ELECTRONICS INSTRUMENTS
&
MEASUREMENTS
COURSE CODE : 4041

SYLLABUS

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<u>Module -1</u> : ANALOG AND DIGITAL MULTIMETERS

Characteristics of instruments

Instruments are the one which are used to measure the quantity (voltage, current, resistance etc). These are eight different characteristics of an instruments.

1. Accuracy
2. Precision
3. Sensitivity
4. Resolution
5. Hysteresis
6. Dead time
7. Dead zone
8. Drift

<u>Accuracy</u> : It is the measure of closeness of measured quantity to the true value.

The accuracy of an instrument can be related to

- maximum measured value possible for the instrument
- maximum range for the instrument
- actual output from the instrument

Precision : It indicates the degree of closeness among measured value. When same input value is measured by the same instruments under same condition, a precision will give same reading.

<u>Sensitivity</u> : It indicates the relation between change in output reading for change in input reading for an instrument.

<u>Resolution :</u> the smallest observed change in input that an instrument can respond is called resolution.

<u>Hystersis :</u>

Hysteris is when unloading applied input don't creates the same output.

An example can be a nut that is screwed a number of turns on a threaded rod. When turned back the same number of turns the nut will not be in the exact the same position as at the start. This is a typical a problem that must be addressed in applications like cnc machines and 3D printers

Dead Time

The pointer take some minimum time to start from its zero position because of the inertia of moving system. This minimum time is called dead time.

Dead Zone :

For a large change in input for change there is no output is called dead zone.

Drift :

It is the error constant throughout the range of scale. For an instrument there is a variation in output which is not caused by change in input.

Error

If the measured value is no closer to the standard value, it is counted as an error.

The term error in a measurement is defined as:

Error = Instrument reading – true reading

Instrument Error are classified into three categories:

1. Gross errors
2. Random errors
3. Systematic errors

Gross errors arise due to human mistakes such as mistake of recording the measured data in calculating a derived measured. Careful reading and recording of the data can reduce the gross errors

Random errors, cause of such errors are clearly unknown and they affect the readings in a random way

Systematic errors affects all the reading in a particular fashion. Calibrating the instruments with standard measurement can reduce the error. Zero error is an example for systematic error.

Environment can be the cause of systematic error

Zero error can simply say as, A device is showing a particular value even if there is no input to the device is a Zero error.

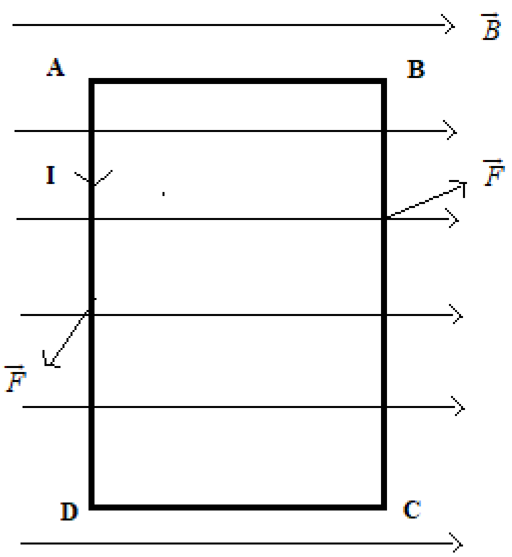
Galvanometer

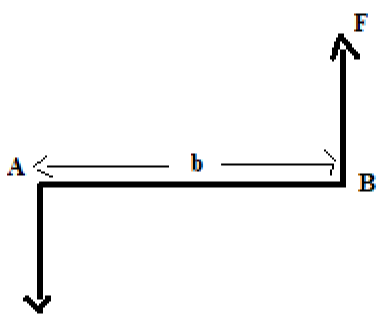
A galvanometer is a device that is used to detect small electric current or measure its magnitude. The current and its intensity is usually indicated by a magnetic needle's movement or that of a coil in a magnetic field that is an important part of a galvanometer. Today the main type of galvanometer type that is used widely is the D'Arsonval/Weston type or the moving coil type. A galvanometer is basically a historical name that has been given to a moving coil electric current detector.

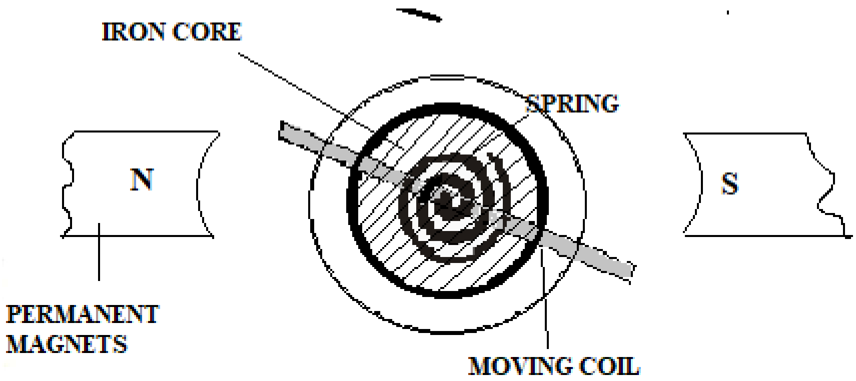
Working of Moving Coil Galvanometer

Let a current I flow through the rectangular coil of n number of turns and a cross-sectional area A. When this coil is placed in a uniform radial magnetic field B, the coil experiences a torque τ.

Let us first consider a single turn ABCD of the rectangular coil having a length l and breadth b. This is suspended in a magnetic field of strength B such that the plane of the coil is parallel to the magnetic field. Since the sides AB and DC are parallel to the direction of the magnetic field, they do not experience any effective force due to the magnetic field. The sides AD and BC being perpendicular to the direction of field experience an effective force F given by F = BIl







Using Fleming's left-hand rule we can determine that the forces on AD and BC are in opposite direction to each other. When equal and opposite forces F called couple acts on the coil, it produces a torque. This torque causes the coil to deflect.

We know that torque τ = force x perpendicular distance between the forces

$\tau = F \times b$

Substituting the value of F we already know,

Torque τ acting on single-loop ABCD of the coil = $BIl \times b$

Where lx b is the area A of the coil,

Hence the torque acting on n turns of the coil is given by

$\tau = nIAB$

The magnetic torque thus produced causes the coil to rotate, and the phosphor bronze strip twists. In turn, the spring S attached to the coil produces a counter torque or restoring torque $k\theta$ which results in a steady angular deflection.

Under equilibrium condition:

$k\theta = nIAB$

Here k is called the torsional constant of the spring (restoring couple per unit twist). The deflection or twist θ is measured as the value indicated on a scale by a pointer which is connected to the suspension wire.

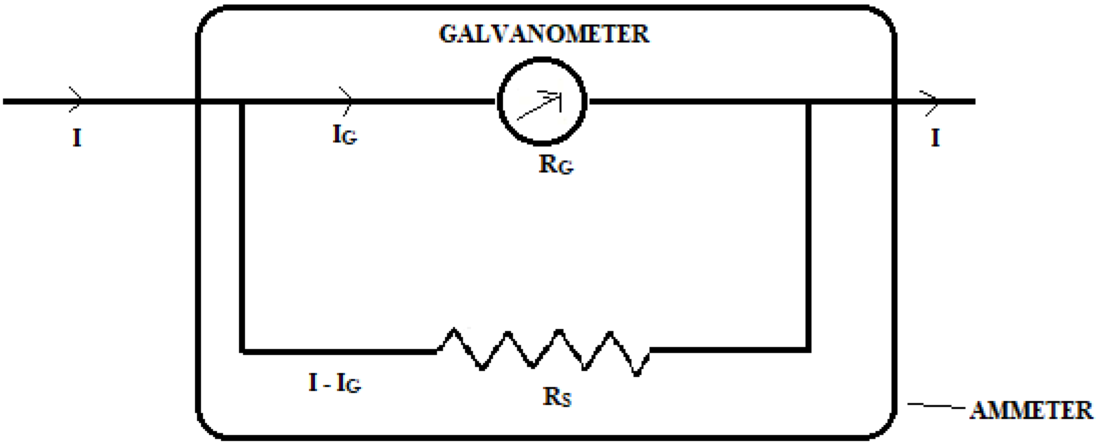
$\theta = (nAB / k)I$

Therefore $\theta \propto I$

The quantity nAB / k is a constant for a given galvanometer. Hence it is understood that the deflection that occurs the galvanometer is directly proportional to the current that flows through it.

Conversion Of Galvanometer To Ammeter

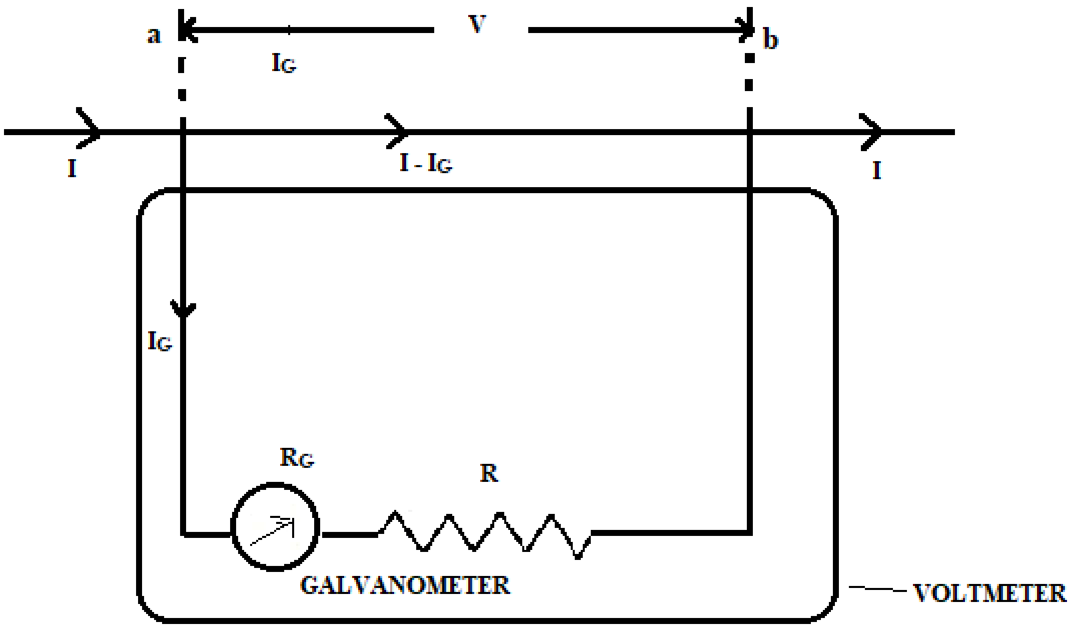
A galvanometer is converted into an ammeter by connecting it in parallel with a low resistance called shunt resistance. Suitable shunt resistance is chosen depending on the range of the ammeter.



CONVERSION OF GALVANOMETER INTO AMMETER

In the given circuit RG – Resistance of the galvanometer
G- Galvanometer coil
I – Total current passing through the circuit
IG – Total current passing through the galvanometer which corresponds to full-scale reading
Rs – Value of shunt resistance

When current IG passes through the galvanometer, the current through the shunt resistance is given by IS = I – IG. The voltages across the galvanometer and shunt resistance are equal due to the parallel nature of their connection.
Therefore RG .IG= (I- IG).Rs
The value of S can be obtained using the above equation.
Conversion Of Galvanometer To Voltmeter
A galvanometer is converted into a voltmeter by connecting it in series with high resistance. A suitable high resistance is chosen depending on the range of the voltmeter.



CONVERSION OF GALVANOMETER INTO VOLTMETER

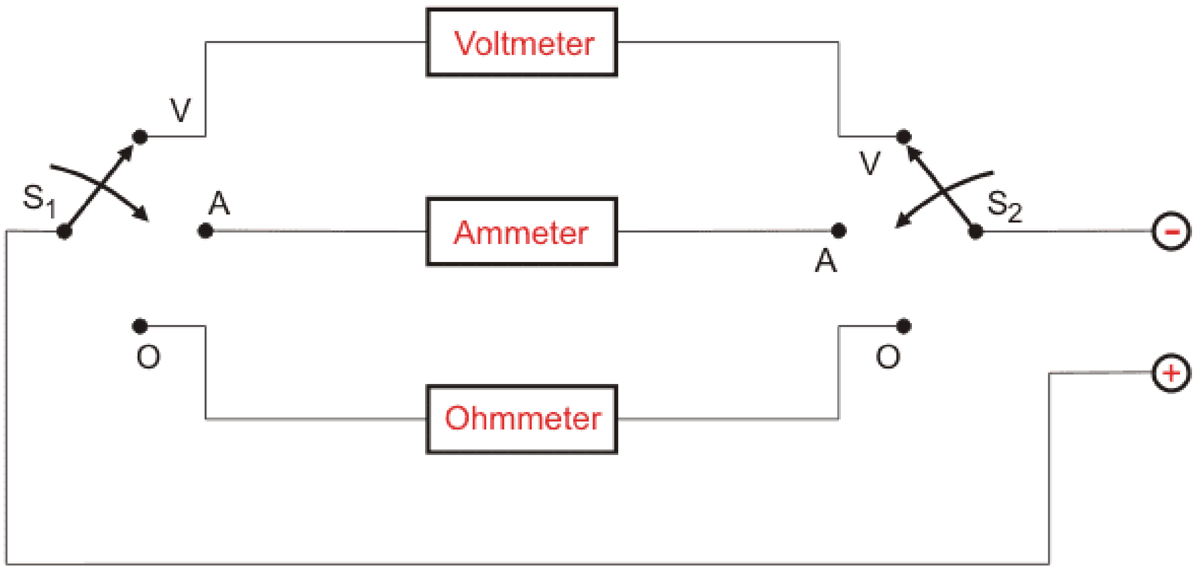
In the given circuit
RG = Resistance of the galvanometer
R = Value of high resistance
G = Galvanometer coil
I = Total current passing through the circuit
IG = Total current passing through the galvanometer which corresponds to a full-scale deflection.
V = Voltage drop across the series connection of galvanometer and high resistance.
When current IG passes through the series combination of the galvanometer and the high resistance R; the voltage drop across the branch ab is given by
V= RG.IG + R.IG
The value of R can be obtained using the above equation.

Difference between moving coil instrument and moving iron instrument

Basis for Comparison	**Moving Iron Instrument**	**Moving Coil Instrument**
Definition	In moving iron instrument the soft iron is used for moving mechanism.	In moving coil instrument the conductor coil is used for measuring the current and voltage.
Working Principle	Magnetism	Similar to working principle of DC Motor
Uses	Both for AC and DC measurement	DC Measurement
Accuracy	Less	More
Scale	Non-uniform	Uniform

Basis for Comparison	Moving Iron Instrument	Moving Coil Instrument
Damping	Air Friction Damping	Eddy Current Damping
Power Consumption	High	Low
Controlling Torque	Gravity or spring	Spring
Deflection	Proportional to Current	Square of current
Hysteresis Loss	Not occurs	Occurs
Can be used as	Ammeter, Voltmeter and Wattmeter	Voltmeter, ammeter, galvanometer, ohmmeter

Block diagram of Analog Multi meter



Multimeters as the name suggest the meters that we use to measure multiple quantities with the same instrument. The most basic multimeter measures voltage, current, and resistance. Since we use it for measuring current (A), voltage (V) and resistance (Ohm), we call it as AVO meter.
Analog multimeter was first of its type, but due to latest technological development after development of digital multimeters, nowadays it is of less use. However, despite such advancements, it is still essential, and we can’t neglect it. An analog multimeter is a PMMC meter. It works based on the d’Arsonval galvanometer principle. It consists a needle to indicate the measured value on the scale. A coil moves in a magnetic field when current passes through it. The indicating needle is fastened to the coil. During the flow of current through the coil, a deflecting torque gets produced due to which the coil rotates at some angle, and the pointer moves over a graduated scale. A pair of hairsprings is attached to the moving spindle to provide the controlling torque. In a multimeter, the galvanometer is a left- zero-type instrument, i.e. needle rests to the extreme left of the scale from where the scale begins with zero.

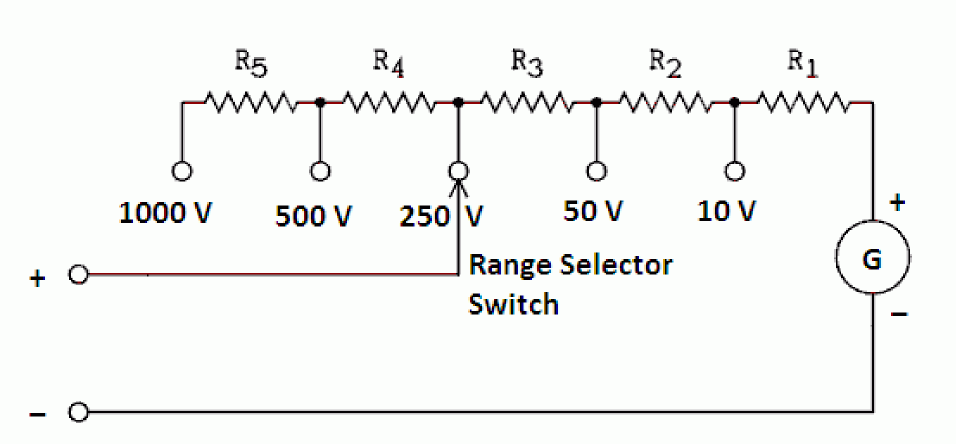
The meter acts as an ammeter with a low series resistance to measure direct current. For measuring high current, we connect a shunt resistor across the galvanometer so that the current through the galvanometer does not cross its maximum allowed value. Here, a significant portion of the current to be measured bypasses through the shunt. With that shunt resistance, an analog multimeter can measure even milli-ammeter or ammeter ranges of current.

For DC voltage measurement, the primary instrument becomes a DC voltage measuring apparatus or DC voltmeter. By adding a multiplier resistance, an analog multimeter can measure the voltage from milli-volts to kilovolts, and this meter works as a millivoltmeter, a voltmeter or even as a kilo voltmeter.

By adding a battery and a resistance network, this instrument can work as an ohmmeter. We can change the range of the ohmmeter by connecting a switch to a suitable shunt resistance. By selecting different values of shunt resistance, we can obtain different scales of resistance measurement. Here below we are showing a basic block diagram of an analog multimeter.

Voltage Measurement by a Multimeter

Generally, a galvanometer has a current sensitivity of the order of 0.1 mA and a small internal resistance of about 500 ohms. As such it cannot measure high voltages. To measure high voltages with it, its range is extended by connecting a high resistance in series with the galvanometer as shown in the figure.



D.C. voltge measurement

If the galvanometer resistance is denoted by G and Ig is the full-scale deflection current and the voltage to be measured is V volts, then the value of series resistance RS is determined as under,

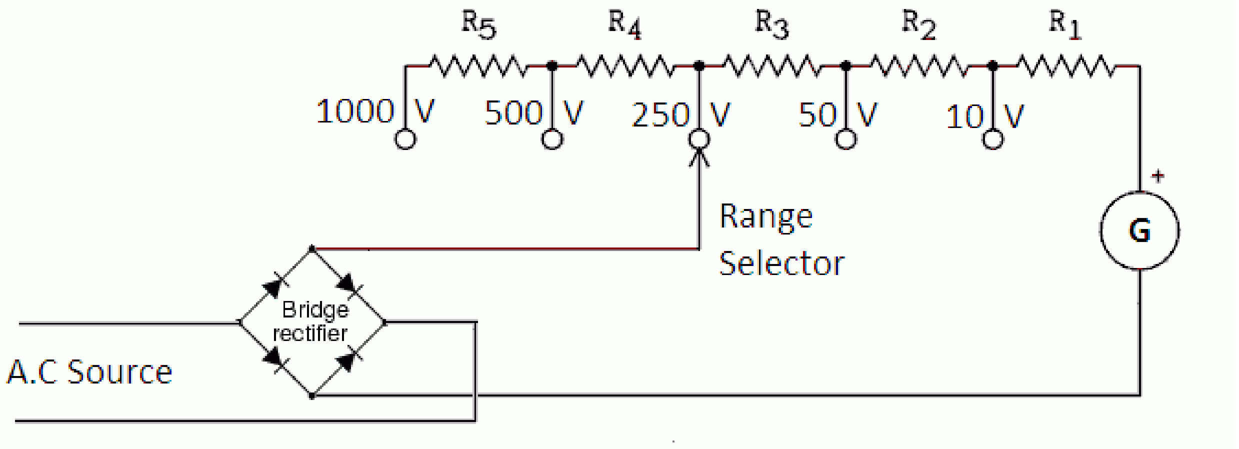
$V = I_g R_s + I_g G$

or $R_s = (V - I_g G) / I_g$

This series resistance is also called multiplier. The voltage range can be increased by increasing the number or value of multipliers. Either a selector switch is provided to select different ranges or a number of sockets indicating the voltage range are provided in a multimeter.

While making, measurement one lead is inserted in the common socket and the other lead in the required voltage range socket.

The multimeter can also measure AC. For this purpose, a full wave rectifier is incorporated in the multimeter. The rectifier converts AC into DC for application to the galvanometer.



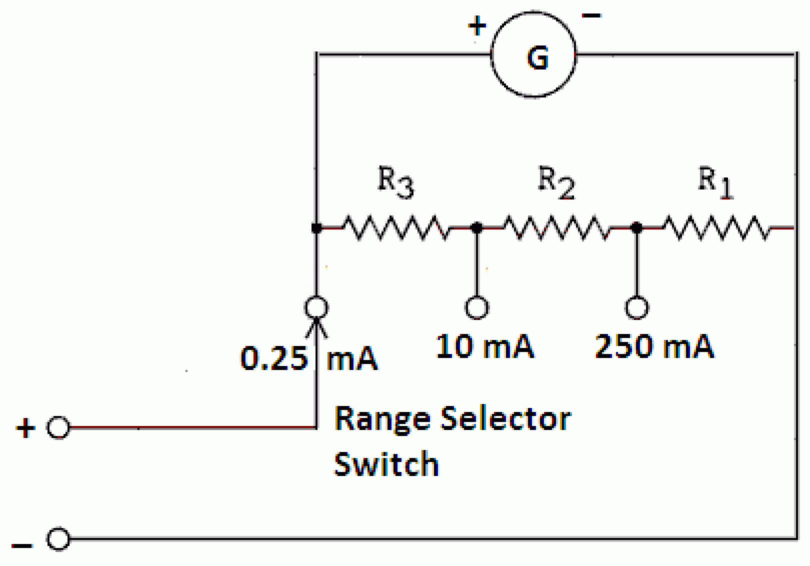
A.C. Voltage Measurement

The desired AC voltage range is selected by the selector switch or sockets. When AC voltage is to be measured, the switch should be thrown to AC or test lead should be inserted in AC socket.

While using an analog multimeter as a voltmeter it must be ensured that it is connected in parallel with the portion of the circuit across which the voltage is being measured. The range of multimeter should also be suitably selected.

Current Measurement by Multimeter

The same galvanometer can be used for measuring current when it is converted into an ammeter by connecting a small resistance Rsh in parallel with the meter as shown in the figure.



D.C. Current measurement by multimeter

If G is the internal resistance of meter, Ig its full-scale deflection current and I is the total current to be measured, then the value of shunt resistance Rsh required can be found as under:

$(I - I_g)R_{sh} = I_g G$

or Rsh = IgG/(I – Ig)

The range of ammeter can be extended to any value within limits by reducing the value of shunt resistance. In effect, a number of low resistances are connected in parallel with the meter through a selector switch as shown in the figure. The desired range can be selected by moving the selector switch to a particular position.

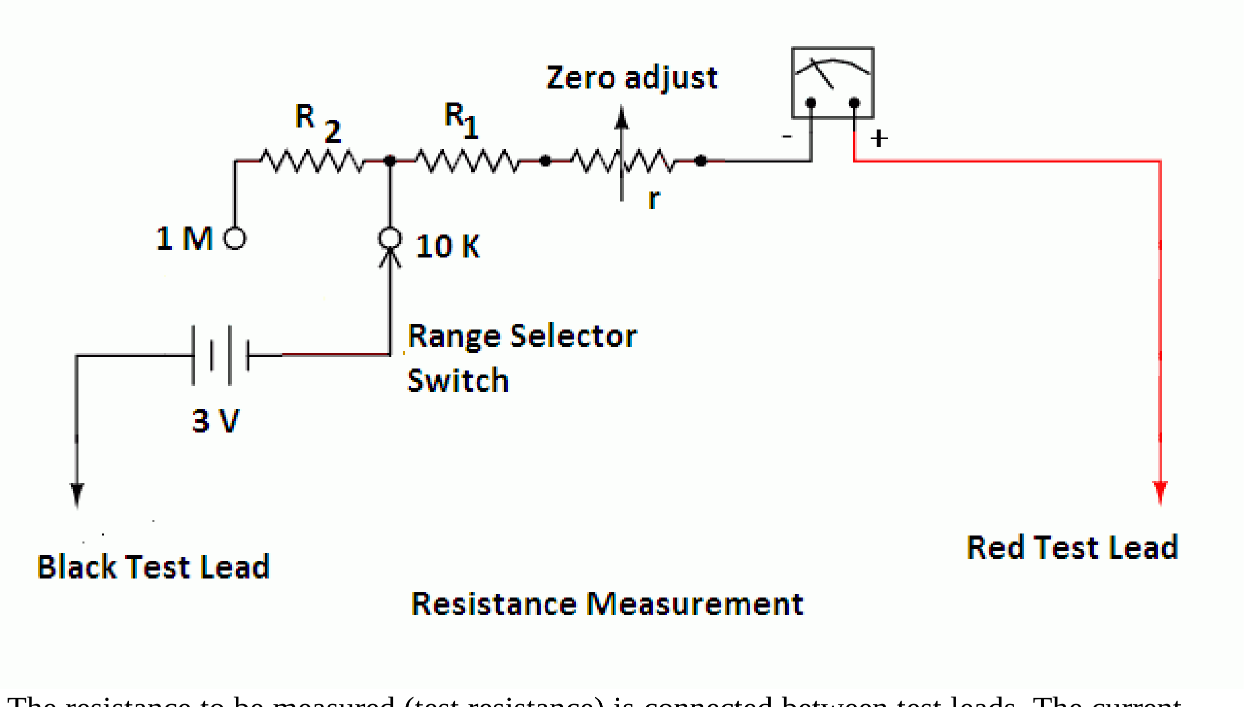
If the total current to be measured I is very high, the value of shunt resistance required Rsh becomes very low which is sometimes practically not possible. In this case, the connections are so arranged that as we move from low range to higher range, the meter resistance is also increased with the decrease in the value of shunt resistance.

When using a multimeter as an ammeter, it must be connected in series with the branch in which the current is to be measured.

Resistance Measurement by a Multimeter

The same basic instrument can be used as an ohmmeter to measure resistances. In this circuit, an internal battery is connected in series with the meter through an adjustable resistance r and the fixed resistances.

The fixed resistances limit the current within the desired range and the variable resistance r is used for zero adjustments.



The resistance to be measured (test resistance) is connected between test leads. The current flowing through the circuit depends upon the resistance of test piece. In effect, the deflection of needle indicates current, but the scale is calibrated in ohms to give the value of resistance directly. The ohmmeter is generally made multi-range instrument by using different values of fixed resistances.

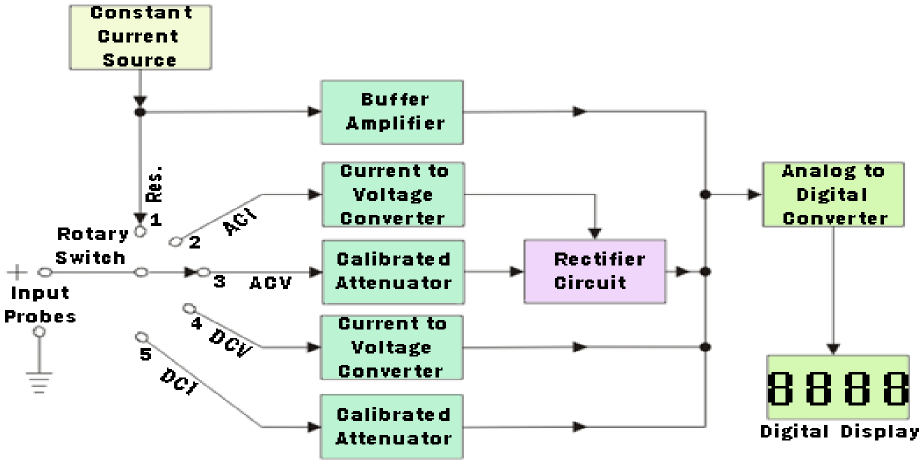
To measure any resistance on the analog multimeter, the suitable range is selected. Then the meter leads are shorted and variable resistance r is adjusted to give full-scale deflection.

Under this condition, the resistance between test leads is zero, therefore, the scale of ohmmeter Indicates zero on the extreme right end. Then the resistance under measurement is connected between terminals test leads.

Digital Multimeter

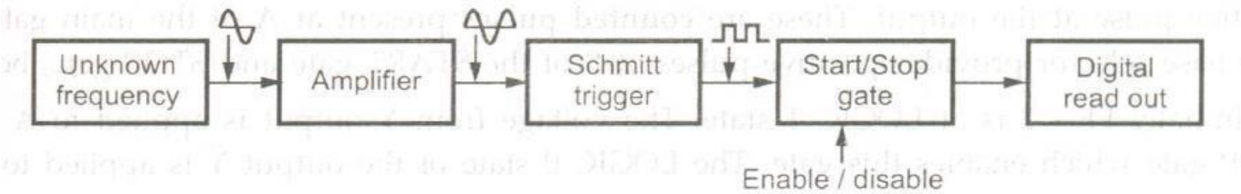
Block diagram

Working



The digital multimeter is an instrument which is capable of measuring a.c. voltages, d.c. voltages, a.c. and d.c. currents and resistances over several ranges. The basic circuit of a digital multimeter is always a d.c. voltmeter as shown in the Fig.
The current is converted to voltage by passing it through low shunt resistance. The a.c. quantities
are converted to d.c. by employing various rectifier and filtering circuits. While for the resistance measurements the meter consists of a precision low current source that is applied across the unknown resistance while gives d.c. voltage. All the quantities are digitized using analog to digital converter and displayed in the digital form on the display. The basic building blocks of digital multimeter are several AID converters, counting circuitry and an attenuation circuit. Generally dual slope integration type ADC is prefprred in the multimeters. The single attenuator circuit is used for both a.c. and d.c. measurements in many commercial multimeters.

Digital frequency meter



The signal waveform whose frequency is to be measured is first amplified. Then the amplified signal is applied to the schmitt trigger which converts input signal into a square wave with fast rise and fall times. This square wave is then differentiated and clipped. As a result, the output from the Schmitt trigger is the train of pulses for each cycle of the signal. The output pulses from the schmitt trigger are fed to a START/STOP gate. When this gate is enabled, the input pulses pass through this gate and are fed directly to the electronic counter, which counts the number of pulses. When this gate is disabled, the counter stops counting the incoming pulses. The counter displays the number of pulses that have passed through it in the time interval between start and stop. If this interval is known, the unknown frequency can be measured The output of unknown frequency is applied to the Schmitt trigger which produces positive pulse at the output. These are **counted pulses** present at A of the t11<lingate. The time base. selector provides positive pulses at B of the START gate and STOP gate, both. Initially FF - 1 is atLOGIC 1 state. The voltage from Y output is applied to A of the STOP gate which enables this gate. The LOGIC a state of the output Y is applied to input A of START gate which disables this gate. When STOP gate enables, positive pulses from the time base pass through STOP gate to S input of FF - 2, setting FF - 2 to LOGIC 1 state. The LOGIC a level of Y of FF - 2 is connected to B of main gate, which confirms that pulses from

unknown frequency source can't pass through the main gate. By applying a positive pulse to R input of FF - I, the operation is started. This changes states of the FF - 1 to Y = 1 and Y = O. Due to this, STOP gate gets disabled, while START gate gets enabled. The same pulse is simultaneously applied to all decade counters to reset all of them, to start new counting.

3.5 AND 4.5 DIGIT METER DISPLAYS

Full Digit

Digital meters are typically described as having "half digit" capability. A full digit is a display segment that can render all the numbers from 0-9, that is 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.

Half Digit

A half digit can display only the number 1. The half digit is always the first digit shown. Because the half digit is basically only a "1" it has limited possible use.

Decimal Point

The decimal point is just a "dot" segment that is manually displayed after the appropriate number segment to show the proper complete number desired. A dot can be displayed after any desired number, typically via a jumper setting. If the jumper is not installed, no dots at all will be displayed.

3.5 Digit Display Example

A 3.5 digit display is actually four segments, one half digit and 3 full digits. Displaying maximum capability it would read 1999. If we wanted to display 30kV on a 3.5 digit meter we would have to "throw out" the leading half digit as we can't make use of it because it's only a "1". We are limited to using the three full digits, so the display would be 300. The decimal point is manually placed via a jumper, so the final display would be 30.0 and the "kV" term would be screened on the front panel overlay.

If we wanted to display 10kV on a 3.5 digit meter we can make use of the leading half digit. In this case we would have four digits of resolution with the meter displaying 1000. Placing the decimal point properly, the final meter reading would be 10.00 with the "kV" term screened on the front panel overlay.

4.5 Digit Display Example

If the DPM4 option is ordered, the standard 3.5 digit meters are upgraded with 4.5 digit meters. A 4.5 digit display is actually five segments, one half digit and 4 full digits. Displaying maximum capability it would read 19999.

Using the examples above, if we wanted to display 30kV on a 4.5 digit meter we would have to "throw out" the leading half digit as we can't make use of it because it's only a "1". We are limited to using the four full digits so the display would be 3000. The decimal point is manually placed via a jumper, so the final display would be 30.00 and the "kV" term would be screened on the front panel overlay.

If we wanted to display 10kV on a 4.5 digit meter we can make use of the leading half digit. In this case we would have five digits of resolution with the meter displaying 10000. Placing the decimal point properly the final meter reading would be 10.000 with the "kV" term screened on the front panel overlay.

Module II
ANALOG AND DIGITAL OSCILLOSCOPES, TRANSDUCERS

Application of CRO

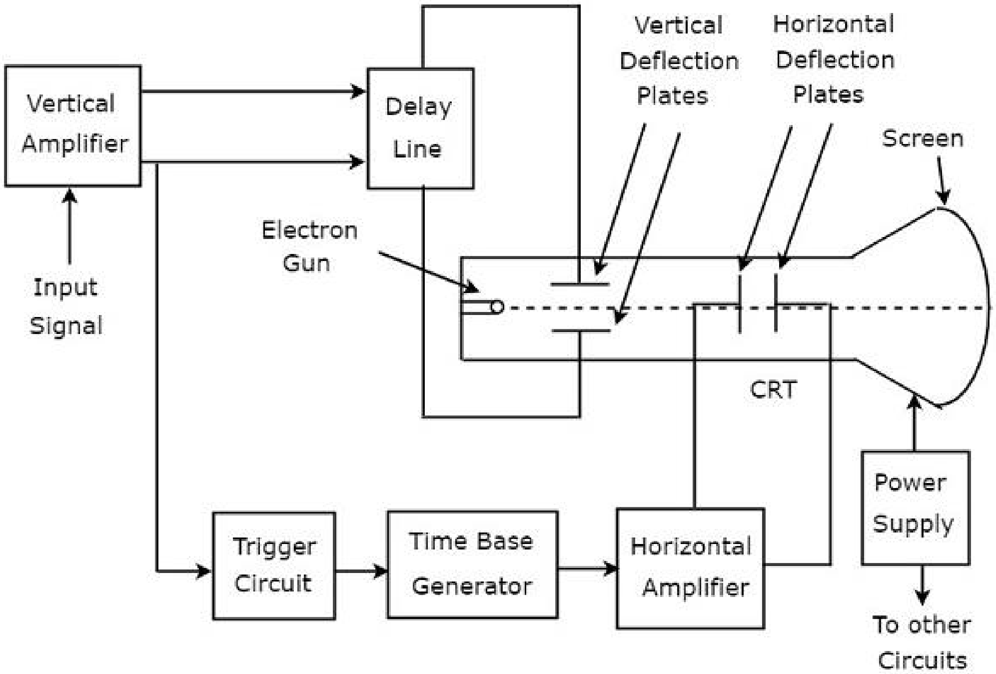
We can do the following measurements by using CRO.

- Measurement of Amplitude
- Measurement of Time Period
- Measurement of Frequency
- Examination of Waveform
- Voltage measurement
- Current measurement

Block Diagram of CRO

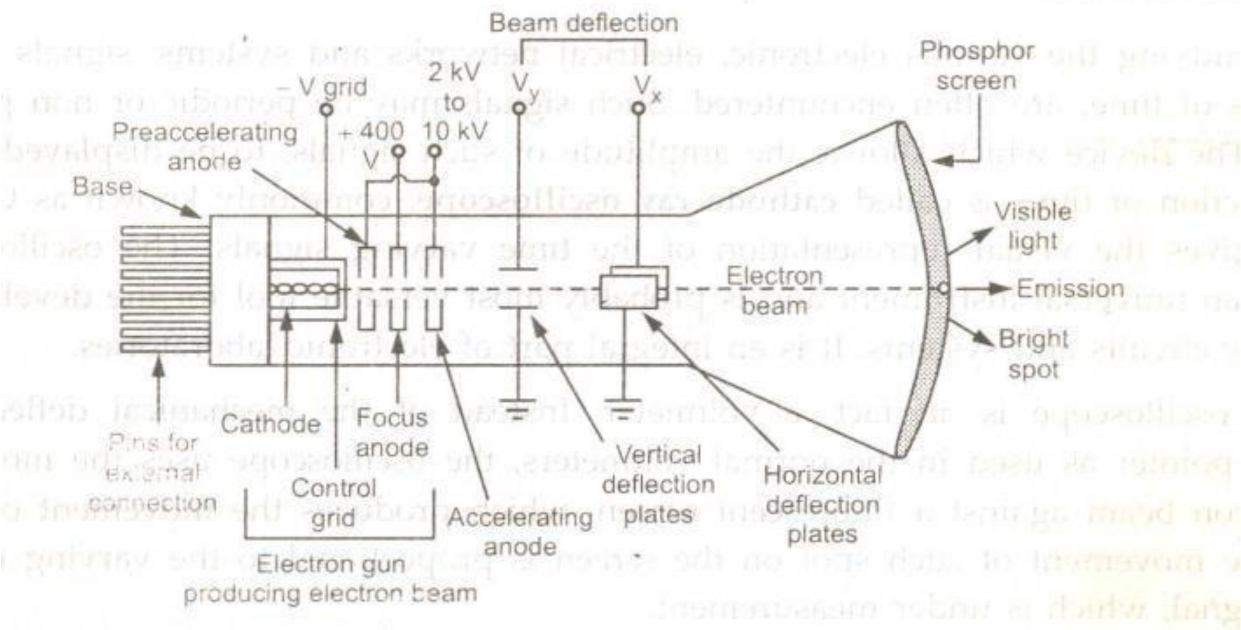
Cathode Ray Oscilloscope (CRO) consists a set of blocks. Those are vertical amplifier, delay line, trigger circuit, time base generator, horizontal amplifier, Cathode Ray Tube (CRT) & power supply. The block diagram of CRO is shown in below figure**.**
The function of each block of CRO is mentioned below.

- Vertical Amplifier: It amplifies the input signal, which is to be displayed on the screen of CRT.
- Delay Line: It provides some amount of delay to the signal, which is obtained at the output of vertical amplifier. This delayed signal is then applied to vertical deflection plates of CRT.
- Trigger Circuit: It produces a triggering signal in order to synchronize both horizontal and vertical deflections of electron beam.
- Time base Generator: It produces a sawtooth signal, which is useful for horizontal deflection of electron beam.
- Horizontal Amplifier: It amplifies the sawtooth signal and then connects it to the horizontal deflection plates of CRT.
- Power supply: It produces both high and low voltages. The negative high voltage and positive low voltage are applied to CRT and other circuits respectively.
- Cathode Ray Tube (CRT): It is the major important block of CRO and mainly consists of four parts. Those are electron gun, vertical deflection plates, horizontal deflection plates and fluorescent screen.
- The electron beam, which is produced by an electron gun gets deflected in both vertical and horizontal directions by a pair of vertical deflection plates and a pair of horizontal deflection plates respectively. Finally, the deflected beam will appear as a spot on the fluorescent screen.



Explain CRT

As shown in the Fig. , the electron beam passes through these plates. A positive voltage applied to the Y input terminal (Vy) Causes the beam to deflect vertically upward due to the attraction forces, while a negative voltage applied to. the Y input terminal will cause the electron beam to deflect vertically downward, due to the repulsion forces. When the voltages are applied simultaneously to vertical and horizontcl1 deflecting plates, the electron beam is deflected due to The momentum of the electrons (their number x their speed) determines the intensity, or brightness, of the light emitted from the fluorescent screen due to the electron bombclrdl1lent. The light emitted is usually of the green colour. Because the electrons are negatively charged, a repulsive force is created by applying a negative voltage to the control grid (in CRT, voltages applied to various grids are stated with respect to cathode, which is taken as common point). This negative control voltage can be made variable.



Electron Gun:
The electron gun section of the cathode ray tube provides a sharply focused electron beam directed :towards the fluorescent-coated screen. This section starts from theql1ally heated cathode, limiting the electrons. The control grid is give!! negative potential with respect to cathode dc. This grid controls the number of electrons in the beam, going to the screen. The momentum of the electrons (their number x their speed) determines the intensity, or brightness, of the light emitted from the fluorescent screen due to the electron bombclrdl1lent. The light emitted is usually of the green colour. Because the electrons are negatively charged, a repulsive force is created by applying a negative voltage to the control grid (in CRT, voltages applied to various grids are stated with respect to cathode, which is taken as common point). This negative control voltage can be made variable.

Deflection System:
When the electron beam is accelerated it passes through the deflection system, with which beam can be positioned anywhere on the screen. The deflection system of the cathode-ray-tube consists of two pairs of parallel plates, referred to as the vertical and horizontal deflection plates. One of the plates' in each set is connected to ground (0 V), To the other plate of each set, the external deflection voltage is applied through an internal adjustable gain amplifier stage, To apply the deflection voltage externally, an external terminal, called the Y input or the X input, is available.
As shown in the Fig. , the electron beam passes through these plates. A positive voltage applied to the Y input terminal (Vy) Causes the beam to deflect vertically upward due to the attraction forces, while a negative voltage applied to. the Y input terminal will cause the electron beam to deflect vertically downward, due to the repulsion forces. When the voltages are applied simultaneously to vertical and horizontcl1 deflecting plates, the electron beam is deflected due to the resultant-of these two voltages.

Fluorescent Screen:
The light produced by the screen does not disappear immediately when bombardment by electrons ceases, i.e., when the signal becomes zero. The time period for which the trace remains on the screen after the signal becomes zero is known as "persistence". The persistence may be jSshort as a few microsecond, or as long as tens of seconds ~enminutes. Long persistence traces are used in the study..of transients. Long persistence helps in the study of transients since the trace is still seen on the screen after the transient has disappeared.
Phosphor screen characteristics:
Many phosphor materials having different excitation times and colours as well as different phosphorescence times are available. The type PI, P2, PI1 or P3I are the short persistence phosphors and are used for the general purpose oscilloscope
Medical oscilloscopes require a longer phosphor decay and hence phosphors like P7 and P39 are preferred for such applications. Very slow displays like radar require long persistence phosphors to maintain sufficient flicker free picture. Such phosphors are P19, P26 and, P33.
The phosphors P19, P26, P33 have low burn resistance. The phosphors PI, P2, P4, P7, Pll have medium burn resistance while PIS, P3I have high burn resistance

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Different types of CRO Probe

Current probes:
It is sometimes necessary to measure current waveforms on an oscilloscope. This can be achieved using a current probe. This has a probe that clips around the wire and enables the current to be sensed. Sometimes using the maths functions on a scope along with a voltage measurement on another channel it is possible to measure power,

Active probes:
As frequencies rise, the standard passive probes become less effective. The effect of the capacitance rises and the bandwidth is limited. To overcome these difficulties active probes can be used. They have an amplifier right at the tip of the probe enabling measurements with very low levels of capacitance to be made. Frequencies of several GHz are achievable using active scope probes.

Differential scope probes:
In some instances it may be necessary to measure differential signals. Low level audio, disk drive signals and many more instances use differential signals and these need to be measured as such. One way of achieving this is to probe both lines of the differential signal using one probe each line as if there were two single ended signals, and then using the oscilloscope to add then differentially (i.e. subtract one from the other) to provide the difference.

High voltage probes:
Most standard oscilloscope voltage probes like the X1 or X10 are only specified for operation up to voltages of a few hundred volts at most. For operation higher than this a proper high voltage probe with specially insulated probe is required. It also will step down the voltage for the input to the scope so that the test instrument is not damaged by the high voltage. Often voltage probes may be X50 or X100.

Measurements by using CRO

Lissajous figure is the pattern which is displayed on the screen, when sinusoidal signals are applied to both horizontal & vertical deflection plates of CRO. These patterns will vary based on the amplitudes, frequencies and phase differences of the sinusoidal signals, which are applied to both horizontal & vertical deflection plates of CRO.

Measurement of Amplitude
CRO displays the voltage signal as a function of time on its screen. The amplitude of that voltage signal is constant, but we can vary the number of divisions that cover the voltage signal in vertical direction by varying volt/division knob on the CRO panel. Therefore, we will get the amplitude of the signal, which is present on the screen of CRO by using following formula. $A=j\times nv$
Where,
A is the amplitude
j is the value of volt/division
nv is the number of divisions that cover the signal in vertical direction.

Measurement of Time Period
CRO displays the voltage signal as a function of time on its screen. The Time period of that periodic voltage signal is constant, but we can vary the number of divisions that cover one complete cycle of voltage signal in horizontal direction by varying time/division knob on the CRO panel.

Therefore, we will get the Time period of the signal, which is present on the screen of CRO by using following formula. $T = k \times n_h$
Where,
T is the Time period
k is the value of time/division
nh is the number of divisions that cover one complete cycle of the periodic signal in horizontal direction.

Measurement of Frequency
The frequency, f of a periodic signal is the reciprocal of time period, T. Mathematically, it can be represented as $f = 1/T$
So, we can find the frequency, f of a periodic signal by following these two steps.
 Step1: Find the Time period of periodic signal.
 Step2: Take reciprocal of Time period of periodic signal, which is obtained in Step1.
We will discuss about special purpose oscilloscopes in next chapter.

Dual Beam Oscilloscope

The Oscilloscope, which displays two voltage waveforms is called Dual Beam Oscilloscope. Its block diagram is shown in below figure

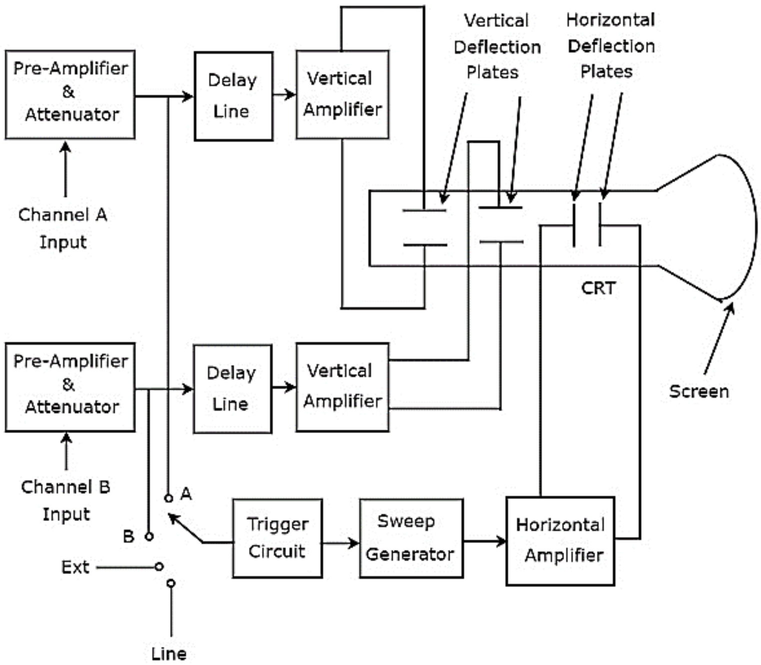
As shown in above figure, the CRT of Dual Beam Oscilloscope consists of two sets of vertical deflection plates and one set of horizontal deflection plates.

The combination of the following blocks together is called a channel.

- Pre-Amplifier & Attenuator
- Delay Line
- Vertical Amplifier
- A set of Vertical Deflection Plates

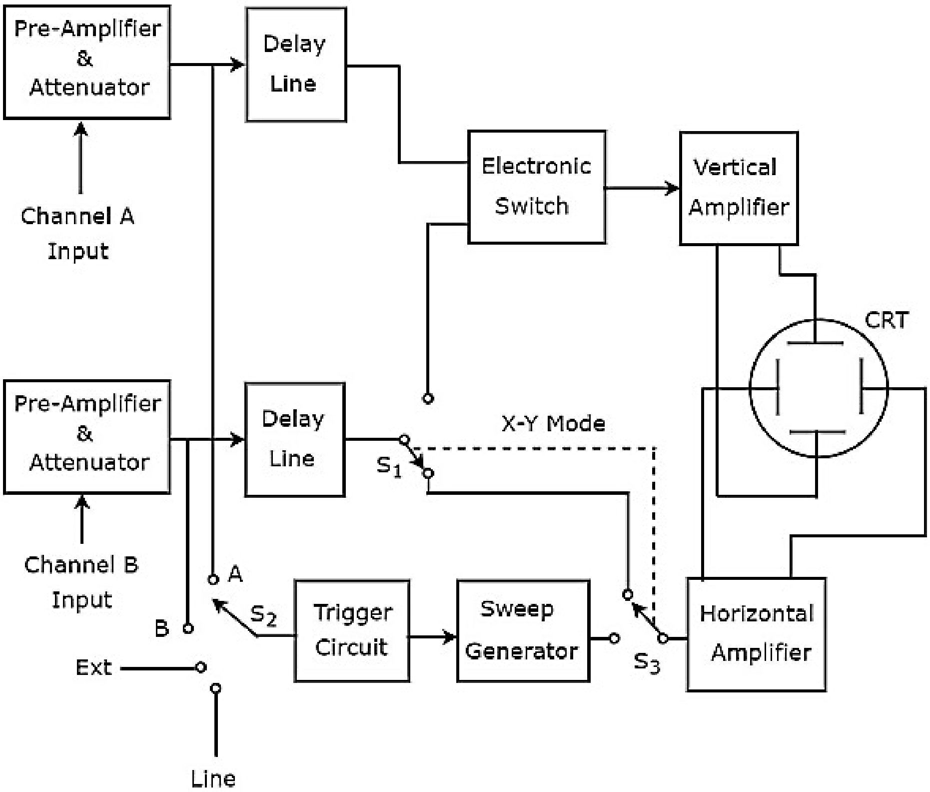
There are two channels in Dual Beam Oscilloscope. So, we can apply the two signals, namely A & B as input of channel A & Channel B respectively. We can choose any one of these four signals as trigger input to the trigger circuit by using a switch. Those are input signals A & B, External signal (Ext) and Line input.

This oscilloscope will produce two vertically deflected beams, since there are two pairs of vertical deflection plates. In this oscilloscope, the blocks which are useful for deflecting the beam in horizontal direction is common for both the input signals. Finally, this oscilloscope will produce the two input signals simultaneously on the screen of CRT



Dual Trace Oscilloscope

The Oscilloscope, which produces two traces on its screen is called Dual Trace Oscilloscope. Its block diagram is shown in below figure



As shown in above figure, the CRT of Dual Trace Oscilloscope consists of a set of vertical deflection plates and another set of horizontal deflection plates. channel consists of four blocks, i.e. pre-Amplifier & attenuator, delay line, vertical amplifier and vertical deflection plates.

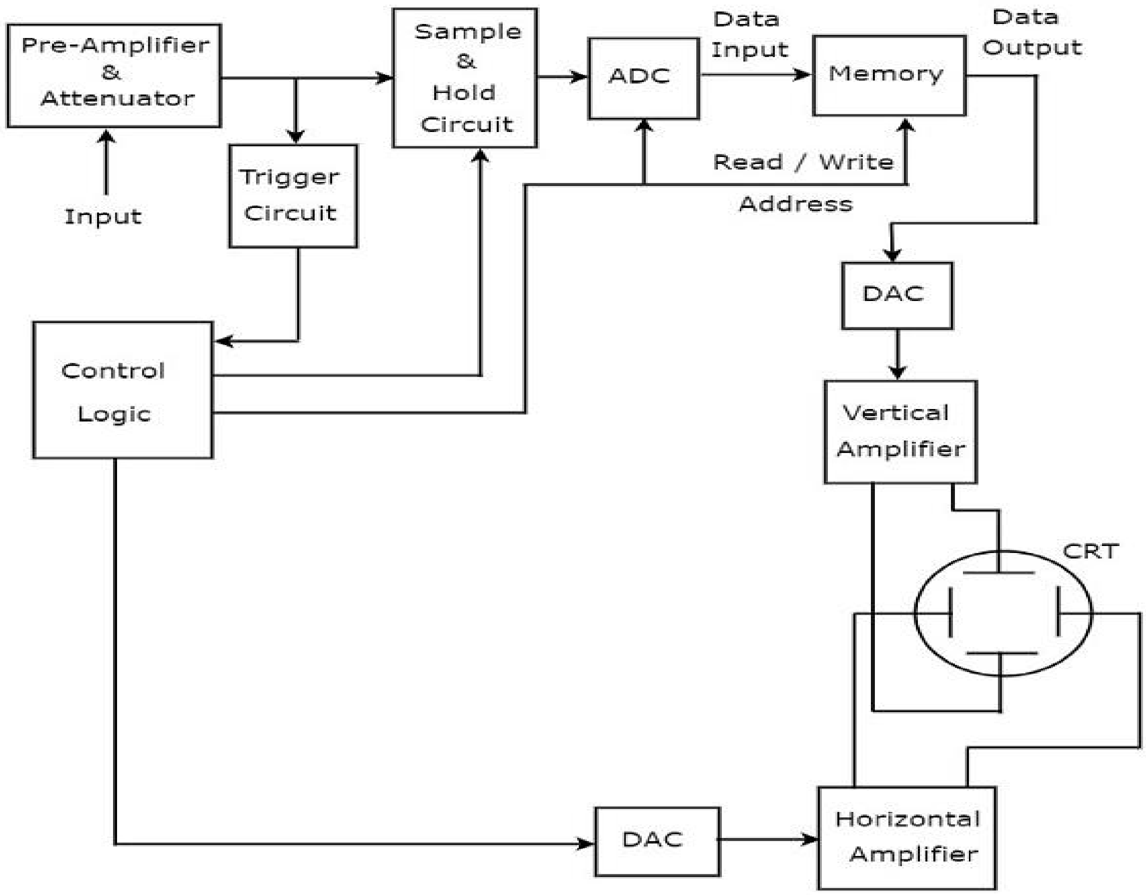
In above block diagram, the first two blocks are separately present in both channels. The last two blocks are common to both the channels. Hence, with the help of electronic switch we can connect the delay line output of a specific channel to vertical amplifier.

We can choose any one of these four signals as trigger input to the trigger circuit by using a switch. Those are input signals A & B, External signal (Ext) and Line input.

This oscilloscope uses same electron beam for deflecting the input signals A & B in vertical direction by using an electronic switch, and produces two traces. the blocks that deflect the beam horizontally is common for both the input signals

Digital Storage Oscilloscope

The oscilloscope, which stores the waveform digitally is known as digital storage oscilloscope. The block diagram of (digital) storage oscilloscope is below



Additional blocks required for digital data storage are added to a basic oscilloscope to make it convert it into a Digital Storage Oscilloscope. The blocks that are required for storing of digital data are lies between the pre-amplifier & attenuator and vertical amplifier in Digital Storage Oscilloscope. Those are Sample and Hold circuit, Analog to Digital Converter (ADC), Memory & Digital to Analog Converter.

Control logic controls the first three blocks by sending various control signals. The blocks like control logic and Digital to Analog Converter are present between the trigger circuit and horizontal amplifier in Digital Storage Oscilloscope.

The Digital Storage Oscilloscope stores the data in digital before it displays the waveform on the screen. Whereas, the basic oscilloscope doesn't have this feature.

Types of Electrical Transducers

Mainly, the electrical transducers can be classified into the following two types.

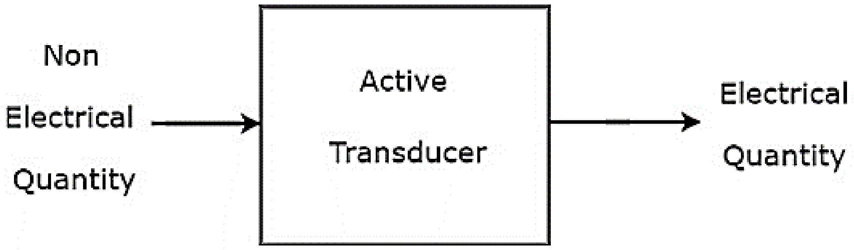
1. Active Transducers
2. Passive Transducers

Now, let us discuss about these two types of transducers briefly.

Active Transducers

The transducer, which can produce one of the electrical quantities such as voltage and current is known as active transducer. It is also called self-generating transducer, since it doesn't require any external power supply.

The block diagram of active transducer is shown in below figure.



As shown in the figure, active transducer will produce an electrical quantity (or signal), which is equivalent to the non-electrical input quantity (or signal).

Examples

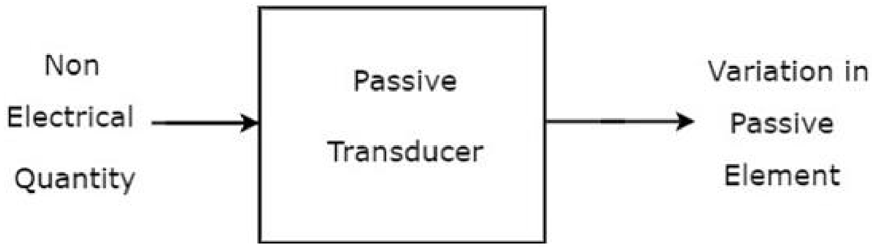
Following are the examples of active transducers.

- Piezo Electric Transducer
- Photo Electric Transducer
- Thermo Electric Transducer

Passive Transducers

The transducer, which can't produce the electrical quantities such as voltage and current is known as passive transducer. But, it produces the variation in one of passive elements like resistor (R), inductor (L) and capacitor (C). Passive transducer requires external power supply.

The block diagram of passive transducer is shown in below figure.



As shown in the figure, passive transducer will produce variation in the passive element in accordance with the variation in the non-electrical input quantity (or signal).

Examples

Following are the examples of passive transducers.

1. Resistive Transducer
2. Inductive Transducer
3. Capacitive Transducer

Resistive Transducer

A passive transducer is said to be a resistive transducer, when it produces the variation (change) in resistance value. the following formula for resistance, R of a metal conductor.

$R=\rho l/A$

Where,

ρ is the resistivity of conductor

l is the length of conductor

A is the cross sectional area of the conductor

The resistance value depends on the three parameters ρ, l & A. So, we can make the resistive transducers based on the variation in one of the three parameters ρ, l & A. The variation in any one of those three parameters changes the resistance value.

- Resistance, R is directly proportional to the resistivity of conductor, ρ. So, as resistivity of conductor, ρ increases the value of resistance, R also increases. Similarly, as resistivity of conductor, ρ decreases the value of resistance, R also decreases.
- Resistance, R is directly proportional to the length of conductor, l. So, as length of conductor, l increases the value of resistance, R also increases. Similarly, as length of conductor, l decreases the value of resistance, R also decreases.
- Resistance, R is inversely proportional to the cross sectional area of the conductor, A. So, as cross sectional area of the conductor, A increases the value of resistance, R decreases. Similarly, as cross sectional area of the conductor, A decreases the value of resistance, R increases.

Potentiometric Transducer

A resistive potentiometer (pot) consists of a resistance element provided with a sliding contact, called a wiper. The motion of the sliding contact may betranslatory or rotational. Some have a combination of both, with resistive elements in the form of a helix, as shown in Fig. (c). They are known as helipots Translatory resistive elements, as shown in Fig. (a), are linear (straight) devices. Rotational resistive devices are circular and are used for the measurement of angular displacement, as shown in Fig. Helical resistive elements are multi turn rotational devices which can be used for the measurement of either translatory or rotational motion. A potentiometer is a passive transducer since it requires an external power source for its operation.

Advantage of Potentiometers

1. They are inexpensive.
2. Simple to operate and are very useful for applications where the requirements are not particularly severe.
3. They are useful for the measurement of large amplitudes of displacement.
4. Electrical efficiency is very high, and they provide sufficient output to allow control operations.

Disadvantages of Potentiometers

1. When using a linear potentiometer, a large force is required to move the sliding contacts.
2. The sliding contacts can wear out, become misaligned and generate noise.

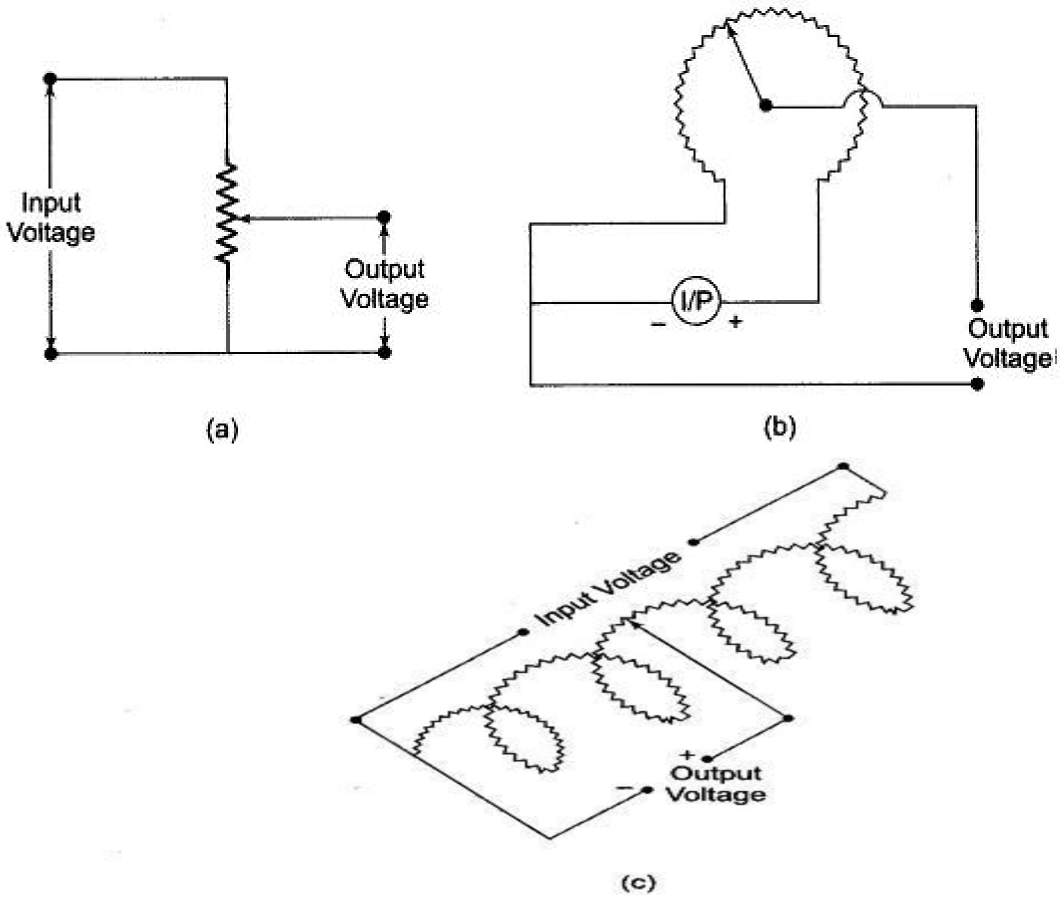


Fig. 13.1 (a) Translatory Type (b) Rotational Type (c) Helipot (Rotational)

Strain gauges

The strain gauge is an example of a passive transducer that uses electric resistance variation in wires to sense the strain produced by a force on wires. It is a very versatile detector and transducer for measuring weight, pressure, mechanical force, or displacement. The construction of a bonded strain gauge (see figure) shows a fine wire element looped back and forth on a mounting plate, which is usually cemented to the member undergoing stress. A tensile stress tends to elongate the wire and thereby increase its length and decrease its cross-sectional area. Bonded type strain gauges are three types, namely

1. Wire Strain Gauges
2. Foil Strain Gauge
3. Semiconductor Strain Gauge

Wire Strain Gauges:

Wire Strain Gauges has three types namely,

1. Grid type
2. Rossette type
3. Torque type
4. Helical type

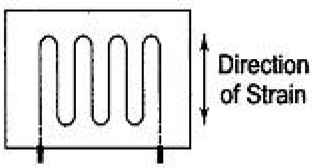


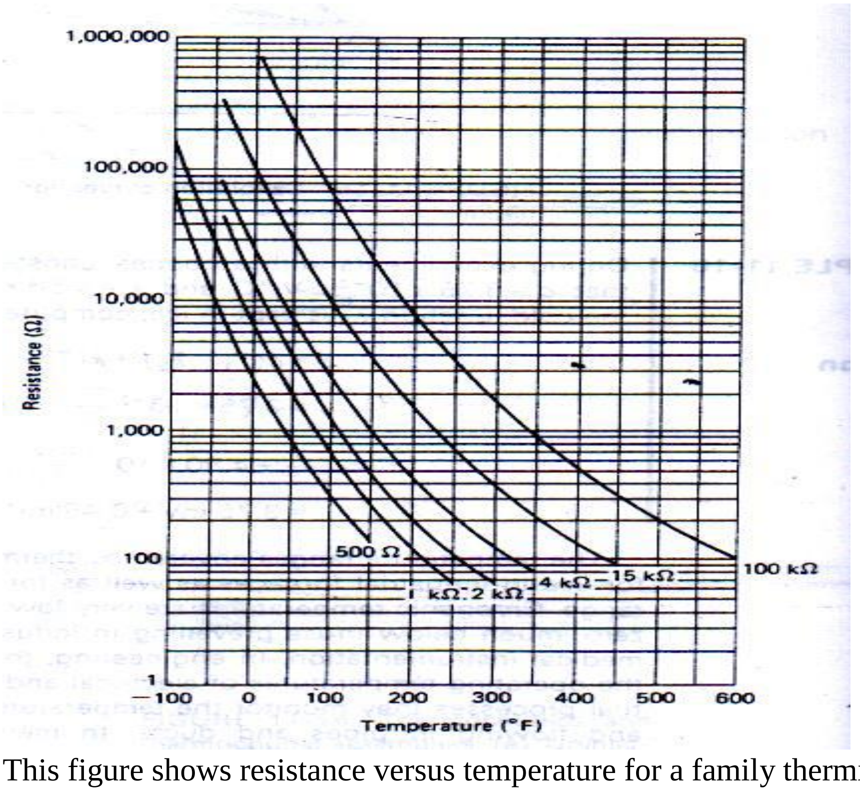
Fig. 13.6 Grid Type Strain Gauge

The grid arrangement of the wire element in a bonded strain gauge creates a problem not encountered in the use of unbonded strain gauges. To be useful as a strain gauge, the wire element must measure strain along one axis. Therefore complete and accurate analysis of strain in a rigid member is impossible, unless the direction and magnitude of stress are known. The measuring axis of a strain gauge is its longitudinal axis, which is parallel to the wire ele-ment, as shown in Fig. 13.6. When a strain occurs in the member being measured, along the transverse axis of the gauge, it also affects the strain being measured parallel to the longitudinal axis. This introduces an error in the response of the gauge.

Thermistor

Thermistor is a semiconductor made by sintering mixtures of metallic oxide, such as oxides of manganese, nickel, cobalt, copper and uranium. Termistors have negative temperature coefficient (NTC). That is, their resistance decreases as their temperature rises.

Types of thermistor	Resistance
Disc	1 to 1MΩ
Washer	1 to 50kΩ
Rod	high resistance



This figure shows resistance versus temperature for a family thermistor. The resistance value marked at the bottom end of each curve is a value at 250C The resistance decreases as their temperature rises-NTC

Advantages of thermistor

- Small size and low cost
- Fast response over narrow temperature range
- Good sensitivity in Negative Temperature Coefficient

(NTC) region

- Cold junction compensation not required due to dependence of resistance on absolute temperature.
- Contact and lead resistance problems not encountered due to large resistance

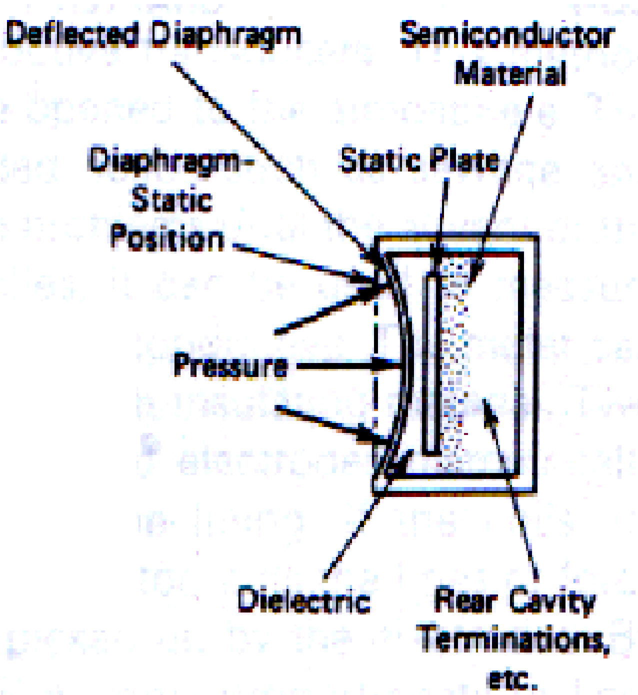
Capacitive Transducer

The capacitance of a parallel plate capacitor is given by

$$C = \frac{kA\varepsilon_0}{d}(Farads)$$

where
k = dielectric constant
A = the area of the plate, in m_2
$\varepsilon_o = 8.854 \times 10^{-12}$ F/m
d = the plate placing in m
The capacitance of this unit proportional to the amount of the fixed plate that is covered, that shaded by moving plate. This type of transducer will give sign proportional to curvilinear displacement or angular velocity.

MICROPHONE TYPE TRANSDUCER



It consists of a fixed cylinder and a moving cylinder. These pieces are configured so the moving piece fits inside the fixed piece but insulated from it. A transducer that varies the spacing between surfaces. The dielectric is either air or vacuum. Often used as Capacitance microphones.

Inductive Transducer

Inductive transducers may be either of the self generating or passive type. The self generating type utilises the basic electrical generator principle, i.e, a motion between a conductor and magnetic field induces a voltage in the conductor (generator action). This relative motion between the field and the conductor is supplied by changes in the measured.

Linear variable differential transformer (LVDT)

When an externally applied force moves the core to the left-hand position, more magnetic flux links the left-hand coil than the right-hand coil. The emf induced in the left-hand coil, ES], is therefore larger than the induced emf of the right-hand [oil, Es2' The magnitude of the output voltage is then equal to the difference between the two secondary voltages and it is in phase with the voltage of the left-hand coil.

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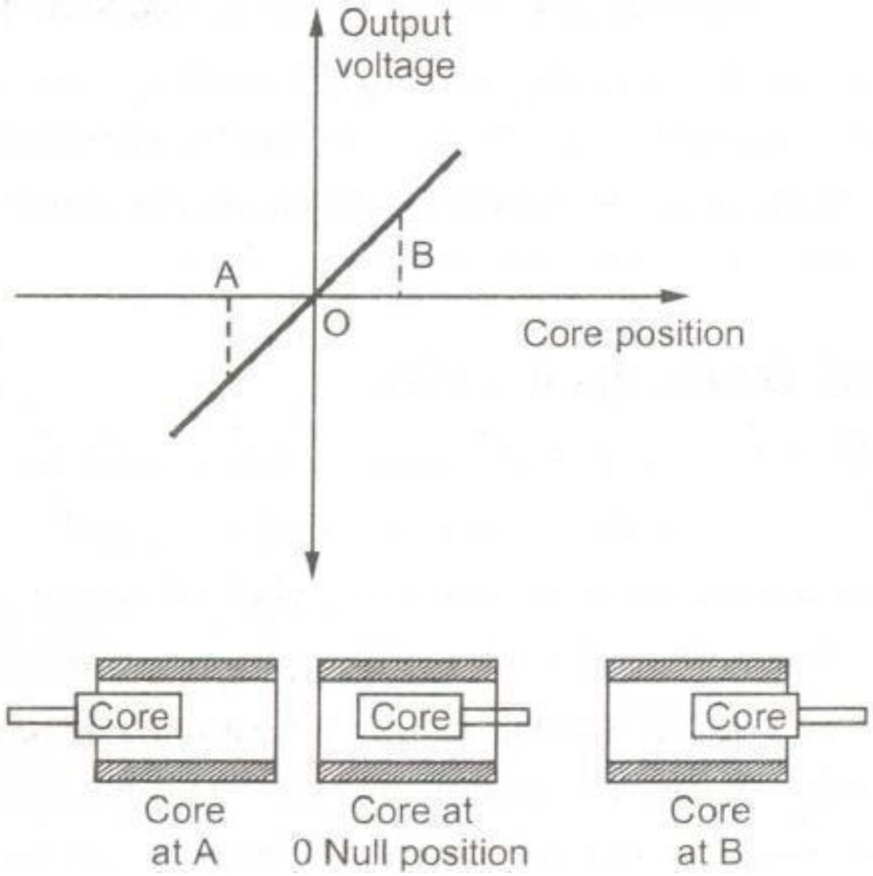
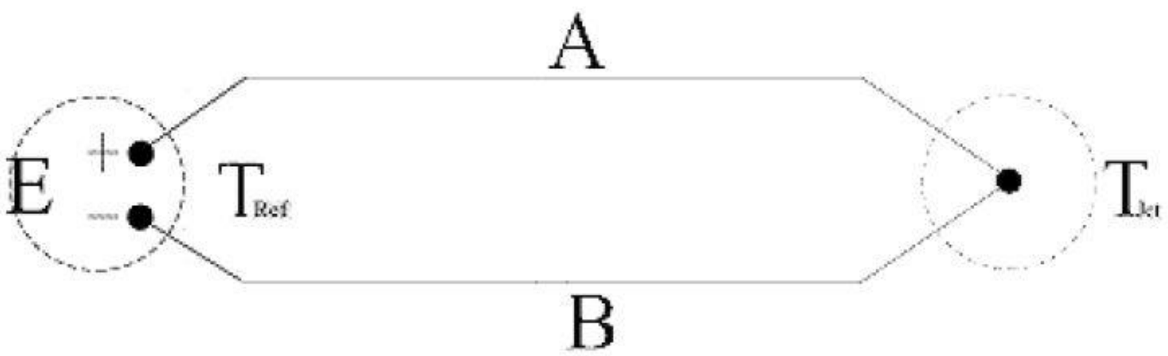


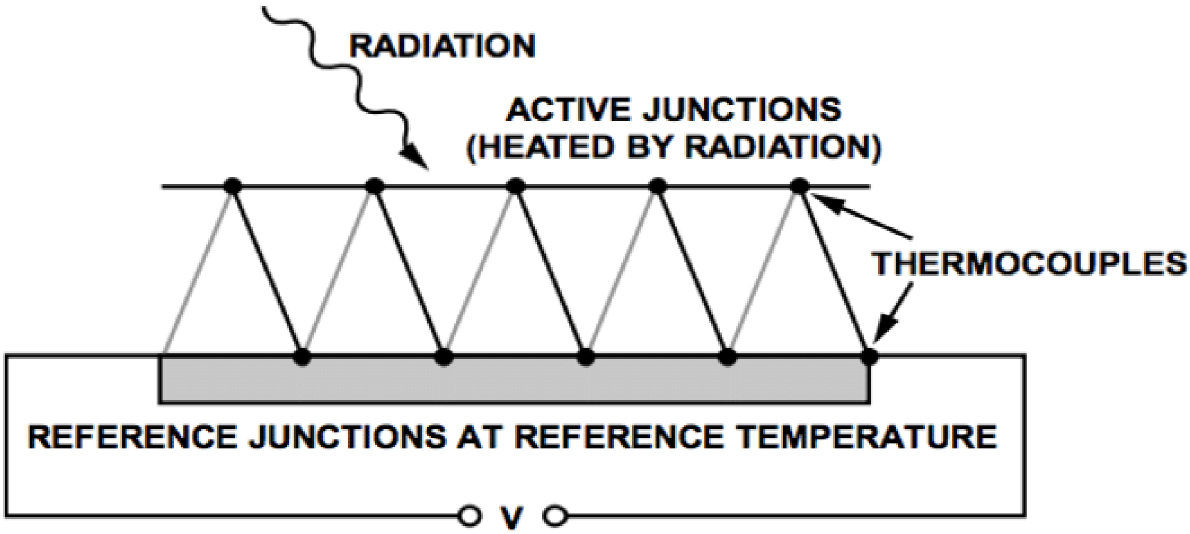
Thermocouple



Most frequently used method to measure temperatures with an electrical output signal Thermocouples operate under the principle that a circuit made by connecting two dissimilar metals produces a measurable voltage (emf-electromotive force) when a temperature gradient is imposed between one end and the other. They are inexpensive, small, rugged and accurate when used with an understanding of their peculiarities.

Thermocouples Principle of Operation
In, 1821 T. J. Seebeck observed the existence of an electromotive force (EMF) at the junction formed between two dissimilar metals (Seebeck effect). – Seebeck effect is actually the combined result of two other phenomena, Thomson and Peltier effects.
Thomson observed the existence of an EMF due to the contact of two dissimilar metals at the junction temperature.
Peltier discovered that temperature gradients along conductors in a circuit generate an EMF.
The Thomson effect is normally much smaller than the Peltier effect.
It is generally reasonable to assume that the emf is generated in the wires, not in the junction. The signal is generated when dT/dx is not zero. When the materials are homogeneous, e, the thermoelectric power, is a function of temperature only. Two wires begin and end at the same two temperatures

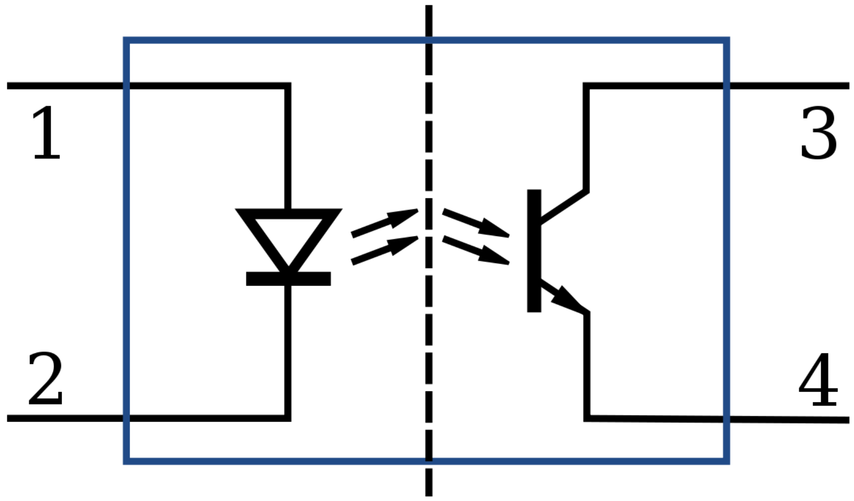
Thermopile



A thermopile is an electronic device that converts thermal energy into electrical energy. It is composed of several thermocouples connected usually in series or, less commonly, in parallel.

OPTOCOUPLER TRANSDUCER

Opto-coupler is an electronic component that transfers electrical signals between two isolated circuits. Optocoupler also called Opto-isolator, photo coupler or optical isolator.



Optocoupler is used to isolate circuitry to prevent electrical collision chances or to exclude unwanted noises. This the internal structure of the opto-coupler. On the left side pin 1 and pin 2 are exposed, it is a LED (Light Emitting Diode), the LED emit infrared light to the photosensitive transistor on the right side. The photo-transistor switches the output circuitry by its collector and emitter, same as typical BJT transistors. Intensity of the LED directly controls the photo-transistor. Since the LED can be controlled by a different circuitry and the photo transistor can control different circuitry so two independent circuits can be controlled by Optocoupler. Also, between the photo-transistor and the Infrared LED, the space is transparent and non-conductive material; it is electrically isolating two different circuits. The hollowed space between LED and photo-transistor can be made using Glass, air, or a transparent plastic, the electrical isolation is much higher, typically 10 kV or higher.
there are many different types of Optocouplers are available commercially based on their needs and switching capabilities. Depending on the use there are mainly four types of optocouplers are available.

- Opto-coupler which use Photo Transistor.
- Opto-coupler which use Photo Darlington Transistor.
- Opto-coupler which use Photo TRIAC.
- Opto-coupler which use Photo SCR.

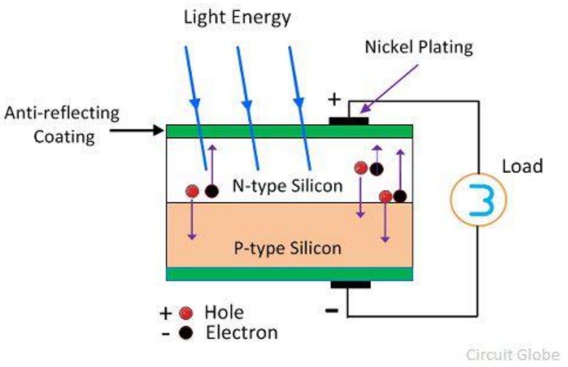
As the Optocoupler does not allow direct electrical connection between two sides, the main application of the Optocoupler is to isolate two circuits. From switching other application, same as like where transistor can be used to switch application the Optocoupler can be used. It can be used in various microcontroller related operations where digital pulses or analog information needed from a high voltage circuitry, Optocoupler can be used for excellent isolation between this two.

PHOTO VOLTAIC CELL

A photovoltaic (PV) cell, also known as a solar cell, is an electronic component that generates electricity when exposed to photons, or particles of light. This conversion is called the photovoltaic effect, A photovoltaic cell is made of semiconductor materials that absorb the photons emitted by the sun and generate a flow of electrons. When the photons strike a semiconductor material like silicon , they release the electrons from its atoms, leaving behind a vacant space. The stray electrons move around randomly looking for another “hole” to fill.

To produce an electric current, however, the electrons need to flow in the same direction. This is achieved using two types of silicon. The silicon layer that is exposed to the sun is doped with atoms of phosphorus, which has one more electron than silicon, while the other side is doped with atoms of boron , which has one less electron. The resulting sandwich works much like a battery: the layer that has surplus electrons becomes the negative terminal (n) and the side that has a deficit of electrons becomes the positive terminal (p). An electric field is created at the junction between the two layers.

When the electrons are excited by the photons, they are swept to the n-side by an electric field, while the holes drift to the p-side. The electrons and holes are directed to the electrical contacts applied to both sides before flowing to the external circuit in the form of electrical energy. This produces direct current. An anti-reflective coating is added to the top of the cell to minimize photon loss due to surface reflection.



For low-power portable electronics, like calculators or small fans, a photovoltaic array may be a reasonable energy source rather than a battery. Although using photovoltaics lowers the cost (over time) of the device to the user-who will never need to buy batteries-the cost of manufacturing devices with photovoltaic arrays is generally higher than the cost of manufacturing devices to which batteries must be added. Therefore, the initial cost of photovoltaic devices is often higher than battery-operated devices.

SENSORS

A sensor is a transducer that converts a physical stimulus from one form into a more useful form to measure the stimulus.
Sensors can be classified into two basic categories:
1. Analog (continuous)
Examples: thermocouple, strain gauges, potentiometers.
2. Discrete

- Binary (on/off)

Examples: Limit switch, photoelectric switches.

- Digital (e.g., pulse counter)

Examples: photoelectric array, optical encoder.

ACTUATORS

Actuators: are hardware devices that convert a controller command signal into a change in a physical parameter. The change is usually mechanical (e.g., position or velocity).
An actuator is also a transducer because it changes one type of physical quantity into some alternative form (e.g. electric current to rotational speed of electric motor).

Types of Actuators

1. Electrical actuators

- Electric motors (linear or rotational)
  - !DC servomotors
  - AC motors
  - Stepper motors
- Solenoids
- Relay

2. Hydraulic actuators

- Use hydraulic fluid as the driving force

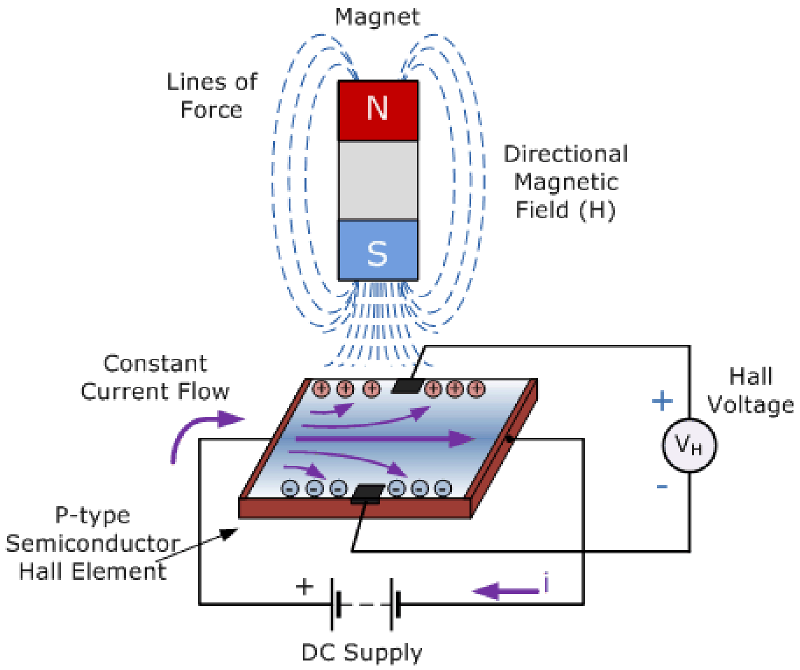
3. Pneumatic actuators

- Use compressed air as the driving force

HALL EFFECT SENSOR

Magnetic sensors are designed to respond to a wide range of positive and negative magnetic fields in a variety of different applications and one type of magnet sensor whose output signal is a function of magnetic field density around it is called the Hall Effect Sensor.

Hall Effect Sensors are devices which are activated by an external magnetic field. We know that a magnetic field has two important characteristics flux density, (B) and polarity (North and South Poles). The output signal from a Hall effect sensor is the function of magnetic field density around the device. When the magnetic flux density around the sensor exceeds a certain pre-set threshold, the sensor detects it and generates an output voltage called the Hall Voltage, VH. Consider the diagram below.

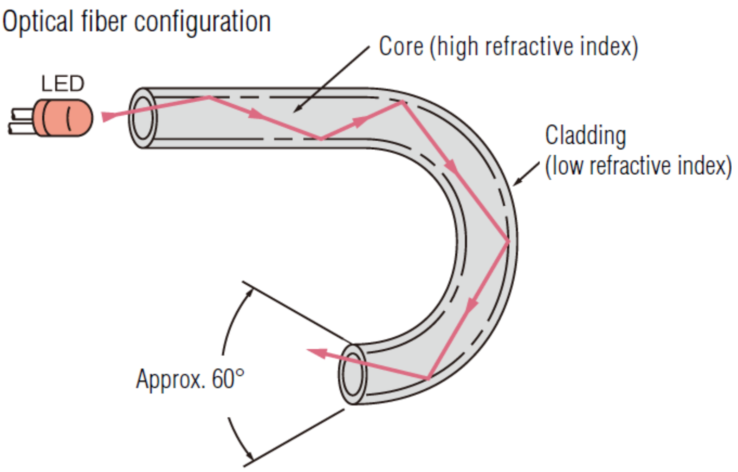


Hall Effect Sensors consist basically of a thin piece of rectangular p-type semiconductor material such as gallium arsenide (GaAs), indium antimonide (InSb) or indium arsenide (InAs) passing a continuous current through itself. When the device is placed within a magnetic field, the magnetic flux lines exert a force on the semiconductor material which deflects the charge carriers, electrons and holes, to either side of the semiconductor slab. This movement of charge carriers is a result of the magnetic force they experience passing through the semiconductor material. As these electrons and holes move side wards a potential difference is produced between the two sides of the semiconductor material by the build-up of these charge carriers. Then the movement of electrons through the semiconductor material is affected by the presence of an external magnetic field which is at right angles to it and this effect is greater in a flat rectangular shaped material.

The effect of generating a measurable voltage by using a magnetic field is called the Hall Effect after Edwin Hall who discovered it back in the 1870's with the basic physical principle underlying the Hall effect being Lorentz force. To generate a potential difference across the device the magnetic flux lines must be perpendicular, (90o) to the flow of current and be of the correct polarity, generally a south pole. The Hall effect provides information regarding the type of magnetic pole and magnitude of the magnetic field. For example, a south pole would cause the device to produce a voltage output while a north pole would have no effect. Generally, Hall Effect sensors and switches are designed to be in the "OFF", (open circuit condition) when there is no magnetic field present. They only turn "ON", (closed circuit condition) when subjected to a magnetic field of sufficient strength and polarity.

FIBER OPTIC SENSOR

The fibre optic sensor has an optical fibre connected to a light source to allow for detection in tight spaces or where a small profile is beneficial. The optical fibre consists of the core and the cladding, which have different refractive indexes. The light beam travels through the core by repeatedly bouncing off the wall of the cladding. The light beam, having passed through the fibre without any loss in light quantity, is dispersed at an angle of approximately 60° and emitted to the target.



The cores are divided into the following types:

Plastic type

The core of the plastic-fibre consists of one or more acrylic-resin fibres 0.25 to 1 mm in diameter, encased in a polyethylene sheath. Plastic fibres are light, cost-effective, and flexible which is why they are the most common type of fibre sensor.

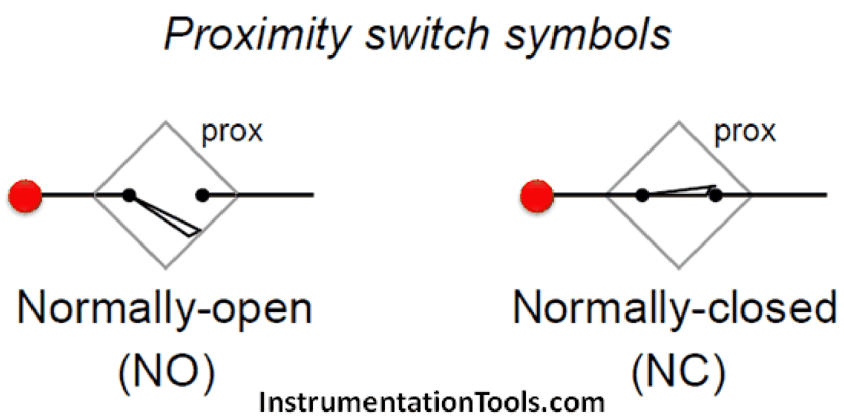
Glass type

The glass-fibre consists of 10 to 100 µm diameter glass fibres encased in stainless steel tubing. This allows it to be used at high operating temperatures (350°C max.).

PROXIMITY SWITCHES

A proximity switch is one detecting the proximity (closeness) of some object. By definition, these switches are non-contact sensors, using magnetic, electric, or optical means to sense the proximity of objects. A proximity switch will be in its "normal" status when it is distant from any detectable object. Being non-contact in nature, proximity switches are often used instead of direct-contact limit switches for the same purpose of detecting the position of a machine part, with the advantage of never wearing out over time due to repeated physical contact.

Most proximity switches are active in design. That is, they incorporate a powered electronic circuit to sense the proximity of an object. Inductive proximity switches sense the presence of metallic objects through the use of a high-frequency magnetic field. Capacitive proximity switches sense the presence of non-metallic objects through the use of a high-frequency electric field. Optical proximity switches detect the interruption of a light beam by an object. Ultrasonic proximity switches sense the presence of dense matter by the reflection of sound waves.



Many proximity switches, though, do not provide “dry contact” outputs. Instead, their output elements are transistors configured either to source current or sink current. The terms“sourcing” and “sinking” are best understood by visualizing electric current in the direction of conventional flow rather than electron flow. The following schematic diagrams contrast the two modes of switch operation, using red arrows to show the direction of current (conventional flow notation). In both examples, the load being driven by each proximity switch is a light-emitting diode (LED):

Principle of Operation:

Proximity Switch consists a sensor circuit and a driver circuit. The sensor circuit purpose is used to detect any near by objects. The sensor circuit sends an output High signal to the transistor based driver circuit when any object found near to the sensor circuit. The transistor based driver circuit may use NPN or PNP transistors and it depends on the application we use.

When a signal received from the sensor circuit, the transistor will be turned ON and the output will be ON. When the object is moved away from sensor circuit, the sensor output is OFF so transistor is OFF and the output will be OFF.

Relay

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

Magnetic latching relays require one pulse of coil power to move their contacts in one direction, and another, redirected pulse to move them back. Repeated pulses from the same input have no effect. Magnetic latching relays are useful in applications where interrupted power should not affect the circuits that the relay is controlling.

Magnetic latching relays can have either single or dual coils. On a single coil device, the relay will operate in one direction when power is applied with one polarity, and will reset when the polarity is reversed. On a dual coil device, when polarized voltage is applied to the reset coil the contacts will transition. AC controlled magnetic latch relays have single coils that employ steering diodes to differentiate between operate and reset commands. It was used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another.

Switch

In electrical engineering, a switch is an electrical component that can "make" or "break" an electrical circuit, interrupting the current or diverting it from one conductor to another.

The mechanism of a switch removes or restores the conducting path in a circuit when it is operated. It may be operated manually, for example, a light switch or a keyboard button, may be operated by a moving object such as a door, or may be operated by some sensing element for pressure, temperature or flow. A switch will have one or more sets of contacts, which may operate simultaneously, sequentially, or alternately. Switches in high-powered circuits must operate rapidly to prevent destructive arcing, and may include special features to assist in rapidly interrupting a heavy current. Multiple forms of actuators are used for operation by hand or to sense position, level, temperature or flow. Special types are used, for example, for control of machinery, to reverse electric motors, or to sense liquid level. Many specialized forms exist. A common use is control of lighting, where multiple switches may be wired into one circuit to allow convenient control of light fixtures.

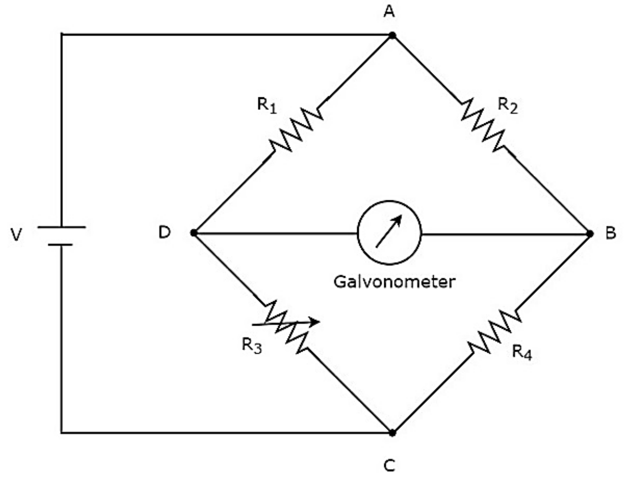
By analogy with the devices that select one or more possible paths for electric currents, devices that route information in a computer network are also called "switches" - these are usually more complicated than simple electromechanical toggles or pushbutton devices, and operate without direct human interaction.

MODULE III
BRIDGES AND SIGNAL ANALYSER

Two types of bridge circuits are used in measurement:
1) DC bridge
2) AC bridge

DC Bridges

If the bridge circuit can be operated with only DC voltage signal, then it is a DC bridge circuit or simply DC bridge. DC bridges are used to measure the value of unknown resistance. The circuit diagram of DC bridge looks like as shown in below figure



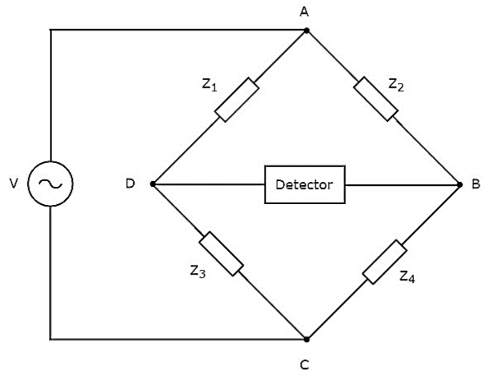
The above DC bridge has four arms and each arm consists of a resistor. Among which, two resistors have fixed resistance values, one resistor is a variable resistor and the other one has an unknown resistance value.

The above DC bridge circuit can be excited with a DC voltage source by placing it in one diagonal. The galvanometer is placed in other diagonal of DC bridge. It shows some deflection as long as the bridge is unbalanced. Vary the resistance value of variable resistor until the galvanometer shows null (zero) deflection. Now, the above DC bridge is said to be a balanced one. So, we can find the value of unknown resistance by using nodal equations.

AC Bridges

If the bridge circuit can be operated with only AC voltage signal, then it is said to be AC bridge circuit or simply AC bridge. AC bridges are used to measure the value of unknown inductance, capacitance and frequency.

The circuit diagram of AC bridge looks like as shown in below figure.



The circuit diagram of AC bridge is similar to that of DC bridge. The above AC bridge has four arms and each arm consists of some impedance. That means, each arm will be having either single or combination of passive elements such as resistor, inductor and capacitor.

Among the four impedances, two impedances have fixed values, one impedance is variable and the other one is an unknown impedance. The above AC bridge circuit can be excited with an AC voltage source by placing it in one diagonal. A detector is placed in other diagonal of AC bridge. It shows some deflection as long as the bridge is unbalanced. Vary the impedance value of variable impedance until the detector shows null (zero) deflection. Now, the above AC bridge is said to be a balanced one. So, we can find the value of unknown impedance by using balanced condition.

Wheatstone bridge

The Wheatstone bridge is an electrical bridge circuit used to measure resistance.It consists of a voltage source and a galvanometer that connects two parallel branches, containing four resistors. One parallel branch contains one known resistance and one unknown; the other parallel branch contains resistors of known resistances. In the circuit at right, R4 is the unknown resistance; R1, R2 and R3 are resistors of known resistance where the resistance of R3 is adjustable. How to determine the resistance of the unknown resistor, R4? “The resistances of the other three are adjusted and balanced until the current passing through the galvanometer decreases to zero”.

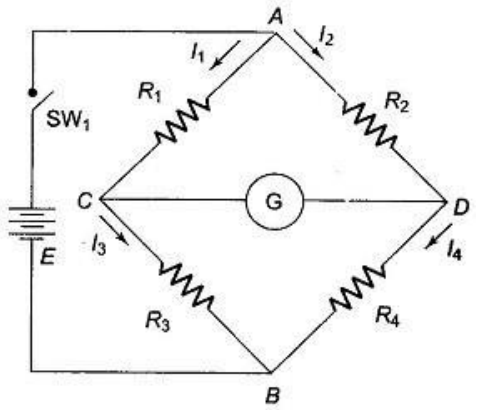


Fig. 11.1 Wheatstone's Bridge

R3 is varied until voltage between the two midpoints (B and D) will be zero and no current will flow through the galvanometer. When the bridge is in balance condition (no current flows through galvanometer G), we obtain;

voltage drop across R1 and R2 is equal,

I1R1 = I2R2

voltage drop across R3 and R4 is equal,

I3R3 = I4R4

For the galvanometer current to be zero, the following conditions should be satisfied

$$I_1 = I_3 = \frac{E}{R_1 + R_3} \quad (11.2)$$

$$I_2 = I_4 = \frac{E}{R_2 + R_4} \quad (11.3)$$

Substituting in Eq.

$$\frac{E \times R_1}{R_1 + R_3} = \frac{E \times R_2}{R_2 + R_4}$$

$$R_1 \times (R_2 + R_4) = (R_1 + R_3) \times R_2$$

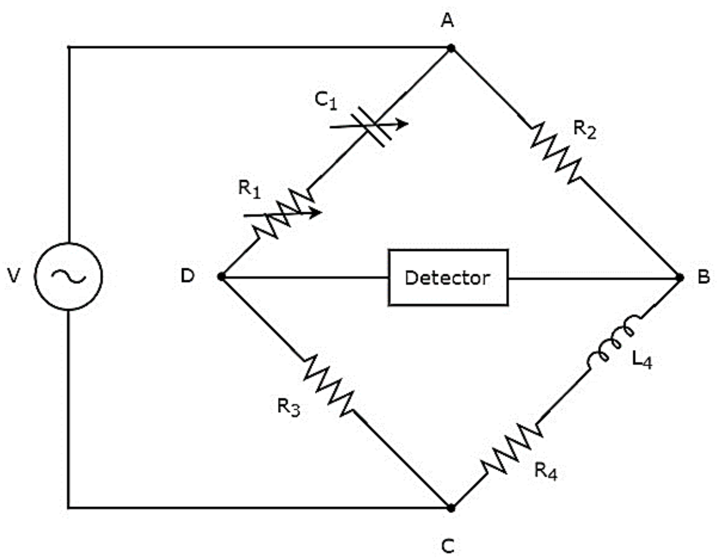
$$R_1 R_2 + R_1 R_4 = R_1 R_2 + R_3 R_2$$

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

By substituting the known values of resistors $R1$, $R2$ and $R3$ in above equation, we will get the value of resistor, $\boldsymbol{R4}$

HAY'S BRIDGE

Hay's bridge is a modified version of Maxwell's bridge, which we get by modifying the arm, which consists of a parallel combination of resistor and capacitor into the arm, which consists of a series combination of resistor and capacitor in Maxwell's bridge. Hay's bridge is used to measure the value of high inductance. The circuit diagram of Hay's bridge is shown in the below figure.



In above circuit, the arms AB, BC, CD and DA together form a rhombus or square shape. The arms, AB and CD consist of resistors, $R2$ and $R3$ respectively. The arm, BC consists of a series combination of resistor, $R4$ and inductor, $L4$. The arm, DA consists of a series combination of resistor, $R1$ and capacitor, $C1$.

Let, $Z1$, $Z2$, $Z3$ and $Z4$ are the impedances of arms DA, AB, CD and BC respectively. The values of these impedances will be

$$Z_1 = R_1 + \frac{1}{j\omega C_1}$$

$$=> Z_1 = \frac{1 + j\omega R_1 C_1}{j\omega C_1}$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_4 = R_4 + j\omega L_4$$

Substitute these impedance values in the following balancing condition of AC bridge.

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

$$R_4 + j\omega L_4 = \frac{R_2 R_3}{\left(\frac{1 + j\omega R_1 C_1}{j\omega C_1}\right)}$$

$$=> R_4 + j\omega L_4 = \frac{R_2 R_3 j\omega C_1}{(1 + j\omega R_1 C_1)}$$

Multiply the numerator and denominator of right hand side term of above equation with

$$=> R_4 + j\omega L_4 = \frac{R_2 R_3 j\omega C_1}{(1 + j\omega R_1 C_1)} \times \frac{(1 - j\omega R_1 C_1)}{(1 - j\omega R_1 C_1)}$$

$$=> R_4 + j\omega L_4 = \frac{\omega^2 {C_1}^2 R_1 R_2 R_3 + j\omega R_2 R_3 C_1}{(1 + \omega^2 {R_1}^2 {C_1}^2)}$$

By comparing the respective real and imaginary terms of above equation, we will get

$$R_4 = \frac{\omega^2 {C_1}^2 R_1 R_2 R_3}{(1+\omega^2 {R_1}^2 {C_1}^2)} \qquad \text{Equation 3}$$

$$L_4 = \frac{R_2 R_3 C_1}{(1+\omega^2 {R_1}^2 {C_1}^2)} \qquad \text{Equation 4}$$

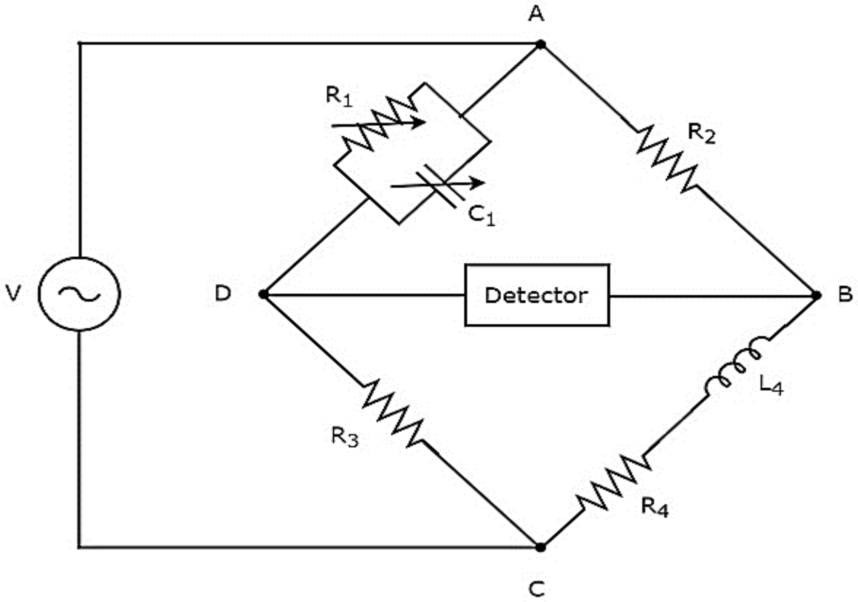
By substituting the values of R_1, R_2, R_3, C_1 and ω in Equation 3 and Equation 4, we will get the values of resistor, R_4 and inductor, L_4.

Maxwell's Bridge

Maxwell's bridge is an AC bridge having four arms, which are connected in the form of a rhombus or square shape. Two arms of this bridge consist of a single resistor, one arm consists of a series combination of resistor and inductor & the other arm consists of a parallel combination of resistor and capacitor.

An AC detector and AC voltage source are used to find the value of unknown impedance. Hence, one of these two are placed in one diagonal of Maxwell's bridge and the other one is placed in other diagonal of Maxwell's bridge.

Maxwell's bridge is used to measure the value of medium inductance. The circuit diagram of Maxwell's bridge is shown in the below figure.



In above circuit, the arms AB, BC, CD and DA together form a rhombus or square shape. The arms AB and CD consist of resistors, $R2$ and $R3$ respectively. The arm, BC consists of a series combination of resistor, $R4$ and inductor, $L4$. The arm, DA consists of a parallel combination of resistor, $R1$ and capacitor, $C1$.
Let, $Z1$, $Z2$, $Z3$ and $Z4$ are the impedances of arms DA, AB, CD and BC respectively. The values of these impedances will be

$$Z_1 = \frac{R_1\left(\frac{1}{j\omega C_1}\right)}{R_1 + \frac{1}{j\omega C_1}}$$

$$=> Z_1 = \frac{R_1}{1 + j\omega R_1 C_1}$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_4 = R_4 + j\omega L_4$$

Substitute these impedance values in the following balancing condition of AC bridge.

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

$$R_4 + j\omega L_4 = \frac{R_2 R_3}{\left(\frac{R_1}{1 + j\omega R_1 C_1}\right)}$$

$$=> R_4 + j\omega L_4 = \frac{R_2 R_3 (1 + j\omega R_1 C_1)}{R_1}$$

$$=> R_4 + j\omega L_4 = \frac{R_2 R_3}{R_1} + \frac{j\omega R_1 C_1 R_2 R_3}{R_1}$$

$$=> R_4 + j\omega L_4 = \frac{R_2 R_3}{R_1} + j\omega C_1 R_2 R_3$$

By comparing the respective real and imaginary terms of above equation, we will get

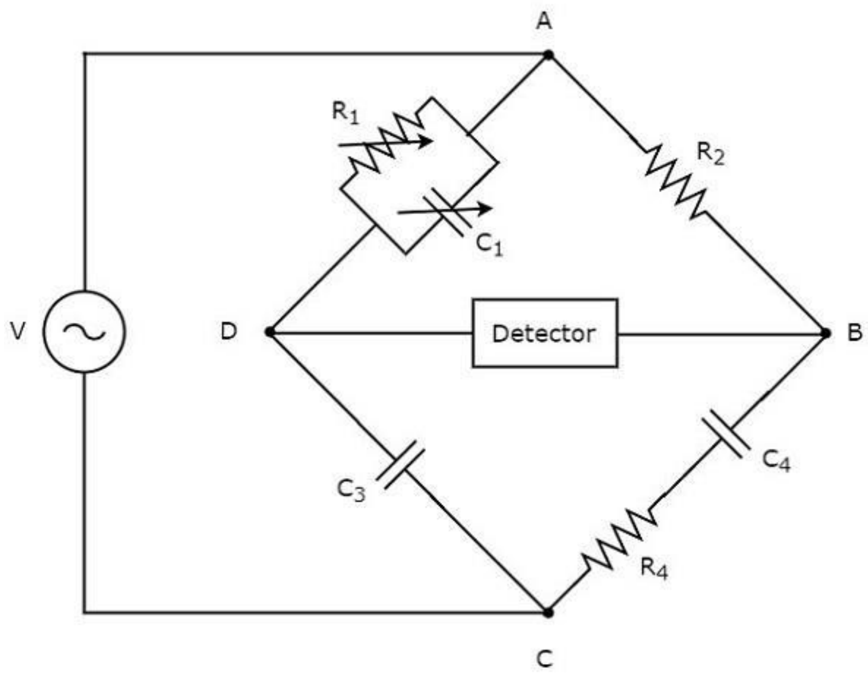
$$R_4 = \frac{R_2 R_3}{R_1} \qquad \text{Equation 1}$$

$$L_4 = C_1 R_2 R_3 \qquad \text{Equation 2}$$

By substituting the values of resistors $R1$, $R2$ and $R3$ in Equation 1, we will get the value of resistor, $R4$. Similarly, by substituting the value of capacitor, $C1$ and the values of resistors, $R2$ and $R3$ in Equation 2, we will get the value of inductor, $L4$.
The advantage of Maxwell's bridge is that both the values of resistor, $R4$ and an inductor, $L4$ are independent of the value of frequency

Schering Bridge

Schering bridge is an AC bridge having four arms, which are connected in the form of a rhombus or square shape, whose one arm consists of a single resistor, one arm consists of a series combination of resistor and capacitor, one arm consists of a single capacitor & the other arm consists of a parallel combination of resistor and capacitor.
The AC detector and AC voltage source are also used to find the value of unknown impedance, hence one of them is placed in one diagonal of Schering bridge and the other one is placed in other diagonal of Schering bridge.
Schering bridge is used to measure the value of capacitance. The circuit diagram of Schering bridge is shown in the below figure.



In above circuit, the arms AB, BC, CD and DA together form a rhombus or square shape. The arm AB consists of a resistor, R_2. The arm BC consists of a series combination of resistor, R_4 and capacitor, C_4. The arm CD consists of a capacitor, C_3. The arm DA consists of a parallel combination of resistor, R_1 and capacitor, C_1.

Let, Z_1, Z_2, Z_3 and Z_4 are the impedances of arms DA, AB, CD and BC respectively. The **values of these impedances** will be

$$Z_1 = \frac{R_1\left(\frac{1}{j\omega C_1}\right)}{R_1 + \frac{1}{j\omega C_1}}$$

$$=> Z_1 = \frac{R_1}{1 + j\omega R_1 C_1}$$

$$Z_2 = R_2$$

$$Z_3 = \frac{1}{j\omega C_3}$$

$$Z_4 = R_4 + \frac{1}{j\omega C_4}$$

$$=> Z_4 = \frac{1 + j\omega R_4 C_4}{j\omega C_4}$$

Substitute these impedance values in the following balancing condition of AC bridge.

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

$$\frac{1 + j\omega R_4 C_4}{j\omega C_4} = \frac{R_2\left(\frac{1}{j\omega C_3}\right)}{\frac{R_1}{1 + j\omega R_1 C_1}}$$

$$=> \frac{1 + j\omega R_4 C_4}{j\omega C_4} = \frac{R_2(1 + j\omega R_1 C_1)}{j\omega R_1 C_3}$$

$$=> \frac{1 + j\omega R_4 C_4}{C_4} = \frac{R_2(1 + j\omega R_1 C_1)}{R_1 C_3}$$

$$=> \frac{1}{C_4} + j\omega R_4 = \frac{R_2}{R_1 C_3} + \frac{j\omega C_1 R_2}{C_3}$$

By **comparing** the respective real and imaginary terms of above equation, we will get

$$C_4 = \frac{R_1 C_3}{R_2} \qquad \text{Equation 1}$$

$$R_4 = \frac{C_1 R_2}{C_3} \qquad \text{Equation 2}$$

By substituting the values of R_1, R_2 and C_3 in Equation 1, we will get the value of capacitor, C_4. Similarly, by substituting the values of R_2, C_1 and C_3 in Equation 2, we will get the value of resistor, R_4.

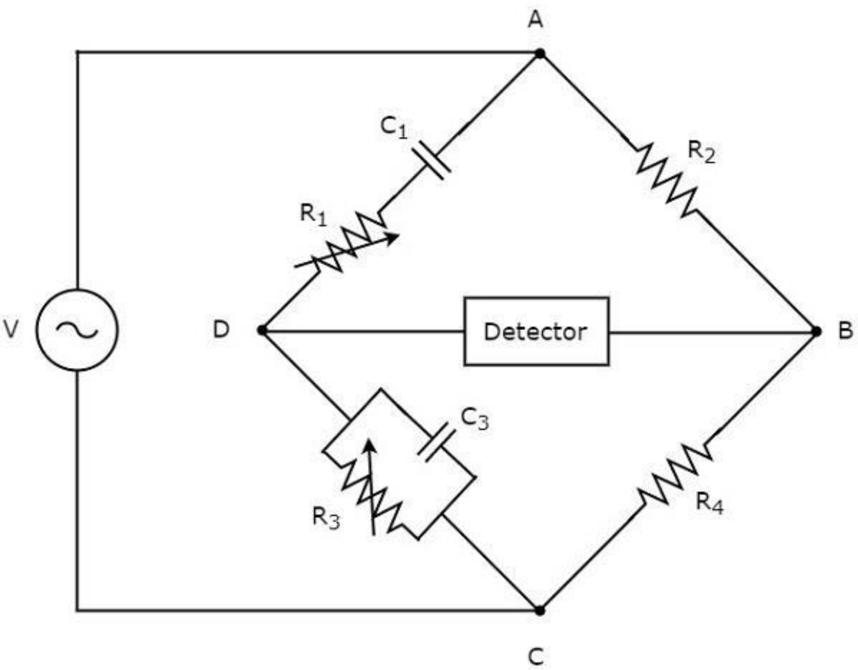
The **advantage** of Schering bridge is that both the values of resistor, R_4 and capacitor, C_4 are independent of the value of frequency.

Wien's Bridge

Wien's bridge is an AC bridge having four arms, which are connected in the form of a rhombus or square shape. Amongtwo arms consist of a single resistor, one arm consists of a parallel combination of resistor and capacitor & the other arm consists of a series combination of resistor and capacitor.

The AC detector and AC voltage source are also required in order to find the value of frequency. Hence, one of these two are placed in one diagonal of Wien's bridge and the other one is placed in other diagonal of Wien's bridge.

The **circuit diagram** of Wien's bridge is shown in the below figure.



In above circuit, the arms AB, BC, CD and DA together form a rhombus or **square shape**. The arms, AB and BC consist of resistors, R_2 and R_4 respectively. The arm, CD consists of a parallel combination of resistor, R_3 and capacitor, C_3. The arm, DA consists of a series combination of resistor, R_1 and capacitor, C_1.

Let, Z_1, Z_2, Z_3 and Z_4 are the impedances of arms DA, AB, CD and BC respectively. The **values of these impedances** will be

$$Z_1 = R_1 + \frac{1}{j\omega C_1}$$

$$=> Z_1 = \frac{1 + j\omega R_1 C_1}{j\omega C_1}$$

$$Z_2 = R_2$$

$$Z_3 = \frac{R_3\left(\frac{1}{j\omega C_3}\right)}{R_3 + \frac{1}{j\omega C_3}}$$

$$=> Z_3 = \frac{R_3}{1 + j\omega R_3 C_3}$$

$$Z_4 = R_4$$

Substitute these impedance values in the following balancing condition of AC bridge.

$$Z_1Z_4 = Z_2Z_3$$

$$\left(\frac{1+j\omega R_1C_1}{j\omega C_1}\right)R_4 = R_2\left(\frac{R_3}{1+j\omega R_3C_3}\right)$$

$$=> (1+j\omega R_1C_1)(1+j\omega R_3C_3)R_4 = j\omega C_1R_2R_3$$

$$=> (1+j\omega R_3C_3 + j\omega R_1C_1 - \omega^2R_1R_3C_1C_3)R_4 = j\omega C_1R_2R_3$$

$$=> R_4(1-\omega^2R_1R_3C_1C_3) + j\omega R_4(R_3C_3+R_1C_1) = j\omega C_1R_2R_3$$

Equate the respective **real terms** of above equation.

$$R_4(1-\omega^2R_1R_3C_1C_3) = 0$$

$$=> 1-\omega^2R_1R_3C_1C_3 = 0$$

$$=> 1 = \omega^2R_1R_3C_1C_3$$

$$=> \omega^2 = \frac{1}{R_1R_3C_1C_3}$$

$$=> \omega = \frac{1}{\sqrt{R_1R_3C_1C_3}}$$

Substitute, $\omega=2\pi f$ in above equation.

$$=> 2\pi f = \frac{1}{\sqrt{R_1R_3C_1C_3}}$$

$$=> f = \frac{1}{2\pi\sqrt{R_1R_3C_1C_3}}$$

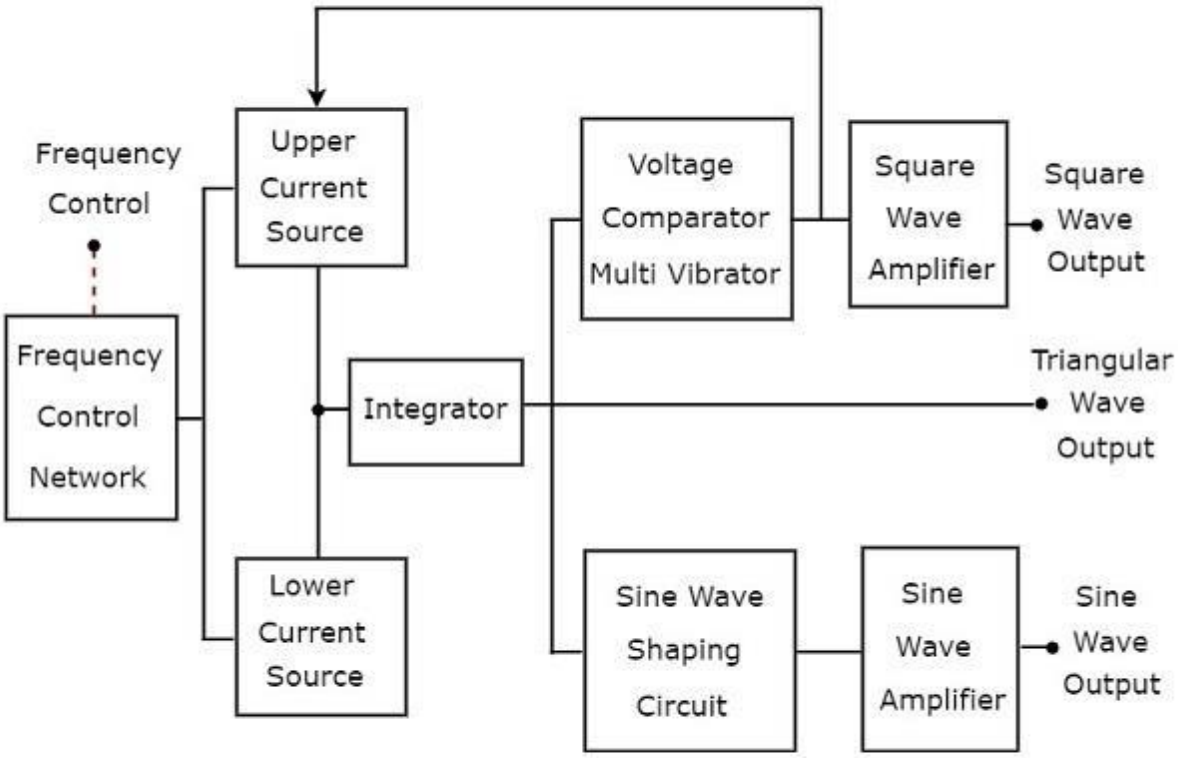
We can find the value of frequency, f of AC voltage source by substituting the values of R_1, R_3, C_1 and C_3 in above equation.
If $R_1=R_3=R$ and $C_1=C_3=C$, then we can find the value of frequency, f of AC voltage source by using the following formula.

$$f = \frac{1}{2\pi RC}$$

The Wein's bridge is mainly used for finding the **frequency value** of AF range.

Function Generator

Function generator is a signal generator, which generates three or more periodic waves. Consider the following block diagram of a Function generator, which will produce periodic waves like triangular wave, square wave and sine wave



There are two current sources, namely upper current source and lower current source in above block diagram. These two current sources are regulated by the frequency-controlled voltage.

Triangular Wave

Integrator present in the above block diagram, gets constant current alternately from upper and lower current sources for equal amount of time repeatedly. So, the integrator will produce two types of output for the same time repeatedly:

- The output voltage of an integrator **increases linearly** with respect to time for the period during which integrator gets current from upper current source.
- The output voltage of an integrator **decreases linearly** with respect to time for the period during which integrator gets current from lower current source.

In this way, the integrator present in above block diagram will produce a **triangular wave**.

Square Wave & Sine Wave

The output of integrator, i.e. the triangular wave is applied as an input to two other blocks as shown in above block diagram in order to get the square wave and sine wave respectively. Let us discuss about these two one by one.

Square Wave

The triangular wave has positive slope and negative slope alternately for equal amount of time repeatedly. So, the **voltage comparator multi vibrator** present in above block diagram will produce the following two types of output for equal amount of time repeatedly.

- One type of constant (**higher**) **voltage** at the output of voltage comparator multi vibrator for the period during which the voltage comparator multi vibrator gets the positive slope of the triangular wave.

- Another type of constant (**lower**) **voltage** at the output of voltage comparator multi vibrator for the period during which the voltage comparator multi vibrator gets the negative slope of the triangular wave.

The voltage comparator multi vibrator present in above block diagram will produce a **square wave**. If the amplitude of the square wave that is produced at the output of voltage comparator multi vibrator is not sufficient, then it can be amplified to the required value by using a square wave amplifier.

Sine Wave

The **sine wave shaping circuit** will produce a sine wave output from the triangular input wave. Basically, this circuit consists of a diode resistance network. If the amplitude of the sine wave produced at the output of sine wave shaping circuit is insufficient, then it can be amplified to the required value by using sine wave amplifier.

The electronic instrument used to analyze waves is called **wave analyzer**. It is also called signal analyzer, since the terms signal and wave can be interchangeably used frequently.

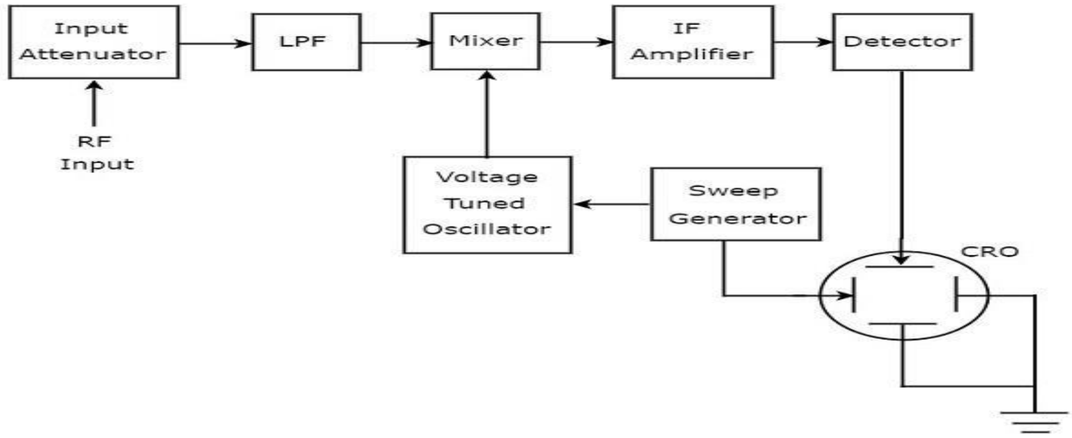
We can represent the **periodic signal** as sum of the following two terms.

- DC component
- Series of sinusoidal harmonics

So, analyzation of a periodic signal is analyzation of the harmonics components presents in it.

SPECTRUM ANALYZER.

The electronic instrument, used for analyzing waves in frequency domain is called spectrum analyzer. Basically, it displays the energy distribution of a signal on its CRT screen. Here, x-axis represents frequency and y-axis represents the amplitude.



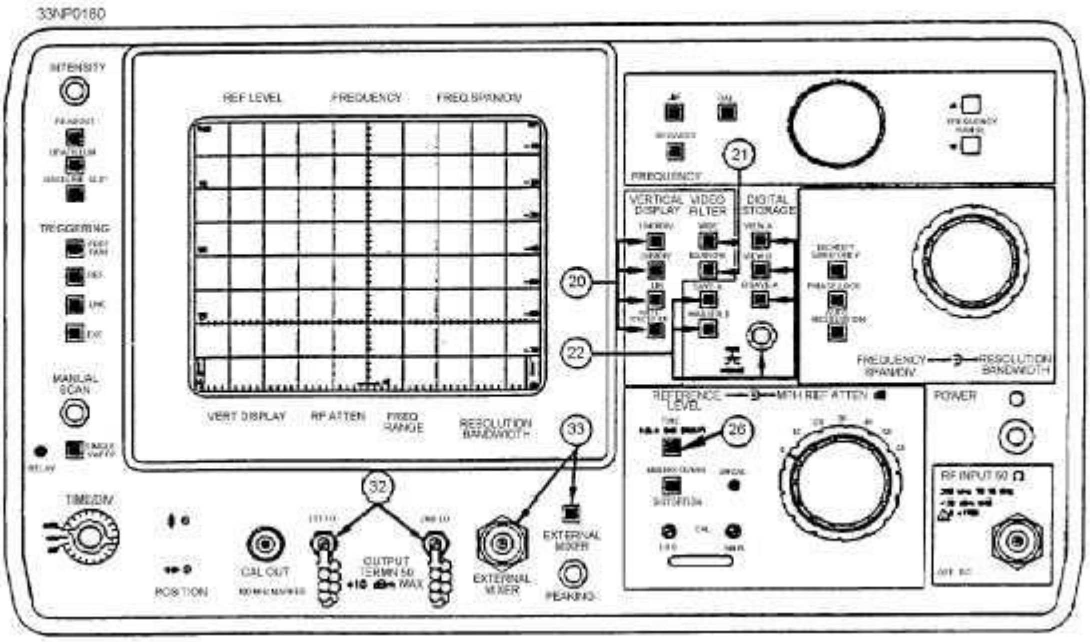
The working of spectrum analyzer is mentioned below.

- The RF signal, which is to be analyzed is applied to input attenuator. If the signal amplitude is too large, then it can be attenuated by an input attenuator.
- Low Pass Filter (LPF) allows only the frequency components that are less than the cut-off frequency.
- Mixer gets the inputs from Low pass filter and voltage tuned oscillator. It produces an output, which is the difference of frequencies of the two signals that are applied to it.
- IF amplifier amplifies the Intermediate Frequency (IF) signal, i.e. the output of mixer. The amplified IF signal is applied to detector.
- The output of detector is given to vertical deflection plate of CRO. So, CRO displays the frequency spectrum of RF signal on its CRT screen.

So, we can choose a particular spectrum analyzer based on the frequency range of the signal that is to be analyzed.

SPECTRUM ANALYZER APPLICATIONS

Figure shows a typical spectrum analyzer. The previously mentioned measurement capabilitiescan be seen with a spectrum analyzer. However, you will find that the spectrum analyzer generally is usedto measure spectral purity of multiplex signals, percentage of modulation of AM signals, and modulationcharacteristics of fm and pulse-modulated signals. The spectrum analyzer is also used to interpret thedisplayed spectra of pulsed rf emitted from a radar transmitter.

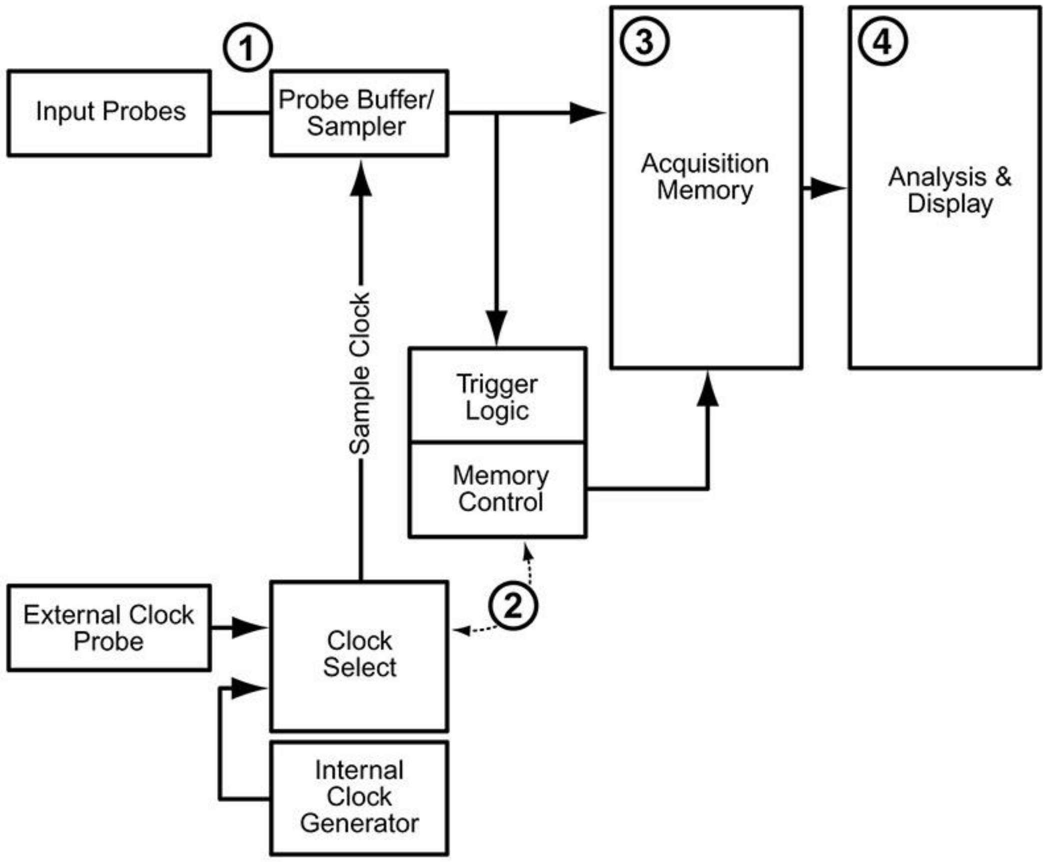


COMPLEX WAVE FORMS
Complex waveforms are divided into two groups, periodic waves and non periodic waves. Periodic waves contain the fundamental frequency and its related harmonics. Non periodic waves contain a continuous band of frequencies resulting from the repetition period of the fundamental frequency approaching infinity and thereby creating a continuous frequency spectrum.

MODULATION MEASUREMENTS
In all types of modulation, the carrier is varied in proportion to the instantaneous variations of the modulating waveform. The two basic properties of the carrier available for modulation are the amplitude characteristic and angular (frequency or phase) characteristic. Amplitude Modulation The modulation energy in an amplitude-modulated wave is contained entirely within the sidebands. Amplitude modulation of a sinusoidal carrier by another sine wave would be displayed as shown in figure5-14. For 100% modulation, the total sideband power would be one-half of the carrier power; therefore,

LOGIC ANALYSER
Logic analysers are one of the less common pieces of test and measuring equipment, but they’re extremely useful in many different ways.
Simply put, a logic analyser does exactly what its name implies. It’s designed to read the high speed 1’s and 0’s which make up every digital signal, and tell you what they mean.
Logic analysers generally fall into two different categories: self-contained units which have a display and miniature computer on board and process all of the data within themselves, or

those that connect via USB to a host computer. The self-contained units are generally much larger and more expensive than the USB logic analysers, however both can be equally useful. Logic analysers have a variety of functions and features depending on the model, however the two features which almost every analyser should have is the ability to capture and visualise the data, and to interpret various communication protocols such as SPI, I2C, USB etc. and tell you what data type is being transferred and decode each byte.



LOGIC ANALYZER APPLICATION

This logic analyzer application is my second custom program for the DSO Quad. The device has buffer space for 4096 samples by default, which is enough for analog work but somewhat limiting with digital signals. Furthermore, the default firmware makes browsing cumbersome by not letting you change the timebase when the capture is paused.
This program only stores the transitions: if there is no traffic on the wires, no buffer space is consumed. About 20 kB of RAM is allocated for the buffer, which equals 10 to 20 thousand events. For example, this is plenty for 2 kB of data traffic on an RS232 line.
Long idle periods are collapsed on screen.
I have tried to make navigating the signal as easy as possible. The two navigation switches are dedicated to zooming and scrolling, and both of these work quite fast. Only at the smallest zoom levels the scrolling will slow down, as redrawing the whole signal takes time. I intend to improve the performance in the future by adding some caching of the intermediate values.

Q Meter

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.rlc-circuit

At resonant frequency f_0, $X_C = X_L$ The value of capacitance reactance is $X_C = \frac{1}{2}\pi f_0 C = \frac{1}{\omega_0 C}$ At inductive reactance, $X_L = \frac{1}{2}\pi f_0 L = \frac{1}{\omega_0 L}$

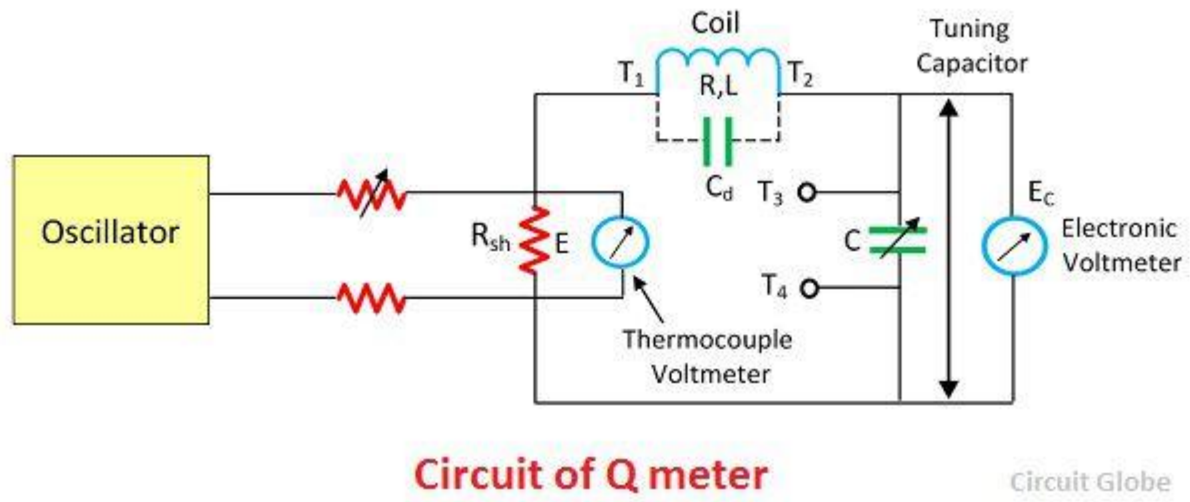
At the resonant frequency, $f_0 = \frac{1}{2\pi\sqrt{LC}}$ and current at resonance becomes $I_0 = \frac{E}{R}$

The voltage across the capacitor is expressed as $E_C = I_0 X_C = I_0 X_L = I_0 \omega_0 L$ Input voltage $E = I_0 r$ $\frac{E_C}{E} = \frac{I_0 \omega_0 L}{I_0 R} = \frac{\omega_0 L}{R} = Q$ $E_0 = QE$ 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.

Applications of the Q-meter

The following are the applications of the Q-meter.

1. Measurement of Q – The circuit used for measurement of Q is shown in the figure.



The oscillator and tuning capacitor adjust to the desired frequency for obtaining the maximum value of E_0. Under this condition, the value of the quality factor is expressed as

$$Q_{max} = \frac{\omega_0 L}{R}$$

$$Q_{max} = \frac{\omega_0 L}{R}$$ True value is given as $$Q_{true} = Q_{meas}\left(1 + \frac{R_{sh}}{R}\right)$$ The value of the quality factor is obtained by the voltmeter which is connected across the capacitor. The measured value is the Q factor of the whole circuit and not only of the coil. Thus, errors occur in the reading because of the shunt resistance and distributed capacitance.

$$Q_{true} = Q_{meas}\left(1 + \frac{C_d}{C}\right)$$ The above equations show that the measured value of the Q is smaller than the true value.

Circuit Globe Electrical Measurement Q Meter

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**.

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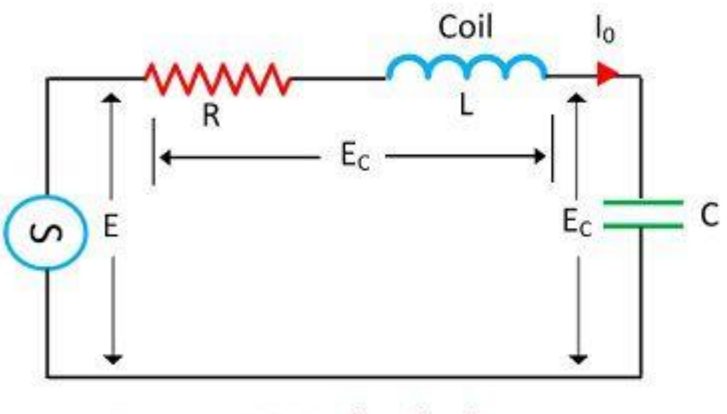

Resonant RLC Series Circuit

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At resonant frequency f_0, $X_C = X_L$

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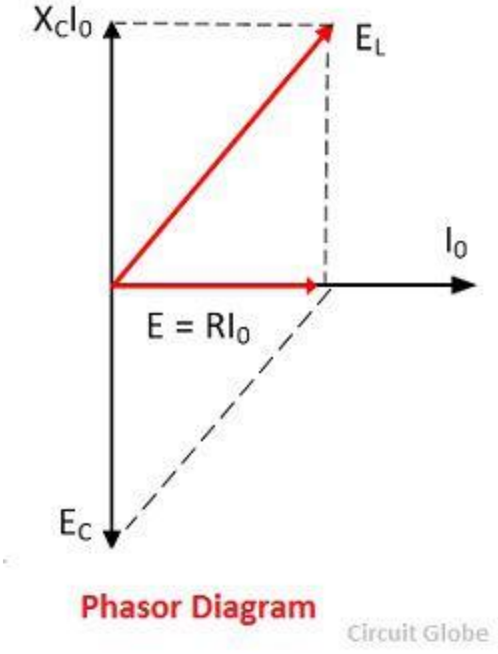
At inductive reactance, $X_L = \frac{1}{2}\pi f_0 L = \frac{1}{\omega_0 L}$

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



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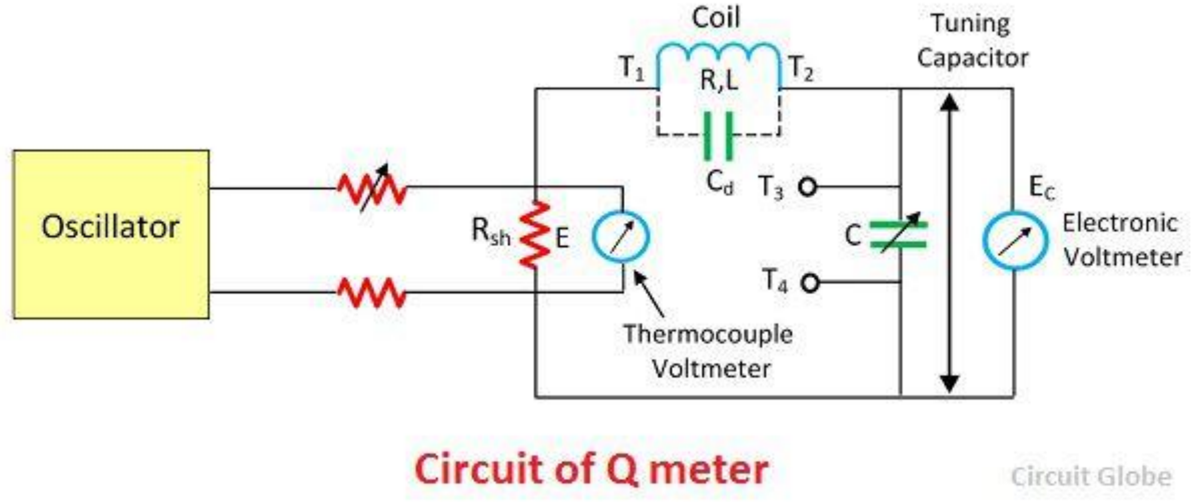

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$$Q_{true} = Q_{meas}\left(1 + \frac{C_d}{C}\right)$$

capacitance.

The above equations show that the measured value of the Q is smaller than the true value.

Measurement of Inductance – The inductance is measured by the equation shown below.

$$L = {}^{1}\!/_{4\pi^2 f_0^2 C}$$

The value of f_0 & C is required for calculating the value of inductance.

Measurement of Effective resistance – The equation computes the value of effective resistance

$$R = \frac{\omega_0 L}{Q_{true}}$$

5. **Measurement of Self-Capacitance –** The self-capacitance is determined by measuring the two capacitance at different frequencies. The capacitor is adjusted to the high value, and the circuit is resonated by adjusting the oscillator frequency. The resonance of the Circuit is determined by the Q meter

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1 + C_d)}}$$

Thus

$$f_2 = \frac{1}{2\pi\sqrt{L(C_2 + C_d)}}$$

$$f_2 = 2f_1$$

$$\frac{1}{2\pi\sqrt{L(C_2 + C_d)}} = 2 \times \frac{1}{2\pi\sqrt{L(C_1 + C_d)}}$$

or distributed capacitance

$$C_d = \frac{C_1 - 4C_2}{3}$$

5. **Measurement of Bandwidth – T**he equation below calculates the bandwidth

$$Q_{max} = \frac{\omega_0 L}{R}$$

6. **Measurement of Capacitance –** The capacitance is determined by connecting the dummy coil across the terminal T_1 and T_2. Let the capacitor under test is connected across the terminal T_3 and T_4. The circuit is again resonated by varying the value of tuning capacitor C_2. The value of testing capacitance is determined by subtracting the C_1 and C_2.

MODULE IV
DATA RECORDERS AND DAS

DATA RECORDERS

Data recorders are electronic devices which record data due to built-in or external sensors. A record is a hard copy of information. We find many types of information to be recorded. The information can be broadly termed as data. Therefore we need data recorders. Even in the real world that does not relate to electronics, we maintain data records. The simple example of a data recorder is the attendance register of students in a class. The subject teacher records the attendance of the students for every period. Thus over months and finally over the end of the academic year this attendance data shows the attendance of the students, from which the eligibility of the student will be judged for presenting the student to the annual examination.

Galvanometric Recorders

These recorders operate on the "deflection principle" that is, when current passes through the coil of the galvanometer, it shows deflection (θ). The deflection 'θ' is a measure of current passing through it. This current is proportional to the quality' being measured.
Construction:

A coil of the wire is wounded on a rectangular aluminium frame. It is mounted in the air space between the poles of a permanent magnet as shown in figure. In these recorders, the writing arm is a pen or an 'ink filled stylus', which is attached to the coil.

Hardened steel pivots attached to the coil fit into jewelled bearings so that the coil rotates with a minimum of friction. Springs attached to the coil frame return the pen and coil always to a fixed reference point. The drive motor consists of a synchronous motor and a gear box, to move the paper or chart with a constant speed. A constant speed is the basic requirement of the 'drive motor' because the recorded events are time correlated.

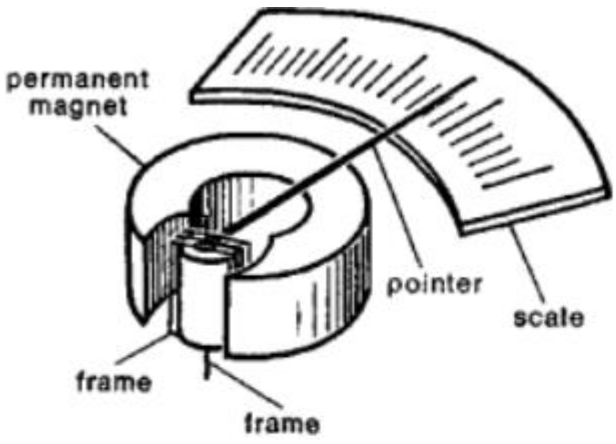
Working:

When current flows through the coil, a magnetic field is developed. This magnetic field interacts with the magnetic field of the permanent magnet. It causes the coil to deflect or to change its angular position. The direction of the rotation depends upon the direction of flow of current in the coil. The better the amplitude of the incoming signal, the better is the deflection that is, the scale of pen deflection is proportional to the current runs through the coil. When the coil deflects, the pen presses against the paper and writes on it.

In the pen type of galvanometer recorder the wiring may be done with ink flowing through the pen. The method is very simple but has the following disadvantages.

(i) the recording is curved, (curvilinear) which is difficult to study.
(ii) the ink tends to dry up inside the pen.

In the new types of recorders, these two disadvantages are eliminated by using 'heated stylus' instead of ink pen. The paper used with such a recorder has a special coating which turns black at points where a heated stylus touches the paper with the heated stylus recorder, rectilinear recording is obtained and there is problem of ink clogging.



Advantages or uses of galvanometric recorders:

(a) These recorders are generally used in clinical laboratories, because of their low cost.
(b) They will give the permanent record of the quantity being measured.

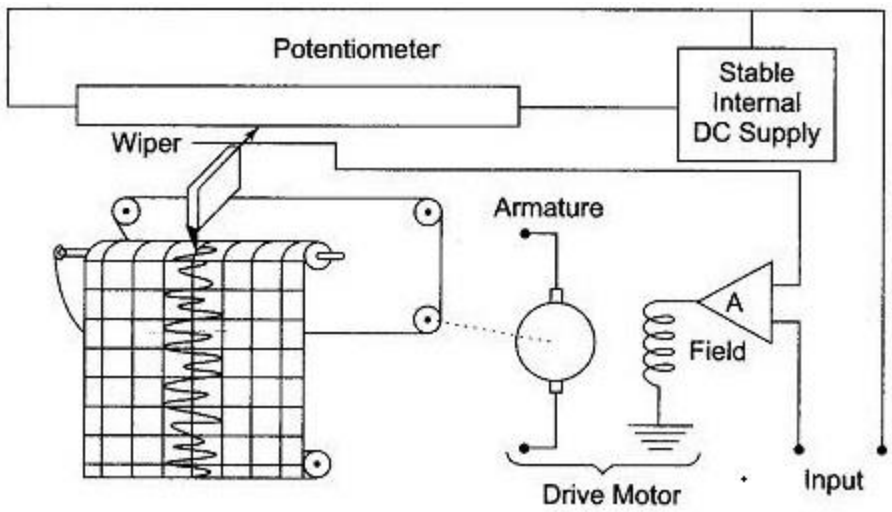
Disadvantages of galvanometric recorders:

(a) Frequency response is very low. The overall frequency response of these recorders is limited to 0-45 Hz.
(b) These recorders are not useful for recording fast variations (current or voltage or power), because, the moving parts of the galvanometer have more weight and large moment of inertia and friction of the writing arm over paper. They introduce a damping effect. Hence, the galvanometer can not move very fast.
(c) Since the pen of the galvanometer passes against the paper there are frictional forces opposing the movement of the pen. In addition, the pen together with the galvanometer coil has considerable inertia. As a result considerable torque is required to move the pen. Therefore, the current through the galvanometer coil must be high.
(d) It has low input impedance and a limited sensitivity.

Potentiometric Recorder

The disadvantage of the galvanometer recorder can be eliminated by using an amplifier between the test terminals and the moving coil meter. However this reduces the accuracy of the record. In a potentiometric recorder the accuracy is improved by a process of comparison of input signal with a reference voltage. The reference voltage will be supplied from an internal source of the recorder itself. When the input signal is given it is applied in series with the reference signal such that the difference of the input signal and the reference signal will produce an error. If the input is lower than the reference voltage the error can be taken as negative. If the input is more than the reference voltage the error can be taken as positive. Only in one condition when the input equals the reference voltage the error will be zero.

The error signal will be given to the amplifier. The amplifier output will control a motor. The speed and direction of rotation of the motor depend on the output of the amplifier which is the error signal. Self balance is obtained by sliding the slider of the potentiometer to get a null output. Reversible motors are used in the D.C. system. In A.C. system a two phase motor is used.



he self balancing type recorder is also called the potentiometric recorder. T he constructional details are shown in figure. From the block diagram shown, it can be seen that the input signal is applied to the amplifier in series with the part of the potentiometer. The potentiometer is supplied with a reference voltage derived from an internal power supply. The output of the internal power supply is made stable.

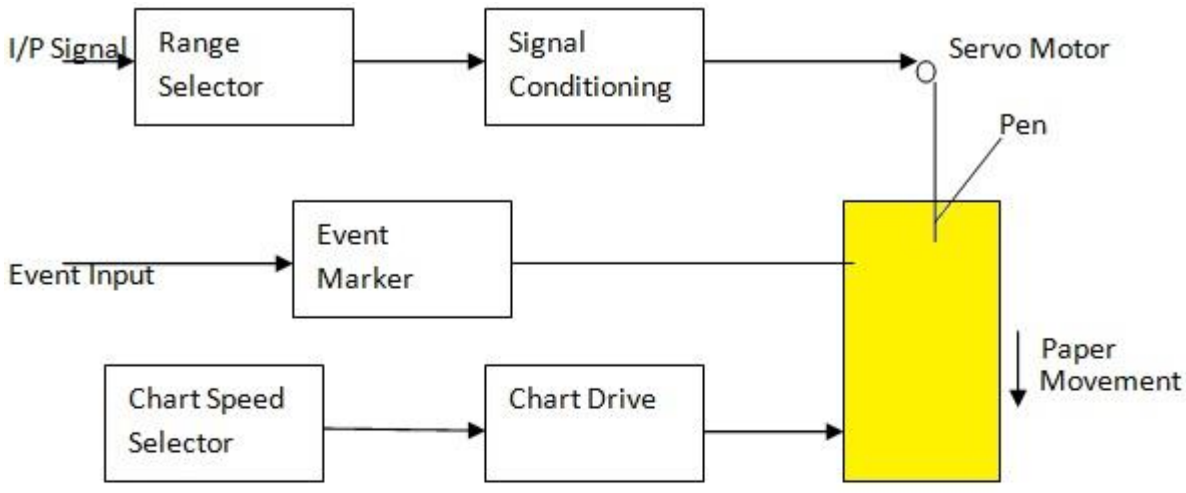
The field coil of the motor is energized by the output of the amplifier. The output of the amplifier is the error signal. The variable arm/slider/wiper of the potentiometer is connected to the armature of the motor. The wiper carries a pen. The paper feed mechanism moves the paper with a constant speed.

(b) Potentiometric Recorder Working:

It can be seen from the block diagram that the input signal and the part of the voltage across the potentiometer are in series. The difference between these voltages is the error signal. This error signal is available at the input terminals of the amplifier. The field coil of the motor is connected to the output of the amplifier. The construction of the motor is such that, it turns in a direction that rotates the wiper of the potentiometer to reduce the error The balance is obtained by the current through the armature of the motor flowing in one direction or the other depending on whether the input is higher or lower than the reference voltage. When the error reduces to zero the motor slows down and stops. At the instant of zero error the motor stops giving null balance.

As- the wiper of the potentiometer is driven by the motor's armature and as a pen is arranged over the wiper, the pen executes motion in the direction of movement of the wiper. As the armature moves in either direction depending on the error the pen moving in synchronized direction records the waveform. The paper feed motor will be synchronized with power line frequency. Capillary action of a recorder is defined as the process of establishing flow of ink from the reservoir through the tubing and into the hallow of the pen.

Strip Chart Recorder
The block diagram of a strip chart recorder is shown in Figure. The data will be recorded on a roll of chart paper. The paper continuously moves at a constant speed.



Strip Chart Recorder with Block Diagram

The block diagram of a strip chart recorder is shown in Figure. The data will be recorded on a roll of chart paper. The paper continuously moves at a constant speed.

block diagram of strip chart recorder

The basic components of a strip chart recorder are:

1. Stylus [pen]: to mark on the paper
2. The stylus driving system
3. Chart paper drive system
4. Chart paper speed selector.

Generally a pointer will be attached to the stylus. This permits measurement of instantaneous value of the quantity under measurement directly on a calibrated scale.

A servo feedback system will be used to see that the displacement of the pen over the paper tracks the input voltage in the desired frequency range.

Commonly potentiometer system will be used to measure the position of the stylus. The uniform movement of the chart paper will be controlled by a stepper motor. The following data recording techniques are used:

1. Pen and Ink stylus
2. Impact printing
3. Thermal writing
4. Electric writing
5. Optical writing

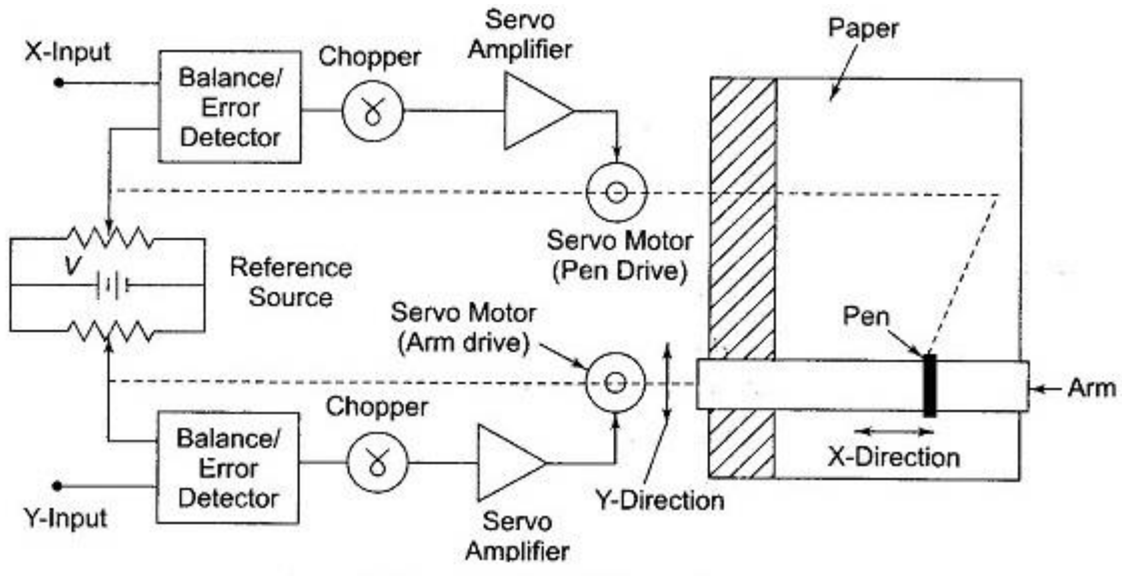
XY Recorder

An XY recorder plots the instantaneous relation between two variables. The writing pen will be deflected in both X direction and Y direction on a stationary chart paper. Depending on the desired application one or more write pens are used.

XY recorders are also employed using proper transducers for recording of physical quantities as function of other physical quantities. The motion of the pen in X and Y directions is obtained by servomotors. A sliding pen and moving arm arrangement is used with X-Y recorders.

Block Diagram of an X-Y Recorder:

The block diagram is shown in Figure. From the block diagram we find that the X input and Y input are supplied to the error detector in series with the standard reference voltage offered by the internal reference source.



The output of the error detector is given to a chopper. The servo amplifier is driven by the chopper. The amplifiers output drives the pen. The Y amplifier's output drives the arm. Square shaped graph paper will be used. It is fixed over a pad by electrostatic attraction or by vacuum.

Working:

The input signals are attenuated to around 0.5 mV which is withir the dynamic range of the recorder. Both X and Y signals are compared with the internal reference source. This is done in the balancing or Error detector block. The X and Y channel error output will be the DC error, which is the difference between the input signals and the reference voltage.
The DC error signal of both channels is used in the choppers to convert it in to an AC signal. The magnitude of the AC output of the choppers is insufficient to drive the motors of the pen and the arm. Therefore the output of the two choppers will be amplified in the servo amplifiers. The servomotors drive the pen and the arm. The pen and the arm execute motion in proper direction to reduce the error. The movement of the pen and arm is to bring the system to balance. The variation of X and Y signals, move the pen and the arm in the appropriate directions to keep the system in balance. This movement produces a record of the signal components on the paper. It is to be remembered that the both X and Y channels and the total system works simultaneously.

Advantages of Digital Recorders:

The following are the advantages of digital recorders

1. Number of input channels can be provided for sampling and storage simultaneously.
2. Number of desired trigger modes can be incorporated.

3. They have the provision to display pre-trigger data.
4. Multi-pen Multi Ink plotting is possible.
5. Analysis of records with respect to data, time and setup condition is possible.
6. They will be able to draw grids and axis.
7. Communication interface facility with other digital equipment is possible.
8. Desired specifications and functions are obtainable by the use of specially programmed software packages.

(f) Applications:

X-Y recorders are used in recording:

1. The speed torque characteristics of motors.
2. Regulation characteristics of power supply
3. Characteristics of electronic devices like transistors and diodes etc.
4. Hysteresis curves, stress-strain characteristics.
5. Electrical characteristics of material. Ex: Resistance versus temperature.

Functional elements of an instruments:

Any instrument or a measuring system can be described in general with the help of a block diagram. While describing the general form of a measuring system, it is not necessary to go into the details of the physical aspects of a specific instrument. The block diagram indicates the necessary elements and their functions in a general measuring system. The entire operation of an instrument can be studied in terms of these functional elements. The Fig. shows the block

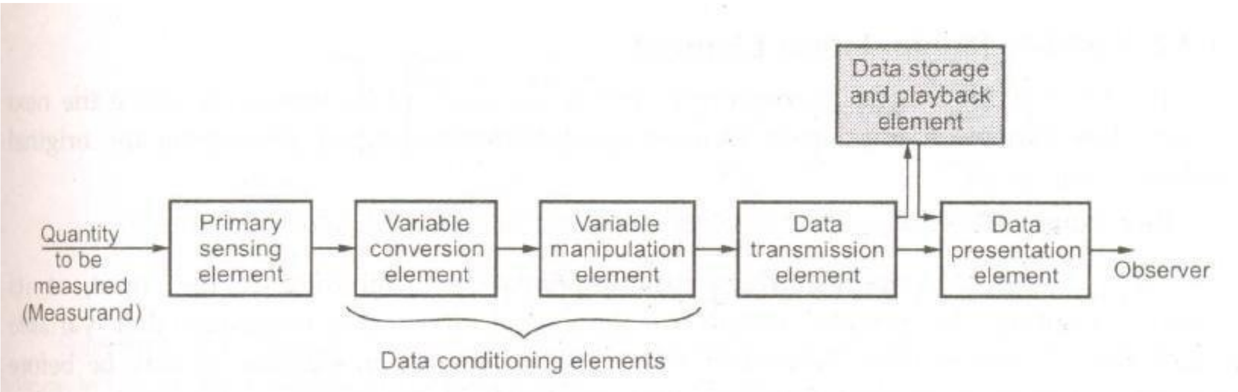


diagram instrument can be studied interms of these functional elements.

Primary sensing element

The primary sensing element is also known as sensor. Basically transducers are used as a primary sensing element. Here, the physical quantity (such as temperature, pressure etc.) are sensed and then converted into analogues signal.

Variable conversion element

It converts the output of primary sensing element into suitable form without changing information. Basically these are secondary transducers.

Variable manipulation element

The output of transducer may be electrical signal i.e. voltage, current or other electrical parameter. Here, manipulation means change in numerical value of signal. This element is used to convert the signal into suitable range.

Data transmission element

Sometimes it is not possible to give direct read out of the quality at a particular place (Example – Measurement of temperature in the furnace). In such a case, the data should transfer from one place to another place through channel which is known as data

transmission element. Typically transmission path are pneumatic pipe, electrical cable and radio links. When radio link is used, the electronic instrumentation system is called as telemetry system.
Data presentation or controlling element
Finally the output is recorded or given to the controller to perform action. It performs different functions like indicating, recording or controlling.

DIFFERENTIATE BETWEEN OPEN LOOP AND CLOSE LOOP CONTROL SYSTEM

Sr. no	Point of Difference	Closed loop control system	Open loop control system
1	**Definition**	Change in output affects input	No change in input with change in output
2	**Feedback loop**	Present	Not Present
3	**Error Correction**	Possible	Not possible
4	**Accuracy**	Very accurate	Inaccurate
5	**Bandwidth**	Large	Small
6	**Stability**	Stability should be considered during designing	Stable
7	**Construction**	Complex	Simple
8	**Sensitivity to noise**	Less sensitive	Highly sensitive
9	**Effect of non linearities**	Effect is reduced	Highly affected
10	**Block Diagram**		
11	**Examples**	Missile launching system, Voltage stabilizer	Water sprinkler, Traffic light controller.

DATA ACQUISITION SYSTEMS

The systems, used for data acquisition are known as **data acquisition systems**. These data acquisition systems will perform the tasks such as conversion of data, storage of data, transmission of data and processing of data.
Data acquisition systems consider the following **analog signals**.

- Analog signals, which are obtained from the direct measurement of electrical quantities such as DC & AC voltages, DC & AC currents, resistance and etc.

- Analog signals, which are obtained from transducers such as LVDT, Thermocouple & etc.

Types of Data Acquisition Systems
Data acquisition systems can be classified into the following **two types**.

- Analog Data Acquisition Systems
- Digital Data Acquisition Systems

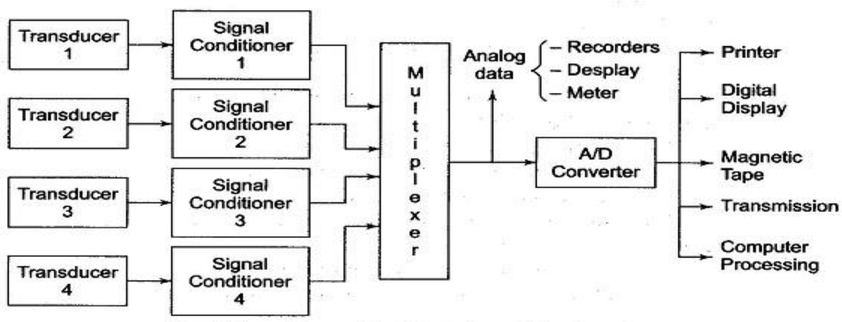


Fig. 17.1 Generalised Data Acquisition System

Analog Data Acquisition Systems
The data acquisition systems, which can be operated with analog signals are known as **analog data acquisition systems**. Following are the blocks of analog data acquisition systems.

- **Transducer:** It converts physical quantities into electrical signals.
- **Signal conditioner:** It performs the functions like amplification and selection of desired portion of the signal.
- **Display device:** It displays the input signals for monitoring purpose.
- **Graphic recording instruments:** These can be used to make the record of input data permanently.
- **Magnetic tape instrumentation:** It is used for acquiring, storing & reproducing of input data.

Digital Data Acquisition Systems
The data acquisition systems, which can be operated with digital signals are known as **digital data acquisition systems**. So, they use digital components for storing or displaying the information
Mainly, the following **operations** take place in digital data acquisition.

- Acquisition of analog signals
- Conversion of analog signals into digital signals or digital data
- Processing of digital signals or digital data

Following are the blocks of **Digital data acquisition systems**.

- **Transducer:** It converts physical quantities into electrical signals.

- **Signal conditioner:** It performs the functions like amplification and selection of desired portion of the signal.

- **Multiplexer:** It connects one of the multiple inputs to output. So, it acts as parallel to serial converter.

Analog to Digital Converter: It converts the analog input into its equivalent digital output.

- **Display device:** It displays the data in digital format.
- **Digital Recorder:** It is used to record the data in digital format

Data acquisition systems are being used in various applications such as biomedical and aerospace. So, we can choose either analog data acquisition systems or digital data acquisition systems based on the requirement

ROLE OF TELEMETRY IN INSTRUMENTATION SYSTEM

Telemetry is an automated communications process, which is usually associated with SCADA systems. The word is derived from Greek roots: tele = remote, and metron = measure. Telemetry is defined as the sensing and measuring of information at some remote location and then transmitting that information to a central or host location. There, it can be monitored and used to control a process at the remote site. The information can be measurements, such as voltage, speed or flow. These data are transmitted to another location through a mediumsuch as cable, telephone or radio. Information may come from multiple locations. A way of addressing these different sites is incorporated in the system. Although the term commonly refers to wireless data transfer mechanisms (e.g., using radio, ultrasonic, or infrared systems), it also encompasses data transferred over other media such as a telephone or computer network, optical link or other wired communications like power line carriers. Many modern telemetry systems take advantage of the low cost and ubiquity of GSM networks by using SMS to receive and transmit telemetry data.

A telemeter is a device used to remotely measure any quantity. It consists of a sensor, a transmission path, and a display, recording, or control device. Telemeters are the physical devices used in telemetry. Electronic devices are widely used in telemetry and can be wireless or hard-wired, analog or digital. Other technologies are also possible, such as mechanical, hydraulic and optical..