipotential surfaces are shown. A pd is kept between these two electrodes so that an electric field is generated between them. Spreading of electric field is caused because of repulsion between electric lines. If equipotential lines are drawn, as shown in figure, they would bulge at the centre of the two anodes. As we know that electrons move in a direction opposite to that of electric field lines and equipotential surfaces are perpendicular to the electric field lines so force on the electron is exerted in the direction normal to the equipotential surface.



Electrons entering at the centre line of the two anodes experience no force but electrons displaced from the centre line experience a force normal to the direction of equipotential surface and deflect, as shown in figure. An equi potential surface is shown, in which an electron with velocity V_1 and at an angle θ. to the normal of equipotential surface enters and experiences a force in a direction normal to the equipotential surface. Thus the velocity of the electron increases to V_2. This force on the electron is exerted in the direction normal to equipotential surface so only the normal component of electron velocity V_{1N} increases to V_{2N} and the tangential component of velocity V_{1T} remains the same.



Refraction of an Electron Ray at an Equipotential Surface

From figure

$\mathbf{V_{1T} = V_1 \sin_{\theta 1}}$,

$\mathbf{V_{2T} = V_2 \sin_{\theta 2}}$

But $V_{1T} = V_{2T}$

$V_1 \sin_{\theta 1} = V_2 \sin_{\theta 2}$

Or $V_2/V_1 = \sin_{\theta 1} / \sin_{\theta 2}$

From the above expression it is obvious that equipotential surface acts as a concave lens in geometrical optics. That is why, this focusing system is named as an electrostatic lens. Now if we go back and refer figure, it can be seen that because of middle anode to a lower potential, electron beam coming from the cathode and passing through the first concave electrostatic lens tends to become more aligned with the axis of CRT and when it enters at the second concave electrostatic lens, formed between two anodes at different potentials, it is focused at the phosphor screen. Focal length of the electrostatic lens can lie adjusted by varying potential of middle anode with respect to other two anodes. Thus electron beam can be made to focus at the screen very precisely.

Deflection Sensitivity of CRT:

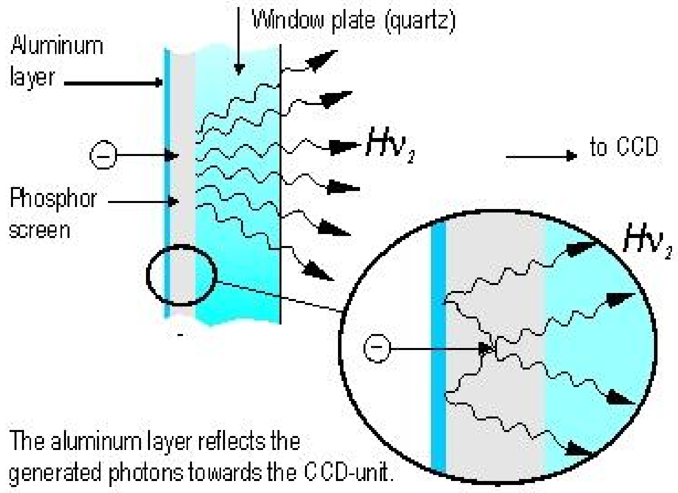
The shift of the spot of light on the screen per unit change in voltage across the deflection plates is known as deflection sensitivity of *CRT*. For instance, if a voltage of 100 V applied to the vertical plates produces a vertical shift of 3 mm in the spot, then deflection sensitivity is 0.03 mm/V. In general,

Spot deflection = Deflection sensitivity × Applied voltage

The deflection sensitivity depends not only on the design of the tube but also on the voltage applied to the accelerating anode. The deflection sensitivity is low at high accelerating voltages and vice-versa.

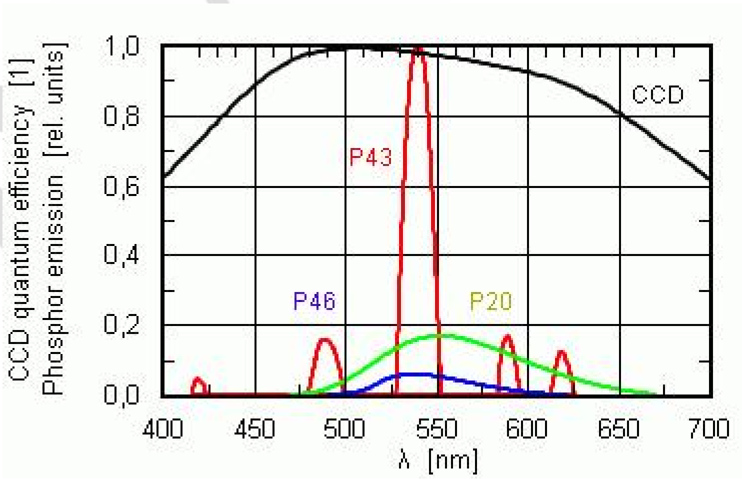
SCREEN PHOSPOR:

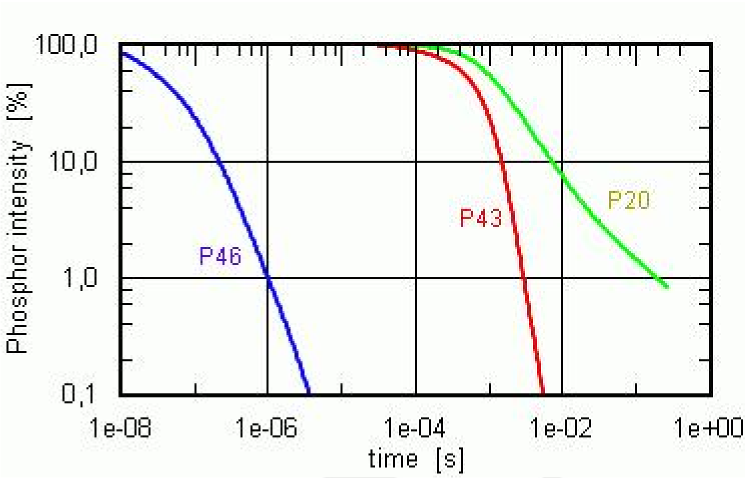
The phosphor screen emitted photons if accelerated electrons hit the material. The most common use of phosphor screens are cathode ray tube displays which are used in the early TV's and oscilloscopes. Phosphors for these cathode ray tubes were standardized and designated by the letter "P" followed by a number. The phosphor screen of image intensifiers converts the electron a valance from the micro channel plate back into photons.



Typical conversion factors of the used phosphor screens are between 20 and 200 photons per electron, depending on the phosphor type and the kinetic energy of the electrons, i.e. the acceleration voltage. In order to increase the number of photons emitted in the direction towards the CCD sensor, the backside of the phosphor is coated with an aluminium layer that reflects photons towards the proper direction, as shown in the enlarged detail above.

Several different phosphors types are available which differ in the emitted spectrum and in decay time, i.e. in fluorescence lifetime, as shown in the according pictures below.





An optimum phosphor screen will be chosen for the specific requirements of your application. There are three important considerations in choosing a phosphor screen. First the efficiency, second the phosphor decay time and last the spatial resolution.

The two mostly used phosphor screens for image intensifiers are P43 and P46. The P43 phosphor screen has a higher efficiency and higher spatial resolution due to smaller grain size. However, it has a long decay time. For fast applications e.g. double frame mode with a interfacing time of 500ns the faster decaying P46 phosphor screen is necessary to avoid gost images from the previous exposure. The trade-off of the P46 phosphor screen are lower efficiency and lower spatial resolution.

Especially, at the double frame mode it need to be ensured that the fluorescence of the phosphor from the last image has sufficiently died down before the CCD sensor read out the second image. This is to avoid any loss of light and, even more important, to avoid crosstalk to the next image.

Phosphor screen	**P43**	**P46**	
Conversion Efficiency	200	95	photons per electron
decay time 100% => 10%	1500	0.2	µs
decay time 100% => 1%	3200	20	µs

SYNCHRONIZATION:

There must be synchronization between the sweep and the signal being measured. Synchronization is done to produce stationary pattern. There are three sources of synchronization which can be selected by synchronization selector and they are written below:

Internal

In this trigger is obtained from the signal being measured through vertical amplifier.

External

In this trigger an external trigger source is required.

Line

In this method trigger is obtained power supply.

Intensity Modulation

Intensity modulation can be done by inserting the signal between the ground and the cathode. Intensity modulation causes the brightening of the display.

Positioning Controls

Position can be control by applying small independent internal direct voltage sources to the deflecting plates and with the help of potentiometer (using it as voltage divider) we can control the position of signal.

Focus Control

Focus can be controlled by changing the focal length of the focusing electrode which acts like a lens and focal length can be changed by the changing potential of the focusing anode.

Intensity Control

The intensity can be varied by changing the grid potential with respect to cathode.

Calibration Circuit

Calibrating voltage has a square shape which is usually internally generated of known amplitude.

Astigmatism

By adjusting the focus the spot can be made sharp in order to avoid the problem of astigmatism.

VISUAL PERSISTENCE:

The actual conversion of electrical energy to light energy takes place on the display screen when electrons strike a material known as a phosphor. A phosphor is a chemical that glows when exposed to electrical energy. A commonly used phosphor is the compound zinc sulfide. When pure zinc sulfide is struck by an electron beam, it gives off a greenish glow. The exact color given off by a phosphor also depends on the presence of small amounts of impurities. For example, zinc sulfide with silver metal as an impurity gives off a bluish glow, while zinc sulfide with copper metal as an impurity gives off a greenish glow.

The selection of phosphors to be used in a cathode-ray tube is very important. Many different phosphors are known, and each has special characteristics. For example, the phosphor known as yttrium oxide gives off a red glow when struck by electrons, and yttrium silicate gives off a purplish-blue glow.

The rate at which a phosphor responds to an electron beam is also of importance. In a color television set, for example, the glow produced by a phosphor has to last long enough, but not too long. Remember that the screen is being scanned 25 times every second. If the phosphor continues to glow too long, color will remain from the first scan when the second scan has begun, and the overall picture will become blurred. On the other hand, if the color from the first scan fades out before the second scan has begun, the screen will go blank briefly, making the picture flicker.

Cathode-ray tubes differ in their details of construction depending on the use to which they will be put. In an oscilloscope, for example, the electron beam has to be able to move about on the screen very quickly and with high precision, although it needs to display only one color. Factors such as size and durability are also more important in an oscilloscope than they might be in a home television set. In a commercial television set, on the other hand, color is obviously an important factor. In such a set, a combination of three electron guns is needed—one for each of the primary colors used in making the color picture.

TIME BASE OPERATION:

Time base circuit uses a uni junction transistor, which is used to produce the sweep. The saw tooth voltage produced by the time base circuit is required to deflect the beam in the horizontal section. The spot is deflected by the saw tooth voltage at a constant time dependent rate.

FRONT PANEL CONTROL:

Vertical Deflection System:

The input signal for examining are fed to the vertical deflection system plates with the help of input attenuator and a number of amplifier stages. The main function of these amplifiers is to amplify the weak the weak signals so that the amplified signal can produce the desirable signals.

Horizontal Deflection System:

Like the vertical system horizontal system also consists of horizontal amplifiers to amplify the weak input voltage signals but in contrast to vertical deflection system, horizontal deflection plates are fed by a sweep voltage that provides a time base as shown above. As shown in the circuit diagram, the saw tooth sweep generator is triggered by the synchronizing amplifier when the sweep selector switch is in the internal position and thus the triggered saw tooth generator gives input to the horizontal amplifier by following this mechanism. Now there are four types of sweeps:

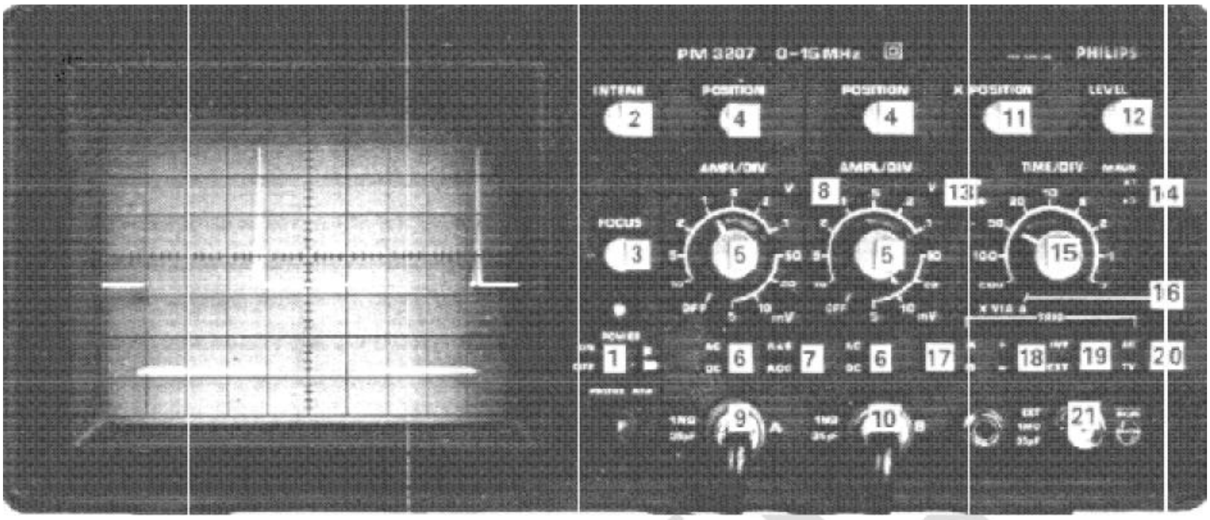
(1) Free running or recurrent sweep: As the name suggests, the saw tooth waveform is repetitive i.e. a new sweep is started immediately after the previous sweep.

(2) Triggered sweep: Some time the waveform to be observed may not be periodic so it is desired that the sweep circuit remain inoperative and the sweep be initiated by the waveform under examination. In such cases we use triggered sweep.

(3) Driven sweep: Generally a driven sweep is used where the sweep is free running but triggered by the signal under test.

(4) Non saw tooth sweep: This is used for Important oscilloscope specification

Typical front panel control:



1. On–off switch.

2. INTENS. This is the intensity control connected to the grid G to control the beam intensity and hence the brightness of the screen spot. Don’t run the intensity too high, just bright enough for clear visibility. Always have the spot sweeping left to right or the beam may “burn” a hole in the screen.

3. FOCUS allows you to obtain a clearly defined line on the screen.

4. POSITION allows you to adjust the vertical position of the wave form on the screen.(There is one of these for each channel).

5. AMPL/DIV. is a control of the Y (ie. vertical) amplitude of the signal on the screen.(There is one of these for each channel).

6. AC/DC switch. This should be left in the DC position unless you cannot get a signal on-screen otherwise. (There is one of these for each channel).

7. A&B/ADD switch. This allows you to display both input channels separately or to combine them into one.

8. +/- switch. This allows you to invert the B channel on the display.

9. Channel A input

10. Channel B input

11. X POSITION These allow you to adjust the horizontal position of the signals on the screen.

12. LEVEL This allows you to determine the trigger level; ie. the point of the waveform at which the ramp voltage will begin in timebase mode.

13. ms/µsThis defines the multiplication factor for the horizontal scale in timebase mode. (See 15 below.)

14. MAGN The horizontal scale units are to be multiplied by this setting in both timebase and xy modes. To avoid confusion, leave it at x1 unless you really need to change it.

15. Time/DivThis selector controls the frequency at which the beam sweeps horizontally across the screen in timebase mode, as well as whether the oscilloscope is in timebase mode or xy (x VIA A) mode. This switch has the following positions:

(a) X VIA A In this position, an external signal connected to input A is used in place of the internally generated ramp. (This is also known as xy mode.)

(b) .5, 1, 2, 5, etc. Here the internally generated ramp voltage will repeat such that each large (cm) horizontal division corresponds to .5, 1, 2, 5, etc. ms. or µs depending on the multiplier andmagnitude settings. (Note also the x1/x5 switch in 14 above.)

16. The following controls are for triggering of the scope, and only have an effect in timebase mode.

17. A/B selector. This allows you to choose which signal to use for triggering.

18. -/+ will force the ramp signal to synchronise its starting time to either the decreasing or increasing part of the unknown signal you are studying.

19. INT/EXT This will determine whether the the ramp will be synchronised to the signal chosen by the A/B switch or by whatever signal is applied to the EXT. SYNC. input. (See 21 below.)

20. AC/TV selectors. I’ve never figured out what this does; find whichever position works.

22. External trigger input.

SPECIFICATIONS OF CRO AND THEIR SIGNIFICANCE:

When purchasing an oscilloscope, a buyer has to consider various oscilloscope specifications in order to meet his needs for a particular requirement.

One significant oscilloscope specification is related to the waveform’s speed and determined by the oscilloscope’s bandwidth. It was discovered that the ability of the oscilloscope to display the waveforms accurately declines with the increase of frequency. The manner in which it is specified can be viewed in IEEE 1057, which describes electrical bandwidth as the state when the amplitude of the sine wave input is lowered by three dB with regards to its level at a minimal reference frequency.

The bandwidth specification of an oscilloscope will usually be quoted in this format — Bandwidth = -3dB at 1500 MHz. If the specification of the oscilloscope for the -3dB point is not adequately high, it will be noted that the edges of square waves and pulses are also slower attributed to the reduced high frequency components.

For adequate oscilloscope specification, one must ensure that the oscilloscope bandwidth is higher than its operating frequency. A Five Times Rule is generally employed as a rule of thumb. Thus, a bandwidth should be five times the signal’s highest frequency component. With this rule, errors caused by frequency limitations will be lower than ± 2%.

Another important oscilloscope specification is vertical DC gain accuracy. Since oscilloscopes are not designed to be utilized in lieu of digital multimeters, its voltage elements will not likely be as accurate. Oscilloscope users are therefore advised to be aware of the accuracy of the measurement made when measuring the signal’s amplitude.

Because most oscilloscopes today employ all digital techniques converting the X axis or incoming vertical voltage to a digital format, oscilloscope users should be aware of the scale’s resolution. Dynamic range and resolution determine the largest measurement made without the need of clipping the waveform and the measurement’s “granularity”, respectively. Checking the oscilloscope’s resolution will ensure that the device will deliver correct resolution and dynamic range.

Rise time specification is also an important specification particularly for digital circuits where edges on pulses and square waves are of paramount importance. An oscilloscope should have fast rise time for it to accurately capture rapid transitions, otherwise the results could be misleading and significant information may not be displayed.

Rise time is comparable to an operational amplifier’s slew rate, where the voltage change’s rate is the limiting factor. And like bandwidth, rise time should also be sufficiently high to enable the oscilloscope to capture the required detail.

The influx of digital oscilloscopes gave birth to another important oscilloscope specification — sample rate, which is specified as samples per second (S/s). An oscilloscope with fast sampling rate also offers greater resolution of the waveform’s detail. Faster sampling rate also reduces the chance of losing any critical information.

finding the phase difference between the two voltages. Another important application is that we can compare frequency of input voltages using non saw tooth sweep.

Possible 2 mark question

1. Write a short notes about CRO.
2. Define the term“deflection sensitivity”.
3. What is meant by aquadag?
4. Define the term “deflection factor”.
5. Write down the main parts of a CRT.
6. Write short notes on Electron gun.
7. Write short notes on fluorescent screen.
8. Draw the block diagram of CRO.

Possible 6 mark question

1. Draw the block diagram of a general purpose CRO and explain the functions of it.
2. Write short notes of the following.

   (i) Electron gun (ii) fluorescent screen
3. Describe the different parts of CRT.
4. Explain various sources of Synchronization.
5. Discuss about electrostatic focusing with suitable diagram.
6. Explain the construction of a Cathode Ray Tube.
7. Explain the working principle of CRT.
8. Briefly discuss about the screen phosphor and visual persistence of a CRO.
9. Explain the various parts present in a Cathode Ray Oscilloscope.

Karpagam Academy Of Higher Education
Coimbatore -21
Department of Physics
II B.Sc Physics
Basic Instumenation Skills [17PHU404A]

Unit -3

What CRT element provides for control of the number of electrons passing farther into the tube?
For display of signal pattern ______ voltage is applied to the horizontal plates of a CRO
The material used to coat inside the face of CRT is _______ .
The most accurate device for measuring voltage is ______
If the negative potential on the control grid of CRT is increased, the intensity of spot _______ .
The horizontal plates of a CRO are supplied with _____ to observe the waveform of signal.
What element of a CRT releases electrons when heated indirectly by a filament?
Considered as the “heart” of the cathode ray oscilloscope.
A pattern displayed by oscilloscopes which has a steady characteristic is called
Which part of the following is not a basic part of a CRT?
What provides visual display showing the form of the signal applied as a waveform on the front screen of a cathode
CRO gives the visual representation of time varying signals. The display of the signal is
Principally CRO is a
The light emitted by the zinc silicate coated fluorescent screen of cathode ray tube is usually of
If the bombardment of electrons ceases i.e. when the signal becomes zero then the light emitted by the screen will
The time base signal in a CRO is a :
The units for the deflection sensitivity of a CRO are :
The colour of the spot on the screen of a CRO is a characteristic of :
A dual-trace CRO has :
The deflection sensitivity of a CRT depends inversely on the :
A dual – trace CRO has :
_______ converted electrical energy into light energy in CRO.
The deflection factor of CRT is defined as the _____ of sensitivity.
The electron beam is focused by the
_____ emits electron in CRO.
Focusing system in a CRT is known as ______.
Number of electrons from grid reaching screen determines the
In CRO, grid is connected to the
Cathode ray oscilloscope displays graph of waveforms based on
In a CRO which of the following is not a part of electron gun
An oscilloscope cannot be used to indicate
The focusing anode is connected to a lower adjustable voltage of _____ V
The minus sign indicates that the force acts in the ______ direction to that the field.
The field intensity is ____ in the end.
The equipotential surfaces are shown as _____
The pre accelerating anode is connected to a _______ potential.
The typical choice of phosphor is

The brightness is less then ______ percentage of that of a CRT without a liquid crystal shutter.
The control grid is usually a ______ cylinder.
_______ oscilloscopes are used for high speed applications,
_______ oscilloscopes can be used for capturing transient signals.
Many oscilloscopes are available with _____ bus capabilities.
_____ is a universal tool in all kind of electrical and electronic investigations.
The luminous spot thus traces the waveform of the _____ with respect to time.
The inner walls of *CRT* between neck and screen are usually coated with a conducting voltage material, called
If ________ is used as the fluorescent material, green light spot is produced.
The _____ is heated, it emits plenty of electrons.
The deflection sensitivity of a CRT is 0.01 mm/V. what is the shift produced in the spot when 400 V are applied to
The deflection sensitivity of a CRT is 0.03 mm/V. If an unknown voltage is appliedto the horizontal plates, the spo
By adjusting ____ control the image can be moved up or down as required.
By adjusting this control, the spot can be moved to right or left as required
In an oscilloscope, 200 V, 50 Hz signal produces adeflection of 2 cm corresponding to a certain setting of vertical g
The pre accelerating anode and the accelerating anode are connected to a common positive high voltage of about __
Unit of deflection factor of a CRO
When two equal voltages of equal frequency but with the phase shift φ are applied to a CRO we obtain ____.
The arrangement of electrodes which produce a focussed beam of electrons is called the
Spot deflection =
The deflection sensitivity is ____ at high accelerating voltages.
The deflection sensitivity of a CRT is 0.01 mm/V. what is the shift produced in the spot when 600 V are applied to
Important application of CRO is

Cathode	Control gri	Anode	Phosphor screen	**Control grid**
Sinusoidal	Rectangula	Sawtooth	None of the above	**Sawtooth**
Carbon	Sulphur	Silicon	Phosphorous	**Phosphorous**
Voltmeter	Multimeter	CRO	VTVM	**CRO**
Is increase	Is decrease	Remains th	None of the above	**Is decreased**
Sinusoidal	Cosine wav	Sawtooth w	None of the above	**Sawtooth wave**
Cathode	Grid	Anode	Phosphor screen	**Cathode**
Cathode ra	Sawtooth g	Horizontal	Vertical amplifier	**Cathode ray tube (CRT)**
Lissajous p	Nyquist pa	Barkhauser	Fermat's pattern	**Lissajous pattern**
Electron gu	Focusing a	Horizontal	Sawtooth generator	**Sawtooth generator**
Television	Computer	Meter face	CRT	**CRT**
One dimen	Two dimen	Three dime	Four dimensional	**Two dimensional**
Ammeter	Voltmeter	Wattmeter	Watt-hour meter	**Voltmeter**
Green colo	Yellow col	Blue colou	White colour	**Green colour**
Disappear i	Persist for	Will not di	None of these	**Persist for some time then it will disappear**
Rectangula	High frequ	High frequ	Square wave form	**High frequency saw tooth wave form**
Meter/volt	Mm/volt	Mm/m-volt	M/m-volt	**Meter/volt**
Electron gu	The type o	The coating	The velocity of the ele	**The coating material on the screen**
One-vertica	Two vertic	One vertica	Two vertical and two h	**One-vertical and one horizontal amplifier**
length of th	distance be	defecting v	separation between Y-	**separation between Y- plates**
one electro	two electro	one electro	two electron guns and	**one electron gun and two- pole switch**
Phosphorou	CRT	Electron gr	Electron gun	**Phosphorous**
Inversely p	Directly pr	Reciprocal	None of these	**Reciprocal**
Focusing a	Focusing c	Focusing p	Focusing grid	**Focusing anode**
CRT	Electron gu	Electron gr	Accelerating anode	**Electron gun**
Focusing le	Electron le	Double cor	Anode lens	**Focusing lens**
brightness	Sound qual	Picture qua	Noise reduction	**brightness level**
Positive po	Negative po	AC Source	DC Source	**Negative potential**
Current	Potential di	Voltage	Amplitude	**Voltage**
Cathode	Grid	Acceleratin	X-Y plates	**X-Y plates**
Frequency	Peak signal	Energy	Wave shapes	**Energy**
100	200	500	400	**500**
Opposite	Same	Positive	None of these	**Opposite**
More	Equal	Less	Small	**Less**
Solid lines	Field lines	Equipotent	Incident lines	**Solid lines**
High negat	High positi	Low negati	Low positive	**High positive**
P40	P33	P31	P28	**P31**

50	25	10	20	**20**
Nickel	Iron	Copper	Mica	**Nickel**
Simple	Sampling	Cathode ra	Dual trace	**Sampling**
Simple	Storage	Cathode ra	Dual trace	**Storage**
IEEE 488	RS 232	RS 485	IE 234	**IEEE 488**
Voltmeter	Multimeter	CRO	Signal generators	**CRO**
Input volta	Output volt	Breakdown	Peak voltage	**Input voltage**
Aquadag	Silicon	Germaniun	Phosphor	**Phosphor**
Phosphor	Copper	Silver	zinc orthosilicate	**zinc orthosilicate**
Anode	Control gri	Cathode	Screen	**Cathode**
5mm	6mm	3mm	4mm	**4mm**
10 v	100 v	45 v	74 v	**100 v**
intensity cc	focus contr	astigmatisn	Vertical position contr	**Vertical position control**
Horizontal	intensity cc	astigmatisn	focus control	**Horizontal position control**
500v	300v	200v	100v	**300v**
1500	2000	1000	4000	**1500**
Volt/ meter	Mm/volt	Mm/m-volt	M/m-volt	**Volt/ meter**
Straight lin	Circle	Ellipse	Vertical straight line	**Ellipse**
Electron G	Horizontal	Vertical de	Electron gun	**Electron gun**
Deflection	Deflection	Deflection	Applied voltage / Defle	**Deflection sensitivity × Applied voltage**
low	more	equal	moderate	**low**
3mm	4mm	5mm	6mm	**6mm**
Examinatic	Voltage me	Frequency	All the above	**All the above**

UNIT -4

SYLLABUS

CRO Measurement: Use of CRO for the measurement of voltage (dc and ac frequency, time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: Block diagram and principle of working.
Signal Generators and Analysis Instruments: Block diagram, explanation and specifications of low frequency signal generators. pulse generator, and function generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis.

DUAL TRACE CRO – SPECIAL FEATURES:

Two different input signals are used i.e. Channels A& B with attenuators and pre amplifiers. A delay line is used between electronic switch & vertical amplifier that alternately connects the input to main vertical amplifiers. There are two common operating mode for electronic switch called as

1. Alternate mode

In this mode, the CRO spot traces channel A signal on one sweep & channel B on next. These signals have calibrated input attenuators and vertical position control and also amplitude of these signals can be adjusted individually and two images are placed separately on the screen.

2. Chop mode

This mode is used for higher frequencies, say of order 100kHz to 500kHz.In this mode, the switch connects small segments of A & B waveform to main amplifier at a fast chopping rate of 500kHz i.e. equal to 1microsecond sweep of each waveform is fed to CRT for display.The switch S2 allows the circuit to be triggered on either of the inputs A or B channel or on line frequency or an external signal

The horizontal amplifier can be fed from sweep generator or through channel B via switch S1.If channel B,it is called X-Y mode

In X-Y mode, the oscilloscope operates from channel A to vertical amplifier and the other vice versa

Several output modes can be selected from front panel of CRO.

Advantages of Dual Beam for Multiple Trace Oscilloscopes

1. A multiple trace oscilloscope making use of dual beam provides a simultaneous display of the two input waveforms on the CRO screen. Hence dual beam CRO is used to compare one signal with another signal.

2. It can capture two fast transient events.

3. It also provides a continuous display of the signals, whereas the display of the two signals provided by a dual trace oscilloscope consists of small gaps in the trace.

4. It has two separate vertical channels for two input signals.

5. It can also have two separate time base circuits (i.e. horizontal deflection systems). Hence, in dual beam CRO two input signals can be swept horizontally at different rates. Due to this feature, a fast signal can be graphically compared with a slow signal simultaneously on the CRO screen.

USE OF CRO FOR THE MEASUREMENT OF VOLTAGE, FREQUENCY, TIME PERIOD:

The modern cathode ray oscilloscope provides a powerful tool for solving problems in electrical measurements. Some important applications of *CRO* are :

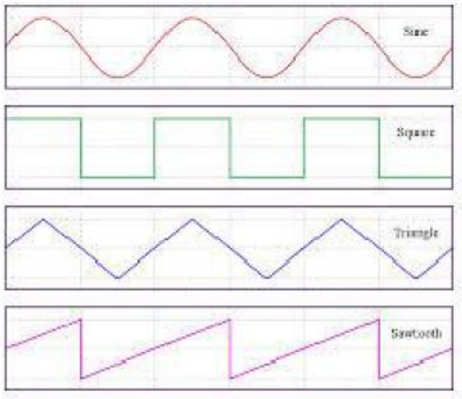
1. Examination of waveforms

2. Voltage measurement

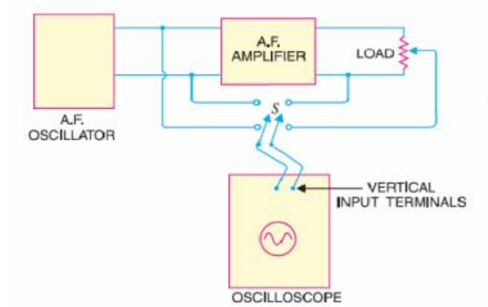
3. Frequency measurement

1. Examination of waveform.

One of the important uses of CRO is to observe the wave shapes of voltages in various types of electronic circuits. For this purpose, the signal under study is applied to vertical input (i.e., vertical deflection plates) terminals of the oscilloscope.



The sweep circuit is set to internal so that sawtooth wave is applied to the horizontal input *i.e.* horizontal deflection plates. Then various controls are adjusted to obtain sharp and well defined signal waveform on the screen. Fig shows the circuit for studying the performance of an audio amplifier. With the help of switch *S*, the output and input of amplifier is applied in turn to the vertical input terminals. If the waveforms are identical in shape, the fidelity of the amplifier is excellent.



2. Voltage measurement. As discussed before, if the signal is applied to the vertical deflection plates only, a vertical line appears on the screen. The height of the line is proportional to peak to-peak voltage of the applied signal. The following procedure is adopted for measuring voltages with *CRO*.

(*i*) Shut off the internal horizontal sweep generator.

(*ii*) Attach a transparent plastic screen to the face of oscilloscope. Mark off the screen with vertical and horizontal lines in the form of graph.

(*iii*) Now, calibrate the oscilloscope against a known voltage. Apply the known voltage, say 10 V, to the vertical input terminals of the oscilloscope. Since the sweep circuit is shut off, you will get a vertical line. Adjust the vertical gain till a good deflection is obtained. Let the deflection sensitivity be *V* volts/mm.

(*iv*) Keeping the vertical gain unchanged, apply the unknown voltage to be measured to the vertical input terminals of *CRO*.

(*v*) Measure the length of the vertical line obtained. Let it be *l* mm. Then, Unknown voltage = $l \times V$ volts

3. Frequency measurement. The unknown frequency can be accurately determined with the help of a *CRO*. The steps of the procedure are as under :

(*i*) A known frequency is applied to horizontal input and unknown frequency to the vertical input.

(*iv*) The number of loops cut by the horizontal line gives the frequency on the vertical plates (*fv*) and the number of loops cut by the vertical line gives the frequency on the horizontal plates (*fH*).

$$\frac{f_v}{f_H} = \frac{\text{No. of loops cut by horizontal line}}{\text{No. of loops cut by vertical line}}$$

For instance, suppose during the frequency measurement test, a pattern shown in Fig is obtained. Let us further assume that frequency applied to horizontal plates is 2000 Hz. If we draw horizontal and vertical lines, we find that one loop is cut by the horizontal line and two loops by the vertical line. Therefore,

$$\frac{f_v}{f_H} = \frac{\text{No. of loops cut by horizontal line}}{\text{No. of loops cut by vertical line}}$$

or $$\frac{f_v}{2000} = \frac{1}{2}$$

or $$f_v = 2000 \times 1/2 = 1000 \text{ Hz}$$

i.e. Unknown frequency is 1000 Hz.

INTRODUCTION TO DIGITAL OSCILLOSCOPE:

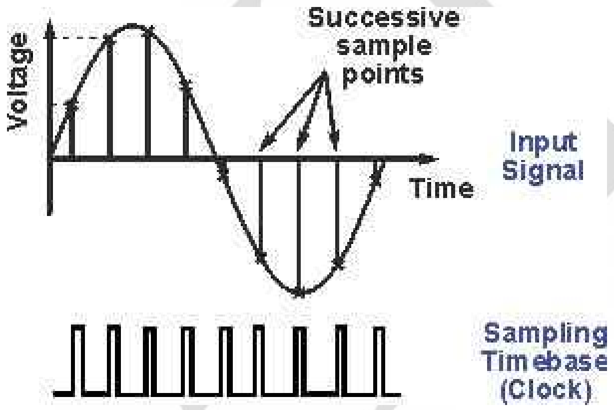
Digital oscilloscopes are now the major form of oscilloscope that is available on the teat equipment market. These scope may be referred to as digital oscilloscope or digital storage oscilloscope. Although these two names used to indicate separate types of instrument, they are often used interchangeably.

Digital oscilloscope technology

The basic concept behind digital oscilloscopes / DSOs is the conversion of the incoming analogue signal into a digital format where it can be processed using digital signal processing techniques.

When the signal enters the scope it is first pre-conditioned by some analogue circuits to ensure that the optimum signal is presented to the next stage.

This next stage involves the acquisition of the digital samples. To achieve this, an analog-to-digital converter, ADC, takes samples are discrete regular time intervals.



Digital oscilloscope sampling

The times and rate at which samples are taken is determined by the system clock. The rate at which samples are taken is often defined as part of the specification of the scope. This is measured in samples per second, and often quoted in Mega samples per second M samples per second.

The samples from the ADC are stored in memory and referred to as waveform points and together these points make up the overall waveform record. The number of waveform points within the record is referred to as the waveform length.

The waveform record is initiated by the trigger and again stopped by the timebase circuit after the given amount of time.

The waveform record is then processed by the processing circuitry and presented to the display for visual inspection by the user**.**

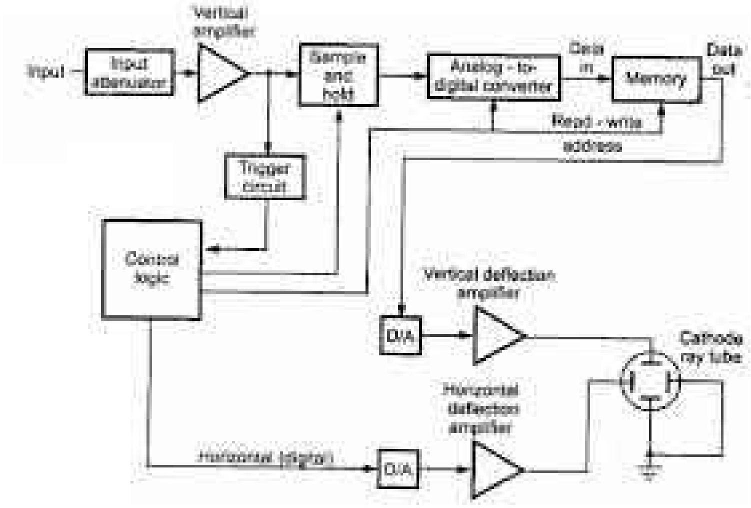
DIGITAL STORAGE OSCILLOSCOPE BLOCK DIAGRAM AND PRINCIPLE OF WORKING:

Block Diagram

The block diagram of digital storage oscilloscope is shown in the Fig.

- The input signal is applied to the amplifier and attenuator section.
- The oscilloscope uses same type of amplifier and attenuator circuitry as used in the conventional oscilloscopes.
- The attenuated signal is then applied to the vertical amplifier.
- To digitize the analog signal, analog to digital (A/D) converter is used.
- The output of the vertical amplifier is applied to the A/D converter section.
- The successive approximation type of A/D converter is most oftenly used in the digital storage oscilloscopes.
- The sampling rate and memory size are selected depending upon the duration & the waveform to be recorded.
- Once the input signal is sampled, the A/D converter digitizes it.
- The signal is then captured in the memory.
- Once it is stored in the memory, many manipulations are possible as memory can be readout without being erased.
- The digital storage oscilloscope has three modes:

1. Roll mode
2. Store mode
3. Hold or save mode.



Advantages:

i) It is easier to operate and has more capability.

ii) The storage time is infinite.

iii) The display flexibility is available. The number of traces that can be stored and recalled depends on the size of the memory.

iv) The cursor measurement is possible.

v) The characters can be displayed on screen along with the waveform which can indicate waveform information such as minimum, maximum, frequency, amplitude etc.

vi) The X-Y plots, B-H curve, P-V diagrams can be displayed.

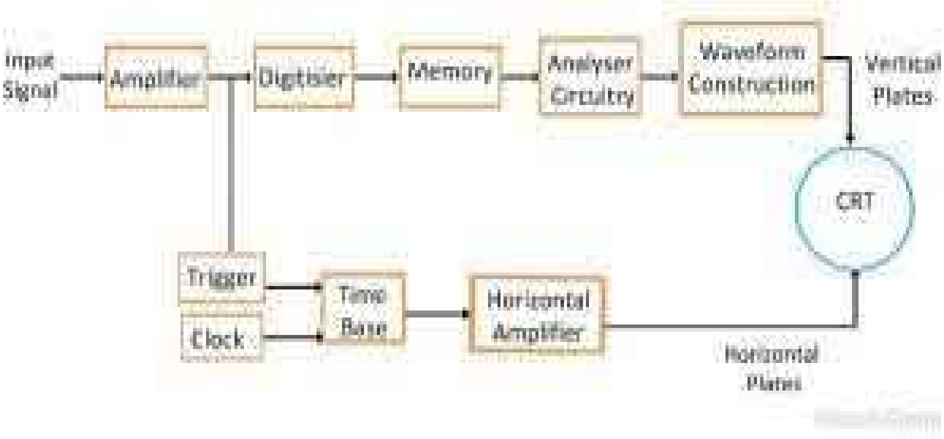
vii) The pretrigger viewing feature allows to display the waveform before trigger pulse.

viii) Keeping the records is possible by transmitting the data to computer system where the further processing is possible

ix) Signal processing is possible which includes translating the raw data into finished information e.g. computing parameters of a captured signal like r.m.s. value, energy stored etc.

Working principle:

The digital oscilloscope digitises and stores the input signal. This can be done by the use of CRT (Cathode ray tube) and digital memory.



The block diagram of the basic digital oscilloscope is shown in the figure below. The digitisation can be done by taking the sample input signals at periodic waveforms.

The maximum frequency of the signal which is measured by the digital oscilloscope depends on the two factors. These factors are the

1. Sampling rate
2. Nature of converter.

Sampling Rate – For safe analysis of input signal the sampling theory is used. The sampling theory states that the sampling rate of the signal must be twice as fast as the highest frequency of the input signal. The sampling rate means analogue to digital converter has a high fast conversion rate.

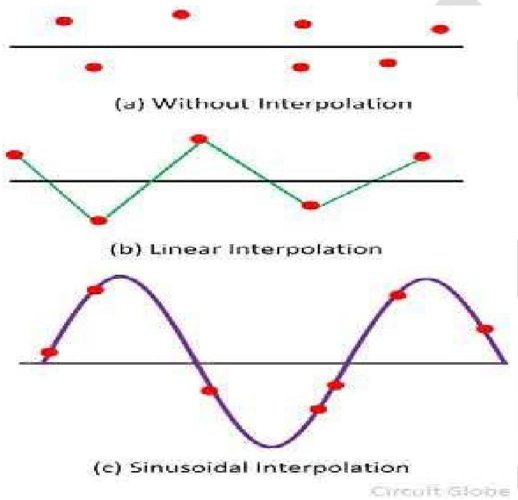
Converter – The converter uses the expensive flash whose resolution decreases with the increases of a sampling rate. Because of the sampling rate, the bandwidth and resolution of the oscilloscope are limited.

The need of the analogue to digital signal converters can also be overcome by using the shift register. The input signal is sampled and stored in the shift register. From the shift register, the signal is slowly read out and stored in the digital form. This method reduces the cost of the converter and operates up to 100 megasample per second.

The only disadvantage of the digital oscilloscope is that it does not accept the data during digitisation, so it had a blind spot at that time.

Waveform Reconstruction:

For visualising the final wave, the oscilloscopes use the technique of inter-polarization. The inter-polarization is the process of creating the new data points with the help of known variable data points. Linear interpolation and sinusoidal interpolation are the two processes of connecting the points together.



In interpolation, the lines are used for connecting the dot together. Linear interpolation is also used for creating the pulsed or square waveform. For sine waveform, the sinusoidal interpolation is utilised in the oscilloscope.

BLOCK DIAGRAM AND EXPLANATION OF LOW FREQUENCY SIGNAL GENERATORS (RF GENERATORS):

The low-frequency signal generator is a portable source of electrical frequency oscillations (sound, ultrasound). In the basic mode, a sinusoidal signal, in an additional mode, a square wave signal. Low-frequency signal generators are used to regulate and adjust systems and devices that are used in the radio electronic industry, in communication devices, in various automatic, computing, measuring devices, and in the instrument-making industry. In the low-frequency generator, it is possible to smoothly adjust the output voltage by means of a dial indicator. The LF generator can memorize the settings of the device, system, thus saving much time for the engineer.

The low-frequency signal generator has excellent operating conditions, as it can withstand significant temperature changes: from minus 10 to plus 50 degrees Celsius, with relative humidity of 95% and atmospheric pressure up to 800 mm. Mercury column.

Device Descriptio:

The generator is a radio electronic device, consisting of various functional units.

The driving oscillator is a tunable frequency oscillator. Stabilization of the signal amplitude at the output is automatic. The power amplifier provides a given power in the load circuit, eliminates the influence of the load on the master oscillator and its operation. The amplifier looks like an operational amplifier, covered by a negative feedback.

Output signal generator (rectangular) – converts the sinusoidal signal into a rectangular one. A rectangular signal is formed in series, bilaterally limiting the sinusoidal signal by diodes, and then amplifying the limited signal by means of two differential amplifiers on transistors.

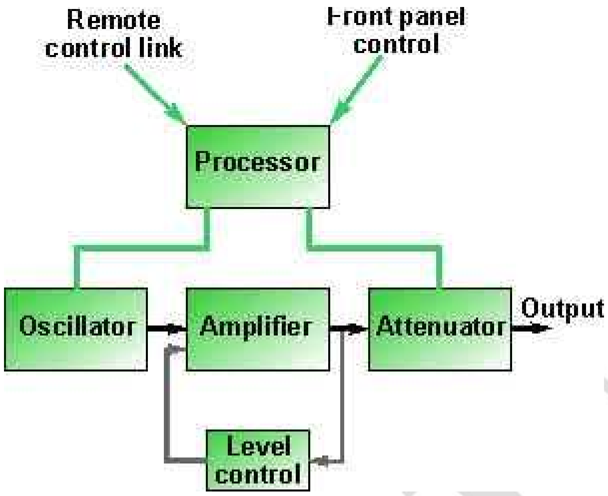
The power supply unit consists of two multipolar sources, adjustable, with a constant voltage of 24 V. It has protection against electrical surges.

An amplifier of generators is use for obtaining an output voltage of up to 25 V, at frequencies of 10 Hz to 10 MHz, with a resistance of one kΩ.

Also, low-frequency signal generators include an output attenuator, various modulators, time interval generators, frequency synthesizers and other devices.

RF signal generator operation:

In order to understand the operation of a generic microwave or RF signal generator it is useful to understand what is included in terms of a basic block diagram.



The diagram shows a very simplified block diagram for an RF / Microwave signal generator.

From this, it can be seen that the generator has a few major blocks within it:

Oscillator: The most important block within the RF signal generator is the oscillator itself. This can be any form of oscillator, but today it would almost certainly be formed from a frequency synthesizer. This oscillator would take commands from the controller and be set to the required frequency.

Amplifier: The output from the oscillator will need amplifying. This will be achieved using a special amplifier module. This will amplify the signal, typically to a fixed level. It would have a loop around it to maintain the output level accurately at all frequencies and temperatures.

Attenuator: An attenuator is placed on the output of the signal generator. This serves to ensure an accurate source impedance is maintained as well as allowing the generator level to be adjusted very accurately. In particular the relative power levels, i.e. when changing from one level to another are very accurate and represent the accuracy of the attenuator. It is worth noting that the output impedance is less accurately defined for the highest signal levels where the attenuation is less.

Control: Advanced processors are used to ensure that the RF and microwave signal generator is easy to control and is also able to take remote control commands. The processor will control all aspects of the operation of the test equipment.

RF signal generator functions:

Microwave and RF signal generators are able to offer a large variety of functions and facilities these days. These include some that are detailed below:

Frequency range: Naturally the frequency range of the RF signal generator is of paramount importance. It must be able to cover all the frequencies that are likely to need to be generated. For example when testing a receiver in an item of equipment, be it a mobile phone or any other radio receiver, it is necessary to be able to check not only the operating frequency, but other frequencies where the issues such as image rejection, etc.

Output level: The output range for an RF and microwave signal generator is normally controlled to a relatively high degree of accuracy. The output within the generator itself is maintained at a constant level and then passed through a high grade variable attenuator. These are normally switch to give the highest degree of accuracy. The range is normally limited at the top end by the final amplifier in the RF signal generator.

Modulation: Some RF or microwave signal generators have inbuilt oscillators that can apply modulation to the output signal. Others also have the ability to apply modulation from an external source. With modulation formats for applications such as mobile communications becoming more complicated, so the capabilities of RF signal generators have had to become more flexible, some allowing complex modulation formats such as QPSK, QAM and the like. Signal generators that support complex modulation are often referred to as vector signal generators.

Sweep: On some RF signal generators it is necessary to sweep the signal over a range. Some generators offer this capability.

Control: There are many options for controlling RF and microwave signal generators these days. While they tend to have traditional front panel controls, there are also many options for remote control. Most items of laboratory bench test equipment come with GPIB fitted as standard, but options such as RS-232, and Ethernet / LXI. Rack technologies where instrument cards are slotted into a rack with other items of test equipment are also popular. The first of these was VXI, but cheaper options such as PXI and PXI express are more widely used.

Radio frequency signal generators are a form of electronic test equipment found in virtually every radio frequency design or test laboratory. These signal generators are used wherever an RF signal needs to be supplied to a circuit or unit that is being developed or tested. As such RF signal generators are essential items for RF development and testing.

BLOCK DIAGRAM AND EXPLANATION OF PULSE GENERATOR:

A device that produces an electrical discharge at regular intervals, which can be modified as needed, as in an electronic pacemaker.

A pulse differs from a square wave in that it needs neither base line, nor left-right symmetry. Pulse generator consists of three parts called square wave generator (i.e. stable multivibrator). Monostable Multivibrator (i.e. one shot) and a attenuator.

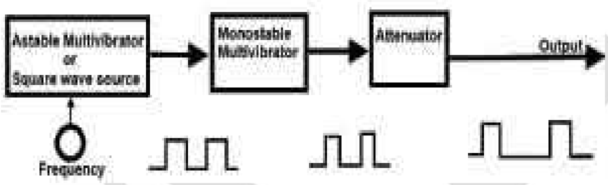


Figure 1: Pulse Generator Block Diagram

Figure 1 shows the block diagram to contract a pulse generator. A Monostable multivibrator i.e. one shot follows a square wave oscillator. The pulse repetition rate is set by the square wave frequency. The one shot triggers on the leading edge of the square wave and produced me output pulse for each input cycle. The duration of each output pulse is set by the one time of the one shot, and may be either very short or may approach the period of the square wave.

Figure shows the circuit of pulse generator. The first part of the circuit consists of a operational amplifier stable multivibrator which produce square wave. The output of the stable multivibrator is provided to the input of the Monostable multivibrator i.e. it triggers the Monostable. Frequency range can be changed using anyone of the capacitor C1, C2 and C3 while frequency continuously changed with resistor R1. Monostable produced a desired width pulse when it is triggered. The width of the pulse can be changed using variable resistor R6.

At the output of the circuit, a inverting operational amplifier is used as a attenuator. A purpose of this attenuator is to adjust the amplitude of the output. Also a low impedance is obtained. The ratio of R11 / R2 is the voltage gain of the amplifier.

The amplifier of the pulse is less if value of R11 is less than the value of R7. It means that there is attenuation and hence we can have desired output amplitude to adjust variable resistor.

Applications:

Pulses can then be injected into a device that is under test and used as a stimulus or clock signal or analyzed as they progress through the device, confirming the proper operation of the device or pinpointing a fault in the device. Pulse generators are also used to drive devices such as switches, lasers and optical components, modulators, intensifiers as well as resistive loads.The output of a pulse generator may also be used as the modulation signal for a signal generator. Non-electronic applications include those in material science, medical, physics and chemistry.

BLOCK DIAGRAM AND EXPLANATION OF FUNCTION (SIGNAL) GENERATOR:

Function or signal generator is one of the most important component used in designing electronics circuits especially for practical or experimental applications. I think you are already aware of the importance of a function generator.

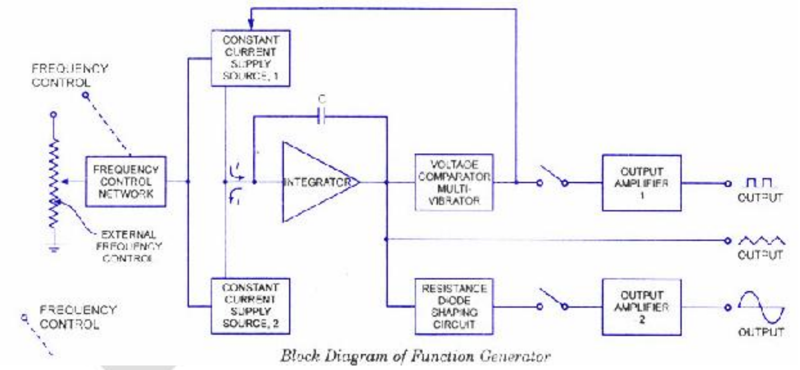
However, here we are going to discuss about Signal generators.A function generator is a signal source that has the capability of producing different types of waveforms as its output signal. The most common out of them are

- Sine waves
- Triangular waves
- Square waves
- Sawtooth waves

The frequencies of all these waveforms can be adjusted from a fraction of a hertz to megahertz range. Actually the function generators are very versatile instruments as they are capable of producing a wide variety of waveforms and frequencies. In fact each of these waveforms are suitable for specific applications.

All the function generators are capable of producing two different waveforms simultaneously from two different outputs. This may find helpful for certain application which requires more than one output waveforms at a time. For instance, by providing a square wave for linearity measurements in an audio system, a simultaneous sawtooth output may be used to drive the horizontal deflection amplifier of an oscilloscope, providing visual display of the measurement result.

Another important feature of some function generator is their capability of phase locking to an external signal source. One function generator may be used to phase lock a second function generator, and the two output signals can be displaced in phase by an adjustable amount. In addition, one function generator may be phase locked to a harmonic of the sine wave of another function generator. By adjusting the phase and amplitude of the harmonics almost any waveform may be produced by the summation of the fundamental frequency generated by one signal generator and the harmonic generated by the other. The signal generator can also be phase locked to an accurate frequency standard, and all its output waveforms will have the same frequency, stability, and accuracy as the standard.



Block Diagram of Function Generator

The block diagram of a function generator is given in the figure. In this instrument, the frequency is controlled by varying the magnitude of the current that drives the integrator. This instrument provides different types of waveforms (such as sinusoidal, triangular and square waves) as its output signal with a frequency range of 0.01 Hz to 100 kHz.

The frequency controlled voltage regulates two current supply sources. Current supply source 1 supplies a constant current to the integrator whose output voltage rises linearly with time.

An increase or decrease in the current increases or reduces the slope of the output voltage and thus controls the frequency.

The voltage comparator multivibrator changes state at a predetermined maximum level, of the integrator output voltage. This change cuts-off the current supply from supply source 1 and switches to the supply source 2. The current supply source 2 supplies a reverse current to the integrator so that its output drops linearly with time. When the output attains a pre- determined level, the volage comparator again changes state and switches on to the current supply source. The output of the integrator is a triangular wave whose frequency depends on the current supplied by the constant current supply sources. The comparator output provides a square wave of the same frequency as output. The resistance diode network changes the slope of the triangular wave as its amplitude changes and produces a sinusoidal wave with less than 1% distortion.

SPECIFICATIONS OF FUNCTION (SIGNAL) GENERATOR:

Function Generator Outputs:	Sine, square, sawtooth and triangle waveforms
Frequency Range:	1 Hz to 65,535 Hz
Frequency Accuracy:	Better than 0.01%
Frequency tuning steps:	1, 10 or 100 Hz across the entire range
Tuning Method:	Continuous rotary dial
Output Levels:	50mV, 500mV and 5Vpp
Output Level Adjustment:	Fully adjustable across each range
Outputs:	Normal and inverted outputs
Output Impedance:	600 ohm impedance (approx)
Distortion:	< 0.2% (Sine waveform)
Display:	Simple LCD display of waveform and frequency
Power:	9V battery (35mA w/o backlight, 65mA with backlight)

Possible 2 marks

1. What is meant by Lissajous Pattern.?
2. Define function generator.
3. What are main applications of CRO?
4. Define pulse generator and give its frequency.
5. Write a short notes about wave analysis.

Possible 6 marks

1. Describe how the following measurements can be made with the use of a CRO.
   (i) Frequency (ii) Phase angle
2. Explain the principle of working and circuit diagram of a digital oscilloscopes.
3. Describe an overview of applications of a CRO.
4. Write a short notes about the following generators.
   (i) Pulse generator (ii) Frequency signal generator
5. How will you make the voltage and frequency measurement with a CRO.
6. Briefly discuss about the three types of probes.
7. Explain the main applications of Cathode Ray Oscilloscopes.
8. Draw and explain the block diagram of function generator.
9. How you observe and measure the waveform , current and voltage in a CRO.

Karpagam Academy Of Higher Education
Coimbatore -21
Department of Physics
II B.Sc Physics
Basic Instumenation Skills [16PHU404A]

Unit -4

An oscillos	instantane	Rms	peak to pea	Average	**peak to peak**
A CRO is u	Voltage	Frequency	Phase	All of above	**All of above**
When the v	top center	vertical cer	horizontal c	bottom center	**vertical center**
In an oscill	intensity cc	focus contr	astigmatisn	position control	**intensity control**
In CRO the	Y-plates	X-plates	Either X-pl	Both X-plate and Y-pla	**X-plates**
In CRO ast	Source of g	Media for a	An additio	Time-delay control in t	**An additional focus control**
What instru	Multimeter	DMM	Oscillosco	Telescope	**Oscilloscope**
What provi	Cathode ra	Cathode ra	Spectrum a	VTVMs	**Cathode ray oscilloscope (CRO)**
A material	Aquadag	Silicon	Germaniun	Phosphor	**Phosphor**
The sweep	Sinusoidal	Saw tooth v	Sinusoidal	Saw tooth voltage for t	**Saw tooth voltage for the horizo**
In terms of	Average vo	RMS volta	Peak to pea	Maximum voltage	**Peak to peak voltage**
If the two i	Straight lin	Circle	Ellipse	Vertical straight line	**Circle**
A 10MHz (	5MHz swe	10MHz ver	10MHz hor	10MHz supply frequen	**10MHz horizontal oscillator**
The basic c	Waveforms	Duty cycles	Frequency	Cost	**Duty cycles**
In function	Sinusoidal	Square	Triangular	Saw-tooth	**Triangular**
The Lissajo	Amplitude	Current in a	Phase shift	Distortion in a system	**Phase shift and frequency**
A CRO car	AC signals	DC signals	Both AC ar	Time-invariant signals	**Both AC and DC signals**
The X- and	a straight li	a circle	an elipse	a figure of eight	**a straight line**
Post accele	Less than 1	More than	More than	More than 10 MHz	**More than 10 MHz**
____ is a vo	CRO	Signal gene	CRT	Saw tooth generator	**CRO**
In a CRO l	Electron gu	Electron gr	Fluorescen	Focusing anode	**Fluorescent screen**
The norma	Time Base	Electron be	Dead time	Grid	**Time Base**
The source	Electron G	Horizontal	Vertical de	Electron gun	**Electron gun**
CRT scree	100 mm x	100 mm x	10 mm x 1(	1000 mm x 100 mm	**100 mm x 100 mm**
Inside surfa	2 to 4	1 to 3	3 to 5	2 to 3	**2 to 3**
Activators	Silver	Manganese	Copper	All the above	**All the above**
Light is em	Fluorescen	Phosphores	Persistence	Cathodoluminiscence	**Fluorescence**
The electro	Light	Heat	Both A and	All the above	**Both A and B**
Example o	Shadow ma	Television	Computer c	All the above	**All the above**
A liquid cr	3	4	2	5	**3**
Lissajous p	Wave form	Current	Frequency	Time period	**Frequency**
Probes are	4	5	2	3	**3**
_____ play	Probes	Signal gene	CRT	CRO	**Probes**
_______ pr	Direct	Isolation	Detector	Indirect	**Direct**
____ probe	Direct	Isolation	Detector	Indirect	**Isolation**
Detector pr	AM	FM	TV receive	All the above	**All the above**
Oscillosco	1 GHz	10 GHz	100 MHz	1 MHz	**1 GHz**

Cathode ra	Sinusoidal	Cos wave f	Saw tooth	Square waveform	**Saw tooth waveform**
Electronic	graph plott	plotting de	Printing de	Writing device	**graph plotting device**
In a dual tr	Low freque	Low freque	High frequ	High frequency signals	**High frequency signals are obser**
The bandw	1 GHz	10 GHz	100 KHz	1 MHz	**100 KHz**
The imped	Increases w	Is independ	Is not impo	Decreases with frequen	**Decreases with frequency**
A transforn	Only ac cu	Only dc cu	Both ac an	None of these	**Only ac current**
A hall effe	Only ac cu	Only dc cu	Both ac an	None of these	**Both ac and dc current**
A probe ca	Inductive l	Capacitive	Resistive l	All the above	**All the above**
A capacitiv	Decrease t	Increase th	Increase th	Increase the impedance	**Increase the rise time**
Triggering	Generates t	Provides in	Provides st	Chops the input signal	**Provides stability in a repeated v**
Basic funct	Increase th	Stabilize re	Adjust the	Adjust the phase	**Stabilize repeating waveforms**
The colour	Signal bein	Primary ele	Coating ma	Acceleration voltage	**Coating material of the screen**
The time b	Sinusoidal	Cos wave f	Saw tooth	Square waveform	**Saw tooth waveform**
The input i	Be high	Be low	Appear cap	Appear inductive	**Be high**
In a DPO,	Intensity m	Intensity m	Storage fac	Horizontal input is not	**Intensity modulation can be prov**
A sinusoid	Ground inp	Ac input co	Dc input co	High bandwidth CRO	**Dc input coupling**
The high fr	Adjusting t	Using dela	Adjusting t	Adjusting intensity	**Using delayed triggering**
Lissajous p	Amplitude	Amplitude	Only phase	Frequency and phase r	**Frequency and phase relationshi**
To measure	100 MHz	100 KHz	1 GHz	10 KHz	**100 MHz**
In signal ge	Created	Generated	Converted	Supplied by ac input to	**Converted from a dc source into**
To design a	Astable mu	Monostable	Bistable m	None of these	**Monostable multivibrator**
A digital ge	D/A conver	Clock	Memory	Address generator	**D/A converter**

ntal deflection of electron beam

·rved in Chop mode

vaveform

vided

p

ac energy

UNIT – 5

SYLLABUS

Impedance Bridges & Q-Meters: Block diagram of bridge. working principles of basic (balancing type) RLC bridge. Specifications of RLC bridge. Block diagram & working principles of a Q- Meter. Digital LCR bridges.
Digital Instruments: Principle and working of digital meters. Comparison of analog& digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter.
Digital Multimeter: Block diagram and working of a digital multimeter. Working principle of time interval, frequency and period measurement using universal counter/ frequency counter, time- base stability, accuracy and resolution.

BLOCK DIAGRAM AND WORKING PRINCIPLE OF DIGITAL MULTIMETER:

Digital Multimeter:

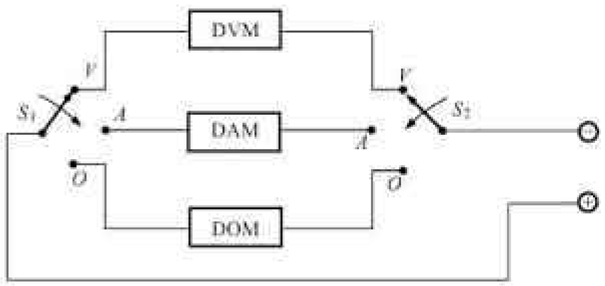
A Digital multimeter or DMM is a test equipment used for resistance, voltage, current measurement and other electrical parameters as per requirement and displaying the results in the mathematical digits form on an LCD or LED readout. It is a type of multimeter which functions digitally. Digital multimeters are widely accepted worldwide as they have better accuracy levels and ranging from simple 3 ½ to 4 ½ digit handheld DMM to very special system DMM.

Features of Digital Multimeter:

- Digital multimeter is most advanced instruments that make use of modern Integrated circuits for making electrical measurements. Some of its features which make it famous in the eyes of professional technicians are:
- It is light in weight.
- Capable of giving more accurate readings.
- It measures lots of physical quantities like voltage, current, resistance, frequency etc.
- It is less costly.
- It measures different electrical parameters at high frequencies with the help of special probes.

Block diagram of Digital multimeter :

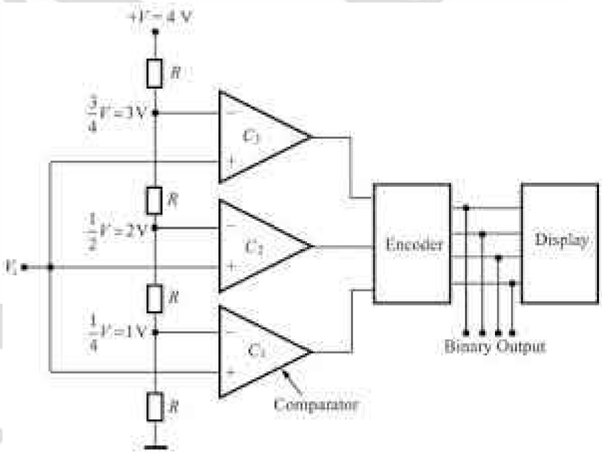
In digital multimeter, we can incorporate many types of meters like ohmmeter, ammeter, a voltmeter for the measurement of electrical parameters. Its block diagram is shown below in the figure. Let us have a look at its working and specification one by one.



(i) Digital voltmeter (DVM):

Digital voltmeter is the basic instrument used for measurement of voltage through the use of Analog to Digital converter. The basic principle behind the digital multimeters is the Analog to digital converter because without this we are not able to convert the analog output into digital form. There are several ADC available in the market, but we mainly use Flash type ADC due to its simplicity and fastest speed. Let's have a look at its basic operation.

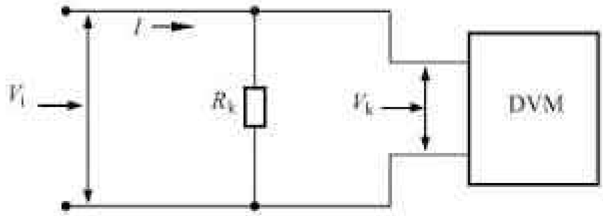
(a) Flash AD converter: It comprises of comparators, encoder, and digital display. Comparators are driven by resistor divider network, the encoder converts its inputs to corresponding outputs which drive the digital display.



As shown above, three resistors of value R drives the comparators C1, C2, C3. Let the input voltage Vi = 1v, +V= 4V and comparators i.e. C1 , C2, C3 voltages equal to 1V, 2V and 3V respectively. If the output of the C1 = +1 and C2=C3= 0, then we fed 001 as the input to the encoder which further converts it into 0001. This binary output drives the seven segment display to read 1V on it. With the help of this method, we read the voltages of magnitude 1V, 2V, 3V and we also add more comparators for more accurate readings as per our requirement.

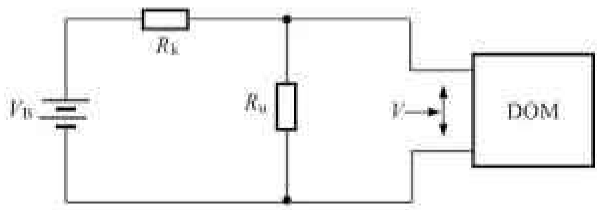
(ii) Digital Ammeter (DAM):

Digital ammeter uses a shunt resistor to produce a calibrated voltage proportional to the current flowing. As shown in the diagram, to read the current we must first convert the current to be measured into a voltage by using a known resistance RK. The voltage so developed is calibrated to read the input current.



(iii) Digital ohm meter (DOM):

A digital ohmmeter is used to measure electrical resistance which obstructs the path to the flow of current.



As shown in the diagram, resistance network comprising a known resistance RK and unknown resistance Ru used to develop a voltage across the unknown resistance. The voltage is given by:

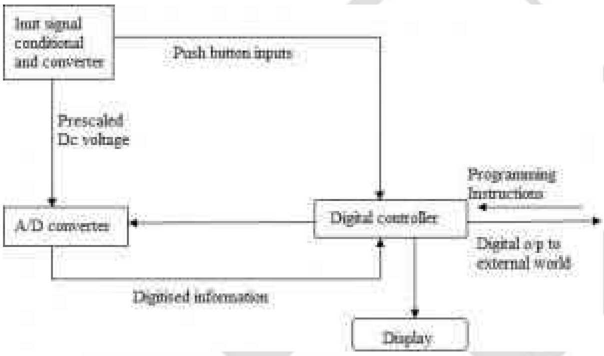
V = VB Ru / RK + Ru

where VB = Voltage of the built-in battery

After calibrating voltage, the meter can be calibrated in terms of ohms.

Working Principle of Digital Multimeter:

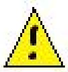
As shown in block diagram, in a typical Digital multimeter the input signal i.e ac or dc voltage, current, resistance, temperature or any other parameter is converted to dc voltage within the range of the ADC. The analog to digital converter then converts the pre-scaled dc voltage into its equivalent digital numbers which will be displayed on the display unit. Sometimes, digital controller block is implemented with a microcontroller or a microprocessor manages the flow of information within the instrument. This block will coordinate all the internal functions as well as transferring information to external devices such as printers or personal computer. In the case of some hand held multimeter, some of or all of these blocks may be implemented in a VLSI circuit while A/D converter and display driver can be in the same IC.



Digital Multimeter symbols:

Some common Digital multimeter symbols and its description are given in the table below. These symbols are often found on the multimeter & its schematics are designed to symbolize components and reference values of electrical parameters.

Symbol	Measurement function	Description
˜	AC Voltage	Measures amount of Ac voltage
______ - -	DC Voltage	Measures amount of Dc voltage
Hz	Hertz	Measures Frequency
Ω	Ohms	Measurement of resistance to the flow of electron

	Diode	Device used to control direction of flow of current
µF	Microfarad	Unit of capacitor
	Capacitor	Device used to store electrical charge
	Continuity	Audible indication of continuity for low resistance
A	Ampere	Measures amount of electron flow
	Ground	Used for grounding the device
CE	European union directive	It indicates the guarantee of instrument
	Caution	Refers to the instruction before use and indicates that its misuse results in equipment failure
Δ	REL	Measures relative or offset reading
Min/Max	Measures relative or offset reading	It shows highest and lowest recorded readings

DMM Parts and functions:

A Digital Multimeter is divided into three parts:

(i) Display: The LCD screen present on the upper portion of the multimeter basically displays four or more digits and also shows negative value if necessary. A few or today's multimeters have illuminated the display for better viewing in low light situations.

(ii) Selection Dial: It allows the user to set the multimeter to read different electrical parameter such as milliamps (mA) of current, voltage, resistance, capacitance etc. You can easily turn the dial anywhere for specific parameter measurement.

(iii) Ports: Two ports are available on the front of every multimeter except in some four ports are available for measuring current in mA or A. We plugged two probes into these ports which are of different colour i.e. one is of red colour and other is of black color.Ports are:

(a) COM: It stands for common and is almost connected to ground or considered as a -ve connection of a circuit. We generally insert the black color probe into COM port.

(b) mAVΩ: This port allows the measurement of current (up to 200 mA), voltage and resistance or considered as a +ve connection of a circuit. We generally insert the red color probe into mAVΩ port.

DMM leads:

In the box of a digital multimeter, we got leads of different colors. Here we are going to explain these leads in detail. DMM leads are subdivided into four parts:

(i) Red lead:

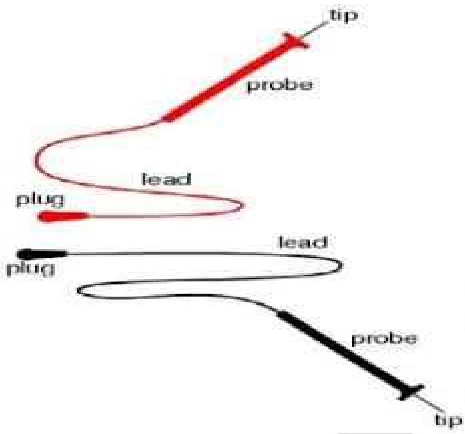
1. Connected to voltage, resistance or ampere port.

2. Considered as a +ve connection of a circuit

(ii) Black lead:

1. Connected to the common or ground port

2. Considered as a -ve connection of a circuit



(iii) Probes:

These are the handles used to hold the tip on the tested connection. There are different types of probes available, they are:

Banana to Alligator Clips: These are great cables for connecting to large wires or pins on a breadboard. Good for performing longer term tests where you don't have to hold the probes in place while you manipulate a circuit.

Banana to IC Hook: IC hooks work well on smaller ICs and legs of ICs.

Banana to Tweezers: Tweezers are handy if you need to test SMD components.

Banana to Test Probes: If you ever break a probe, they are cheap to replace.

(iv) Tip:

These are present at the end of the probes and basically, provide a connection point.

DMM Safety Precaution:

Before operating multimeters, we have to follow some safety precautions. Here we are going to explain you some safety information of DMM.

If the DMM test leads are damaged then never use the meter.

Always ensures that the test leads and dial are in right position for the desired measurement.

When a test lead is plugged into the 10 A or 300mA input jack then never touch the probes to a voltage source.

When power is applied never measure resistance in a circuit.

While making measurements always keep your fingers behind the finger guards on the test probes.

To avoid damage or injury, never use the meter on circuits that exceed 4800 watts.

Replace the battery as soon as possible to avoid false readings which could lead to possible electric shock or personal injury.

Be careful when working with voltages above 60 V DC or 30 V AC RMS. Such voltages pose a shock hazard.

COMPARISION OF ANALOG AND DIGITAL METERS:

ANALOG	DIGITAL
The instrument which gives output that varies continuously as quantity to be measured is known as analog instrument.	The instrument which gives output that varies in discrete steps and only has finite number of values is known as digital instrument.
The accuracy of analog instrument is less.	The accuracy of digital instrument is more.
The analog instruments required more power.	The digital instruments required less power.
Sensitivity of analog instrument is more.	Sensitivity of digital instrument is less.
The analog instruments are cheap.	The digital instruments are expensive.
The analog instruments are extremely portable.	The digital instruments are not easily
The resolution of analog instruments is less.	The resolution of digital instruments is more.

FREQUENCY COUNTER:

A frequency counter is an electronic instrument, or component of one, that is used for measuring frequency. Frequency counters usually measure the number of oscillations or pulses per second in a periodic electronic signal. Such an instrument is sometimes referred to as a cymometer, particularly one of Chinese manufacture.

Operating principle:

Most frequency counters work by using a counter which accumulates the number of events occurring within a specific period of time. After a preset period known as the *gate time* (1 second, for example), the value in the counter is transferred to a display and the counter is reset to zero. If the event being measured repeats itself with sufficient stability and the frequency is considerably lower than that of the clock oscillator being used, the resolution of the measurement can be greatly improved by measuring the time required for an entire number of cycles, rather than counting the number of entire cycles observed for a pre-set duration (often referred to as the *reciprocal technique*). The internal oscillator which provides the time signals is called the *timebase*, and must be calibrated very accurately.

If the event to be counted is already in electronic form, simple interfacing to the instrument is all that is required. More complex signals may need some conditioning to make them suitable for counting. Most general purpose frequency counters will include some form of amplifier, filtering and shaping circuitry at the input. DSP technology, sensitivity control and hysteresis are other techniques to improve performance. Other types of periodic events that are not inherently electronic in nature will need to be converted using some form of transducer. For example, a mechanical event could be arranged to interrupt a light beam, and the counter made to count the resulting pulses.

Frequency counters designed for radio frequencies (RF) are also common and operate on the same principles as lower frequency counters. Often, they have more range before they overflow. For very high (microwave) frequencies, many designs use a high-speed percale to bring the signal frequency down to a point where normal digital circuitry can operate. The displays on such instruments take this into account so they still display the correct value. Microwave frequency counters can currently measure frequencies up to almost 56 GHz.

Above these frequencies the signal to be measured is combined in a mixer with the signal from a local oscillator, producing a signal at the difference frequency, which is low enough to be measured directly.

ACCURACY AND RESOLUTION:

The accuracy of a frequency counter is strongly dependent on the stability of its timebase. A timebase is very delicate like the hands of a watch, and can be changed by movement, interference, or even drift due to age, meaning it might not "tick" correctly. This can make a frequency reading, when referenced to the timebase, seem higher or lower than the actual value. Highly accurate circuits are used to generate timebases for instrumentation purposes, usually using a quartz crystal oscillator within a sealed temperature-controlled chamber, known as an oven controlled crystal oscillator or crystal oven.

WORKING PRINCIPLE DIGITAL VOLTMETER:

Voltmeter is an electrical measuring instrument which is used to measure potential difference between two points. The voltage to be measured may be AC or DC. Two types of voltmeters are 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.

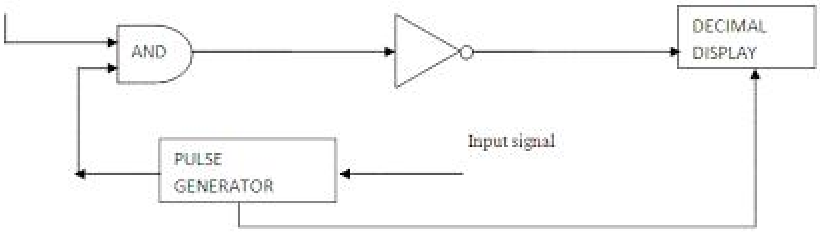
With the passage of time analog voltmeters are replaced by digital voltmeters due to the same advantages associated with digital systems. Although analog voltmeters are not fully replaced by digital voltmeters, still there are many places where analog voltmeters are preferred over digital voltmeters. 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:

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.

Train pulse

Rectangular pulse

Output of AND gate

NOT gate: It inverts the output of AND gate.

Output of NOT gate

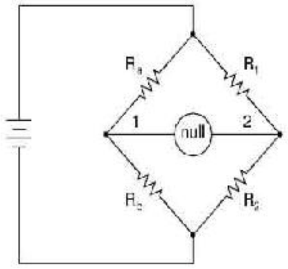
Decimal Display: It counts the numbers of impulses and hence the duration and display the value of voltage on LED or LCD display after calibrating it.

1. Now we are in situation to understand the working of a digital voltmeter as follows:
2. Unknown voltage signal is fed to the pulse generator which generates a pulse whose width is proportional to the input signal.
3. Output of pulse generator is fed to one leg of the AND gate.
4. The input signal to the other leg of the AND gate is a train of pulses.
5. Output of AND gate is positive triggered train of duration same as the width of the pulse generated by the pulse generator.
6. This positive triggered train is fed to the inverter which converts it into a negative triggered train.
7. 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.
8. Thus, counter can be calibrated to indicate voltage in volts directly.
9. 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. working of digital voltmeter 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
    - Approximation type digital voltmeter

BRIDGE CIRCUITS:

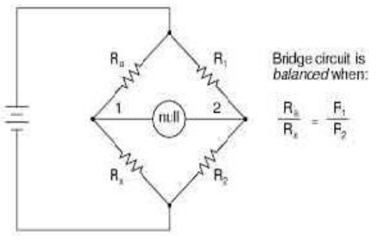
No text on electrical metering could be called complete without a section on bridge circuits. These ingenious circuits make use of a null-balance meter to compare two voltages, just like the laboratory balance scale compares two weights and indicates when they're equal. Unlike the "potentiometer" circuit used to simply measure an unknown voltage, bridge circuits can be used to measure all kinds of electrical values, not the least of which being resistance.

The standard bridge circuit, often called a Wheatstone bridge, looks something like this:



When the voltage between point 1 and the negative side of the battery is equal to the voltage between point 2 and the negative side of the battery, the null detector will indicate zero and the bridge is said to be "balanced." The bridge's state of balance is solely dependent on the ratios of Ra/Rb and R1/R2, and is quite independent of the supply voltage (battery). To measure resistance with a Wheatstone bridge, an unknown resistance is connected in the place of Ra or Rb, while the other three resistors are precision devices of known value. Either of the other three resistors can be replaced or adjusted until the bridge is balanced, and when balance has been reached the unknown resistor value can be determined from the ratios of the known resistances.

A requirement for this to be a measurement system is to have a set of variable resistors available whose resistances are precisely known, to serve as reference standards. For example, if we connect a bridge circuit to measure an unknown resistance Rx, we will have to know the exact values of the other three resistors at balance to determine the value of Rx:



Each of the four resistances in a bridge circuit are referred to as arms. The resistor In a bridge circuit are referred to as arms. The resistor in series with the unknown resistance Rx (this would be Ra in the above schematic) is commonly called the rheostat of the bridge, while the other two resistors are called the ratio arms of the bridge.

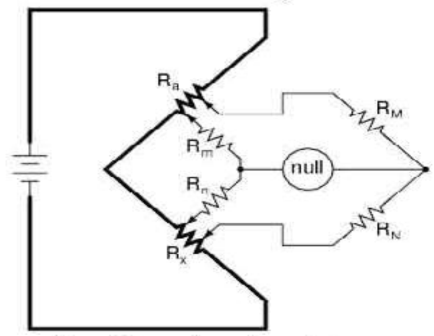
Accurate and stable resistance standards, thankfully, are not that difficult to construct. In fact, they were some of the first electrical “standard” devices made for scientific purposes. Here is a photograph of an antique resistance standard unit:

This resistance standard shown here is variable in discrete steps: the amount of resistance between the connection terminals could be varied with the number and pattern of removable copper plugs inserted into sockets.

Wheatstone bridges are considered a superior means of resistance measurement to the series battery-movement-resistor meter circuit discussed in the last section. Unlike that circuit, with all its nonlinearities (nonlinear scale) and associated inaccuracies, the bridge circuit is linear (the mathematics describing its operation are based on simple ratios and proportions) and quite accurate.

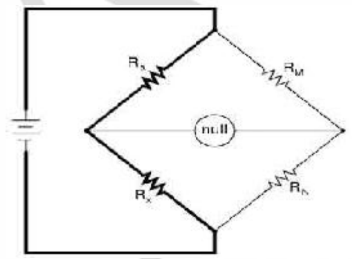
Given standard resistances of sufficient precision and a null detector device of sufficient sensitivity, resistance measurement accuracies of at least +/- 0.05% are attainable with a Wheatstone bridge. It is the preferred method of resistance measurement in calibration laboratories due to its high accuracy.

There are many variations of the basic Wheatstone bridge circuit. Most DC bridges are used to measure resistance, while bridges powered by alternating current (AC) may be used to measure different electrical quantities like inductance, capacitance, and frequency.



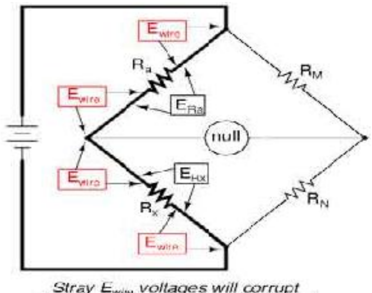
The low-value resistors are represented by thick-line symbols, and the wires connecting them to the voltage source (carrying high current) are likewise drawn thickly in the schematic. This oddly-configured bridge is perhaps best understood by beginning with a standard Wheatstone bridge set up for measuring low resistance, and evolving it step-by-step into its final form in an effort to overcome certain problems encountered in the standard Wheatstone configuration.

If we were to use a standard Wheatstone bridge to measure low resistance, it would look something like this:



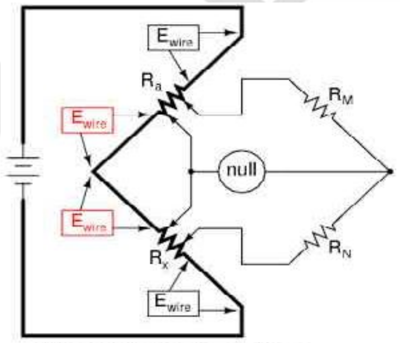
When the null detector indicates zero voltage, we know that the bridge is balanced and that the ratios Ra/Rx and RM/RN are mathematically equal to each other. Knowing the values of Ra, RM, and RN therefore provides us with the necessary data to solve for Rx . . . almost.

We have a problem, in that the connections and connecting wires between Ra and Rx possess resistance as well, and this stray resistance may be substantial compared to the low resistances of Ra and Rx. These stray resistances will drop substantial voltage, given the high current through them, and thus will affect the null detector’s indication and thus the balance of the bridge:



Stray E_{wire} voltages will corrupt the accuracy of R_x's measurement

Since we don't want to measure these stray wire and connection resistances, but only measure Rx, we must find some way to connect the null detector so that it won't be influenced by voltage dropped across them. If we connect the null detector and RM/RN ratio arms directly across the ends of Ra and Rx, this gets us closer to a practical solution:



Now, only the two E_{wire} voltages are part of the null detector loop

Now the top two E wire voltage drops are of no effect to the null detector, and do not influence the accuracy of Rx's resistance measurement. However, the two remaining E wire voltage drops will cause problems, as the wire connecting the lower end of Ra with the top end of Rx is now shunting across those two voltage drops, and will conduct substantial current, introducing stray voltage drops along its own length as well.

Knowing that the left side of the null detector must connect to the two near ends of Ra and Rx in order to avoid introducing those Ewire voltage drops into the null detector's loop, and that any direct wire connecting those ends of Ra and Rx will itself carry substantial current and create more stray voltage drops, the only way out of this predicament is to make the connecting path between the lower end of Ra and the upper end of Rx substantially resistive:

We can manage the stray voltage drops between Ra and Rx by sizing the two new resistors so that their ratio from upper to lower is the same ratio as the two ratio arms on the other side of the null detector. This is why these resistors were labeled Rm and Rn in the original Kelvin Double bridge schematic: to signify their proportionality with RM and RN:

With ratio Rm/Rn set equal to ratio RM/RN, rheostat arm resistor Ra is adjusted until the null detector indicates balance, and then we can say that Ra/Rx is equal to RM/RN, or simply find Rx by the following equation:

$$R_x = R_a \frac{R_N}{R_M}$$

The actual balance equation of the Kelvin Double bridge is as follows (Rwire is the resistance of the thick, connecting wire between the low-resistance standard Ra and the test resistance Rx):

$$\frac{R_x}{R_a} = \frac{R_N}{R_M} + \frac{R_{wire}}{R_a}\left(\frac{R_m}{R_m + R_n + R_{wire}}\right)\left(\frac{R_N}{R_M} - \frac{R_n}{R_m}\right)$$

So long as the ratio between RM and RN is equal to the ratio between Rm and Rn, the balance equation is no more complex than that of a regular Wheatstone bridge, with Rx/Ra equal to RN/RM, because the last term in the equation will be zero, canceling the effects of all resistances except Rx, Ra, RM, and RN.

In many Kelvin Double bridge circuits, RM=Rm and RN=Rn. However, the lower the resistances of Rm and Rn, the more sensitive the null detector will be, because there is less resistance in series with it. Increased detector sensitivity is good, because it allows smaller imbalances to be detected, and thus a finer degree of bridge balance to be attained. Therefore, some high-precision Kelvin Double bridges use Rm and Rn values as low as 1/100 of their ratio arm counterparts (RM and RN, respectively). Unfortunately, though, the lower the values of Rm and Rn, the more current they will carry, which will increase the effect of any junction resistances present where Rm and Rn connect to the ends of Ra and Rx. As you can see, high instrument accuracy demands that all error-producing factors be taken into account, and often the best that can be achieved is a compromise minimizing two or more different kinds of errors.

RLC CIRCUIT:

In RLC circuit, the most fundamental elements like resistor, inductor and capacitor are connected across a voltage supply. All these elements are linear and passive in nature; i.e. they consume energy rather than producing it and these elements have a linear relationship between voltage and current. There are number of ways of connecting these elements across voltage supply, but the most common method is to connect these elements either in series or in parallel. The RLC circuit exhibits the property of resonance in same way as LC circuit exhibits, but in this circuit the oscillation dies out quickly as compared to LC circuit due to the presence of resistor in the circuit.

Series RLC Circuit:

When a resistor, inductor and capacitor are connected in series with the voltage supply, the circuit so formed is called series RLC circuit.

Since all these components are connected in series, the current in each element remains the same,

$I_R = I_L = I_C = I_{(T)}$ Where $I(t) = I_M \sin \omega t$

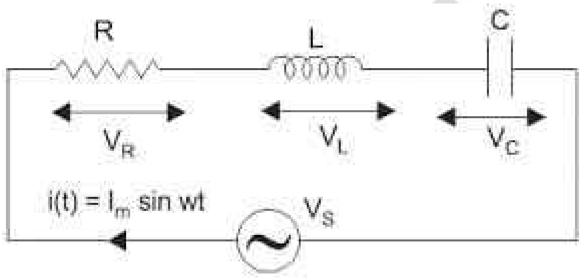
Let VR be the voltage across resistor, R.

VL be the voltage across inductor, L.

VC be the voltage across capacitor, C.

XL be the inductive reactance.

XC be the capacitive reactance.

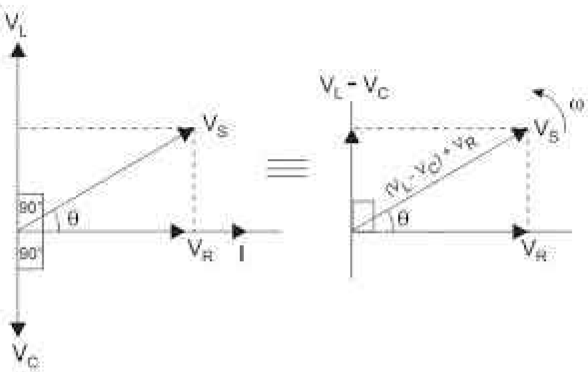


The total voltage in RLC circuit is not equal to algebraic sum of voltages across the resistor, the inductor and the capacitor; but it is a vector sum because, in case of resistor the voltage is in-phase with the current, for inductor the voltage leads the current by 90o and for capacitor, the voltage lags behind the current by 90o. So, voltages in each component are not in phase with each other; so they cannot be added arithmetically. The figure below shows the phasor diagram of series RLC circuit. For drawing the phasor diagram for RLC series circuit, the current is taken as reference because, in series circuit the current in each element remains the same and the corresponding voltage vectors for each component are drawn in reference to common current vector.

$$V_S^2 = V_R^2 + (V_L - V_C)^2 (if V_L > V_C)$$

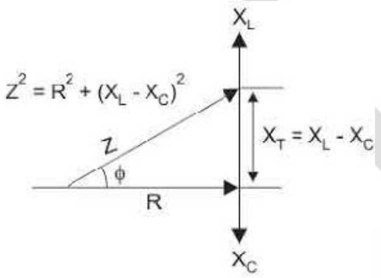
$$V_S^2 = V_R^2 + (V_L - V_C)^2 (if V_L < V_C)$$

$$Where\ V_R = IR, V_L = IX_L, V_C = IX_C$$



The Impedance for a Series RLC Circuit:

The impedance Z of a series RLC circuit is defined as opposition to the flow of current due circuit resistance R, inductive reactance, XL and capacitive reactance, XC. If the inductive reactance is greater than the capacitive reactance i.e XL > XC, then the RLC circuit has lagging phase angle and if the capacitive reactance is greater than the inductive reactance i.e XC > XL then, the RLC circuit have leading phase angle and if both inductive and capacitive are same i.e XL = XC then circuit will behave as purely resistive circuit.



We know that

$$V_S^2 = V_R^2 + (V_L - V_C)^2$$

Where,

$$V_R = IR,\ V_L = I X_L,\ V_C = I X_C$$

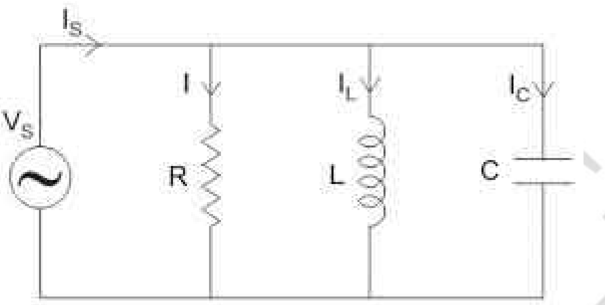
Substituting the values

$$V_S^2 = IR^2 + (I\ X_L - I\ X_C)^2$$

$V_S = I\sqrt{R^2 + (X_L - X_C)^2}$ or impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Parallel RLC Circuit:

In parallel RLC Circuit the resistor, inductor and capacitor are connected in parallel across a voltage supply. The parallel RLC circuit is exactly opposite to the series RLC circuit. The applied voltage remains the same across all components and the supply current gets divided. The total current drawn from the supply is not equal to mathematical sum of the current flowing in the individual component, but it is equal to its vector sum of all the currents, as the current flowing in resistor, inductor and capacitor are not in the same phase with each other; so they cannot be added arithmetically.



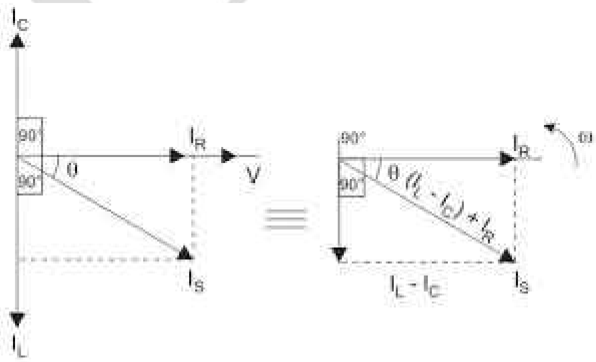
Phasor diagram of parallel RLC circuit, IR is the current flowing in the resistor, R in amps.

IC is the current flowing in the capacitor, C in amps.

IL is the current flowing in the inductor, L in amps.

Is is the supply current in amps.

In the parallel RLC circuit, all the components are connected in parallel; so the voltage across each element is same. Therefore, for drawing phasor diagram, take voltage as reference vector and all the other currents i.e IR, IC, IL are drawn relative to this voltage vector. The current through each element can be found using Kirchhoff's Current Law, which states that the sum of currents entering a junction or node is equal to the sum of current leaving that node.



$$I_S^2 = I_R^2 + (I_L - I_C)^2$$

$$Now,\ I_R = \frac{V}{R}, I_C = \frac{V}{X_C}\ and\ I_L = \frac{V}{X_L}$$

$$I_S = \sqrt{\frac{V^2}{R^2} + \left(\frac{V}{X_L} - \frac{V}{X_C}\right)^2}$$

$$So,\ admitance,\ \frac{1}{Z} = \frac{I_S}{V} = Y = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$$

As shown above in the equation of impedance, Z of a parallel RLC circuit; each element has reciprocal of impedance (1 / Z) i.e. admittance, Y. So in parallel RLC circuit, it is convenient to use admittance instead of impedance.

Resonance in RLC Circuit:

In a circuit containing inductor and capacitor, the energy is stored in two different ways.

- When a current flows in a inductor, energy is stored in magnetic field.
- When a capacitor is charged, energy is stored in static electric field.

The magnetic field in the inductor is built by the current, which gets provided by the discharging capacitor. Similarly, the capacitor is charged by the current produced by collapsing magnetic field of inductor and this process continues on and on, causing electrical energy to oscillate between the magnetic field and the electric field. In some cases at certain frequency called resonant frequency, the inductive reactance of the circuit becomes equal to capacitive reactance which causes the electrical energy to oscillate between the electric field of the capacitor and magnetic field of the inductor. This forms a harmonic oscillator for current. In RLC circuit, the presence of resistor causes these oscillation s to die out over period of time and it is called as the damping effect of resistor.

Q METER:

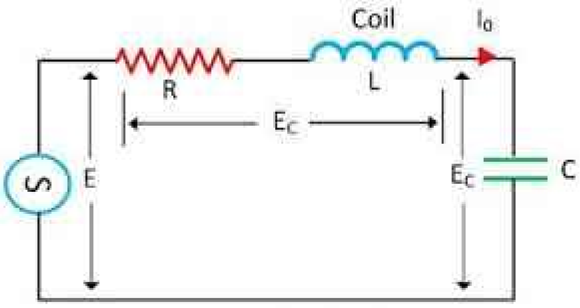
Definition: The instrument which measures the storage factor or quality factor of the electrical circuit at radio frequencies, such type of device is known as the Q-meter. The quality factor is one of the parameters of the oscillatory system, which shows the relation between the storage and dissipated energy.

The Q meter measures the quality factor of the circuit which shows the total energy dissipated by it. It also explains the properties of the coil and capacitor. The Q meter uses in a laboratory for testing the radio frequency of the coils.

Working Principle of Q meter:

The Q meter works on series resonant. The resonance is the condition exists in the circuit when their inductance and capacitance reactance are of equal magnitude. They induce energy which is oscillating between the electric and magnetic field of the capacitor and inductor respectively.

The Q-meter is based on the characteristic of the resistance, inductance and capacitance of the resonant series circuit. The figure below shows a coil of resistance, inductance and capacitance connected in series with the circuit.



Resonant RLC Series Circuit

At resonant frequency f0,

$$X_C = X_L$$

The value of capacitance reactance is

$$X_C = \frac{1}{2}\pi f_0 C = 1/\omega_0 C$$

At inductive reactance,

$$X_L = \frac{1}{2}\pi f_0 L = 1/\omega_0 L$$

At the resonant frequency,

$$F_0 = \frac{1}{2\pi\sqrt{LC}}$$

and current at resonance becomes

$$I_0 = \frac{E}{R}$$

The phasor diagram of the resonance is shown in the figure

The voltage across the capacitor is expressed as

$$E_C = I_O X_C = I_0 X_L = I_O \omega_O L$$

Input voltage

$$E_C = I_O r$$

$$\frac{E_C}{E} = \frac{I_0 \omega_0 L}{I_0 R} = \frac{\omega_0 L}{R} = Q$$
$$E_0 = QE$$

The above equation shows that the input voltage E is Q times the voltage appears across the capacitor. The voltmeter is calibrated for finding the value of Q factor.

CHARACTERISTICS OF DIGITAL METER:

The following features and features can be more convenient for your multimeter.

1. Alarm function will indicate the amount being measured (voltage, resistance, etc.)
2. The contact retention function can be kept on display, you can measure with both hands and then read
3. Single key operation, easy to select the measurement function
4. Overload protection can prevent damage to the meter and circuit, and protect the operator
5. High energy safety tubes can protect the user and the meter in current measurement and overload

6. Automatic range selection, automatic range selection. Manual range allows you to select range
7. Automatic polarity display, will show a negative polarity, even if the wrong test probe, will not damage the table
8. Low battery display
9. The basic functions of digital table mentioned this application manual, in applications such as 180 and 170 in the fluke. There are a lot of fluke have other advantages and functions of the digital multimeter.
10. Such devices, which are common in the laboratory, are generally used as a reference for voltage or resistance, or used to adjust the performance of a multi-function standard.

DIGITAL LCR BRIDGE:

The LCR Meter or LCR Bridge is used for measuring inductance, L, capacitance, C, and resistance, R.

LCR meter introduction :

LCR meters or LCR bridges are used to measure the inductance, capacitance, and resistance of components.

LCR meters tend to be specialist items of equipment, often used for inspection to ensure that the components arriving are correct. They can also be used in a developmentlaboratory where it is necessary to measure the true performance of particular components.

A typical LCR Meter

The LCR meter or LCR bridge takes its name from the fact that the inductance, capacitance and resistance are denoted by the letters L, C, and R respectively. Some versions of the LCR meter use a bridge circuit format as the basis of its circuit giving the name that is often used. A variety of meters are available. Simpler versions of LCR meters provide indications of the impedance only converting the values to inductance or capacitance.

More sophisticated designs of LCR bridge are able to measure the true inductance or capacitance, and also the equivalent series resistance and tanδ of capacitors and the Q factor of inductive components. This makes them valuable for assessing the overall performance or quality of the component.

Example of a typical LCR meter as used in laboratories and production environments, etc. This one manufactured by ThurlbyThandar Instruments

A typical LCR Meter

LCR meter basics:

Two main circuit techniques are used to form the basis of an LCR meter.

Bridge method: This method uses the familiar Wheatstone bridge concept as the basis of its operation. The aim is to aim for a condition where the bridge is balanced and no current flows through the meter. At the balance point the bridge component positions can be used to determine the value of the component under test. This method is typically used for lower frequency measurements - often measurement frequencies of up to 100 kHz or so are used.

In bridge method the device under test, DUT, is placed in a bridge circuit as shown, and its value can be determined from the settings for the other elements in the bridge. It is the LCR meters using this technique that are known as LCR bridges.

The DUT impedance is represented by Zu in the circuit. The impedance Z2 and Z3 are known. The oscillator circuit generally operates at frequencies up to about 100 kHz and can usually be selected before the test.

Then Z1 can be changed until no current flows through D. This is the balance position for the bridge. AT this point the four impedances in the circuit obey the equation:

ZU = (Z3/Z2) Z1

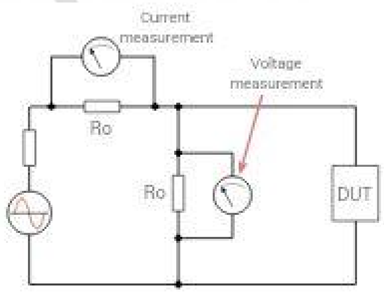
This basic bridge circuit is sometimes used on its own in very primitive LCR meters. Some very old instruments actually have the elements that are manually balanced. However technology has moved on and higher levels of integration coupled with operational amplifier circuitry enable accurate automated versions of the circuit to be used.

Current-voltage measurement: The current voltage approach is normally used for components that are to be used for higher frequency applications. It provides a highly accurate measurement technique that can be used at high frequencies and over a wide range of values.

Often known as the RF I-V measurement method, this technique for LCR measurement uses measurements of current and voltage as the name implies. However, as the frequencies involved are high, it uses an impedance matched measurement circuit. In some cases for very high frequency and high precision measurements a precision coaxial test port may be employed.

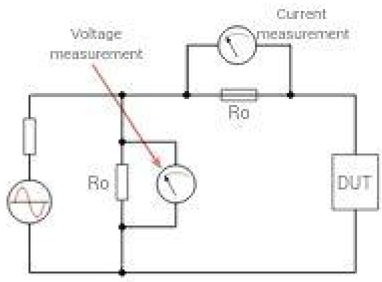
There are two types of the voltmeter and current meter arrangements: one suited to low impedance and the other for high impedance measurements.

Circuit for an LCR meter using IV technique for measuring low impedance circuits



IV LCR Measurement
for low impedance
circuits

Circuit for an LCR meter using IV technique for measuring high impedance circuits.

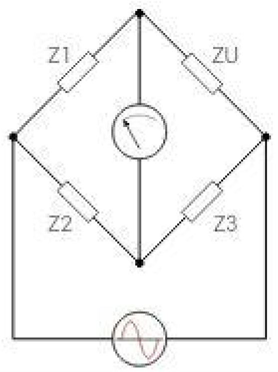


IV LCR Measurement for high impedance circuits

Using the voltage and current values from the measurements, the impedance of the device under test can easily be derived. By using a phase sensitive detector to make these measurements the relative phase of the voltage and current can be used to determine the impedance of the device under test in terms of resistance, capacitance and inductance. The inductance or capacitance and the resistance may then be displayed as separate values.

Often a transformer is used in the circuit to enable these measurements to be made and to isolate the measurements from ground. However this can limit the lower frequencies or the frequency range over which measurements can be made.

LCR bridge measurement guidelines:



Basic bridge based
LCR meter circuit

To make the best measurements using an LCR meter or LCR bridge, a few simple guidelines of hints and tips can be employed.

Effect of lead length: At frequencies above 1 MHz or so the lead length can start to have an effect. As a rough guide a good estimate for lead inductance is around 10 nH per cm of lead. For the best measurements kep the leads as short as possible.

Measure at operational frequency: When making measurements using an LCR meter it helps to use a test frequency as close to the actual operational frequency as possible. This means that the effects of any stray effects or changes due to frequency are minimised - for example inductor cores may have different properties at different frequencies. This can make a noticeable difference in some instances.

Adjust test amplitude: In the same way that it is good practice to measure at a frequency that is as close to the operational frequency as possible, the same is true for the test amplitude. This is because component values may vary with the signal applied. This is particularly true for inductors that use cores such as ferrite that may introduce losses. These may be amplitude dependent.

Discharge capacitors before measurement: Some capacitors may carry a residual charge under some circumstances. It is best to discharge them before any measurements. As charge on some capacitors can linger for some time, it is always best to discharge them before any tests.

LCR meters / bridges are very useful test instruments. They may not be as widely used as in previous years where they were often found in goods-inwards areas for sample testing incoming components. However these days LCR meters tend to be used in some laboratories for testing the performance of components likely to be used in development as well as in may workshops where they can be used as an aid for fault finding.LCR meters / bridges are most often used to display the capacitance, inductance and resistance, but may also be used to measure the Q of an inductor, or the tan δ of a capacitor.

Possible 2 Mark questions

1. Define multimeter.
2. Write the advantages of digital multimeter.
3. Define analog and digital instruments?
4. Define Q-Meter.
5. Write any three specifications of RLC bridge.
6. Write the principle of digital meter.
7. Differentiate digital and analog multimeter.

Possible 6 Mark questions

1. Draw the block diagram of the digital multimeter. Explain the operation.
2. Give the overview of digital voltmeter.
3. Describe the working principle of LCR bridge with a circuit diagram.
4. What are the main advantage and disadvantage of a multimeter.
5. Explain the principle and working of digital meters.
6. Explain the various measurements in a CRO.
7. Write the comparision between the analog and digital instruments.

Karpagam Academy Of Higher Education
Coimbatore -21
Department of Physics
II B.Sc Physics
Basic Instumenation Skills [17PHU404A]

Unit -5

In bridge ci	Equal to th	Very large	Very small	Less than compared to	**Very large compared to the com**
If the impe	The instrun	The instrun	Supply cur	Both (a) & (b)	**Both (a) & (b)**
Q meter is	Inductive c	Non induct	Capacitive	Both (a) and ©	**Both (a) and (c)**
The meters	Digital met	Analog me	Display un	None of these	**Analog meter**
Several dif	Signal gen	Digital met	Analog me	All the above	**Digital meter**
Digital met	Quantizatic	Induction	Repulsion	Thermocouple	**Induction**
A digital m	Its construc	Mechanica	It show dis	All the above	**All the above**
Main unit c	Signal prep	Analog to c	Display un	All the above	**All the above**
Analog to c	Computer	Digital met	Analog me	Both (A) and (B)	**Both (A) and (B)**
Is a type of	Segmental	Dot matrix	Diode	Both (A) and (B)	**Both (A) and (B)**
In a digital	Electronic	Stop watch	Synchrono	None of above	**Electronic counter**
While mea	Unknown r	Known res	Known ind	Known capacitor	**Known resistor**
The symbo	Resonance	Quality fac	Power quo	Quality fraction	**Quality factor**
What is the	Power fact	Reactive fa	Dissipation	1/Q factor	**Dissipation factor**
$V_L = V_C$ in	The value c	The power	The curren	The total voltage is zer	**The value of the impedance is mi**
In a series I	The curren	The curren	X_L leads X	$Z = j X_L$ at resonance	**The current lags by V_L by 90 deg**
A series RI	Unity	Leading	Lagging	Either (B) or (C)	**Either (B) or (C)**
At parallel	Infinite	zeo	unequal	Equal	**Equal**
. In an RL s	Current lea	Current lea	Current lag	Current lags voltage by	**Current leads voltage by 90 degr**
Maxwell-W	Capacitanc	Dielectric l	Inductance	Phase angle	**Inductance**
Anderson b	Owen	Hay's	De Sauty	Maxwell-Wein	**Maxwell-Wein**
The most u	Schering	De Sauty	Wien Serie	Wien Parallel	**De Sauty**
An ____ de	Analog	Digital	Operating	None of these	**Analog**
Analog ins	3	4	5	2	**3**
Voltmeter i	Heating	Magnetic	Electrostati	All the above	**All the above**
Watt meter	Hall	Heating	Magnetic	Electrostatic	**Hall**
Principle o	Heating eff	Magnetic e	Induction e	Hall effect	**Induction effect**
The use of	Absolute	Indicating	Recording	Integrating	**Absolute**
____ instru	Absolute	indicating	Recording	Integrating	**Indicating**
___ instrun	Absolute	indicating	Recording	Integrating	**Integrating**
Which of tl	Ammeters	Voltmeters	Wattmeters	Ampere-hour and watt-	**Ampere-hour and watt-hour me**
Which of tl	Deflecting	Controlling	Damping d	All the above	**All the above**
The pointe	Very light	Very heavy	Either (A) c	Neither (A) or (B)	**Very light**
An ammete	Secondary	Absolute ir	Recording	Integrating instrument	**Secondary instrument**
______ ins	Absolute	indicating	Recording	Integrating	**Recording**
Example o	Ammeters	Voltmeters	Wattmeters	All the above	**All the above**
Example o	Ammeters	Voltmeter	Wattmeters	a.c bridge	**a.c bridge**

Compariso	Induction	Higher acc	Lower prec	Higher precision	**Induction**
Hall effect	Flux meter	Ammeters	Pointing ve	All the above	**All the above**
Integrating	Magnetic	Heating	Electrostati	Induction	**Magnetic**
Alternating	Voltage bri	Current bri	Both (A) ar	None of these	**Current bridge**
The a.c bri	Wheatston	Owen	Hay's	De Sauty	**Wheatstone**
An a.c brid	Three	Four	Five	Six	**Four**
Alternating	Phase shift	Providing f	Amplifiers	All the above	**All the above**
The detect	Head phon	Vibration g	Tuneable a	All the above	**All the above**
Headphone	240	250	230	260	**250**
In digital m	LED	LCD	Both (A) ar	None of these	**Both (A) and (B)**
Digital met	Analog to c	Digital to a	Binary con	Binary converter	**Analog to digital**
which instr	Voltmeter	Voltmeter	Voltmeter	Multimeter	**Multimeter**
The ____ a	Converter	Attenuators	Voltmeter	Ammeter	**Attenuators**
______ pla	Analog to c	Digital to a	Binary con	Binary converter	**Analog to digital**
AVO mete	Voltmeter	Voltmeter	Voltmeter	Multimeter	**Multimeter**

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