ELECTRONICS MEASUREMENT AND INSTRUMENTATION

Unit-1: Qualities of Measurement

1.1 Discuss the Static Characteristics,.

These are those characteristics of an instrument which do not vary with time and are generally considered to check if the given instrument is fit to be used for measurement. The static characteristics are from one form or another by the process called Callibration.

1.2 1.2 Accuracy, sensitivity, reproducibility & static error of instruments

1. **ACCURACY**- It is defined as the ability of a device or a system to respond to a true value of a measure variable under condition

   The degree of exactness (closeness) of a measurement compared to the expected (desired) value.

2. **Sensitivity :** Sensitivity can be defined as a ratio of a change output to the change input at steady state condition.
3. **REPRODUCIBILITY** - Reproducibility of an instrument is the closeness of the output for the same value of input. Perfect reproducibility means that the instrument has no drift
4. **Error :** The deviation of the true value from the desired value.

1.3 Dynamic characteristics& speed of instruments

The Dynamic Characteristics are those which change within a period of time that is generally very short in nature

1. **SPEED OF RESPONSE**-It is the rapidity with which an instrument responds to the changes to in the measurement quantity

1-4 Errors of an instrument & explain various types.

The deviation or change of the value obtained from measurement from the desired standard value.

1-4 Errors of an instrument & explain various types.:

The static error of a measuring instrument is the numerical difference between the true value of a quantity and its value as obtained by measurement

Types of Static Errors are categorized as

1. gross errors or **human errors**,
2. **systematic errors**,
3. **random errors**.

1. **Gross errors or** human errors**,**

- These errors are mainly due to human mistakes in reading or in using instruments or errors in recording observations.
- Errors may also occur due to incorrect adjustment of instruments and computational mistakes.
- The complete elimination of gross errors is not possible, but one can minimize them

2. **Systematic errors:**

- In these types of static error occur due to shortcomings of the instrument, such as defective or worn parts, or ageing or effects of the environment on the instrument.
- A constant uniform deviation of the operation of an instrument is known as a systematic error. There are basically three types of systematic errors
  - **Instrumental,**
  - **Environmental, and**
  - **Observational.**

Instrumental:

Instrumental errors are inherent in measuring instruments, because of their mechanical structure.

For example, in the D'Arsonval movement, friction in the bearings of various moving components, irregular spring tensions, stretching of the spring, or reduction in tension due to improper handling or overloading of the instrument.

1. **selecting a suitable instrument for the particular measurement applications.**
2. **applying correction factors after determining the amount of instrumental error.**
3. **calibrating the instrument against a standard.**

Environmental Errors:

Environmental errors are due to conditions external to the measuring device, including conditions in the area surrounding the instrument, such as the effects of change in temperature, humidity, barometric pressure or of magnetic

1. air conditioning,
2. hermetically sealing certain components in the instruments, and
3. using magnetic shields.

Observational Errors:

Observational errors are errors introduced by the observer. The most common error is the parallax error introduced in reading a meter scale, and the error of estimation when obtaining a reading from a meter scale.
These errors are caused by the habits of individual observers.

Random Errors:
These are errors that remain after gross and systematic errors have been substantially reduced or at least accounted for.
These errors are due to unknown causes, not determinable in the ordinary process of making measurements.

Sources of Error:

The sources of error, other than the inability of a piece of hardware to provide a true measurement, are as follows:

1. Insufficient knowledge of process parameters and design conditions
2. Poor design
3. Change in process parameters, irregularities, upsets, etc.
4. Poor maintenance
5. Errors caused by person operating the instrument or equipment 6. Certain design limitations

Unit-2: Indicating Instruments

2.1 Introduction to Indicator

_The measuring instruments which indicate the magnitude of the electrical quantity at the time when the quantity is being measured are known as **indicating instruments**.

A typical indicating instrument consists of a pointer which moves on a calibrated scale to show the reading of the measured quantity.

The examples of indicating instruments include ammeters, voltmeters, power factor meters, etc.

Display devices & its types

Display devices provide a visual display of numbers, letters, and symbols in response to electrical input is known as display system.

Commonly used displays in the digital electronics field are:

- . Cathode Ray Tube (CRT)
- Liquid Crystal Display (LCD)
- Light Emitting Diode (LED)

2.2 Basic principle of meter movement, permanent magnetic moving coil movement & its advantages & disadvantages

Basic principle of meter movement

- The action of the most commonly dc meter is based on the fundamental principle of the motor
- The motor action is produced by the flow of a small current through a moving coil, which is positioned in the field of a permanent magnet.
- This basic moving coil system is often called the D′ Arsonval galvanometer.

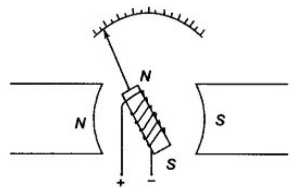


Fig. 2.1 D'Arsonval Principle

- The D Arsonval movement shown in Fig. 2.1 employs a spring-loaded coil through which the measured current flows.
- The coil (rotor) is in a nearly homogeneous field of a permanent magnet (*a magnetic field with parallel lines of force and equal strength throughout*)and moves in a rotary fashion
- The amount of rotation is proportional to the amount of current flowing through the coil.
- A pointer attached to the coil indicates the position of the coil on a scale calibrated in terms of current or voltage.
- It responds to dc current only, and has an almost linear calibration. The magnetic shunt that varies the field strength is used for calibration.

permanent magnetic moving coil movement & its advantages & disadvantages

- Permanent Magnet Moving Coil Instrument (PMMC) have a coil suspended in the magnetic field of a permanent magnet in the shape of a horse-shoe
- The coil is suspended so that it can rotate freely in the magnetic field.
- When current flows in the coil, the developed (electromagnetic) torque causes the coil to rotate.
- The electromagnetic (EM) torque is counterbalanced by a mechanical torque of control springs attached to the movable coil.
- The balance of torques, and therefore the angular position of the movable coil is indicated by a pointer against a fixed reference called a scale. The equation for the developed torque of PMMC,
- erived from the basic law for electromagnetic torque is

$$\tau = B \times A \times I \times N$$

Where

- τ = torque, Newton-meter

- B = flux density in the air gap, Wb/m^2
- A = effective coil area (m^2)
- N = number of turns of wire of the coil
- I = current in the movable coil (amperes)
  - The PMMC equation shows that the developed torque is proportional to the flux density of the field in which the coil rotates, the current coil constants (area and number of turns). Since both flux density and coil constants are fixed for a given instrument, the developed torque is a direct indication of the current in the coil. The pointer deflection can therefore be used to measure current.

Advantages of PMMC Instrument:

1. They can be modified with the help of shunts and resistance to cover a wide range of currents and voltages.
2. They display no hysteresis.
3. Since operating fields of such instruments are very strong, they are not significantly affected by stray magnetic fields.

Disadvantages of PMMC Instrument:

1. Some errors may set in due to ageing of control springs and the permanent magnet.
2. Friction due to jewel-pivot suspension.

2.3 Operation of Moving Iron Instrument

- Moving Iron Instrument can be classified into attraction and repulsion types. Repulsion type instruments are the most commonly used.
- The movement consists of a stationary coil of many turns which carries the current to be measured.
- Two iron vanes are placed inside the coil. One vane is rigidly attached to the coil frame, while the other is connected to the instrument shaft which rotates freely.
- The current through the coil magnetises both the vanes with the same polarity, regardless of the instantaneous direction of current. The two magnetised vanes experience a repelling force, and since

only one vane can move, its displacement is an indicator of the magnitude of the coil current.

- The repelling force is proportional to the current squared, but the effects of frequency and hysteresis tend to produce a pointer deflection that is not linear and that does not have a perfect square law relationship.

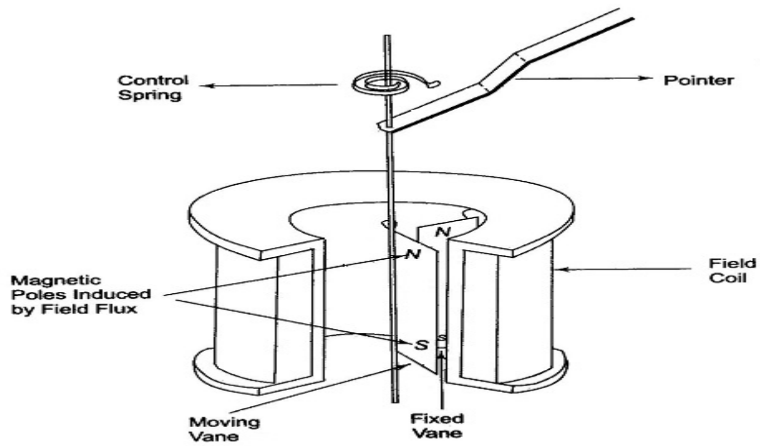


Fig. 2.8 Repulsion Type AC Meter (Radial Vane Type)

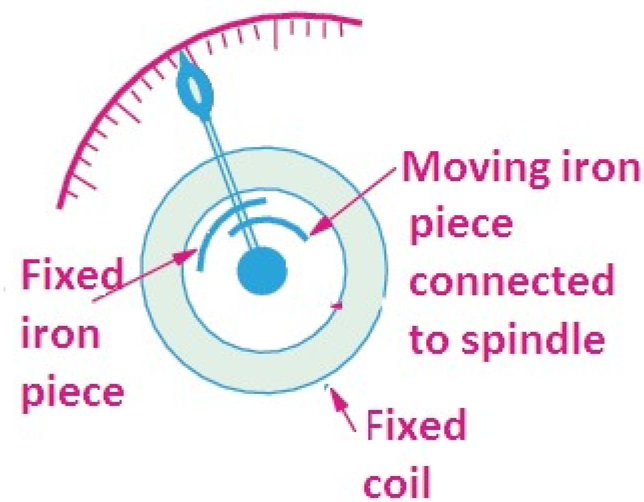
Figure 2.8 shows a radial vane repulsion instrument which is the most sensitive of the Moving Iron mechanisms and has the most linear, scale.

- One of these like poles is created by the instrument coil and appears as an iron vane, fixed in its position within the coil, as shown in Fig. 2.8. The other like pole is induced on the movable iron piece or vane, which is suspended in the induction field of the coil and to which the needle of the instrument is attached.
- Since the instrument is used on ac, the magnetic polarity of the coil changes with every half cycle and induces a corresponding amount of repulsion of the movable vane against the spring tension.
- The deflection of the instrument pointer is therefore always in the same direction, since there is always repulsion between the like poles of the fixed and the movable vane, even though the current in the inducing coil alternates.
- The deflection of the pointer thus produced is effectively proportional to the actual current through the instrument. It can therefore be calibrated directly in amperes and volts.

- The calibrations of a given instrument will however only be accurate for the ac frequency for which it is designed, because the impedance will be different at a new frequency.

- The Moving coil or repulsion type of instrument is usually calibrated to read the effective value of amperes and volts, and is used primarily for rugged and inexpensive meters.

- The iron vane or radial type is forced to turn within the fixed current carrying coil by the repulsion between like poles. The aluminium vanes, attached to the lower end of the pointer, acts as a damping vane, in its close fitting chamber, to bring the pointer quickly to rest



Repusion type instrument

2.4 Basic principle of operation of DC Ammeter and Multi range Ammeter

DC Ammeter –

- The PMMC galvanometer constitutes the basic movement of a dc ammeter. Since the coil winding of a basic movement is small and light, it can carry only very small currents.
- When large currents are to be measured, it is necessary to bypass a major part of the current through a resistance called a shunt, as shown in Fig. 3.1.

- The resistance of shunt can be calculated using conventional circuit analysis.

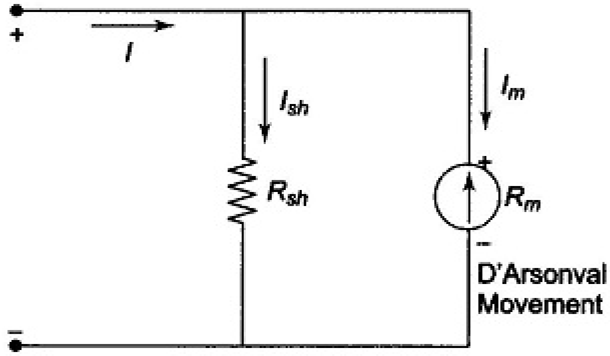


Fig. 3.1 Basic dc Ammeter

- R_m = internal resistance of the movement.
- I_{sh} = shunt current
- I_m = full scale deflection current of the movement
- I = full scale current of the ammeter + shunt (i.e. total current)

Since the shunt resistance is in parallel with the meter movement, the voltage drop across the shunt and movement must be the same.

$$V_{sh} = V_m$$

$$\therefore I_{sh}R_{sh} = I_mR_m$$

$$R_{sh} = \frac{I_mR_m}{I_{sh}}$$

But $I_{sh} = I - I_m$

$$R_{sh} = \frac{I_mR_m}{I - I_m}$$

For each required value of full scale meter current, we can determine the value of shunt resistance

Multirange Ammeters:

- The current range of the dc ammeter may be further extended by a number of shunts, selected by a range switch.

- Such a meter is called a multi range ammeter, shown in Fig. 3.2.

- The circuit has four shunts R_1, R_2, R_3 and R_4, which can be placed in parallel with the movement to give four different current ranges.

- Switch **S** is a multi position switch, (having low contact resistance and high current carrying capacity, since its contacts are in series with low resistance shunts). Make before break type switch is used for range changing.

- This switch protects the meter movement from being damaged without a shunt during range changing.

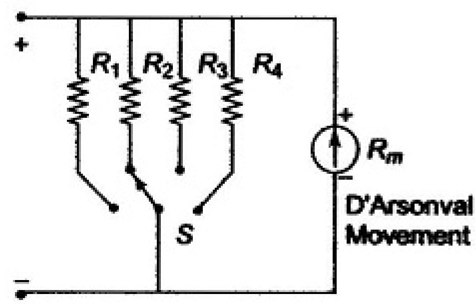


Fig. 3.2 ▬ Multirange Ammeter

- If we use an ordinary switch for range changing, the meter does not have any shunt in parallel while the range is being changed, and hence full current passes through the meter movement, damaging the movement. Hence a make before break type switch is used.

- The switch is so designed that when the switch position is changed, it makes contact with the next terminal (range) before breaking contact with the previous terminal.

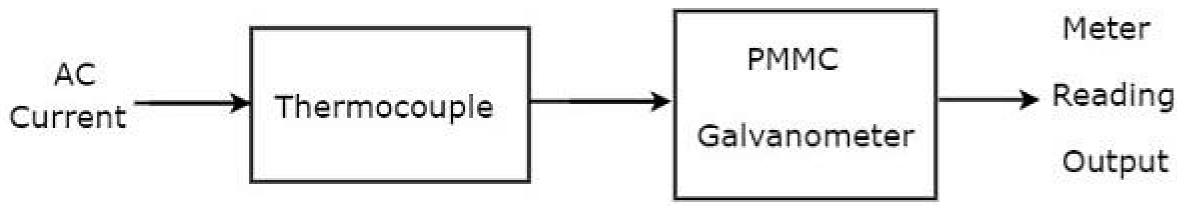
- Therefore the meter movement is never left unprotected. Multi range ammeters are used for ranges up to 50A. When using a multi range ammeter, first use the highest current range, then decrease the range until good upscale reading is obtained.

- The resistance used for the various ranges are of very high precision values, hence the cost of the meter increases.

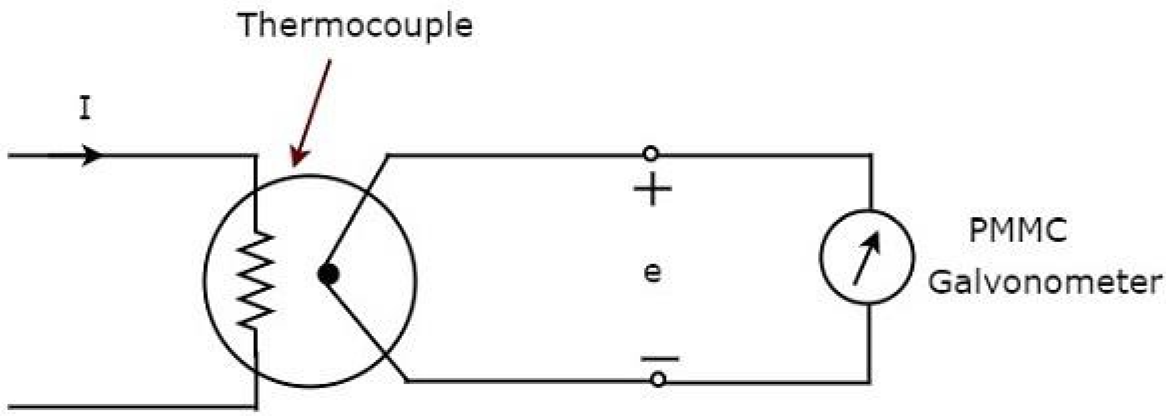
2.5 Basic principle of operation of AC Ammeter and Multi range Ammeter

Thermocouple Type AC Ammeter

If a Thermocouple is connected ahead of PMMC galvanometer, then that entire combination is called thermocouple type AC ammeter. The **block diagram** of thermocouple type AC ammeter is shown in below figure.



The above block diagram consists of mainly two blocks: a thermocouple, and a PMMC galvanometer. We will get the corresponding circuit diagram, just by replacing each block with the respective component(s) in above block diagram. So, the **circuit diagram** of thermocouple type AC ammeter will look like as shown in below figure.



Thermocouple generates an EMF, e, whenever the Alternating Current, I flows through heater element. This EMF, e is directly proportional to the rms value of the current, I that is flowing through heater element. So, we have to calibrate the scale of PMMC instrument to read **rms values of current**.

2.8 Basic principle of Ohm Meter (Series & Shunt type)

ohmmeter, instrument for measuring **electrical resistance,** which is expressed in ohms.

In the simplest ohmmeters, the resistance to be measured may be connected to the instrument in parallel or in series.

Series Type Ohmmeter:

Series Type Ohmmeter – A D' Arsonval movement is connected in series with a resistance R1 and a battery which is connected to a pair of terminals A and B, across which the unknown resistance is connected. This forms the basic type of series ohmmeter, as shown in Fig. 4.28 (a).

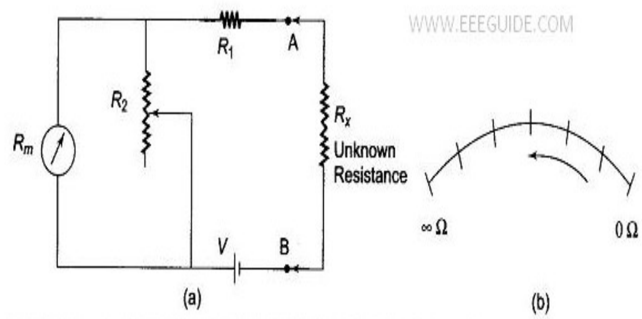


Fig. 4.28 (a) Series Type Ohmmeter (b) Dial of Series Ohmmeter

The current flowing through the movement then depends on the magnitude of the unknown resistance. Therefore, the meter deflection is directly proportional to the value of the unknown resistance.

- R_1 = current limiting resistance
- R_2 = zero adjust resistance
- V = battery
- R_m = meter resistance
- R_X = unknown resistance

Calibration of the Series Type Ohmmeter:

To mark the "0" reading on the scale, the terminals A and B are shorted, i.e. the unknown resistance $R_x = 0$, maximum current flows in the circuit and the shunt resistance R2 is adjusted until the movement indicates full scale current (Ifsd). The position of the pointer on the scale is then marked "0" ohms.

Similarly, to mark the "∞" reading on the scale, terminals A and B are open, i.e. the unknown resistance Rx = ∞, no current flow in the circuit and there is no deflection of the pointer. The position of the pointer on the scale, is then marked as "∞" ohms.

By connecting different known values of the unknown resistance to terminals A and B, intermediate markings can be done on the scale

In a series ohmmeter the scale marking on the dial, has "0" on the right side, corresponding to full scale deflection current, and "∞" on the left side corresponding to no current flow, as given in Fig. 4.28 (b).

Multirange Ohmmeter:

The Multirange Ohmmeter circuit shown in Fig. 4.28 (a) is only for a single range of resistance measurement. To measure resistance over a wide range of values, we need to extend the ohmmeter ranges. This type of ohmmeter is called a multirange ohmmeter, shown in Fig. 4.29.

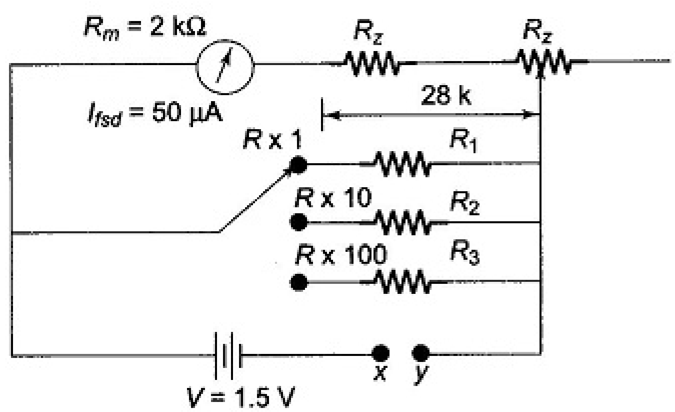


Fig. 4.29 Multirange Ohmmeter

Shunt Type Ohmmeter:

The shunt type ohmmeter given in Fig. 4.30 consists of a battery in series with an adjustable resistor R_1, and a D'Arsonval movement.

The unknown resistance is connected in parallel with the meter, across the terminals A and B, hence the name shunt type ohmmeter.

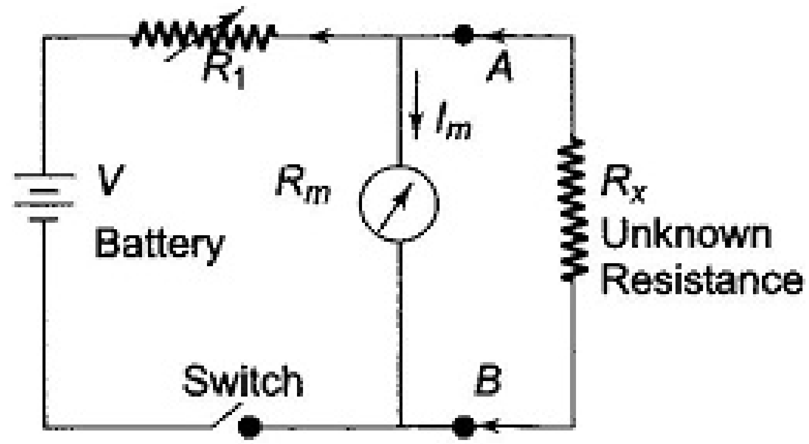


Fig. 4.30 — Shunt Type Ohmmeter

Calibration of the Shunt Type Ohmmeter:

To mark the "0" ohms reading on the scale, terminals A and B are shorted, i.e. the unknown resistance $R_x = 0$, and the current through the meter movement is zero, since it is bypassed by the short-circuit. This pointer position is marked as "0" ohms.

Similarly, to mark "∞" on the scale, the terminals A and B are opened, i.e. $R_x = \infty$ and full current flows through the meter movement; by appropriate selection of the value of R1, the pointer can be made to read full scale deflection current. This position of the pointer is marked "∞" ohms. Intermediate marking can be done by connecting known values of standard resistors to the terminals A and B.

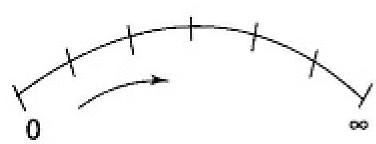


Fig. 4.31 — Dial of Shunt Type Ohmmeter

This ohmmeter therefore has a zero mark at the left side of the scale and an ∞ mark at the right side of the scale, corresponding to full scale deflection current as shown in Fig. 4.31.The shunt type ohmmeter is particularly suited to the measurement of low values of resistance. Hence it is used as a test instrument in the laboratory for special low resistance applications.

2.9 Basic principle of Analog Multimeter, its types & applications:

Working Principle of Multimeter:

A multimeter is basically a PMMC meter. A Working Principle of Multimeter consists of an ammeter, voltmeter and ohmmeter combined, with a function switch to connect the appropriate circuit to the D'Arsonval movement.

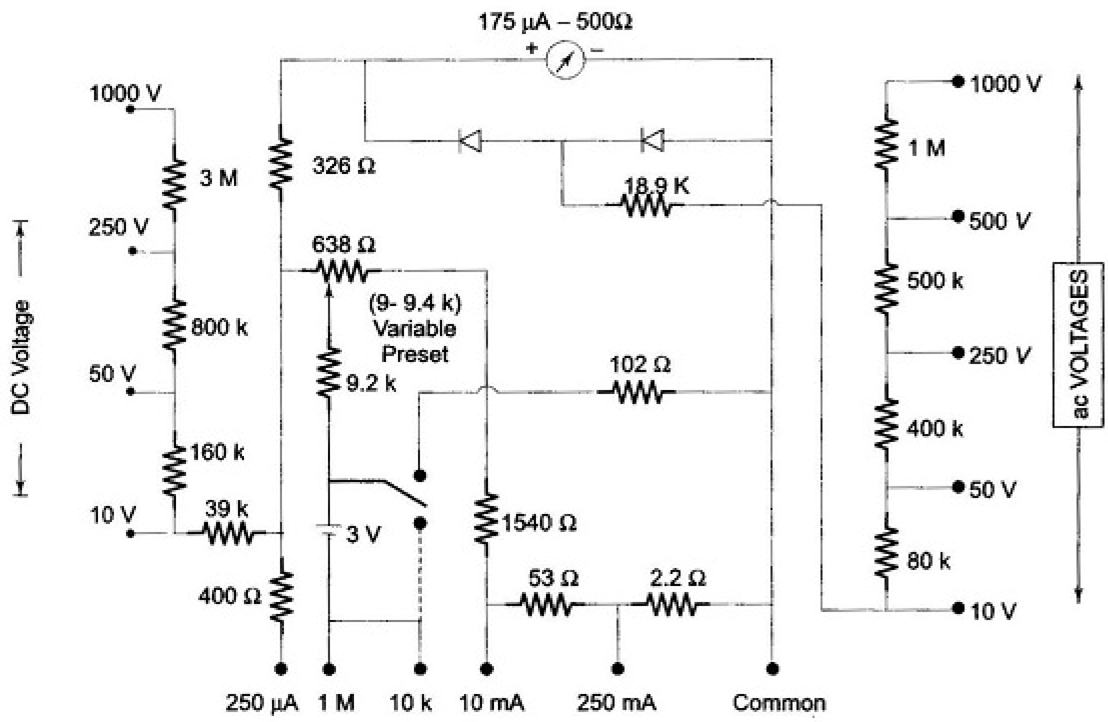


Fig. 4.33 Diagram of a Multimeter

Figure 4.33 shows a meter consisting of a dc milli ammeter, a dc voltmeter, an ac voltmeter, a microammeter, and an ohmmeter.

Microammeter:

Figure 4.34 shows a circuit of a multimeter used as a microammeter.

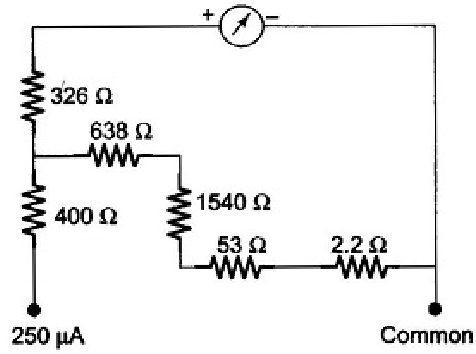


Fig. 4.34 Micro Ammeter Section of a Multimeter

DC Ammeter:

Figure 4.35 shows a working principle of multimeter used as a dc ammeter.

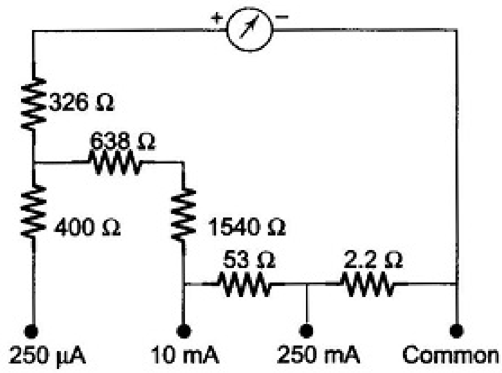


Fig. 4.35 dc Ammeter Section of a Multimeter

DC Voltmeter:

Figure 4.36 shows the dc voltmeter section of a multimeter.

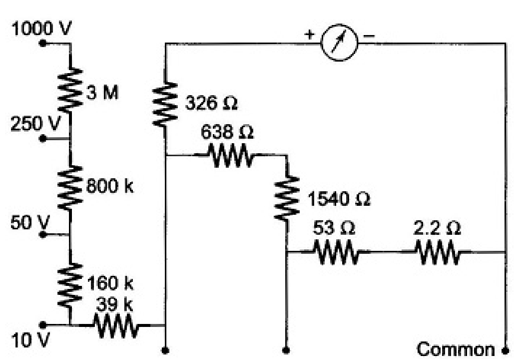


Fig. 4.36 DC Voltmeter Section of a Multimeter

AC Voltmeter:

Figure 4.37 shows the ac voltmeter section of a working principle of multimeter. To measure ac voltage, the output ac voltage is rectified by a half wave rectifier before the current passes through the meter. Across the meter, the other diode serves as protection. The diode conducts when a reverse voltage appears across the diodes, so that current bypasses the meter in the reverse direction.

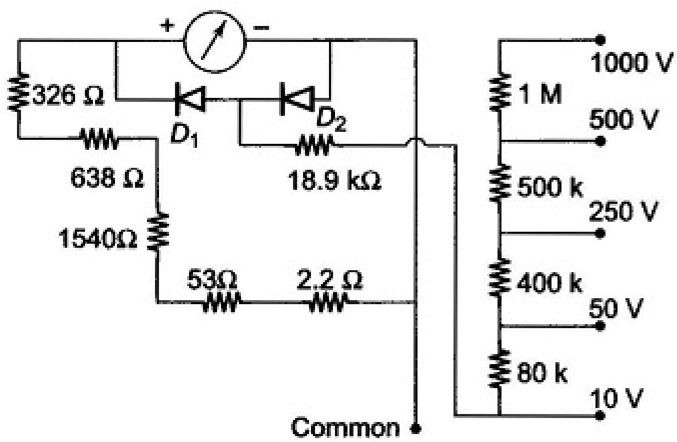


Fig. 4.37 AC Voltmeter Section of a Multimeter

Ohmmeter:

Referring to Fig. 4.38 which shows the ohmmeter section of a multimeter, in the 10 k range the 102 Ω resistance is connected in parallel with the total circuit resistance and in the 1 MΩ range the 102 Ω resistance is totally disconnected from the circuit.

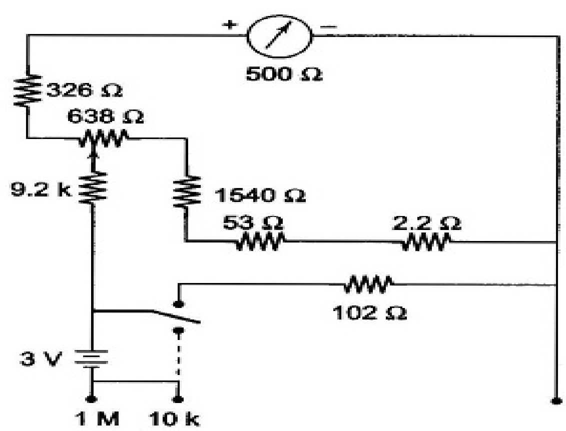


Fig. 4.38 Ohmmeter Section of a Multimeter

The range of an ohmmeter can be changed by connecting the switch to a suitable shunt resistance.

Multimeter Operating Instructions:

The combination volt-ohm-milliammeter is a basic tool in any electronic laboratory. The proper use of this instrument increases its accuracy and life. The following precautions should be observed.

1. To prevent meter overloading and possible damage when checking voltage or current, start with the highest range of the instrument and move down the range successively.
2. For higher accuracy, the range selected should be such that the deflection falls in the upper half on the meter scale.
3. For maximum accuracy and minimum loading, choose a voltmeter range such that the total voltmeter resistance (ohms per volt x full scale voltage) is at least 100 times the resistance of the circuit under test.
4. Make all resistance readings in the un-crowded portion on the meter scale, whenever possible.
5. Take extra precautions when checking high voltages and checking current in high voltage circuits.
6. Verify the circuit polarity before making a test, particularly when measuring dc current or voltages.
7. When checking resistance in circuits, be sure power to the circuit is switched off, otherwise the voltage across the resistance may damage the meter.
8. Renew ohmmeter batteries frequently to insure accuracy of the resistance scale.
9. Re-calibrate the instrument at frequent intervals.
10. Protect the instrument from dust, moisture, fumes and heat.

2-10 Operation of Q meter and its essentials:

Unit-3: Digital Instruments

3.1 Principle of operation of Ramp type Digital Voltmeter & applications

The operating principle of the ramp-type DVM is based on the measurement of the time it takes for a linear ramp voltage to rise from 0 V to the level of the input voltage, or to decrease from the level of the input voltage to zero.

This time interval is measured with an electronic time-interval counter, and the count is displayed as a number of digits on electronic indicating tube Conversion from a voltage to a time interval is illustrated by the waveform diagram of Figure below.

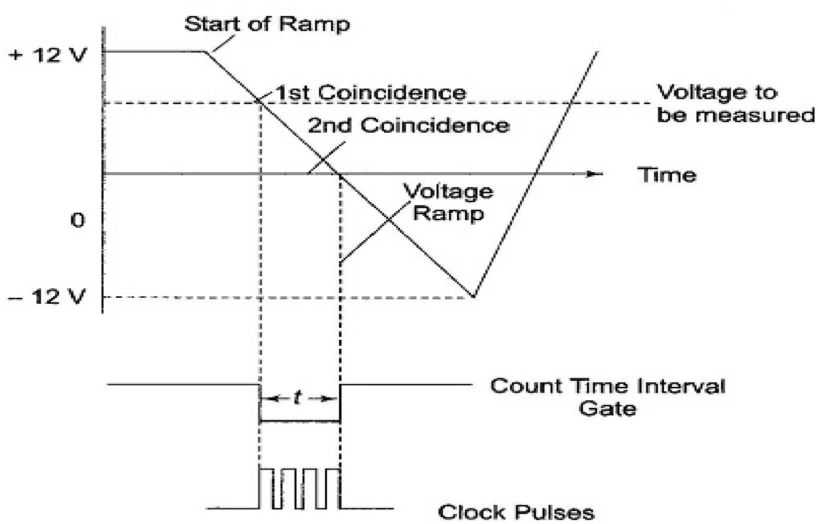


Fig. 5.1 Voltage to Time Conversion

At the start of the measurement cycle, a ramp voltage is initiated; this voltage can be positive-going or negative-going. The negative-going ramp, shown in Fig. , is continuously compared with the unknown input voltage.

At the instant that the ramp voltage equals the unknown voltage, a coincidence circuit, or comparator, generates a pulse which opens a gate.

This gate is shown in the block diagram of below figure. The ramp voltage continues to decrease with time until it finally reaches 0 V (or ground potential) and a second comparator generates an output pulse which closes the gate.

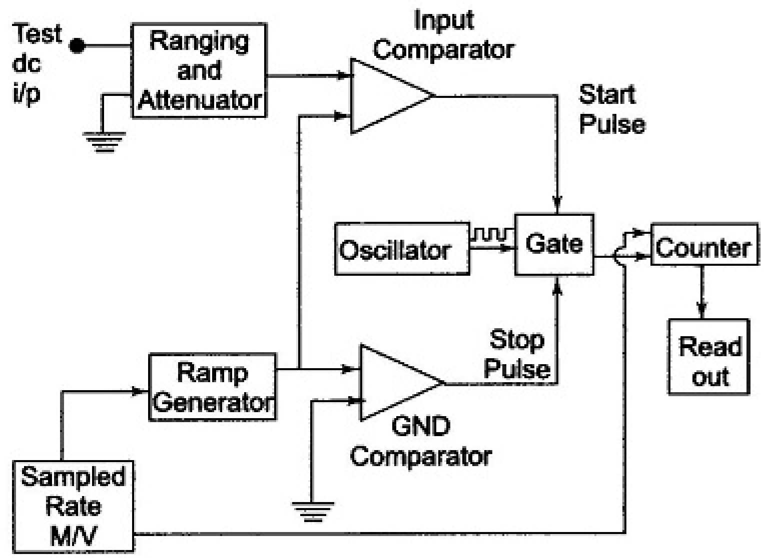


Fig. 5.2 ▬ Block Diagram of Ramp Type DVM

In the time interval between the start and stop pulses, the gate opens and the oscillator circuit drives the counter. The magnitude of the count indicates the magnitude of the input voltage, which is displayed by the readout.

Therefore, the voltage is converted into time and the time count represents the magnitude of the voltage.

The sample rate multi-vibrator determines the rate of cycle of measurement. A typical value is 5 measuring cycles per second, with an accuracy of ± 0.005% of the reading.

The sample rate circuit provides an initiating pulse for the ramp generator to start its next ramp voltage. At the same time a reset pulse is generated, which resets the counter to the zero state.

Any DVM has a fundamental cycle sequence which involves sampling, displaying and reset sequences.

Advantages:

- It has a better resolution and it can be adjusted because the resolution of digital readout is proportional to the frequency of local oscillator.
- The polarity of the signal which is to be measured can be indicated by adding external logic.
- In this the analog to digital signal converted into time and the time can be easily digitized.
- It is easy to design and cost is low.

Disadvantages:

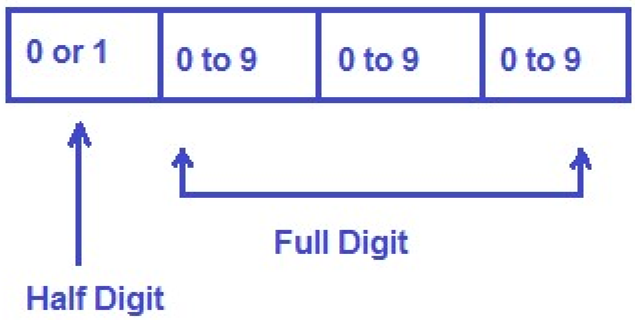
- The accuracy of the system is reduced by the drift and offset of two comparators.
- Basically the swing of ramp is in volt. This limit the range of measurement to the 10 volts.
- Accuracy of the system is depends on linearity of ramp, the slope of ramp and stability of local oscillator. So with the variation in these parameters, the accuracy of the system is changed.

3.2 3.2 Operation of display of 3 1/2, 4 1/2– Digital Multimeter & Resolution and Sensitivity

Basically, there are two types of digits in digital display: Full digit and Half Digit.
A full digit is something which can take any value from 0 to 9. Thus it can have a total of 10 different states. This mean a full digit may have any value 0, 1, 2,….., or 9.
A half digit is something which can either have a value of 0 or 1. This digit is basically the most significant digit and hence has limited use for displaying any number or reading.

3½Digit Display:

3.5 digit displays have four digits: one half digit and three full digits. As half digit is the most significant digit and can either have vale 0 or 1 and full digit can take any value (0 to 9), therefore the range of digital display will be 0 to 1999.



Resolution and Sensitivity:

Resolution:

If n= no. of full digits, then resolution(R) is $\frac{1}{10^n}$

The resolution of a DVM is determined by the number of full or active digits used

If n=3, R=$\frac{1}{10^n} = \frac{1}{10^3} = 0.001 \; or \; 0.1\%$

Sensitivity:

Sensitivity is the smallest change in input which a digital meter is able to detect. Hence it is the full scale value of the lowest voltage range multiplied by the meter's resolution

Sensitivity S=$(fs)_{min}$X R

Where $(fs)_{min} = lowest\ full\ scale\ of\ of\ the\ meter$

R=resolution expressed as decimal

3.3 Basic principle of operation of working of Digital Multimeterits types & applications

A digital multimeter displays the quantity measured as a number,its eliminates parallax errors.

A digital multimeter can measure very precisely the dc and ac voltage, current (dc and ac) and resistance. All quantities save for dc voltage is first converted into an equivalent dc voltage and then measured with the help of a digital voltmeter.

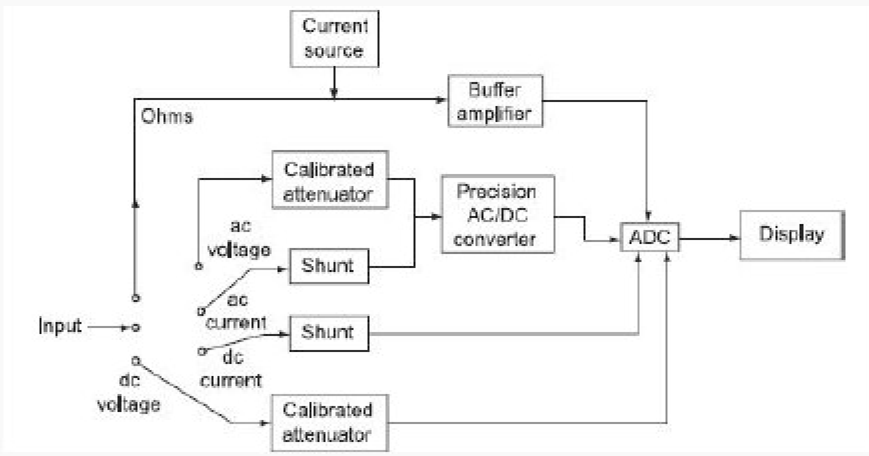


Figure 1.0: Block diagram of a digital multimeter.

The measurement of various quantities is described as follows:

Voltage Measurement

With reference to the figure above, the input ac voltage is fed through a calibrated attenuator, to a precision full-wave rectifier circuit followed by a ripple reduction filter. The resulting dc is fed to an analog digital converter (ADC) and the following display system. In case of dc voltage input, the process is similar to what is described above, except that that the precision AC/DC converter is not involved here.

Current Measurement

For current measurement, the drop across an internal calibrated shunt is measured directly by the analog digital converter (ADC) in the “dc current mode", and after ac to dc conversion in the "ac current mode". This drop is often in the range of 200 mV (corresponding to full scale).

At times, for measurement of current, a current-to-voltage converter may be used as demonstrated below:

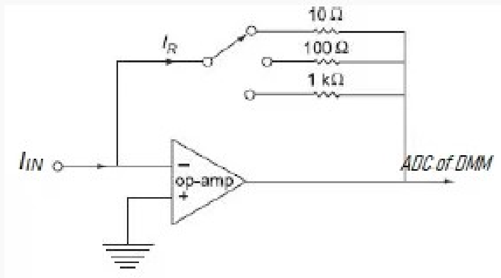


Figure 1.1: Block diagram of a current-to-voltage converter.

The current under measurement is applied to the summing junction at the input of the op-amp. The current in the feedback resistor I_R is equal to the input current I_{IN} because of very high input impedance of the op-amp. The current I_R causes a voltage drop across one of the resistors, which is proportional to the input I_{IN}. Different resistors are used for different ranges.

Resistance Measurement:

In the case of resistance measurement the digital multimeter operates by measuring the voltage across the externally connected resistance, resulting from a current forced through it from a calibrated internal current source.

3.4 Basic principle of operation of working of Digital Frequency Meter

Digital Frequency Meter:

Principle of Operation of Digital Frequency Meter – The signal waveform is converted to trigger pulses and applied continuously to an AND gate, as shown in Fig. 6.4. A pulse of 1 s is applied to the other terminal, and the number of pulses counted during this period indicates the frequency.

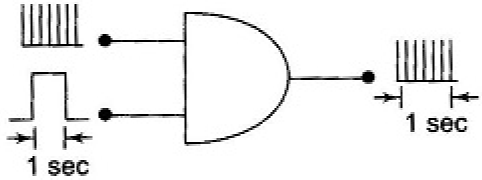


Fig. 6.4 Principle of Digital Frequency Measurement

The signal whose frequency is to be measured is converted into a train of pulses, one pulse for each cycle of the signal. The number of pulses occurring in a definite interval of time is then counted by an electronic counter. Since each pulse represents the cycle of the unknown signal, the number of counts is a direct indication of the frequency of the signal (unknown). Since electronic counters have a high speed of operation, high frequency signals can be measured.

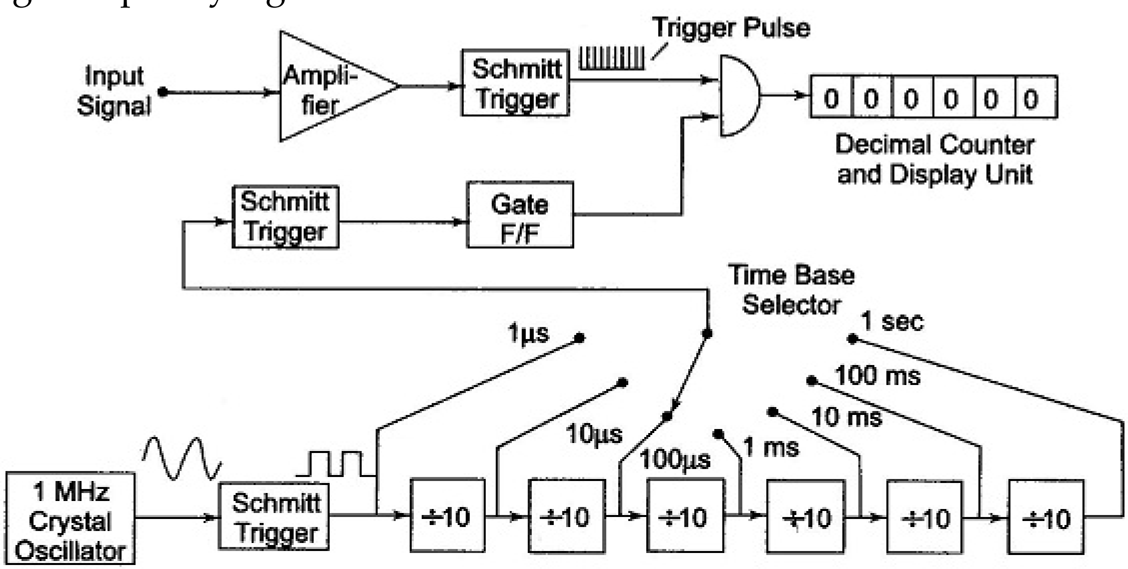


Fig. 6.7 Block Diagram of a Digital Frequency Meter

The input signal is amplified and converted to a square wave by a Schmitt trigger circuit. In this diagram, the square wave is differentiated and clipped to produce a train of pulses, each pulse separated by the period of the input signal. The time base selector output is obtained from an oscillator and is similarly converted into positive pulses.

The first pulse activates the gate control F/F. This gate control F/F provides an enable signal to the AND gate. The trigger pulses of the input signal are allowed to pass through the gate for a selected time period and counted.

The second pulse from the decade frequency divider changes the state of the control F/F and removes the enable signal from the AND gate, thereby closing it. The decimal counter and display unit output corresponds to the number of input pulses received during a precise time interval; hence the counter display corresponds to the frequency.

High Frequency Measurement (Extending the Frequency Range):

This range of a few 100 MHz covers only a small portion of the frequency spectrum. Therefore, techniques other than direct counting have been used to extend the range of digital frequency meters to above 40 GHz. The input frequency is reduced before it is applied to a digital counter. This is done by special techniques. Some of the techniques used are as follows.

Automatic Divider

The high frequency signal is reduced by some factor, such as 100:1, using automatically tuned circuits which generated an output frequency equal to 1/100th or 1/1000th of the input frequency.

3.5 Operation of working of Digital Measurement of Time

Principle of Operation of Digital Measurement of Time – The beginning of the time period is the start pulse originating from input 1, and the end of the time period is the stop pulse coming from input 2.

The oscillator runs continuously, but the oscillator pulses reach the output only during the period when the control F/F is in the 1 state. The number of output pulses counted is a measure of the time period

Time Base Selector:

It is clear that in order to know the value of frequency of the input signal, the time interval between the start and stop of the gate must be accurately known. This is called time base.

The time base consist of a fixed frequency crystal oscillator, called a clock oscillator, which has to be very accurate

The output of this constant frequency oscillator is fed to a Schmitt trigger, which converts the input sine wave to an output consisting of a train of pulses at a rate equal to the frequency of the clock oscillator.

The train of pulses then passes through a series of frequency divider decade assemblies connected in cascade. Each decade divider consists of a decade counter and divides the frequency by ten. Outputs are taken from each decade frequency divider by means of a selector switch; any output may be selected.

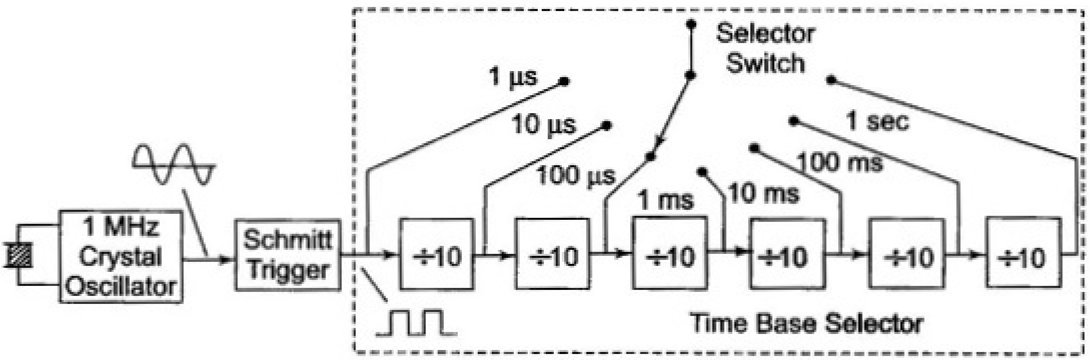


Fig. 6.8 Time Base Selector

The circuit of Fig. 6.8 consists of a clock oscillator having a 1 MHz frequency. 6 decade frequency divider, a time base with a range of 1 μs – 10 μs – 100 μs – 1 ms -10 ms – 100 ms – 1 s can be selected using a selector switch.

Measurement of Time (Period Measurement):

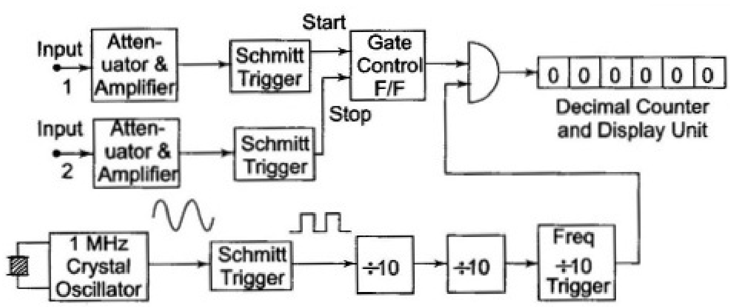


Fig. 6.9 Basic Block Diagram of Time Measurement

In some cases it is necessary for Digital Measurement of Time rather than the frequency. This is especially true in the measurement of frequency in the low frequency range. To obtain good accuracy at low frequency, we should take measurements of the period

The circuit used for measuring frequency can be used for the measurement of time period if the counted signal and gating signal are interchanged.

Figure 6.9 shows the circuit for Digital Measurement of Time period. The gating signal is derived from the unknown input signal, which now controls the enabling and disabling of the main gate.

The number of pulses which occur during one period of the unknown signal are counted and displayed by the decade counting assemblies.

The only disadvantage is that for measuring the frequency in the low frequency range, the operator has to calculate the frequency from the time by using the equation $f = 1/T$.

3.7 Principle of operation of working of Digital Tachometer:

The Tachometer is used to quantify the rotary speed of a rotating shaft. Tachometers are also popularly known as 'Revolution Counter'. Digital Tachometer Working Principle technique employed in measuring the speed of a rotating shaft is similar to the technique used in a conventional frequency counter, except that the selection of the gate period is in accordance with the rpm calibration.

Let us assume, that the rpm of a rotating shaft is R. Let P be the number of pulses produced by the pick up for one revolution of the shaft. Therefore, in one minute the number of pulses from the pick up is $R \times P$. Then, the frequency of the signal from the pick up is $(R \times P)/60$. Now, if the gate period is G s the pulses counted are $(R \times P \times G)/60$. In order to get the direct reading in rpm, the number of pulses to be counted by the counter is R. So we select the gate period as $60/P$, and the counter counts.

$$\frac{(R \times P \times 60)}{60 \times P} = R \text{ pulses}$$

and we can read the rpm of the rotating shaft directly. So, the relation between the gate period and the number of pulses produced by the pickup is G = 60/P. If we fix the gate period as one second (G = 1 s), then the revolution pickup must be capable of producing 60 pulses per revolution.

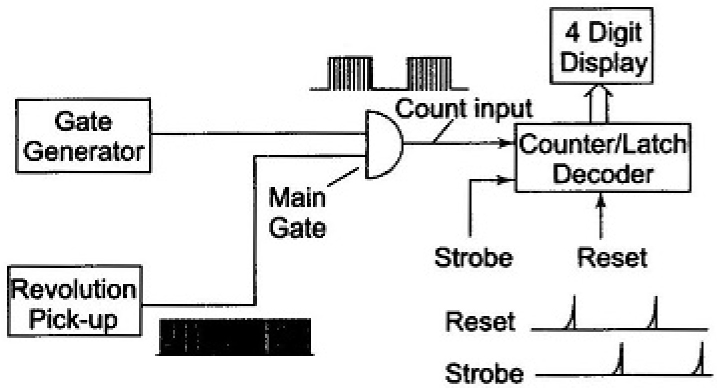


Fig. 6.19 Basic Block Diagram of a Digital Tachometer

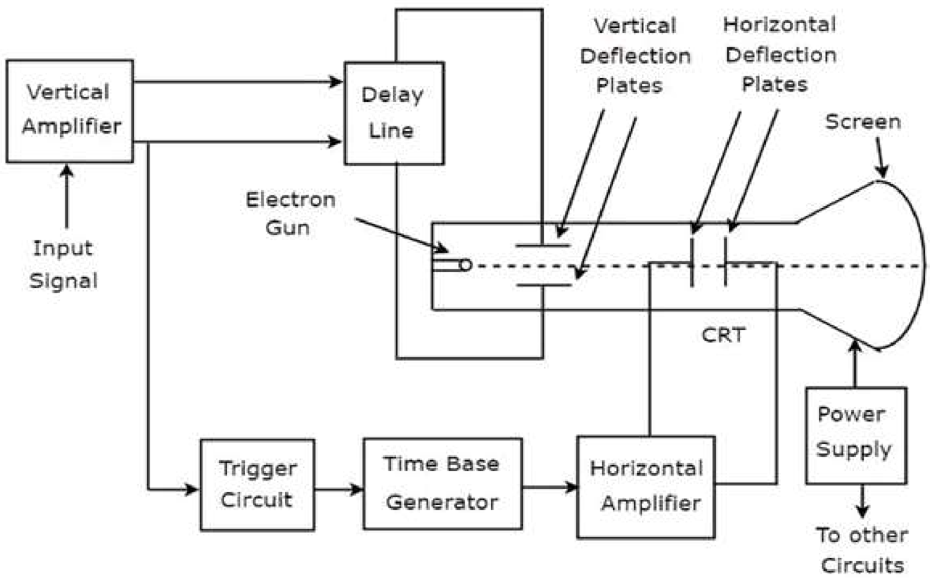
UNIT-4

OSCILLOSCOPE

Oscilloscope is an electronic equipment, which displays a voltage waveform. Among the oscilloscopes, Cathode Ray Oscilloscope (CRO) is the basic one and it displays a time varying signal or waveform.

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 saw tooth signal, which is useful for horizontal deflection of electron beam.

 Horizontal Amplifier: It amplifies the saw tooth 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.

In this way, CRO will display the applied input signal on the screen of CRT. So, we can analyse the signals in time domain by using CRO.

Measurements by using CRO:

We can do the following measurements by using CRO.

☐ Measurement of Amplitude

☐ Measurement of Time Period

☐ Measurement of Frequency

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.

$$A = j \times n_v$$

Where,

A is the amplitude

j is the value of volt/division

n_v 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.

$$T = k \times nh$$

Where,

T is the Time period

k is the value of time/division

n_h 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.

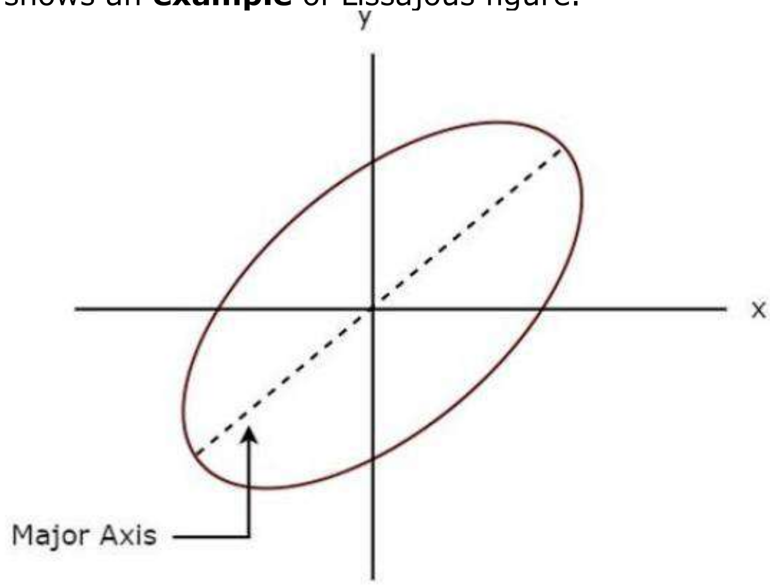
 Step1: Find the **Time period** of periodic signal.

 Step2: Take **reciprocal** of Time period of periodic signal, which is obtained in Step1.

Lissajous figures:

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.
The following figure shows an **example** of Lissajous figure.



The above Lissajous figure is in **elliptical shape** and its major axis has some inclination angle with positive x-axis.

Measurements using Lissajous Figures:

We can do the following **two measurements** from a Lissajous figure.

☐ Frequency of the sinusoidal signal

☐ Phase difference between two sinusoidal signals

Now, let us discuss about these two measurements one by one.

Measurement of Frequency

Lissajous figure will be displayed on the screen, when the sinusoidal signals are applied to both horizontal & vertical deflection plates of CRO. Hence, apply the sinusoidal signal, which has standard **known frequency** to the horizontal deflection plates of CRO. Similarly, apply the sinusoidal signal, whose **frequency** is **unknown** to the vertical deflection plates of CRO.
Let, f_H and f_V are the frequencies of sinusoidal signals, which are applied to the horizontal & vertical deflection plates of CRO respectively. The relationship between f_H and f_V can be **mathematically** represented as below.

$$fV/fH=nH/nV$$

From above relation, we will get the frequency of sinusoidal signal, which is applied to the vertical deflection plates of CRO as
Where,
nH is the number of horizontal tangencies
nV is the number of vertical tangencies

We can find the values of n_H and n_V from Lissajous figure. So, by substituting the values of n_H, n_V and f_H in Equation 1, we will get the value of f_V, i.e. the **frequency of sinusoidal signal** that is applied to the vertical deflection plates of CRO.

Measurement of Phase Difference:

A Lissajous figure is displayed on the screen when sinusoidal signals are applied to both horizontal & vertical deflection plates of CRO. Hence, apply the sinusoidal signals, which have **same amplitude and frequency** to both horizontal and vertical deflection plates of CRO.

For few Lissajous figures based on their shape, we can directly tell the phase difference between the two sinusoidal signals.

☐ If the Lissajous figure is a **straight line** with an inclination of 45^0 with positive x-axis, then the **phase difference** between the two sinusoidal signals will be 0^0. That means, there is no phase difference between those two sinusoidal signals.

If the Lissajous figure is a **straight line** with an inclination of 135^0 with positive x-axis, then the **phase difference** between the two sinusoidal signals will be 180^0. That means, those two sinusoidal signals are out of phase.

 If the Lissajous figure is in **circular shape**, then the phase difference between the two sinusoidal signals will be 90^0 or 270^0.

We can calculate the phase difference between the two sinusoidal signals by using formulae, when the Lissajous figures are of **elliptical shape**.

If the major axis of an elliptical shape Lissajous figure having an inclination angle lies between 0^0 and 90^0 with positive x-axis, then the phase difference between the two sinusoidal signals will be

$$\emptyset = \sin^{-1}\left(\frac{x_1}{x_2}\right) = \sin^{-1}\left(\frac{y_1}{y_2}\right)$$

If the major axis of an elliptical shape Lissajous figure having an inclination angle lies between 90^0 and 180^0 with positive x-axis, then the phase difference between the two sinusoidal signals will be

$$\emptyset = 180^0 - \sin^{-1}\left(\frac{x_1}{x_2}\right) = 180^0 - \sin^{-1}\left(\frac{y_1}{y_2}\right)$$

Where,

x_1 is the distance from the origin to the point on x-axis, where the elliptical shape Lissajous figure intersects

x_2 is the distance from the origin to the vertical tangent of elliptical shape Lissajous figure

y_1 is the distance from the origin to the point on y-axis, where the elliptical shape Lissajous figure intersects

y_2 is the distance from the origin to the horizontal tangent of elliptical shape Lissajous figure

SPECIAL PURPOSE OSCILLOSCOPE:

In previous chapter, we had discussed about Cathode Ray Oscilloscope (CRO), which is a basic oscilloscope. We will get special purpose oscilloscopes just by including few additional blocks to the basic oscilloscope based on the requirement. Following are the **special purpose oscilloscopes**.

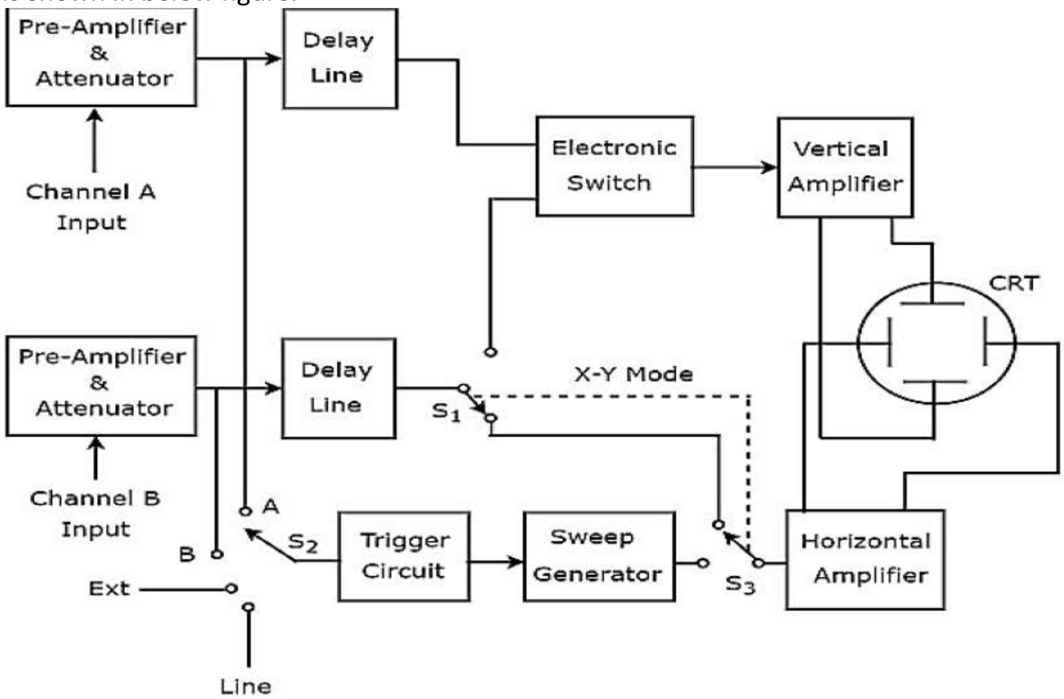
☐ Dual Beam Oscilloscope

☐ Dual Trace Oscilloscope

☐ Digital Storage Oscilloscope

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.

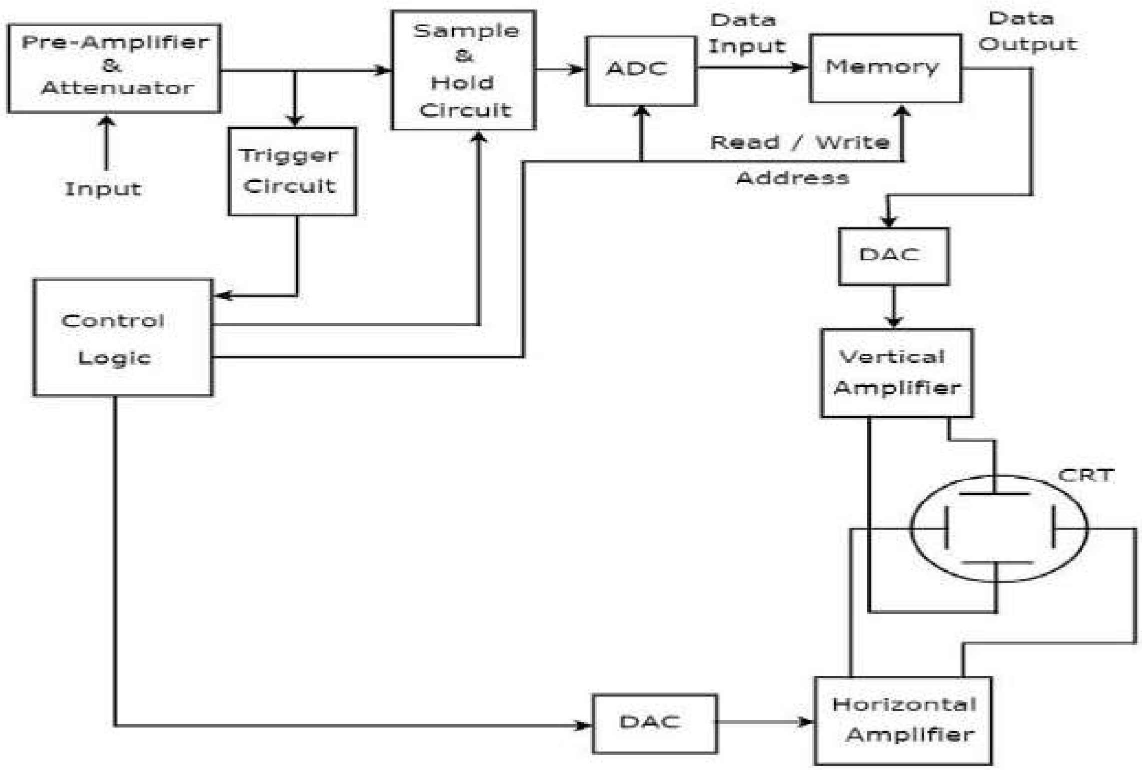
In above block diagram, the first two blocks are separately present in both channels. The last two blocks are common to both the channels. Hence, with the help of **electronic switch** we can connect the delay line output of a specific channel to vertical amplifier.

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.

UNIT- 5

BRIDGES

If the electrical components are arranged in the form a bridge or ring structure, then that electrical circuit is called a **bridge**. In general, bridge forms a loop with a set of four arms or branches. Each branch may contain one or two electrical components.

Types of Bridges:

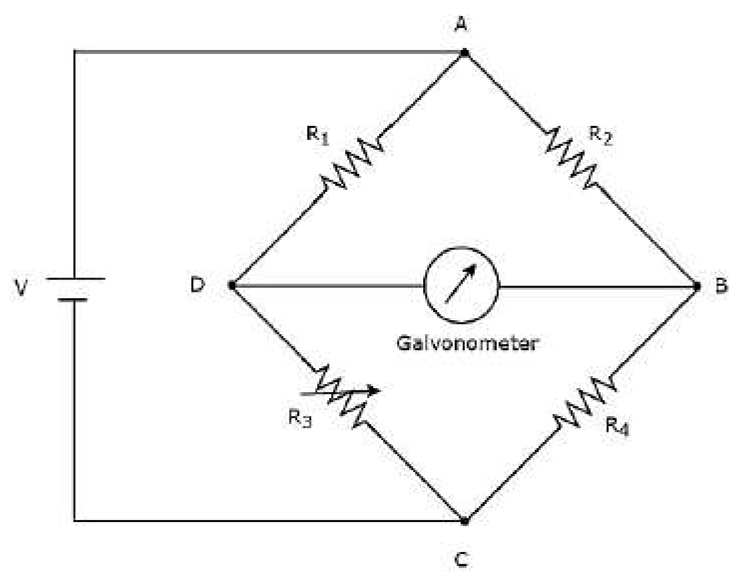
We can classify the bridge circuits or bridges into the following two categories based on the voltage signal with which those can be operated.

- DC Bridges
- AC Bridges

Now, let us discuss about these two bridges briefly.

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.



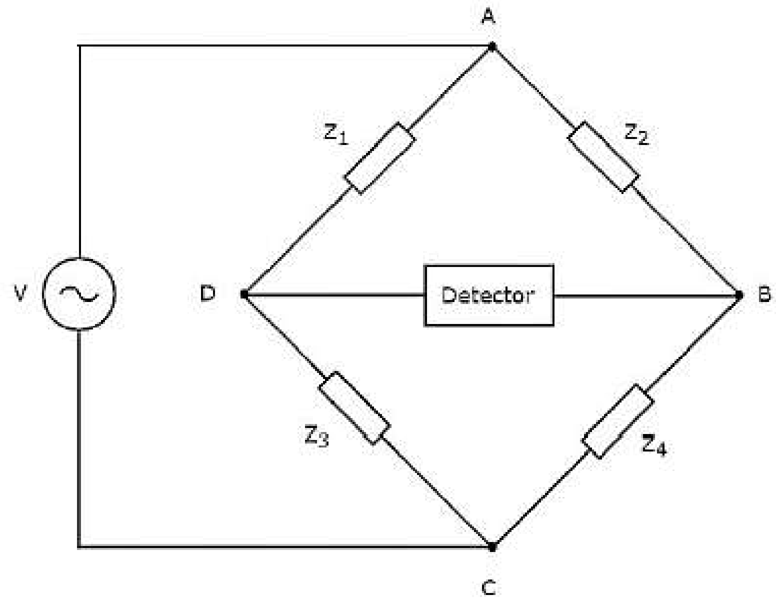
The above DC bridge has **four arms** and each arm consists of a resistor. Among which, two resistors have fixed resistance values, one resistor is a variable resistor and the other one has an unknown resistance value.

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 :

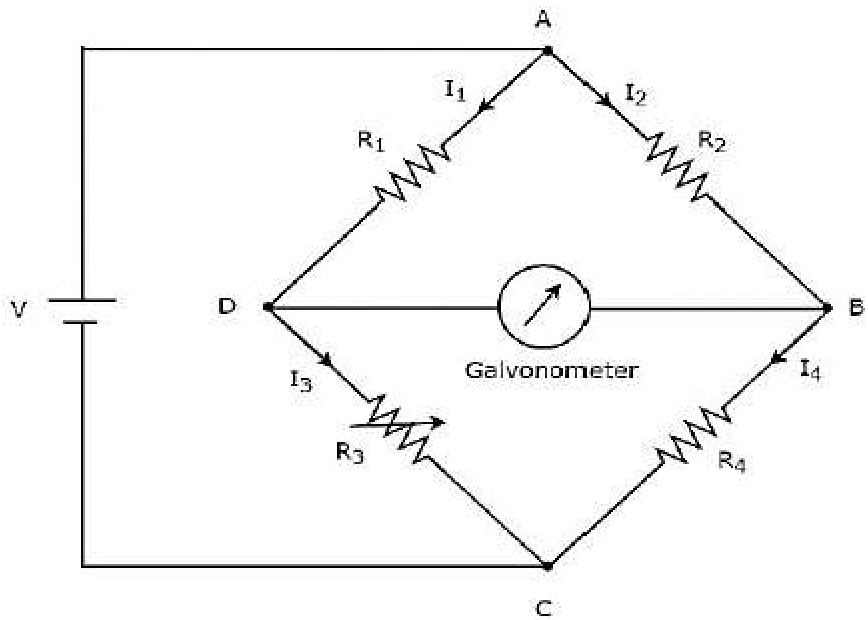
If the bridge circuit can be operated with only AC voltage signal, then it is said to be AC bridge circuit or simply **AC bridge**. AC bridges are used to measure the value of unknown inductance, capacitance and frequency.
The **circuit diagram** of AC bridge looks like as shown in below figure.



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.

DC Bridges (Measurement of Resistance by Wheatstone's Bridge):

Wheatstone's bridge is a simple DC bridge, which is mainly having **four arms**. These four arms form a rhombus or square shape and each arm consists of one resistor.
To find the value of unknown resistance, we need the galvanometer and DC voltage source. Hence, one of these two are placed in one diagonal of Wheatstone's bridge and the other one is placed in another diagonal of Wheatstone's bridge.
Wheatstone's bridge is used to measure the value of medium resistance. The **circuit diagram** of Wheatstone's bridge is shown in below figure.



In above circuit, the arms AB, BC, CD and DA together form a **rhombus** or square shape. They consist of resistors R_2, R_4, R_3 and R_1 respectively. Let the current flowing through these resistor arms is I_2, I_4, I_3 and I_1 respectively and the directions of these currents are shown in the figure.

The diagonal arms DB and AC consists of galvanometer and DC voltage source of V volts respectively. Here, the resistor, R_3 is a standard variable resistor and the resistor, R_4 is an unknown resistor. We can **balance the bridge**, by varying the resistance value of resistor, R_3.

The above bridge circuit is balanced when no current flows through the diagonal arm, DB. That means, there is **no deflection** in the galvanometer, when the bridge is balanced.

The bridge will be balanced, when the following **two conditions** are satisfied.

- The voltage across arm AD is equal to the voltage across arm AB.
  i.e.,

$$V_{AD} = V_{AB}$$

$$=> I_1R_1 = I_2R_2 \qquad \text{Equation 1}$$

- The voltage across arm DC is equal to the voltage across arm BC.
  i.e.,

$$V_{DC} = V_{BC}$$

$$=> I_3R_3 = I_4R_4 \qquad \text{Equation 2}$$

From above two balancing conditions, we will get the following **two conclusions**.

- The current flowing through the arm AD will be equal to that of arm DC. i.e.,

$$I_1 = I_3$$

- The current flowing through the arm AB will be equal to that of arm BC. i.e.,

$$I_2 = I_4$$

Take the ratio of Equation 1 and Equation 2.

$$\frac{I_1 R_1}{I_3 R_3} = \frac{I_2 R_2}{I_4 R_4} \quad \text{Equation 3}$$

Substitute, $I_1 = I_3$ and $I_2 = I_4$ in Equation 3.

$$\frac{I_3 R_1}{I_3 R_3} = \frac{I_4 R_2}{I_4 R_4}$$

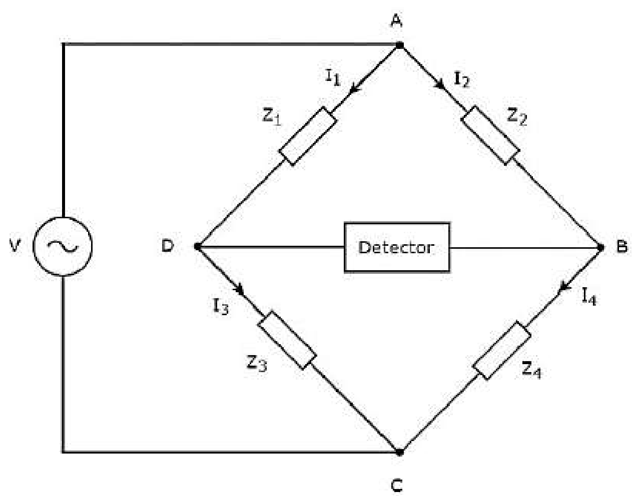
$$=> \frac{R_1}{R_3} = \frac{R_2}{R_4}$$

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

By substituting the known values of resistors R_1, R_2 and R_3 in above equation, we will get the **value of resistor, R_4**.

AC bridges:

In this chapter, let us discuss about the AC bridges, which can be used to measure inductance. AC bridges operate with only AC voltage signal. The **circuit diagram** of AC bridge is shown in below figure.



As shown in above figure, AC bridge mainly consists of four arms, which are connected in rhombus or **square shape**. All these arms consist of some impedance.

The detector and AC voltage source are also required in order to find the value of unknown impedance. Hence, one of these two are placed in one diagonal of AC bridge and the other one is placed in other diagonal of AC bridge. The balancing condition of Wheatstone's bridge as:

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

We will get the **balancing condition of AC bridge**, just by replacing R with Z in above equation.

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

$$=> Z_1 Z_4 = Z_2 Z_3$$

Here, Z_1 and Z_2 are fixed impedances. Whereas, Z_3 is a standard variable impedance and Z_4 is an unknown impedance.

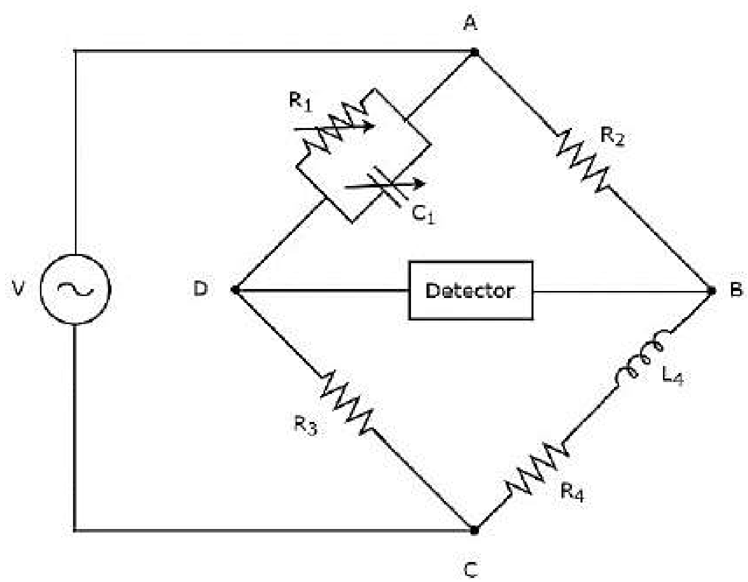
Note: We can choose any two of those four impedances as fixed impedances, one impedance as standard variable impedance & the other impedance as an unknown impedance based on the application.
Following are the two AC bridges, which can be used to measure **inductance**.

- Maxwell's Bridge
- Hay's Bridge

Now, let us discuss about these two AC bridges one by one.

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, R_2 and R_3 respectively. The arm, BC consists of a series combination of resistor, R_4 and inductor, L_4. 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

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

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

$$Z_2 = R_2$$

$$Z_3 = R_3$$

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

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

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

$L_4 = C_1 R_2 R_3$ Equation 2

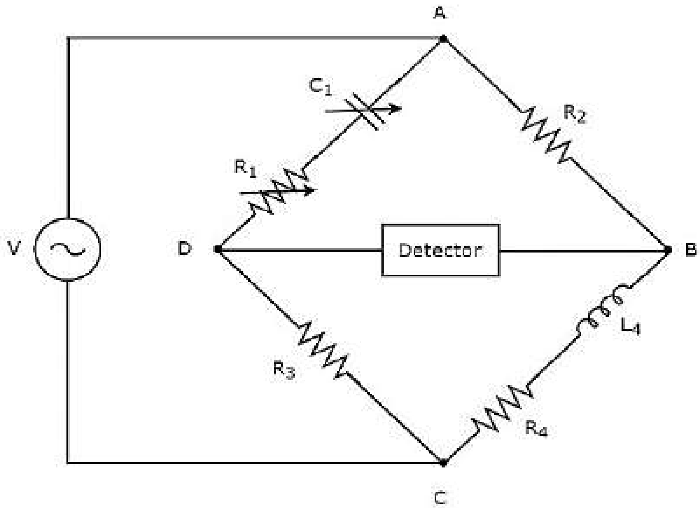
By substituting the values of resistors R_1, R_2 and R_3 in Equation 1, we will get the value of resistor, R_4. Similarly, by substituting the value of capacitor, C_1 and the values of resistors, R_2 and R_3 in Equation 2, we will get the value of inductor, L_4.

The **advantage** of Maxwell's bridge is that both the values of resistor, R_4 and an inductor, L_4 are independent of the value of frequency.

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, R_2 and R_3 respectively. The arm, BC consists of a series combination of resistor, R_4 and inductor, L_4. 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

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

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

$$Z_2 = R_2$$

$$Z_3 = R_3$$

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

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 $1 - j\omega R_1 C_1$.

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

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

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

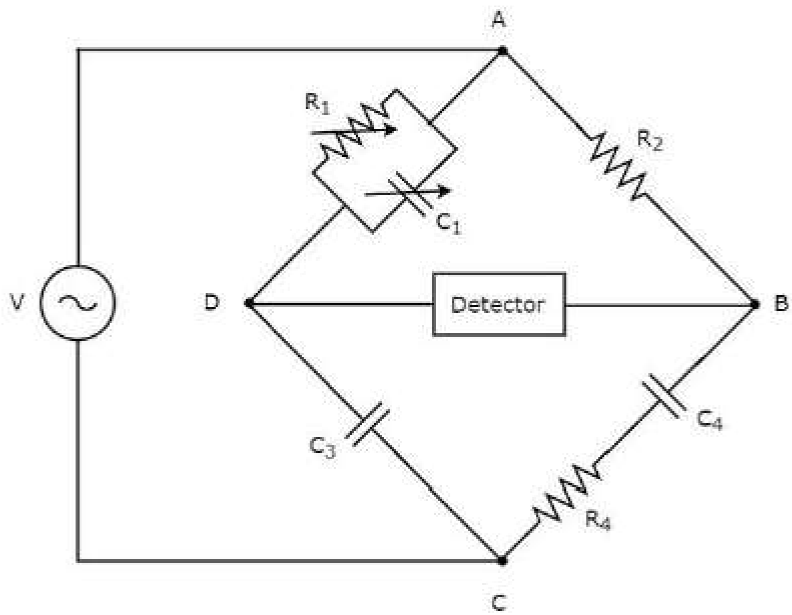
$$R_4 = \frac{\omega^2 {C_1}^2 R_1 R_2 R_3}{(1+\omega^2 {R_1}^2 {C_1}^2)} \qquad \text{Equation 3}$$

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

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.

Measurement of capacitance by Schering's 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

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

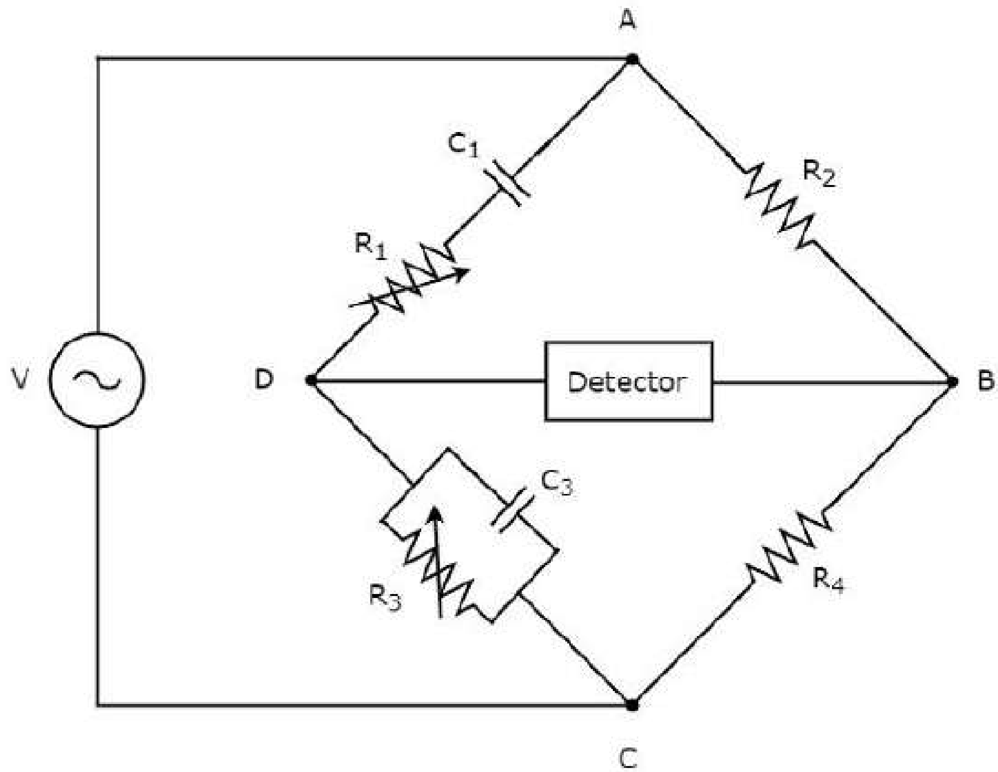
$R_4 = \frac{C_1 R_2}{C_3}$ Equation 2

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, $R4$ and capacitor, $C4$ are independent of the value of frequency.

Measurement 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. Among two 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.

$$Z_1 Z_4 = Z_2 Z_3$$

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

$$=> (1 + j\omega R_1 C_1)(1 + j\omega R_3 C_3) R_4 = j\omega C_1 R_2 R_3$$

$$=> (1 + j\omega R_3 C_3 + j\omega R_1 C_1 - \omega^2 R_1 R_3 C_1 C_3) R_4 = j\omega C_1 R_2 R_3$$

$$=> R_4(1 - \omega^2 R_1 R_3 C_1 C_3) + j\omega R_4(R_3 C_3 + R_1 C_1) = j\omega C_1 R_2 R_3$$

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

$$R_4(1 - \omega^2 R_1 R_3 C_1 C_3) = 0$$

$$=> 1 - \omega^2 R_1 R_3 C_1 C_3 = 0$$

$$=> 1 = \omega^2 R_1 R_3 C_1 C_3$$

$$=> \omega^2 = \frac{1}{R_1 R_3 C_1 C_3}$$

$$=> \omega = \frac{1}{\sqrt{R_1 R_3 C_1 C_3}}$$

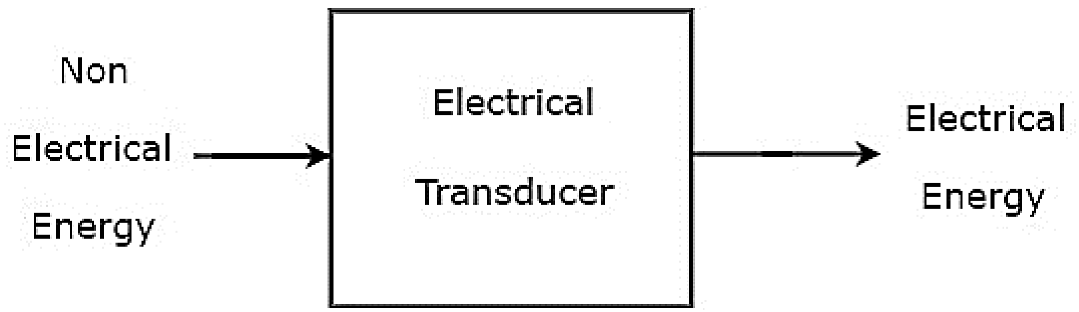
We can find the value of frequency, f of AC voltage source by substituting the values of R_1, R_3, C_1 and C_3 in above equation.

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. $f=1/2\pi RC$

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

UNIT- 6
TRANSDUCER & SENSORS

Basically, Transducer converts one form of energy into another form of energy. The transducer, which converts non-electrical form of energy into electrical form of energy is known as **electrical transducer**. The **block diagram** of electrical transducer is shown in below figure.



As shown in the figure, electrical transducer will produce an output, which has electrical energy. The output of electrical transducer is equivalent to the input, which has non-electrical energy.

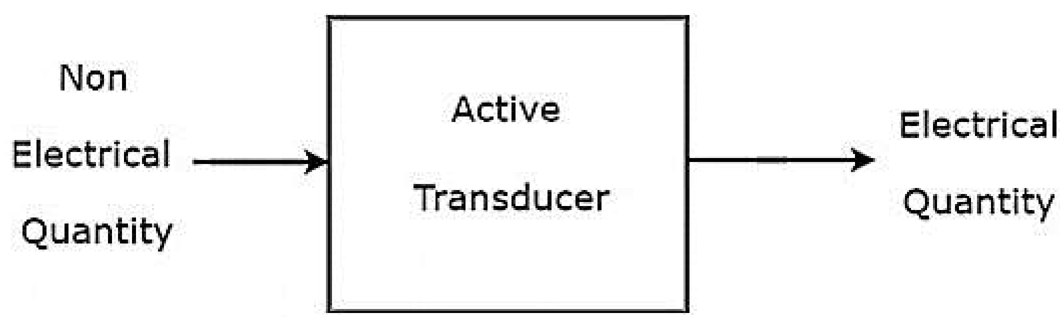
Types of Electrical Transducers:

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

- Active Transducers
- Passive Transducers

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 does not require any external Power supply.
The block diagram of Active transducer as shown below.



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

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.

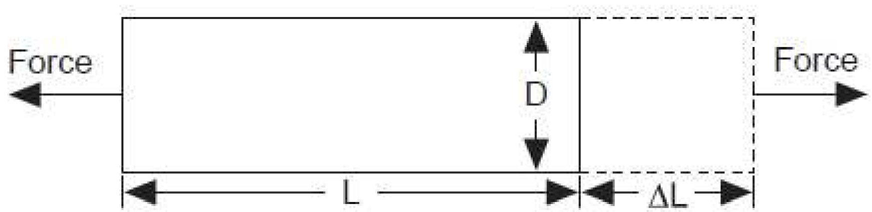
- Resistance, R is directly proportional to the **length** of conductor, l. So, as length of conductor, l increases the value of resistance, R also increases. Similarly, as length of conductor, l decreases the value of resistance, R also decreases.

- 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.

Strain Gauge Measurement:

What is Strain?

Strain is the amount of deformation of a body due to an applied force. More specifically, strain (ε) is defined as the fractional change in length, as shown in Figure 1 below.



$$\varepsilon = \frac{\Delta L}{L}$$

Figure 1. Definition of Strain

Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as microstrain (με), which is $\varepsilon \times 10^{-6}$.

When a bar is strained with a uniaxial force, as in Figure 1, a phenomenon known as Poisson Strain causes the girth of
the bar, D, to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a

material property indicated by its Poisson's Ratio. The Poisson's Ratio ν of a material is defined as the negative ratio of the strain in the transverse direction (perpendicular to the force) to the strain in the axial direction (parallel to the force), or $\nu = -\varepsilon_T/\varepsilon$. Poisson's Ratio for steel, for example, ranges from 0.25 to 0.3.

Working Principle of Strain Gauge:

While there are several methods of measuring strain, the most common is with a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. For example, the piezo resistive strain gauge is a semiconductor device whose resistance varies nonlinearly with strain. The most widely used gauge, however, is the bonded metallic strain gauge.

The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction (Figure 2). The cross sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance. Strain gauges are available commercially with nominal resistance values from 30 to 3000 Ω, with 120, 350, and 1000 Ω being the most common values.

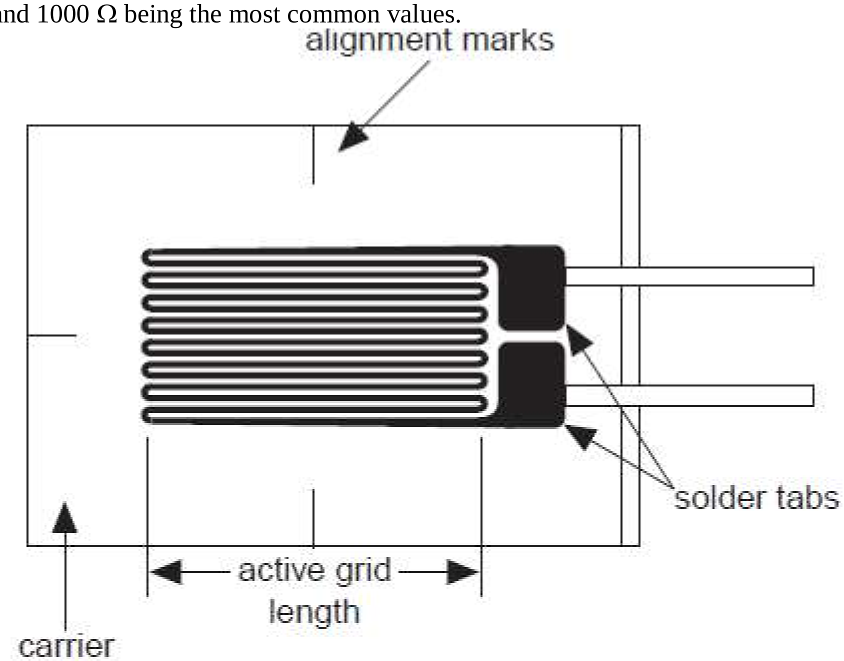


Figure 2. Bonded Metallic Strain Gauge

It is very important that the strain gauge be properly mounted onto the test specimen so that the strain is accurately transferred from the test specimen, though the adhesive and strain gauge backing, to the foil itself. Manufacturers of strain gauges are the best source of information on proper mounting of strain gauges.

A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gauge factor (GF). Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain):

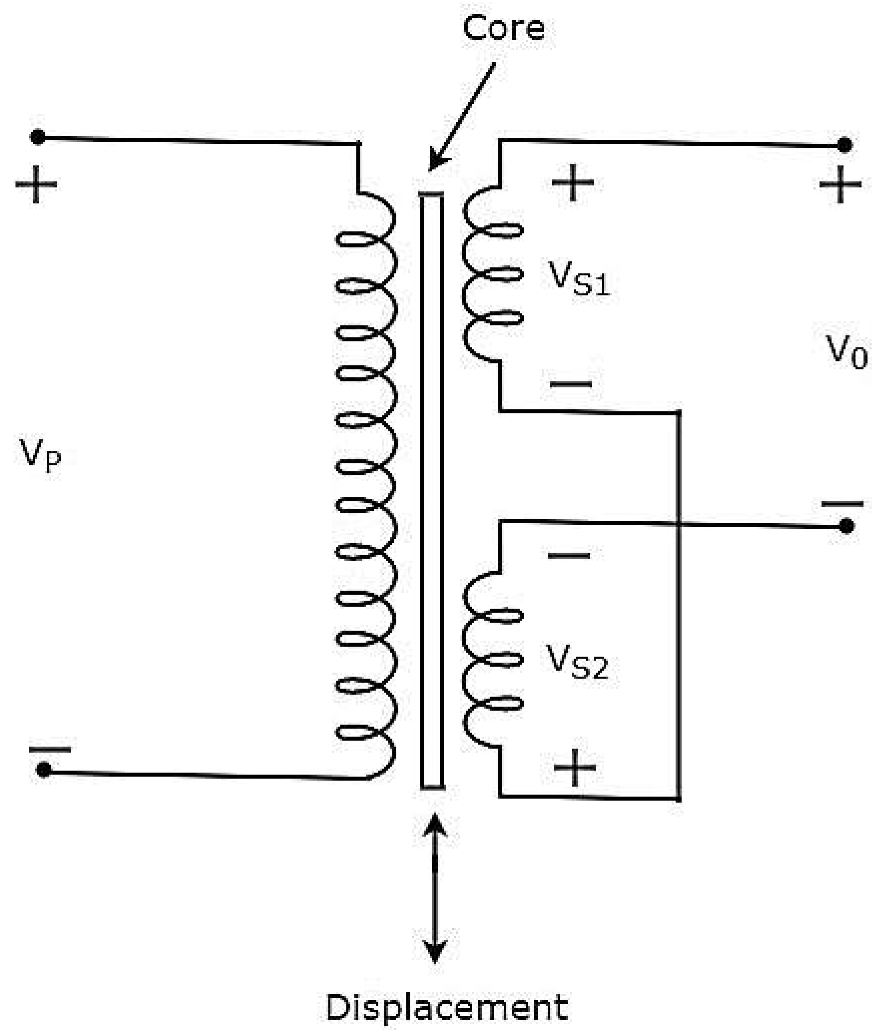
$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

The Gauge Factor for metallic strain gauges is typically around 2.

Working principle of LVDT: (Linear variable differential Transformer)

Measurement of Displacement using Inductive Transducer:

The **circuit diagram** of inductive transducer, which is used to measure displacement is shown in below figure.



The transformer present in above circuit has a primary winding and two secondary windings. Here, the ending points of two secondary windings are joined together. So, we can say that these two secondary windings are connected in **series opposition**.

The voltage, V_P is applied across the primary winding of transformer. Let, the voltage developed across each secondary winding is V_{S1} and V_{S2}. The output voltage, V_0 is taken across the starting points of two secondary windings.

Mathematically, the output voltage, V_0 can be written as $V_0=V_{S1}-V_{S2}$

The transformer present in above circuit is called **differential transformer**, since it produces an output voltage, which is the difference between V_{S1} and V_{S2}.

- If the core is at central position, then the output voltage, V_0 will be equal to zero. Because, the respective magnitudes & phases of V_{S1} and V_{S2} are same.

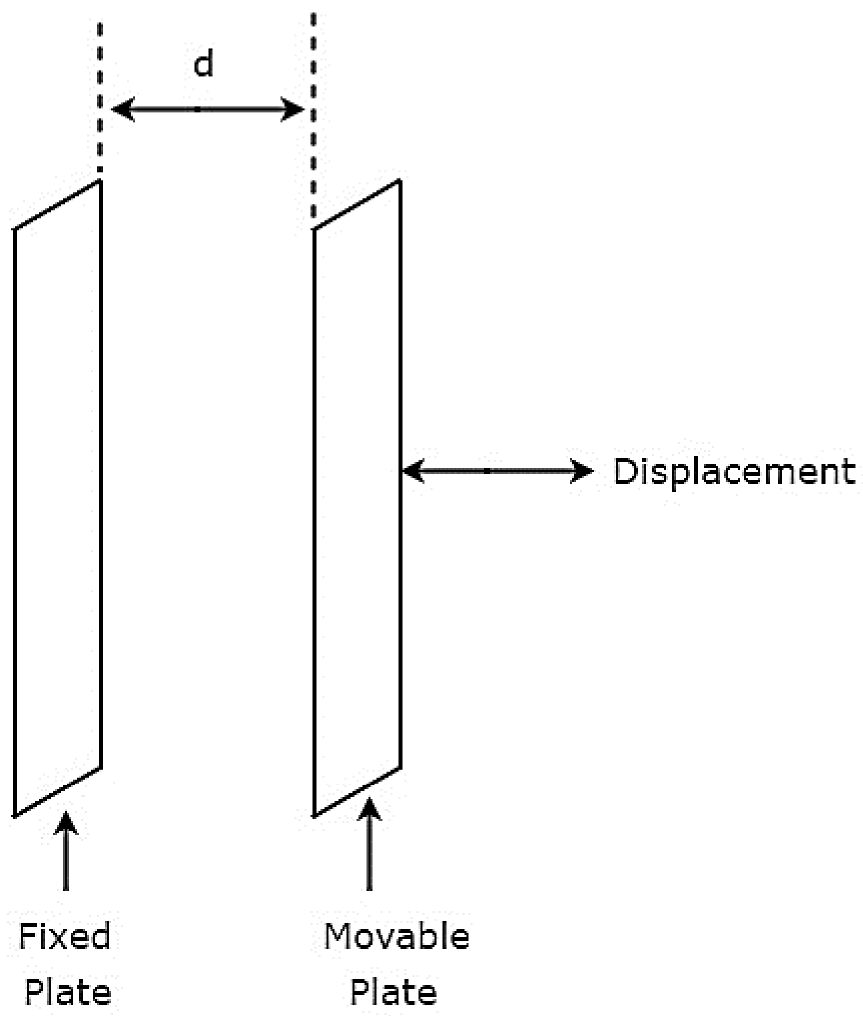
• If the core is not at central position, then the output voltage, V_0 will be having some magnitude & phase. Because, the respective magnitudes & phases of V_{S1} and V_{S2} are not equal.

Therefore, we should connect the body whose displacement is to be measured to the central core. So, whenever the body moves in a straight line, the central position of the core varies. Due to this, the output voltage, V_0 also changes accordingly.

In this case, we can find the **displacement** by measuring the output voltage, V_0. The magnitude & phase of output voltage, V_0 represents the displacement of the body & its direction respectively.

Measurement of Displacement using Capacitive Transducer:

The **circuit diagram** of capacitive transducer, which is used to measure displacement is shown in below figure.



The **capacitor**, which is present in above circuit has two parallel plates. Among which, one plate is fixed and the other plate is a movable one. Due to this, the spacing between these two plates will also vary. the value of capacitance changes as the spacing between two plates of capacitor changes.

Therefore, we should connect the body whose **displacement** is to be measured to the movable plate of a capacitor. So, whenever the body moves in a straight line, the spacing between the two plates of capacitor varies. Due to this, the capacitance value changes.

A passive transducer is said to be a **capacitive transducer**, when it produces the variation (change) in capacitance value. the following formula for **capacitance**, C of a parallel plate capacitor.

$$C=\varepsilon A/d$$

Where,
ε is the permittivity or the dielectric constant
A is the effective area of two plates
d is the distance between two plates
The capacitance value depends on the three parameters ε, A & d. So, we can make the **capacitive transducers** based on the variation in one of the three parameters ε, A & d. Because, the variation in any one of those three parameters changes the capacitance value.

• Capacitance, C is directly proportional to **permittivity**, ε. So, as permittivity, ε increases the value of capacitance, C also increases. Similarly, as permittivity, ε decreases the value of capacitance, C also decreases.

• Capacitance, C is directly proportional to the **effective area of two plates**, A. So, as effective area of two plates, A increases the value of capacitance, C also increases. Similarly, as effective area of two plates, A decreases the value of capacitance, C also decreases.

• Capacitance, C is inversely proportional to the **distance between two plates**, d. So, as distance between two plates, d increases the value of capacitance, C decreases. Similarly, as distance between two plates, d decreases the value of capacitance, C increases.

Working principle of Temperature Transducer:

Thermistor Transducer:

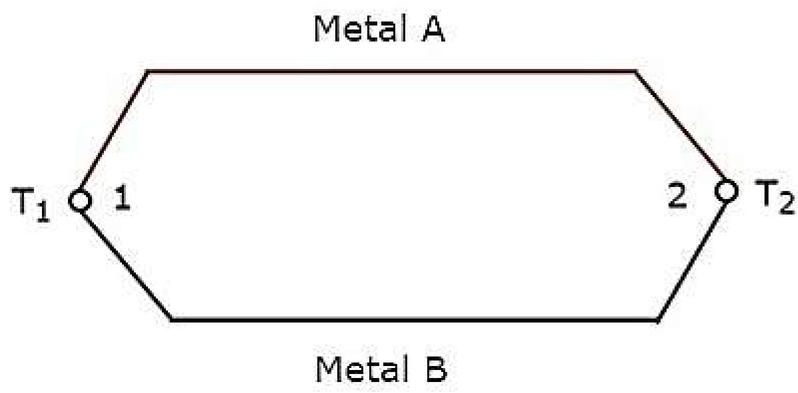
The resistor, which depends on temperature is called thermal resistor. In short, it is called **Thermistor**. The temperature coefficient of thermistor is negative. That means, as temperature increases, the resistance of thermistor decreases.
Mathematically, the relation between resistance of thermistor and temperature can be represented as

$$R_1 = R_2 e^{\left(\beta\left[\frac{1}{T_1}-\frac{1}{T_2}\right]\right)}$$

Where,
$R1$ is the resistance of thermistor at temperature $T10K$
$R2$ is the resistance of thermistor at temperature $T20K$
β is the temperature constant
The advantage of Thermistor transducer is that it will produce a fast and stable response.

Thermocouple Transducer:

Thermocouple transducer produces an output voltage for a corresponding change of temperature at the input. If two wires of different metals are joined together in order to create two junctions, then that entire configuration is called **Thermocouple**. The circuit diagram of basic thermocouple is shown below:



The above thermocouple has two metals, A & B and two junctions, 1 & 2. Consider a constant reference temperature, T_2 at junction 2. Let the temperature at junction, 1 is T_1. Thermocouple generates an **emf** (electro motive force), whenever the values of T_1 and T_2 are different.

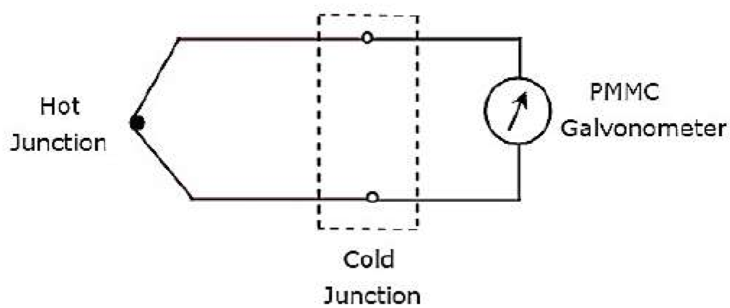
That means, thermocouple generates an emf, whenever there is a temperature difference between the two junctions, 1 & 2 and it is directly proportional to the temperature difference between those two junctions. **Mathematically**, it can be represented as

$$e \, \alpha \, (T_1 - T_2)$$

Where,

e is the emf generated by thermocouple

The above thermocouple circuit can be represented as shown in below figure for practical applications.



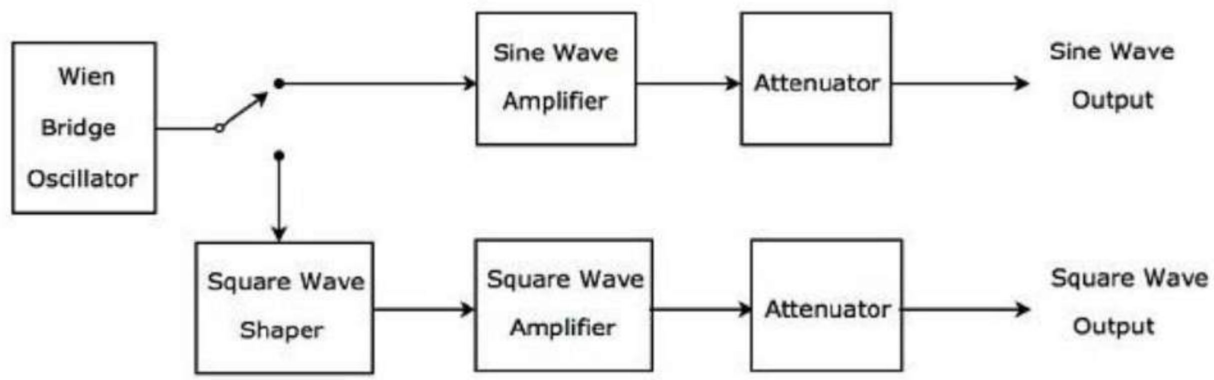
The part of the circuit, which lies between hot & cold junctions including those two junctions is an equivalent model of basic thermocouple. A PMMC galvanometer is connected across the cold junction and it deflects according to the emf generated across cold junction. **Thermocouple transducer** is the most commonly used thermoelectric transducer.

Signal generator is an electronic equipment that provides standard test signals like sine wave, square wave, triangular wave and etc. It is also called an oscillator, since it produces periodic signals.

The signal generator, which produces the periodic signal having a frequency of Audio Frequency (AF) range is called **AF signal generator**. the range of audio frequencies is 20Hz to 20KHz.

AF Sine and Square Wave Generator:

The AF signal generator, which generates either sine wave or square wave in the range of audio frequencies based on the requirement is called AF Sine and Square wave generator. Its **block diagram** is shown in below figure.



The above block diagram consists of mainly **two paths**. Those are upper path and lower path. Upper path is used to produce AF sine wave and the lower path is used to produce AF square wave.

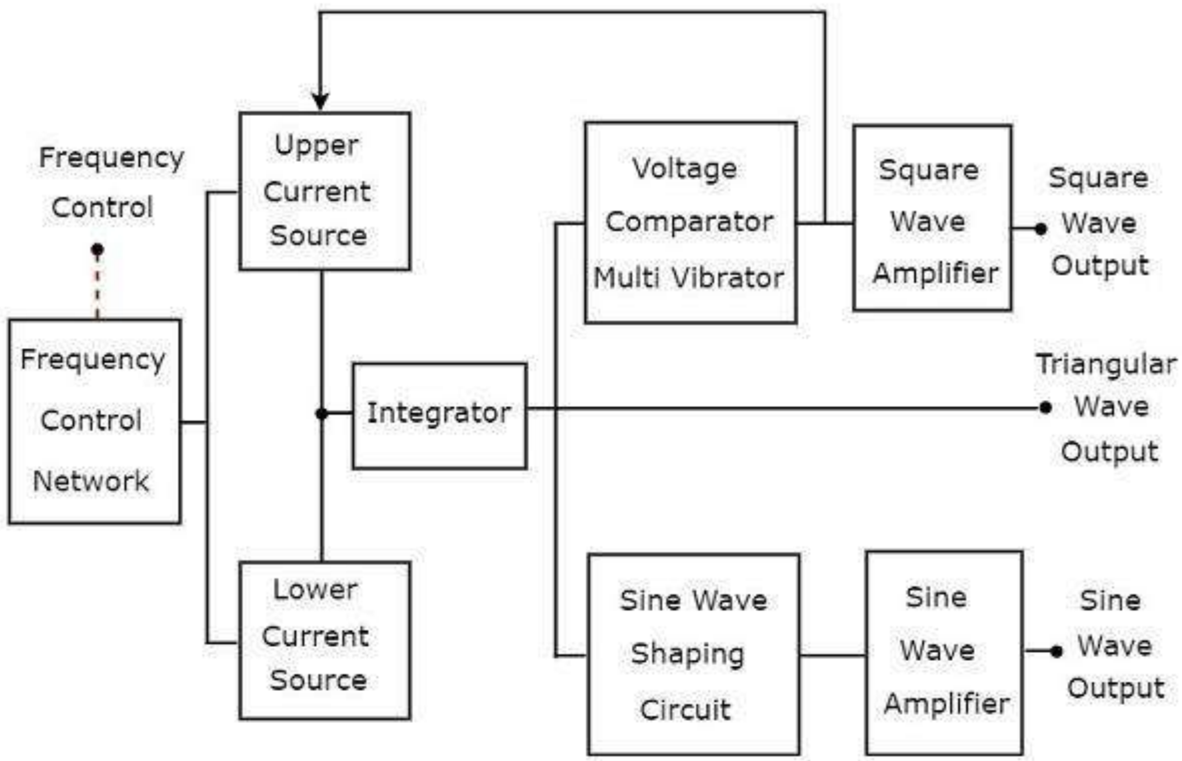
Wien bridge oscillator will produce a sine wave in the range of audio frequencies. Based on the requirement, we can connect the output of Wien bridge oscillator to either upper path or lower path by a switch.

The upper path consists of the blocks like sine wave amplifier and attenuator. If the switch is used to connect the output of Wien bridge oscillator to upper path, it will produce a desired **AF sine wave** at the output of upper path.

The lower path consists of the following blocks: square wave shaper, square wave amplifier, and attenuator. The square wave shaper converts the sine wave into a square wave. If the switch is used to connect the output of Wien bridge oscillator to lower path, then it will produce a desired **AF square wave** at the output of lower path. In this way, the block diagram that we considered can be used to produce either AF sine wave or AF square wave based on the requirement.

Working Principle of 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.

WAVE ANALYZERS

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.

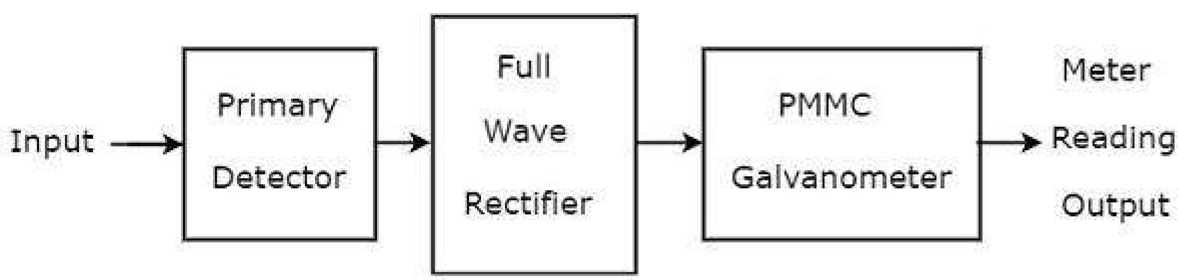
We can represent the **periodic signal** as sum of the following two terms.

- DC component
- Series of sinusoidal harmonics

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

Basic Wave Analyzer:

Basic wave analyzer mainly consists of three blocks: the primary detector, full wave rectifier, and PMMC galvanometer. The **block diagram** of basic wave analyzer is shown in below figure:

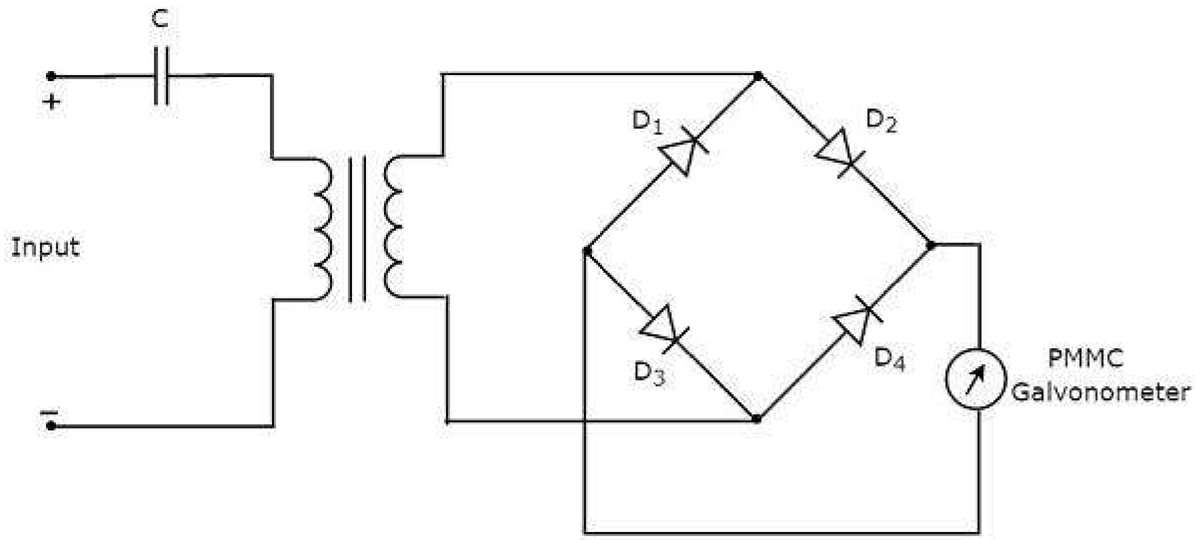


The **function** of each block present in basic wave analyzer is mentioned below.

• **Primary Detector:** It consists of an LC circuit. We can adjust the values of inductor, L and capacitor, C in such a way that it allows only the desired harmonic frequency component that is to be measured.

• **Full Wave Rectifier:** It converts the AC input into a DC output

• **PMMC Galvanometer:** It shows the peak value of the signal, which is obtained at the output of Full wave rectifier.



This basic wave analyzer can be used for analyzing each and every harmonic frequency component of a periodic signal.

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.

Types of Spectrum Analyzers:

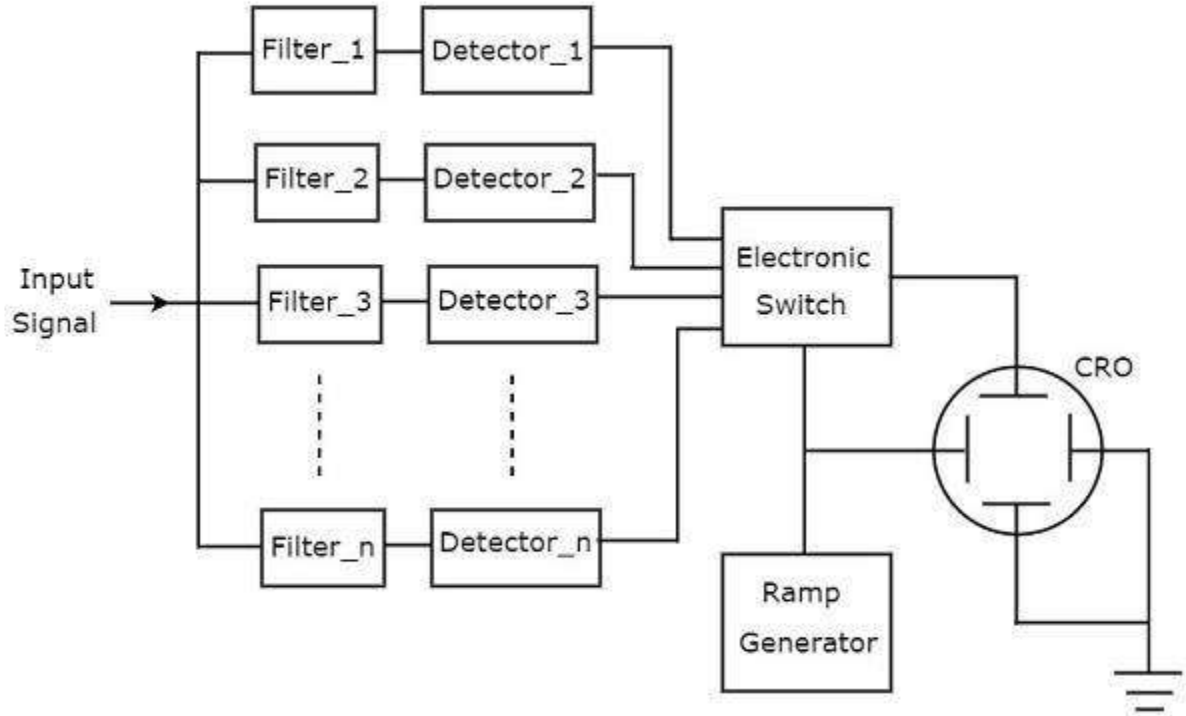
We can classify the spectrum analyzers into the following **two types**.

- Filter bank spectrum analyzer
- Superheterodyne Spectrum analyzer

Filter Bank Spectrum Analyzer:

The spectrum analyzer, used for analyzing the signals are of AF range is called filter bank spectrum analyzer, or **real time spectrum analyzer** because it shows (displays) any variations in all input frequencies.

The following figure shows the **block diagram** of filter bank spectrum analyzer.



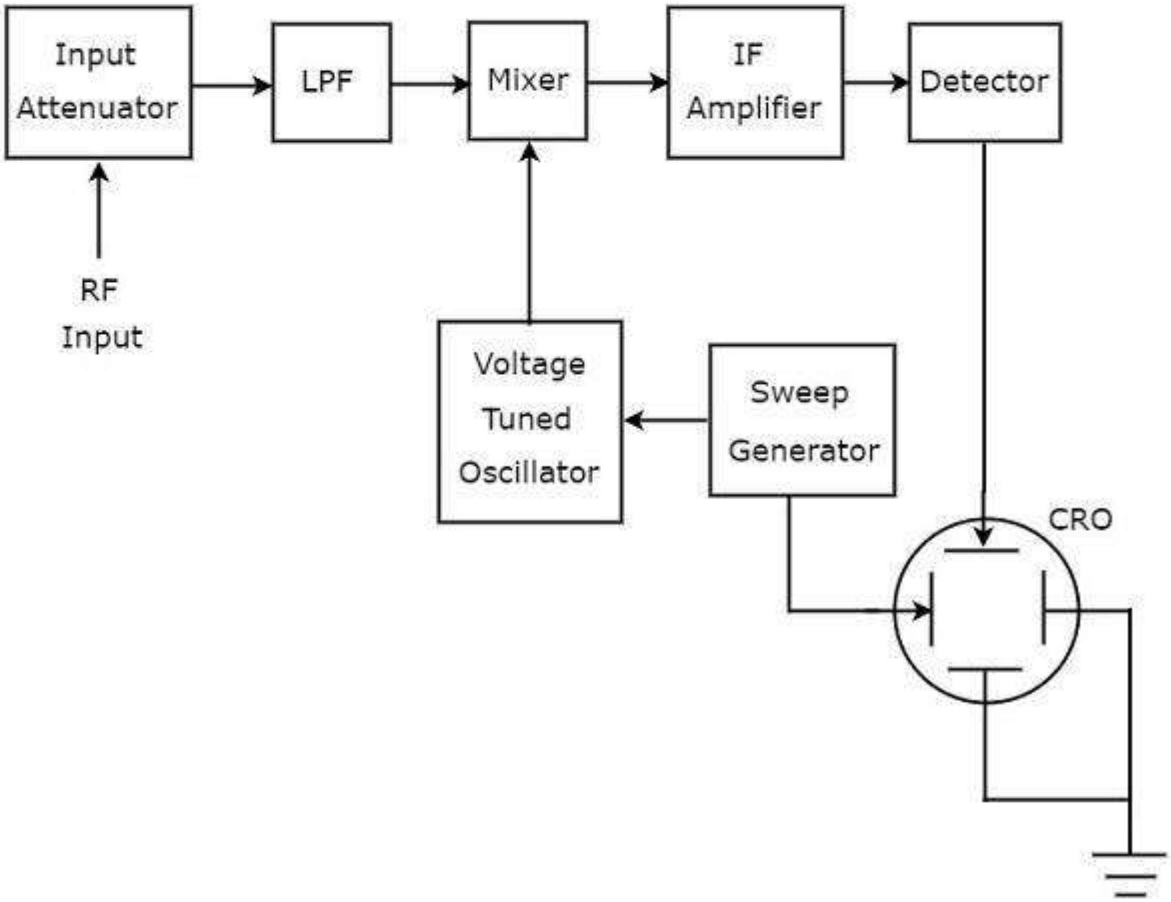
The **working** of filter bank spectrum analyzer is mentioned below.

☐ It has a set of band pass filters and each one is designed for allowing a specific band of frequencies. The output of each band pass filter is given to a corresponding detector.

• All the detector outputs are connected to Electronic switch. This switch allows the detector outputs sequentially to the vertical deflection plate of CRO. So, CRO displays the frequency **spectrum of AF signal** on its CRT screen.

Superheterodyne Spectrum Analyzer:

The spectrum analyzer, used for analyzing the signals are of RF range is called **superheterodyne spectrum analyzer**. Its **block diagram** is shown in below figure



The **working** of superheterodyne 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.

Data Acquisition Systems(DAS):

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 system
- Digital 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.