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CHENNAI – 600 025

STATE PROJECT COORDINATION UNIT

Diploma in Instrumentation and Control Engineering

Course Code: 1042

M – Scheme

e-TEXTBOOK
on

MESUREMENTS AND INSTRUMENTS

for

IV Semester DICE

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34242 - MESUREMENTS AND INSTRUMENTS

Basic forces for indicating instruments – constructional features of permanent magnet and moving coil instrument – moving iron instrument – attraction and repulsion types – rectifier type ac volt meter – ohm meter – series and shunt type – extension of range using shunt and multipliers – analog Multimeter circuits – dynamo meter type wattmeter - 1φ & 3φ induction type energy meter, Multifunctional Meters.

Construction, working, balance equation (derivation not required) and application of measurement of resistance by Wheatstone bridge – measurement of capacitance by Schering bridge – measurement of inductance by Maxwell's bridge –measurement of frequency using Wien bridge - RLC meter.

Block diagram of oscilloscope – construction and working of CRT – horizontal deflection and vertical deflection – time base generator – CRO probes –voltage – current – active – passive probes - applications of CRO.

Block diagram, working and applications of DC power supply –fixed and variable – Audio signal generator – Function generator – Megger – working and applications. Instrument transformer – CT and PT – block diagram, working of recorders – XY recorder – strip chart recorder.

Digital vs Analog instruments – Digital volt meter-Integrated type, Ramp type and successive approximation – Digital Multimeter– auto ranging – auto zeroing – auto polarity – Digital Frequency Meter –Block diagram- circuit diagram – Digital tachometer – digital panel meter using LCD – Digital storage oscilloscope, mixed storage oscilloscope.

Circuit diagram and working of ramp, triangular, square wave generators using operational amplifier – Differential amplifier – Instrumentation amplifier – Charge amp with zero electric crystal –low pass and high pass filters using op. amps –PWM - PLL –Functional block diagram Capture range – Lock range - applications.

Text book:

- A.K.Sawhney, A course in Electrical & Electronic measurements and instrumentation, Dhanpat Rai & sons. 1986.

Reference books:

1. Modern electronics Instrumentation and measurement techniques – ALBERT D.HELFRICK
2. Electrical and Electronics measurements and instrumentation – UMESH SINHA, SATYAPRAKASHAN, Tech India publication 1992.

UNIT – 1

MEASURING INSTRUMENTS

1.1 Introduction to measuring instruments:

The **measurement** of a given quantity is the result of comparison between the quantity whose magnitude is unknown and a predefined standard. Since two quantities are compared the result is expressed in numerical values. Measurements involve the use of instruments as a physical means of determining variables.

Instrument can be defined as a device for measuring the value or magnitude of quantity or variable. Instruments are broadly classified into two categories (i) Absolute instruments (ii) Secondary instruments. Absolute instruments give the magnitude of the quantity under measurement in terms of physical constants of the instruments. Secondary instruments are so constructed that the quantity being measured can only be measured by observing the output indicated by the instruments. The indications are given by a pointer moving over a calibrated scale.

The instrument which measures the voltage in volts across any two points of a circuit is called **voltmeter** while the instrument which measures the current in ampere is called **ammeter**. The instruments which are used to measure the power in watts are called **power meters** or **watt meters**. These instruments are calibrated by comparison with an absolute instrument.

Application of measuring instruments:

Measurements and instruments are used for different applications. They are,

1. Monitoring of processes and operation
2. Control of processes and operations
3. Experimental Engineering analysis

1.2 Basic forces for indicating instrument:

There are three types of forces for indicating instrument. They are

1. Deflecting force
2. Controlling force
3. Damping force

1.2.1 Deflecting Force

It is also called the operating force. It causes the moving system of the instrument to move from its zero position to the indicating position. The zero position of the moving system is the position of it when the instrument connected to the circuit is disconnected from the supply. This force is made to act by utilizing any one of the following effect.

1. Magnetic and electromagnetic effect
2. Heating effect
3. Electrostatic effect
4. Induction effect

1.2.2 Controlling Force

The deflecting of the moving system will be infinite if there were no opposing force. Such an opposing force is called "controlling force". The system producing controlling force is called controlling system. The controlling force limits the movement of the moving system which also ensures that the magnitude of the deflection is always the same for a given value of the quantity to be measured. The controlling torque increases in magnitude with deflection till it balances the deflecting torque. That is for a steady deflection,

Controlling torque = deflecting torque

1.2.3 Damping force:

In a measuring instrument, the damping torque is necessary to bring the moving system to rest to indicate steady reflection in a reasonable short time called **critical damping**. It exists only as long as the pointer is in motion. Under the absence of damping torque the pointer oscillates for a short period of time and comes to steady position and this situation is called **under damping**. If the damping force is too large, then the pointer will come to rest slowly and this is called as **over damping**. These concepts are shown in fig 1.2.3.1

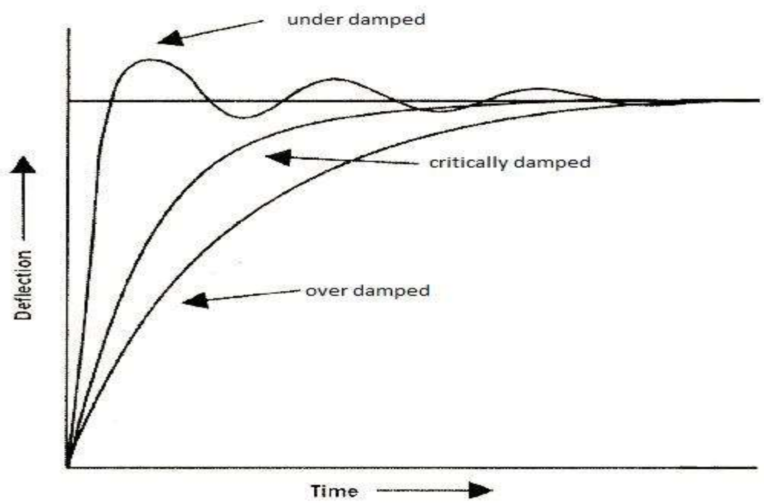


Fig 1.2.3.1 Dynamic response of a measuring instrument

1.3 Permanent Magnet Moving Coil (PMMC) Instruments:

These instruments work on the electromagnetic effect. A permanent magnet is used to produce magnetic flux and a coil that carries the current to be measured moves in this field. As the pointer is connected to the coil it gets deflected in proportion with the current.

Working principle:

A current carrying conductor placed in magnetic field experiences a force. It is given by the expression

$$F = BIL$$

Where F = Force in Newton

B = Flux density in Tesla

I = Current in Ampere

L = Length of conductor in Meter

Construction:

A light rectangular coil is wound on a metal frame (usually aluminium) is pivoted within the air gaps between the two poles of a permanent magnet and a cylindrical soft iron core. This coil carries the current to be measured. Soft iron core provides formation of uniform magnetic field. The aluminium frame supports the coil as well as provides eddy current damping. Two phosphor-bronze springs coiled in opposite directions serve as leads for the current in the coil.

The springs also provide controlling torque. The moving system is balanced by three balance weights. The moving spindle is pivoted in jewellery bearings. The construction of instrument is shown in the fig.1.3.1

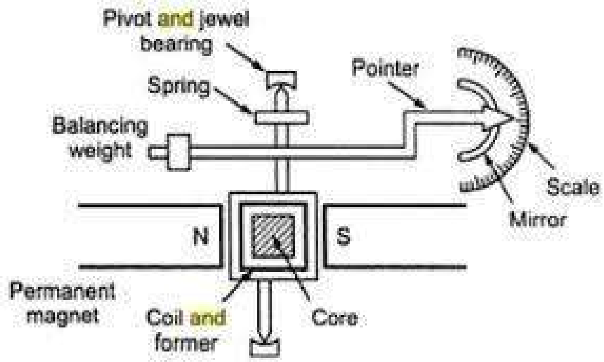


Fig 1.3.1 Construction of PMMC instrument

Deflecting torque equation:

Let length of coil be l meter and width of it be d meter. Assume I is the current flowing in coil having N turns. Assume B as the flux density in the air gap. Then F = BIL (N)

Torque on each side of the coil = F x d / 2

Total Torque = 2 [BIL.N.d/2] = B I L d N

For a given instrument B, L, d and N are constants.

$T_d \alpha G I$

where

G = B.L.d.N

Controlling torque $= T_c$

$= C . \theta$

where

C = control spring constant

θ = deflection of coil from zero position

For steady state, the controlling torque is equal to the deflection torque

$T_c = T_d$

$C \ \theta = G I$

Hence

$\theta \alpha I$

Thus deflection of the pointer is proportional to current passed through the coil. Hence the scale of PMMC instruments is a uniform scale.

Advantages:

i. It has uniform scale
ii. Its sensitivity is high
iii. It consumes low power
iv. It is free from hysteresis error
v. Extension of instrument range is possible with the help of shunt and series resistance.

Disadvantages:

i. The cost of the instrument is high
ii. It is suitable for dc measurements only
iii. Aging of permanent magnets and control springs introduces error

1.4 Moving Iron Instruments:

Where ruggedness is more important than high degree of accuracy, moving iron instruments are used. The following are the two types of moving iron instruments.

1. Attraction type
2. Repulsion type

1.4.1 Attraction Type Instrument:

Attraction type instrument is shown in fig 1.4.1.1. A coil of insulted copper wire is round wound a hollow bobbin. For a voltmeter, the cross-section of a wire is fine and it has many numbers of turns. For an ammeter, the coil is thick and it has few turns.

A small piece of iron, elliptically shaped, is eccentrically pivoted just outside the coil. Whenever the current passes through a coil, moving iron piece gets attracted. It is pulled inside the bobbin and deflecting torque is produced. Moving iron is pivoted by a spindle which carries a pointer.

Moving iron is elliptically shaped so as to obtain a uniform scale. In the figure, gravity control is shown but a spring control also can be used. Using air friction, damping torque is provided. So it can be used for ac as work as dc.

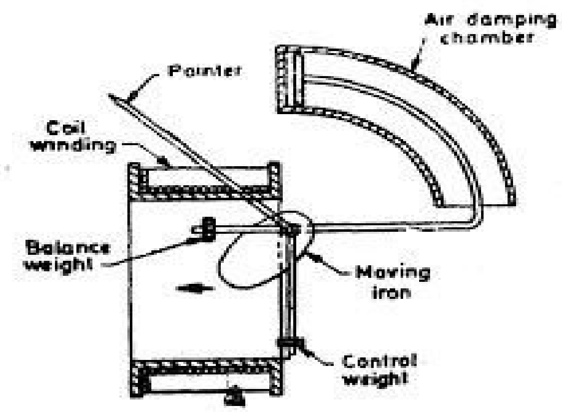


Fig 1.4.1.1 Attraction Type Instrument

1.4.2 Repulsion Type Instrument:

As in fig 1.4.2.1, a coil is wound around a hollow bobbin. Inside the bobbin two pieces of soft iron are placed face to face. One piece is fixed to the wall of bobbin and the other is fixed to the spindle and it is allowed to move.

These iron vanes are similarly magnetized when current flows through the coil. The force of repulsion is produced between the vanes. Hence moving vane deflects. The deflection is shown by a pointer on a scale. Controlling torque is produced using spring. Air friction damping is used to provide damping torque.

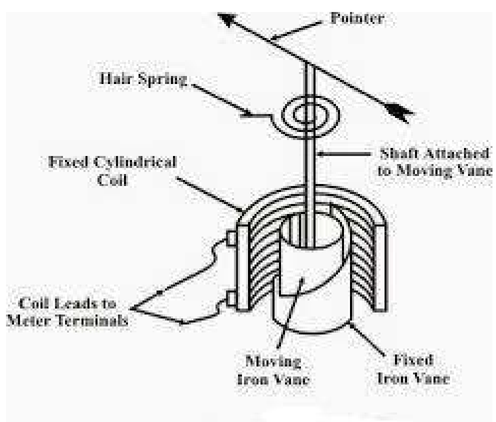


Fig 1.4.2.1 Repulsion Type Instrument

Derivation of deflecting torque equation:

It is based on principle of conservation of energy.

Electrical energy supplied = Change in stored energy + Mechanical work done

Let I = Initial current in Ampere

L = instrument inductance in Henry

θ = deflection in Radians

If current increase by dI, deflection changes by dθ and inductance by dL. To increase the current by dI, there must be increase in applied voltage given by,

$$e = d/dt\,[LI] = L\,dI/dt + I\,dL/dt$$

Electrical energy supplied = eI dt

$$= LI\,dI + I^2\,dL$$

Change in stored energy = $\frac{1}{2}[I + dI]^2\,[L + dL] - \frac{1}{2}LI^2$

$$= \frac{1}{2}[I^2 + 2IdI + DI^2]\,[L + DL] - \frac{1}{2}LI^2$$

Neglecting second and higher order terms, $\simeq IL\,dI + \frac{1}{2}I^2\,dL$

According to the principle of conversation of energy,

Electrical energy supplied = increase in stored energy + mechanical work done

$$I^2\,dL + LI\,dI = IL\,dI + \frac{1}{2}I^2\,dL + T_d\,d\theta$$

$$T_d\,d\theta = \frac{1}{2}I^2\,dL$$

Though basic iron movement has square law response using radial vane design, a nearly linear scale can be obtained.

Advantages:

- It can be used for a.c. as well as d.c. measurement.
- Instrument is robust as moving parts do not carry current
- Cheapness: For covering large ranges ammeter or voltmeter, fixed coil turns and cross-section is varied. Single type of moving element can be used for these different ranges.

Limitations:

- Non uniform scale
- As frequency changes reactance of coil changes, hence calibration of instruments does not remain same for a.c. and d.c.
- The instrument is subjected to error due to temperature variation, frequency variation.

Applications:

- Moving iron instruments are rarely used for d.c. measurement except for very inexpensive indicators such as charge discharge indicators in automobiles.
- They are used extensively on a.c. where 5 to 10 % error is acceptable.

Comparison between moving coil and moving iron instrument:

Sl.No	Moving coil instrument	Moving iron instrument
1	It can be used for D.C. measurement only.	It can be used for both A.C. and D.C. measurement.
2	It has uniform scale.	It has non uniform scale
3	It has very high accuracy	Its accuracy is limited
4	The cost of the instrument is high	Its cost is comparatively low
5	Aging of permanent magnets and control springs introduces errors	The instrument is subjected to error due to temperature and frequency variation

1.5 Rectifier type A.C. Voltmeter:

The PMMC movement used in d.c. voltmeters can be effectively used in a.c. voltmeters. The rectifier is used to convert a.c. voltage to be measured, to d.c. This d.c., if required is amplified and then given to the PMMC movement. The PMMC movement gives the deflection proportional to the quantity to be measured.

A.C. voltmeters can be designed in two ways:

1. First rectifying the a.c. signal and then amplifying
2. First amplifying the a.c. signal and then rectifying

1.5.1 First Rectifying and then Amplifying A.C. Signal:

In this arrangement simple diode rectifier circuit precedes the amplifier and the meter. This is shown in the fig 1.5.1.1

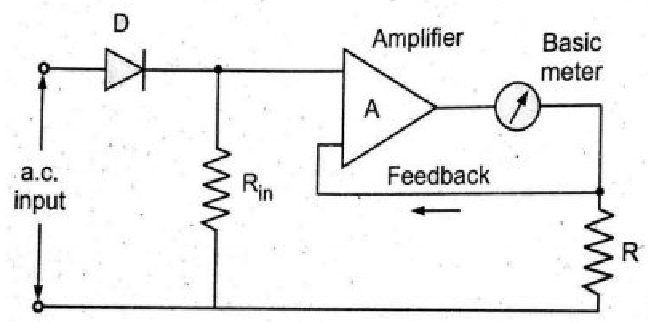


Fig 1.5.1.1 Method of rectifying and amplifying a.c. signal

The a.c. input voltage if first rectified using the diode D_1. This rectified signal is then applied to the amplifier of gain A. The amplified signal is then given to the basic PMMC meter to obtain the deflection. This approach ideally requires a d.c. amplifier with zero drift characteristics and a d.c. meter movement with high sensitivity. The resistance R_2 indicates input resistance of the meter.

1.5.2 First Amplifying and then Rectifying A.C. Signal:

In this approach, the a.c. input signal which is a small signal is amplified first and then rectified after the sufficient amplification. The a.c. signal is applied to an amplifier and hence amplifier is necessarily an a.c. amplifier. This type of approach is shown in the Fig 1.5.2.1

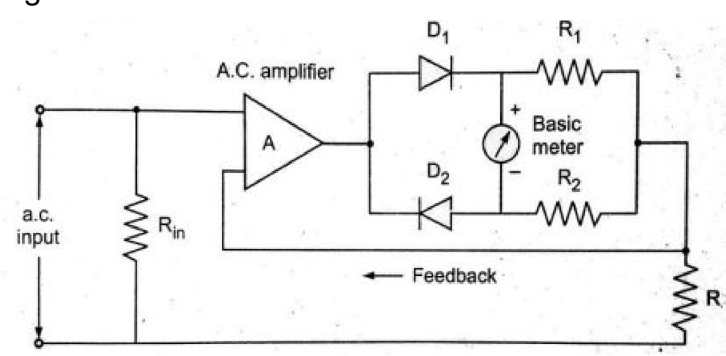


Fig 1.5.2.1 Method of Amplifying and Rectifying A.C. Signal

The a.c. amplifier requires a high open loop gain and the large amount of negative feedback to overcome the nonlinearity of the rectifier diodes. The amplifier output is then applied to full wave rectifier consisting of diodes D1 and D2. The diodes are nonlinear devices, particularly at the low values of the forward current.

Due to this nonlinear behavior of the diodes, the meter scale is also nonlinear and is crowded at the lower end of a low range voltmeter. In this, region, the meter sensitivity is also very low because of high forward resistance of the diode. Dependence of diode characteristics on temperature is also an important factor in a.c. voltmeters.

1.6 Ohmmeter:

The ohmmeter is a convenient direct reading device for measurement of resistance. These instruments have a low degree of accuracy. There is a wide field of application for this instrument in determining the approximate value of resistance. An ohmmeter is useful for determining the approximate resistance of circuit components such as heater elements or machine field coils, measuring and sorting of resistors used in electronic circuits, checking of semiconductor diodes and for checking continuity of circuits. It is also useful in laboratories as an aid to a precision bridge, for it can help to know the approximate value of resistance which can save time in balancing the bridge.

1.6.1 Series-type Ohmmeter:

A circuit of a series-type ohmmeter is shown in Fig 1.6.1.1. It consists of basic d' Arsonval movement connected in parallel with a shunting resistor R_2. This parallel circuit is in series with resistance R_1 and a battery of emf E. The series circuit is connected to the terminals A and B of the unknown resistance R.

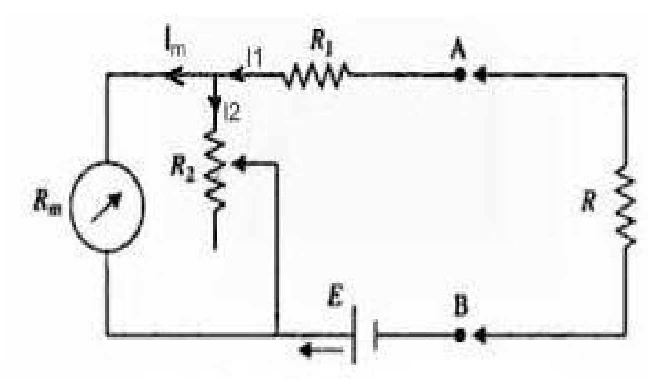


Fig 1.6.1.1 Series-type Ohmmeter

R_1 = current limiting resistor,

R_2 = zero adjusting resistors,

E = emf of internal battery,

and

Rm = internal resistance of d' Arsonval movement.

When the unknown resistance R = 0 (terminals A and B shorted) maximum current flows through the meter. Under this condition resister R2 is adjusted until the basic movement (meter) indicates full scale current Ifs. The full-scale current position of the pointer is marked "0 Ω" on the scale. Similarly when R is removed from circuit, R = ∞ (that is when terminals A and B are open) the current in the meter drops to zero and the movement indicates zero current which is the marked " ∞". Thus the meter will read infinite resistance at the zero current position and zero resistance at full scale current position.

Since zero resistance is indicated when the current in the meter is maximum and hence the pointer goes to the top mark. When the unknown resistance is inserted at terminals A, B the current through the meter is reduced and hence pointer drops lower on the scale. Therefore the meter has "0" at extreme right and "∞" at the extreme left. Intermediate scale markings may be placed on the scale by different known values of resistance R to the instrument.

1.6.2 Shunt type ohmmeter:

The circuit diagram of a shunt type ohmmeter is shown in Fig 1.6.2.1. It consists of a battery in series with an adjustable resistor R1 and a basic d ' Arsonval movement (meter). The unknown resistance is connected across terminals A and B, Parallel with the meter. In this circuit it is necessary to have an "off-on" switch to disconnect the battery from the circuit when the instrument is not in use.

When the unknown resistor Rx = 0 Ω (A and B are shorted), the meter current is zero. If the unknown resistance Rx = ∞ (A and B are open), the current finds path only through the meter and selecting a proper value for resistance R1, the pointer may be made to read full scale. This ohmmeter therefore has “zero” mark on the left hand side of the scale (no current) and infinite mark on the right hand side of the scale (full scale deflection current).

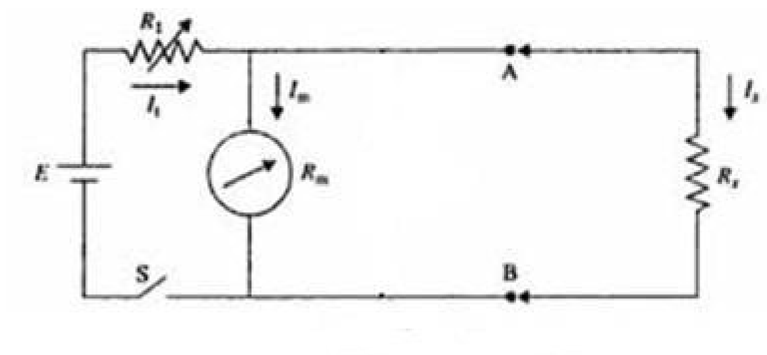


Fig 1.6.2.1 Shunt type ohmmeter

1.7 Extension of range using shunt:

- The basic circuit consists of D’Arsonval galvanometer.
- The coil winding of basic movement is small and it is light in weight. So this coil enables small currents to pass through it.
- If it is required to pass current larger than 100 mA through the coil, then the construction becomes bulky.
- In order to avoid this, a resistor is connected in parallel with the basic movement.
- This resister is called as shunt resistor.
- Its value is small. So major amount of current passes through it and a small current passes through the coil.
- The different notations used in figure are as follows

I = Total current to be measured

R_{sh} = Shunt resistor

I_{sh} = current passing through shunt resistor

R_m = Internal resistance of the coil

I_m = Full scale deflection current (I_{fsd})

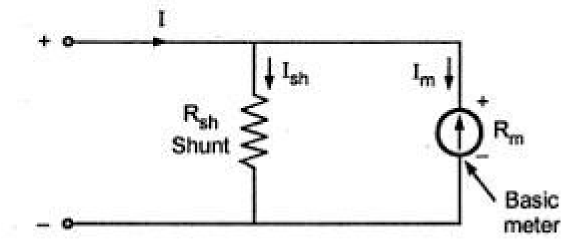


Fig 1.7.1 Extension of range using shunt

Now as shown in figure 1.7.1, resistor R_{sh} and R_m are parallel to each other. So the voltage drop across two resistors is same.

$$I_{sh}.R_{sh} = I_m R_m$$

$$R_{sh} = \frac{I_m R_m}{I_{sh}} \qquad (1)$$

But we have, $I = I_{sh}+I_m$

$$I_{sh} = I - I_m$$

putting this value in equation (1) we get,

$$R_{Sh} = \frac{I_m R_m}{I - I_m}$$

dividing both the numerator and denominator by I_m we get,

$$R_{Sh} = \frac{R_m}{I / I_m - 1} \qquad (2)$$

Now we will define the term ''multiplying power of the shunt''. It is defined as the zero of total current (I) to the current passing through the coil (Im). It is denoted by 'm'

$$m = I / I_m$$

Putting this value in equation (2) we get,

$$R_{Sh} = R_m / (m-1)$$

$$mR_{Sh} - R_{Sh} = R_m$$

$m R_{Sh} = R_m + R_{Sh}$

$m = (R_m + R_{Sh}) / R_{Sh}$

$m = (R_m / R_{Sh}) + 1$

1.8 Extension of range using multiplier:

- The basic meter is based on the PMMC D' Arsonval movement.
- In this case the current cause the deflection of meter.
- The current required to cause the full scale deflection of a meter is termed as full scale deflection current. It is denoted by I_{fsd}.
- The basic dc voltmeter is as shown in fig 1.8.1

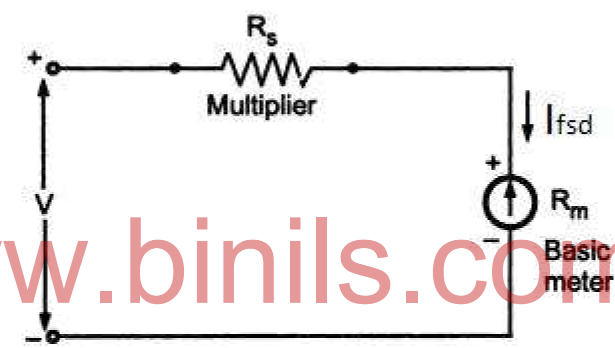


Fig 1.8.1 Extension of range using multiplier

- The basic meter can be converted into dc voltmeter by adding a series resistance. This series resistance is called as **multiplier**.
- The function of this resistance is to control the current passing to the meter.
- It does not allow the current to exceed the value of full scale deflection current. This series resistance is denoted by R_s
- The do voltmeter is used to measure the voltage drop between two points in a dc circuit.
- To measure the dc voltage, the voltmeter is connected to these two points with proper polarity.
- Referring to figure 1.7.1, we can write,

$$V = I_{fsd} (R_s+R_m) \qquad (1)$$

Here,

I_{fsd} = Full scale deflection current

R_s = Series resistance (multiplier)

R_m = Internal resistance of meter

V = Input dc voltage

- The value of multiplier should be selected properly so that the current does not exceed the value of I_{fsd}.
- From equation (1) we get,

$$R_s + R_m = V / I_{fsd}$$

$$R_s = (V / I_{fsd}) - R_m \qquad (2)$$

Equation (2) gives the value of series resistance (multiplier).

1.9 Analog Multimeter:

The schematic circuit of a typical multimeter is shown in fig 1.9. The circuit incorporates the functions of ammeter, voltmeter and ohm meter into one unit which gives versatility and economy that could not be obtained by the use of individual instruments. The combinational of various circuits into one unit is achieved by the use of rotary selector switches S_1, S_2 and S_3.

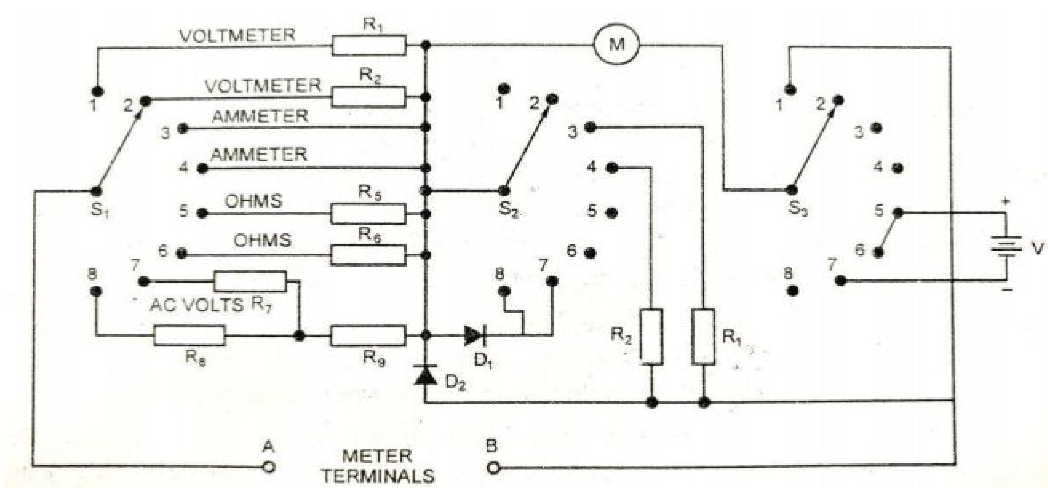


Fig 1.9 Analog multimeter

1.9.1 Voltmeter circuit:

The multimeter circuit shown in figure has voltmeter circuit for the measurements of D.C. and A.C. voltages.

i. D.C. Voltage measurements:

Here, there are voltmeter ranges with multiplier resistance R_1 and R_2 as shown. One range is obtained when switch S_1 is thrown to position 1 and second range is obtained when this switch is thrown to position 2.

The direct voltage to be measured is applied across the terminals A and B of the multimeter. Suppose that switch S_1 is thrown to position 1 for the voltage measurement. Tracing the circuit from the left hand terminal A, through switch S, we find that multiplier resistance R_1 is in series with the meter M and the circuit is completed through switch S_3 to the terminal B of the multimeter. Thus, the meter having high series resistance R_1 acts as a voltmeter.

It may be noted that switch S_2 is not utilized in the circuit as it has no connection in position 1 and position 2.

ii. A.C voltage measurement:

Here, one have two voltmeter ranges with multimeter resistances R_7 and R_8. One range is obtained when switch S_1 is thrown to position 7 and the second range is obtained when this switch is thrown to position 8.

The alternating voltage to be measured is applied across the terminal A and B of the multimeter. Suppose switch S_1 is thrown to position 7 for voltage measurement. Let us trace the circuit from the left hand terminal A of the multimeter. We go from terminal A to position 7 through switch S_1, to multiplier resistance R_7 and to resistance R_9. After R_9, the circuit branches off into two positions:

a) One branch circuit is through diode D_1 to meter M, to switch S_3 and through S_3 to the terminal B of the multimeter.
b) Second branch circuit is through D_2 to the terminal B of the multimeter. Clearly, this diode is across the meter M.

During the positive half of the alternating voltage to be measured the current conduction is through first branch i.e. through R_7, R_9, D_1 meter M to terminal B. No condition is possible through diode D_2 as it is connected to oppose the current flow on this half cycle. During the negative half cycle, the current cycle is through the second branch i.e. through R_7, R_9, D_2 to terminal B. No current flows through the meter on this half. The meter thus operates for ½ cycle of a.c. sine wave.

1.9.2 Ammeter Circuit:

Here, we have two ammeter ranges with shunt resistances R_3 and R_4. One range is obtained when switch S_1 s thrown to position 3 and the second range is obtained when this switch is thrown to position 4.

The multimeter is connected in series with circuit in which current is to be measured. Suppose switch S_1 is thrown to position 3 for current measurement. Let us trace the circuit from left hand terminal A of the multimeter. We go from terminal A to position 3 through switch S_1. At position 3, the current divides into two branches:

a) One path is through meter M to switch S_3 and from S_3 to terminal B of the multimeter.
b) Second path is through switch S_2 to shunt resistance R_4 and to terminal B of the multimeter. Clearly, shunt resistance R_4 is across the meter M.

Thus, the meter M having a low shunt resistance across it acts an ammeter.

1.9.3 Ohm meter circuit:

Here, there are two ohm meter ranges with series resistances R_5 and R_6. One range is obtained when switch S_1 is thrown to position 5 and the second range is obtained when this switch is thrown to position 6. Note that position 5 and 6 of switch S_3 are shorted together so that battery of V volts remains in the circuits for either range.

The resistance to be measured is connected across the terminal A ans B of the multimeter. Suppose the switch S_1 is thrown to position 5 for resistance measurement.

Tracing the circuit, from left hand terminal A, we find that we go through resistance R_5 to meter M, to switch S_3 to battery and then to terminal B. It may be seen that battery, meter M and R_5 are in series, a basic circuit for ohm meter.

1.10 Dynamometer type wattmeter:

These types of instruments have two coils. The two coils are connected in different circuits for measurement of power. The fixed coil or "field coils" are connected in series with the load and so carry the current in the circuit. The fixed coils, therefore form the current coil or simply C.C of the wattmeter.

The moving coil is connected across the voltage and, therefore, carries a current proportional to the voltage. So it is called the pressure coil or simply called P.C of the wattmeter.

1.10.1 Construction of dynamometer wattmeter:

The wattmeter consists of two coils namely (a) one set of fixed coil (b) single moving coil as shown in fig 1.10.1.1. The fixed coil is made of two parts and the moving coil is placed between the two fixed coils.

The fixed coil is used as a current coil. The current coil are made of few turns of thick copper wire and are connected in series with the load to carry the load current. The moving coil is used as a pressure coil. The pressure coil is made of several turns of fine copper wire. A high non inductive resistance is connected in series with the moving coil in order to limit the current.

The jewel supported spindle carrying the pressure coil also carries a pointer, a damping vane and control springs. The pointer is fixed to the pressure coil spindle and moves over a suitably calibrated scale. A cast iron cylinder is placed around the coil to protect against stray magnetic fields. The moving system of the wattmeter is usually spring controlled. Air friction damping is used. The pointer is made of aluminium. The pointer is made thin and the front part is flattened.

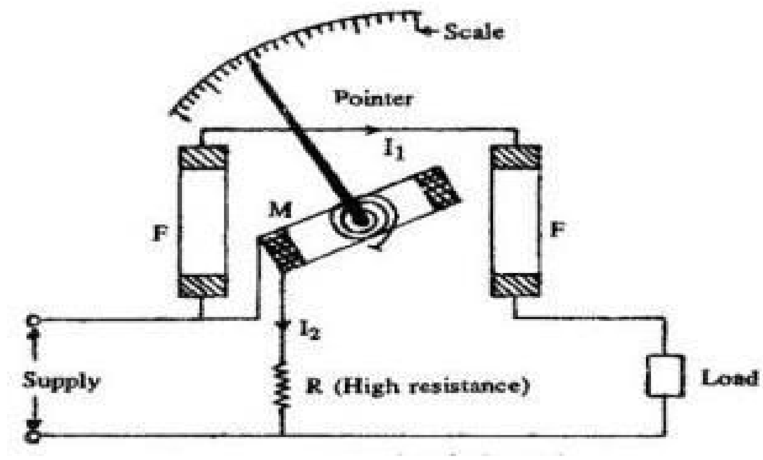


Fig 1.10.1.1. Construction of dynamometer wattmeter

Operation:

The two parts of the fixed coil carry load current and create a flux in the air gap between them. The pressure coil carries another small current proportional to load voltage and hence produces a flux in the air gap. The current coil produces a flux which is in phase with the load current.

The flux produced by the pressure coil is very nearly in phase with the applied voltage. The magnetic fields of fixed and moving coils react on one another causing the moving coil to turn about its axis and a torque is produced on the moving system. This torque is proportional to the product of voltage and current.

$T_d \propto V I$

$T_d \propto$ power

It is concluded that wattmeter reads both a.c and d.c circuit powers.

Advantages:

(i) It can be used to measure power in d.c as well as a.c circuits
(ii) It gives fairly accurate power
(iii) The scale is uniform
(iv) Power consumption is low.

Disadvantages:

(i) Cost is high
(ii) Affected by stray magnetic field
(iii) At low power factors, the inductance of pressure coil introduces serious error

1.11 Energy meters:

Energy is the product of power and time

Energy = power x time

Energy is measured by means of the energy meter (watt-hour meter). It is an integrating instrument. Generally unit of energy is given by kilowatt hour. An energy meter is used to indicate the energy supplied or consumed.

1.11.1 Single phase energy meter:

Induction type instruments are most commonly used as energy meters. Energy meter is an integrating instrument which measures quantity of electricity. Induction type of energy meters are universally used for domestic and industrial applications. These meters record the energy in kilo – watt – hours (kWh).

It works on the principle of induction i.e. on the production of eddy currents in the moving system by the alternating fluxes. These eddy currents induced in the moving system interact with each other to produce a driving torque due to which disc rotates to record the energy. In the energy meter there is no controlling torque and thus due to driving torque only, a continuous rotation of the disc is produced. To have constant speed of rotation breaking magnet is provided. The circuit diagram of single phase energy meter is shown in Fig 1.11.1.1

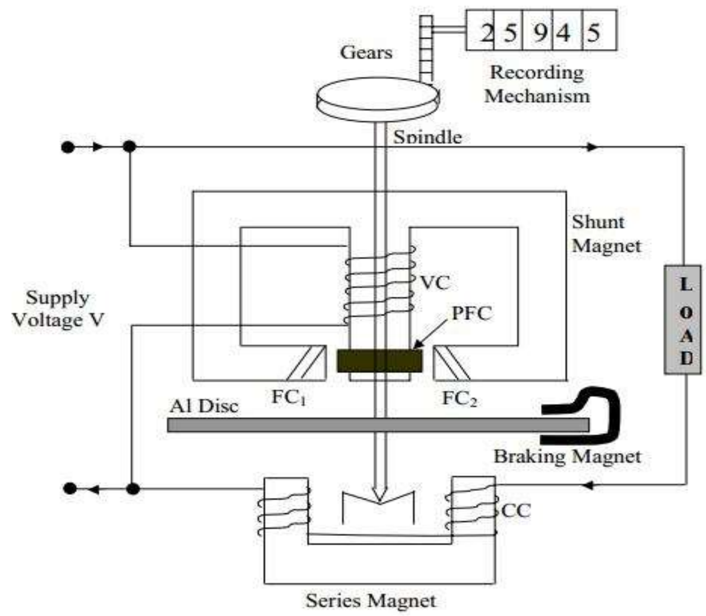


Fig 1.11.1.1 Single phase energy meter

Construction:

There are four main parts of operating mechanism.

1. Driving system
2. Moving system
3. Breaking system
4. Registering system

Driving system:

It consists of two electromagnets whose core is made up of silicon steel lamination. The coil of one of the electromagnets, called current coil, is excited by load current which produces flux further. The coil of another electromagnet is connected across the supply and it carries current proportional to supply voltage. This coil is called pressure coil. These two electromagnets are called series and shunt magnets respectively. The flux produced by shunt magnet is brought in exact quadrature with supply voltage with the help of copper shading bands whose position is adjustable.

Moving system:

Light aluminium disc mounted in a light alloy shaft is the main part of moving system. This disc is position in between series and shunt magnets. It is supported between jewel bearings. The moving system runs on hard and steel pivot. A pinion engages the shaft with the counting mechanism. There are no spring and no controlling torque.

Breaking system:

A permanent magnet is placed near the aluminium disc for breaking mechanism. These magnets reproduce its own field. The disc moves in the field of this magnet and a breaking torque is obtained. The position of the magnet is adjustable and hence braking torque is adjusted by shifting this magnet to different radial positions. This magnet is called breaking magnet.

Registering mechanism:

It records continuously a number which is proportional to the revolutions made by the aluminium disc. By a suitable system, a train of reduction gears, the pinion on the shaft drives a series of pointers. These pointers rotate on round dials which are equally marked with equal divisions.

Working:

Since the pressure coil is carried by shunt magnet which is connected across the supply, it carries current proportional to the voltage. Series magnet carries current coil which carries the load current. Both this coil produce alternative fluxes ϕ_1 and ϕ_2 respectively. This fluxes are proportional to current in there coils.

Parts of each of this fluxes link with the disc and induces e.m.f. in it. Due to the e.m.f. eddy currents are induced in the disc. The eddy current induced in the shunt magnet reactive with magnetic field produced by series magnet. Also eddy current induced by series magnet reactive with magnetic field produced by shunt magnet. Thus each portion of the disc experiences a mechanical force and due to motor action, disc rotate.

The speed of the disc controlled by the C shaped magnet called breaking magnet. When disc rotate in the air gap, eddy current are induced in disc which oppose the cause producing them i.e. relative motion of disc with respect to magnet. Hence breaking torque T_b is generated. This is proportional to speed N of disc. By adjusting position of this magnet, desired speed of disc is obtained. Spindle is connected to recording mechanism through gears which record the energy supplied.

1.11.2 Three phase energy meter:

In a three phase, the measurement of energy is to be carried out by a three phase energy meter. This meter consists of three elements. The construction of an individual element is similar to that of a single phase energy meter. The pressure coils are denoted as P_1, P_2 and P_3. The current coils are denoted as C_1, C_2 and C_3. All the elements are mounted in a vertical line in common case and have a common spindle, gearing and registering mechanism. The coils are connected in such a manner that the net torque produced is sum of the torques due to all the three elements. Three phase energy meter diagram is shown in fig 1.11.2.1

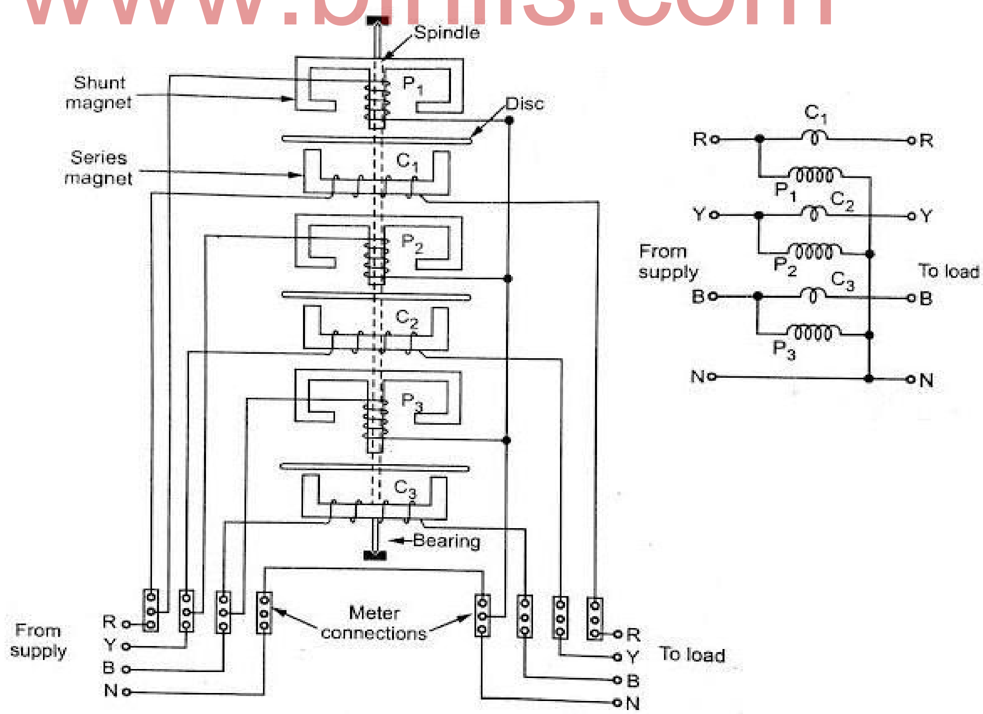


Fig 1.11.2.1 Three phase energy meter

1.11.3 Adjustments in energy meter:

The adjustments are required in the energy meters so that they read accurately with minimum possible errors.

Main speed adjustment:

The measurement of energy is dependent on the speed of rotating disc. For accurate measurement, speed of the disk must be also proportionate. The speed of the meter can be adjusted by means of changing the effective radius of the breaking magnet.

Power factor adjustment:

It is necessary that meter should measure correctly for all power factor conditions of the loads. To have this adjustment, the shading ring called quadrature loop is provided on the center limb of shunt magnet carrying pressure coil. The fine adjustments can be achieved by the movement of this loop upward or downward and meter can be made to read accurately at all the power factors.

Friction adjustment:

In spite of proper design of the bearings and registering mechanism, there exists some friction. Due to this, speed of the meter gets affected which cause error in measurement.

To compensate for this, a metallic loop or strip is provided between central limb of shunt magnet and the disc. Due to this strip an additional torque independent of the load is produced which acts on the disc in the direction of rotation. This compensates for the friction and meter can be made to read accurately.

Creep adjustment:

It is seen that, without any current through current coil, disk rotates due to supply voltage exciting pressure coil. This is called creeping. To eliminate this two holes are drilled in the disc 180° opposite to each other. When this hole comes under the shunt magnet pole, it gets acted upon by a torque opposite to its rotation. This restricts its rotation, on no load condition.

1.12 Multi functional meter:

Multi functional meter measures all electrical parameters such as RMS voltage, current, active power, reactive power, apparent power, power factor, phase angle, frequency, active energy, reactive energy, apparent energy, demand in 3 phase 4 wire and 3 phase 3 wire system.

1.12.1Theory of Operation

The theory of operation of multi functional meter is described in conjunction with the block diagram shown in Fig 1.12.1.

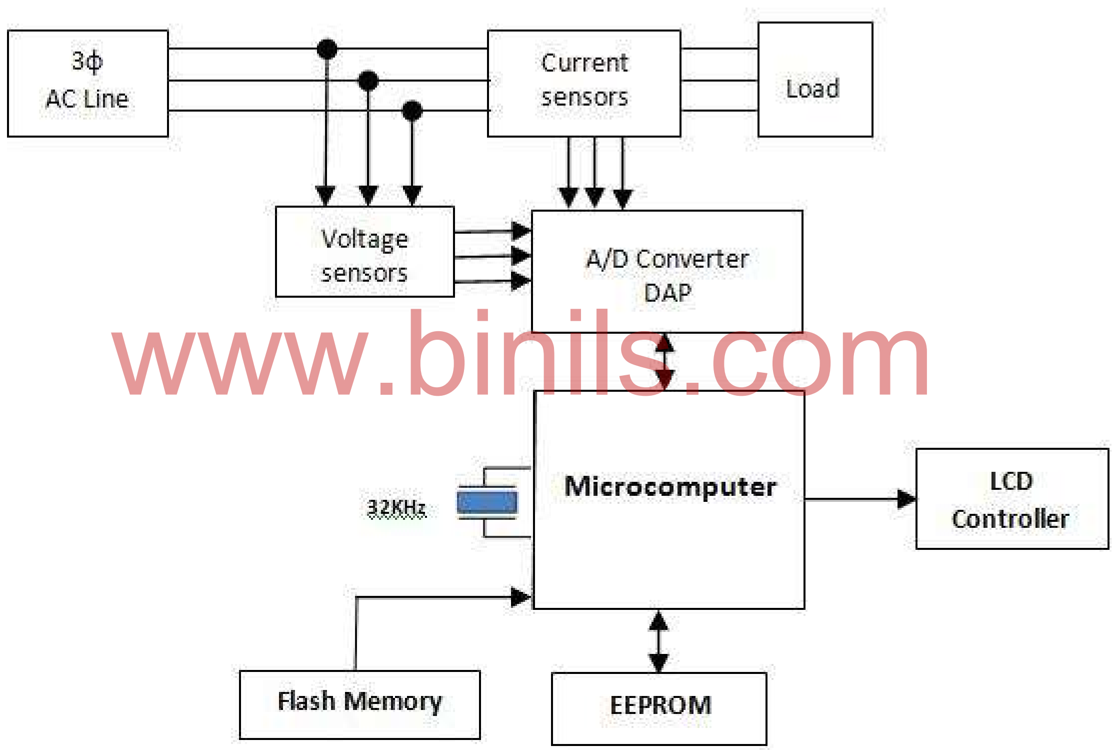


Fig 1.12.1 Multi functional meter

Sensing Devices:

Voltages are sensed by three separate high impedance resistive voltage dividers and currents are sensed by up to three separate resistive current divider structures. The sensors provide scaled signals to the Data Acquisition Platform (DAP) chip.

Data Acquisition:

The Data Acquisition Platform (DAP) chip contains six independent, fully integrated analog to digital converters, one for each current and voltage signal. For a full three element meter, 6 sets of 16-bit samples are processed.

Microcomputer:

The microcomputer is a 32-bit expandable single chip microcomputer. It receives 16 bit data samples from the DAP chip. The microcomputer provides all data processing functions, including sample processing and digital filtering, accumulations, products and calculation of advanced quantities. It does time keeping and provides all register and display functions of the meter. It uses non volatile memories on the circuit board for storage of metered data and program parameters.

Nonvolatile Memory:

The meter is equipped with two nonvolatile memory devices. All data values and program parameters are stored in semiconductor nonvolatile memory. EEPROM memory stores programmed operating parameters and meter data. Flash memory is used for special program provisions and memory intensive data requirements. Meter data quantities are updated at each power fail event. Stored data is constantly checked to prevent errors.

REVIEW QUESTIONS

PART – A (2 Marks)

1. What is measurement?
2. Define instrument and list its categories
3. Define absolute instrument
4. Define secondary instrument
5. Mention the units of different electrical parameters measured using instruments
6. Discuss about deflecting force
7. Write short notes on controlling force
8. Mention the relationship between deflection and current in PMMC instrument
9. List the types of moving iron instruments
10. Mention the applications of moving iron instrument
11. List the type by which rectifier type A.C. voltmeter can be designed
12. What is ohmmeter?
13. Mention the types of ohmmeter.

PART – B (3 Marks)

1. List the types of forces acting on indicating instrument
2. Write short notes on damping force
3. Discuss about the working principle of PMMC instrument
4. List the advantages and disadvantages of PMMC instrument
5. Compare moving coil and moving iron instruments
6. Mention the advantages and disadvantages of Moving iron instruments
7. Define the term "multiplying power of the shunt"
8. List the advantages and disadvantages of dynamometer type wattmeter
9. List the different adjustments in energy meter

1. Explain the construction and working of PMMC instrument
2. Derive an expression for deflecting torque of moving coil instrument
3. Explain briefly attraction and repulsion type moving iron instruments
4. Derive an expression for deflecting torque of moving iron instrument
5. Explain in detail about the design of rectifier type A.C. voltmeter
6. Discuss about series type ohmmeter
7. Write short notes on shunt type ohmmeter
8. Explain how a basic meter range can be extended using shunt resistor
9. Explain how a basic meter range can be extended using series resistor
10. Explain the working of analog multimeter with neat diagram
11. Explain the operation of dynamometer type wattmeter
12. Explain the operation of single phase energy meter
13. Explain the operation of three phase energy meter
14. Discuss about different methods of adjustments made in energy meter for making the meter to read accurately
15. Explain the block diagram of multi functional meter.

UNIT – II

BRIDGES AND OSCILLOSCOPE

2.1 Introduction to bridges:

Bridge circuits of various types are used in Instrumentation systems for the measurement of resistance, inductance and capacitance. The bridges may be either of the two types viz: (i) d.c. type and (ii) a.c. type. There are certain advantages of bridge technique. These are as follows:

(i) The measurement accuracy is very high. This is because in this method an unknown value is compared with known standard value.

(ii) Accuracy is directly proportional to the accuracy of bridge component and not on the accuracy of null indicator.

(iii) The balance equation of the bridge is not dependent on the magnitude of input voltage.

(iv) The balance condition of the bridge is not affected even if the source and detector are interchanged.

Comparison of AC and DC Bridge:

Sl.No.	DC bridge	AC bridge
1	D.C bridge is used for the measurement of unknown resistance	A.C bridge is used for the measurement of unknown capacitance and inductance
2	It needs DC supply for its operation	It needs AC supply for its operation
3	They are less stable than ac bridges	They are more stable and accurate
4	Dc bridge circuits have more noise	They have lower noise
5	They are comparatively slower than ac bridges	The bridges are faster in operation
6	Ex. Wheatstone bridge, Kelvin bridge	Ex. Maxwell bridge, schering bridge

2.2 Wheatstone bridge:

It is the most commonly used DC bridge for measurement of resistance. A Wheatstone bridge has been in use longer than almost any electrical measuring instrument. It is still an accurate and reliable instrument and is extensively used in industry.

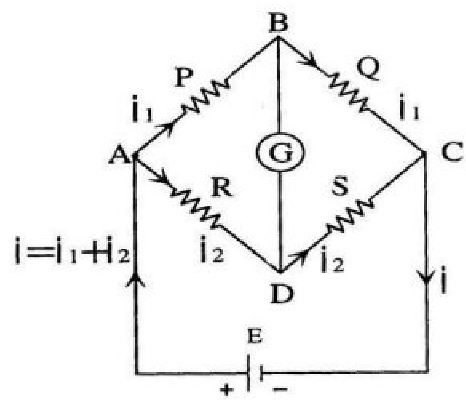


Fig 2.2.1 Wheatstone bridge

Fig 2.2.1 shows the basic circuit of a Wheatstone bridge. It has four resistive arms, consisting of resistances P, Q, R and S together with source of emf (a battery) and a null detector, usually a galvanometer G or other sensitive current meter. The current through the galvanometer depends on the potential difference between point B and D. The bridge is said to be balanced when there is no current through the galvanometer or when the potential difference across the galvanometer is zero.

For bridge balance, we can write:

$$I_1P = I_2R$$

For the galvanometer current to be zero, the following conditions also exist:

$$I_1 = E / (P + Q) \qquad (1)$$

and

$$I_2 = E / (R + S) \qquad (2)$$

where E = emf of the battery

Combining and simplifying (1) and (2), we obtain

$$P / (P + Q) = R / (R + S)$$

From which

$$QR = PS$$

The above equation is the well known expression for the balance of Wheatstone bridge. If three of the resistance is known, the fourth may be determined from equation

$$R = \frac{P}{Q} S$$

where R is the unknown resistance S is called 'standard arm' of the bridge and P and Q are called the 'ratio arms'.

Applications:

(i) It is used to measure the resistance value of unknown resistors of the range 0.1Ω to 1,00,000Ω

(ii) It is used for measurement of small resistance changes that occur in passive resistive transducers like strain gauges, thermistors and resistive thermometers

(iii) It is used to measure the inductance, capacitance and frequency by suitably arranging the components of different arms.

(iv) It is used to measure Q factor, dissipation factors of coils and capacitors

2.3 Schering bridge:

This is one of the most important and useful bridge circuits available for measurement of capacitance, dielectric loss of a capacitor.

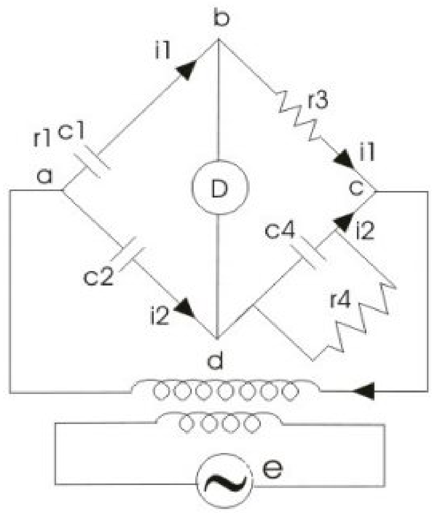


Fig 2.3.1 Schering bridge

The basic circuit arrangement is shown in fig 2.3.1. In this first and second arm contains only a capacitor. The third arm contains only a variable resistor. The fourth arm contains a parallel combination of a resistor and a variable capacitor.

C_1 = capacitor whose capacitor is to be determined

C_2 = a standard air capacitor

R_3 = variable a non-inductive resistor

C_4 = a variable capacitor

R_4 = fixed non -inductive resistor in parallel with variable capacitor C_4

Under balanced condition, the real and imaginary terms are equated.

$$R_1 = \frac{C_4}{C_2} R_3$$

$$C_1 = \frac{R_4}{R_3} C_2$$

Two independent balance equations are obtained if C_4 and R_4 are chosen as the variable elements.

Applications:

(i) Schering bridge is used for measuring power factors of cables.

(ii) It is used for the measurement of relative permittivity of an insulating material.

(iii) It is used for measuring the insulating properties of electrical cables and equipment.

2.4 Maxwell's bridge:

This bridge circuit measures an inductance by comparison with a variable standard self – inductance. The circuit arrangement is shown in fig 2.4.1

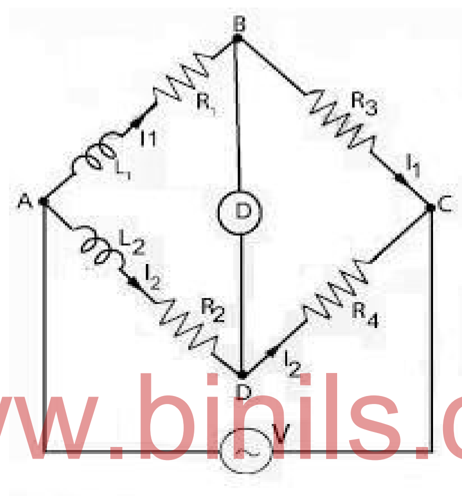


Fig 2.4.1 Maxwell's bridge

L_1 = unknown inductance

L_2 = variable inductance of fixed resistance

R_2 = variable resistance connected in series with inductor L_2

R_3, R_4 = known non-inductive resistances.

At balance,

$$L_1 = \frac{R_3 \, L_2}{R_4}$$

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

Applications:

(i) Maxwell bridge is used for measuring iron losses of the transformer at audio frequency

(ii) It is used for calibrating electromagnetic seismograph

(iii) It is used for measuring medium "Q" of coils.

2.5 Wien bridge:

The Wien's Bridge is primarily known as a frequency determining bridge and is described here not only for its use as an a.c. bridge to measure frequency but also for it's application in various other useful circuits. Fig 2.5.1 shows a Wien's Bridge under balance conditions.

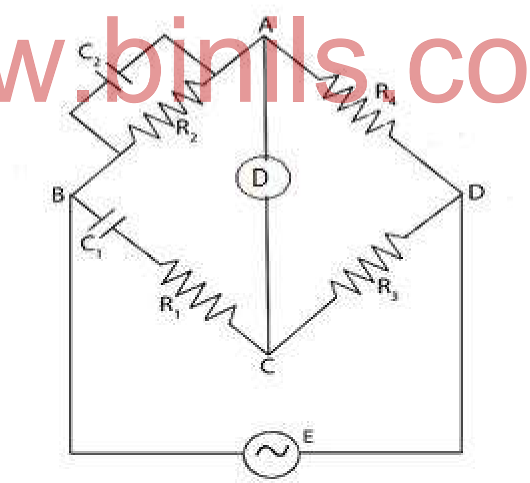


Fig 2.5.1 Wien bridge

At balance the real and imaginary parts are equated.

$$R_3 / R_4 = R_1 / R_2 + C_2 / C_1$$

and frequency $$f = 1 / 2\pi\sqrt{R_1 \; R_2 \; C_1 \; C_2} \text{ Hz}$$

In most Wien Bridges, the components are so chosen that

$$R_1 = R_2 = R \quad \text{and} \quad C_1 = C_2 = C$$

Then equation reduces to

$$R_3 / R_4 = 2$$

$$f = 1 / 2\pi R C$$

Because of its frequency sensitivity, the Wien's Bridge may be difficult to balance unless the wave form of the applied voltage is sinusoidal. The bridge not balanced for any harmonics present in the applied voltage, so that harmonics will sometimes produce an output voltage masking the true balance point. This difficulty can be overcome by connecting a filter in series with the null detector.

Applications:

(i) This bridge is suitable for measurement of frequencies from 100Hz to 100 KHz. It is possible to obtain an accuracy of 0.1 to 0.5 per cent.

(ii) It may be used for measurement of capacitance also.

(iii) It may be employed in harmonic distortion analyzer, where it is used as notch filter, discriminating against one specific frequency.

(iv) It also finds applications in audio and HF oscillators as the frequency determining device.

2.6 RLC meter:

An RLC meter is a type of electronic test equipment used to measure the inductance (L), capacitance (C), and resistance (R) of an electronic component. In the simpler versions of this instrument the impedance was measured internally and converted for display to the corresponding capacitance or inductance value.

Readings should be reasonably accurate if the capacitor or inductor device under test does not have a significant resistive component of impedance. More advanced designs measure true inductance or capacitance, as well as the equivalent series resistance of capacitors and the Q factor of inductive components.

Operation:

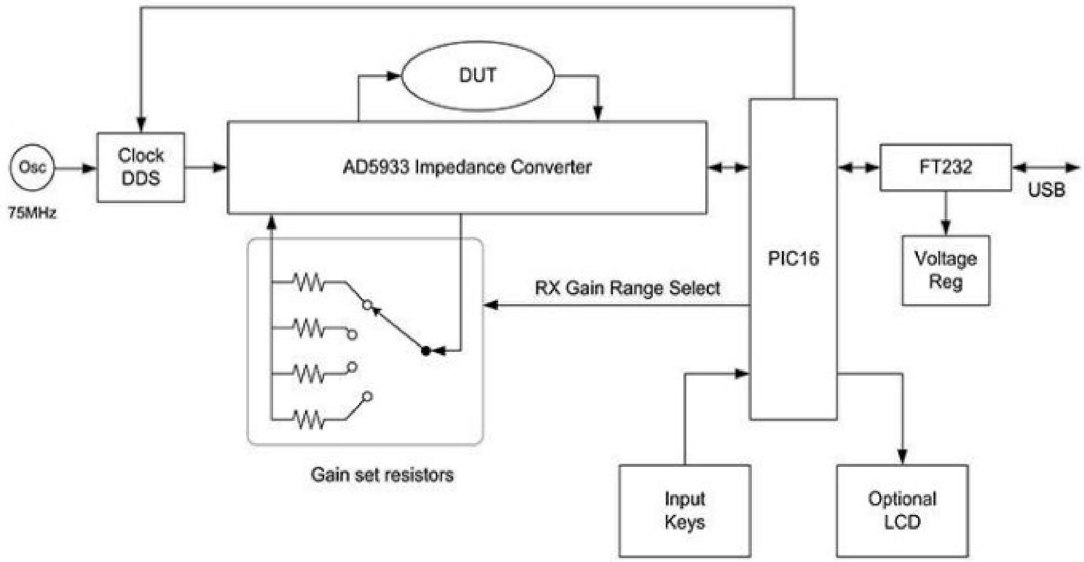


Fig 2.6.1 Block diagram of RLC meter

The block diagram RLC meter is shown in fig 2.6.1. Usually the device under test (DUT) is subjected to an AC voltage source. The meter measures the voltage across and the current through the DUT. From the ratio of these the meter can determine the magnitude of the impedance. The phase angle between the voltage and current is also measured in more advanced instruments; in combination with the impedance, the equivalent capacitance or inductance, and resistance, of the DUT can be calculated

2.7 Introduction to CRO:

The cathode ray oscilloscope (CRO) is a very useful and versatile laboratory instrument used for display, measurement and analysis of waveforms. CROs are also used to investigate waveforms, transient phenomena and other time varying quantities from a very low frequency range to the radio frequencies.

It is an electronic device, which gives the visual indication of signal waveforms. It can be used to study the wave shape of a signal with respect to amplitude, distortion and deviation from the normal. It can also be used to measure voltage, frequency and phase shift.

2.7.1 Block diagram of CRO

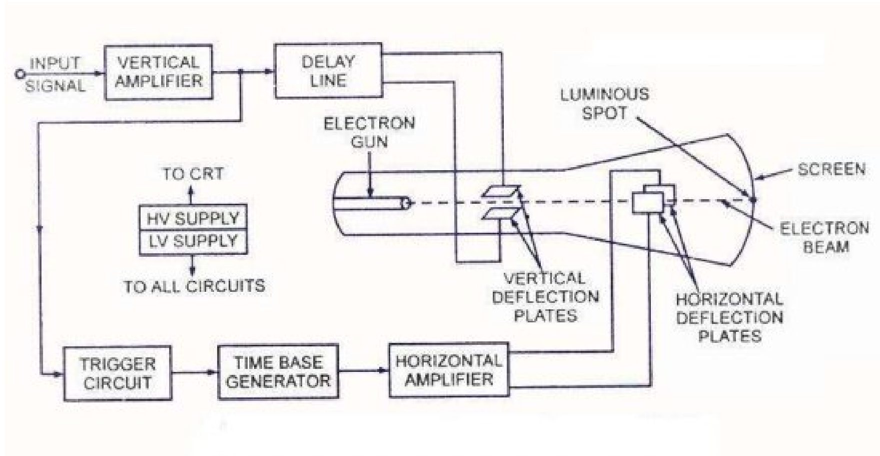


Fig 2.7.1.1 Block diagram of CRO

The block diagram of CRO is shown in fig 2.7.1.1. The various blocks of CRO are as follows.

1. CRT

It consists of an electron gun. The electron gun produces an electron beam. This beam is narrow and is allowed to pass down the tube, and to fall on the screen. The screen is formed by the flat end of glass tube which is coated with the fluorescent material. The point at which the electron beam strikes the screen, a spot is formed. The electron beam passes through two pairs of electrostatic deflection plates i.e. the horizontal and vertical deflecting plates.

The voltages which are applied to these plates defect the beam. Horizontal deflecting plates move the spot in horizontal direction and vertical deflecting plates move the spot on the screen in vertical direction. These two movements i.e. vertical and horizontal are independent of each other and thus the beam may be displayed anywhere on the screen.

2. Vertical amplifier

The signal to be examined is applied to the vertical deflection plate through the input attenuator and vertical amplifier. Vertical amplifier is used to amplify the input signal. In some cases, high voltage signal are to be examined. In such cases, a calibrated attenuator is used to bring the high voltage signal within the range of vertical amplifier.

3. Time base Generator

The time base generator is used to generate the sawtooth voltage, required to deflect the beam in the horizontal section.

4. Horizontal amplifier

Horizontal amplifier is also called as X amplifier. The sawtooth voltage is produced by the time base generator may not be of sufficient strength. Hence before applying this voltage to the horizontal deflection plates it is amplified using the horizontal amplifier.

5. Trigger circuit

The trigger circuit produces trigger pulse to start sawtooth signal (sweep) .To get a steady waveform in the CRO screen, vertical input signal frequency must be equal to or an exact multiple of time base generator signal frequency. This is done by the triggering circuit. A sample of input signal is fed to the trigger circuit through vertical amplifier, to achieve synchronization.

6. Delay line

The purpose of delay line is to delay the arrival of the input signal at the vertical deflection plates, until the trigger and time base circuits start the sweep of the beam.

7. Power supply

The power supply provides the voltage required by the CRT to generate, accelerate and focus the electron beam and for other electronic circuits. High voltage (HV) supply is connected to the accelerating and focusing anodes of the CRT. The low voltage (LV) supply is given to the heater, control grid of CRT and other electronic circuits of CRO.

PRINCIPLE OF OPERTION OF CRO

The signal to be examined or displayed is fed to the vertical amplifier of the CRO. Its amplified input is sent to the vertical deflection plates (Y input). At the same time a sawtooth voltage is applied to the horizontal deflection plates (X input).

In an oscilloscope, the electrons are emitted from a cathode. They are accelerated to a high velocity and brought to focus on fluorescent screen. The screen produces a visible spot (Luminous spot) where the electron beam strikes. This luminous spot is moved over the display area in response to an input voltage.

The CRO uses a horizontal input voltage, which is a sawtooth voltage. This voltage moves the luminous spot periodically in a horizontal direction from left to right over the display area of the screen.

The vertical input voltage moves the spot up and down in accordance with the instantaneous value of voltage. Due to the effect of both voltages, the luminous spot traces the waveform of the input signal with respect to time and can be observed on the screen.

2.7.2 Working of CRT:

The cathode ray tube is the heart of the CRO. The main parts of the CRT are

a. Electron gun assembly
b. Deflection plate assembly
c. Fluorescent screen
d. Glass tube
e. Base.

Fig. 2.7.2.1 shows the internal structure of a CRT

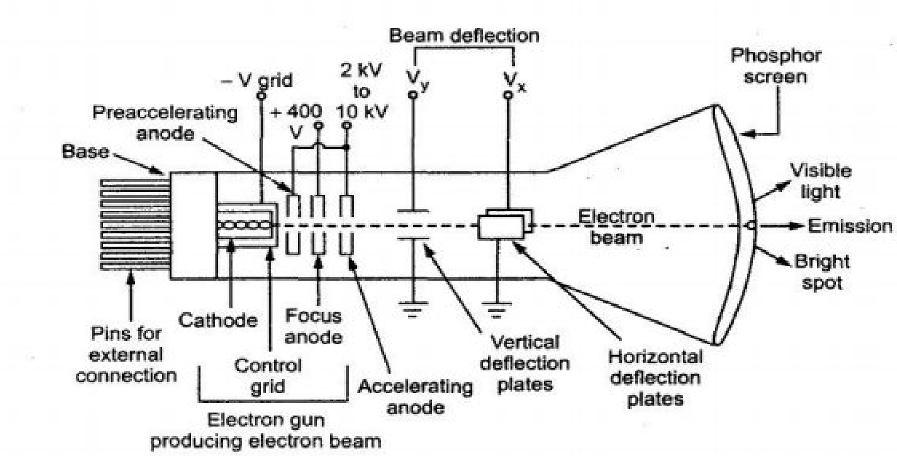


Fig. 2.7.2.1 Internal structure of a CRT

(a) Electron Gun Assembly:

The arrangement of electrodes which produces a focused beam of electrons is called the electron gun. It essentially consists of an indirectly heated cathode, a control grid, a focusing anode and an accelerating anode. The control grid is held at negative potential with respect to cathode whereas the two anodes are maintained at high positive potential with respect to cathode.

The cathode is a nickel cylinder, coated with an oxide coating to provide plenty of electrons. The control grid is a metal cylinder with tiny circular opening to limit the size of the electron beam.

The focusing anode focuses the electron beam into a sharp pin point. The electron gun assembly forms a narrow, accelerated beam of electrons to produce a spot of light on striking the screen.

(b) Deflection Plate Assembly:

When the electron beam is accelerated by the accelerating anodes it passes through the deflection plate assembly. The deflection plate assembly of the CRT consists of the two pairs of parallel plates.

These plates are called as the **vertical deflecting plate** and the **horizontal deflecting plate**. The electron beam can be made to move up and down & right and left on the screen by vertical and horizontal deflection plates respectively.

3. Fluorescent Screen:

The front end of CRT acts as a fluorescent screen. An inner side of the screen is coated with phosphor. When high velocity electron beam strikes the screen, a spot of light is produced at the point of impact.

4. Glass Tube:

The components of a CRT are enclosed in an evacuated glass tube called the envelope. The inner walls of CRT between neck and screen are coated with conducting material, called aquadag. Hence the electrons which strikes the walls accidently, and the electrons resulting from secondary emission from the screen due to electron beam bombardment are returned to anode.

5. Base:

The base is provided to the CRT through which the connections are made to various parts.

2.7.3 Horizontal deflection system:

The horizontal deflection system consists of

(a) Time base generator (b) Trigger Circuit (c) Horizontal amplifier

(a) Time base generator :

The time base generator is used to generate saw tooth voltage, which will deflect the beam in the horizontal direction. The CRT spot is deflected at a constant time dependent rate because of the voltage. Time axis is represented as X axis on the screen.

(b) Trigger Circuit:

It is a circuit, which ensures that the horizontal sweep begins at the same point the vertical input signal. Without the trigger circuit, there will not be synchronization between sweep signal and the signal.

(c) Horizontal amplifier:

It is required to increase the amplitude of the signals generated in the sweep generator to a level, which is required by the horizontal deflection plates of the CRT.

2.7.4 Vertical deflection system:

The signals to be examined are usually applied to the vertical or Y deflection plates through an input attenuator and a number of amplifier stages. Vertical amplifier is required because the signals are not strong enough to produce measurable deflection on the CRT screen. The amplifier response must be wide enough to pass faithfully the entire band of frequencies to be measured.

When high voltage signals are to be examined, they must be attenuated to bring them within the range of vertical amplifier. The vertical amplifier output is also applied to the synchronizing amplifier through the synchronizer selector switch in the internal position. This permits the horizontal sweep circuit to be triggered by the signal being investigated.

2.7.5 Time base Generator:

The time base generator is used to generate the sawtooth voltage, required to deflect the beam in the horizontal section. The CRT spot is deflected at a constant time dependent rate because of the voltage. Time axis is represented as X axis on the screen.

2.8 CRO probes:

The CRO probe is used to connect the vertical amplifier to the circuit under measurement, without loading the circuit. Fig 2.8.1 shows typical general purpose probe

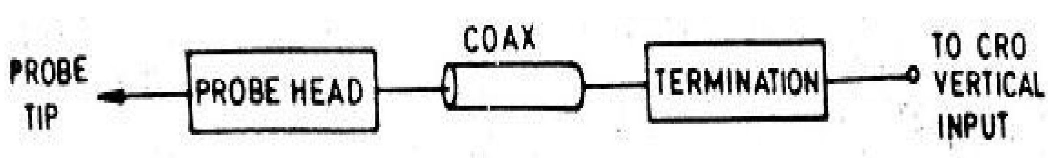


Fig 2.8.1 Block diagram of general purpose probe

The probe head may contain a signal sensing circuitry. This circuit may be passive such as a parallel combination of resistor and a capacitor. It may also be active, such as a FET source follower with associated elements. A coaxial cable is used to couple the probe head to the main circuit. The termination circuit provides the CRO with source impedance and terminates the coaxial cable with its characteristic impedance.

2.8.1 Voltage probe

As the name suggests these probes are used for high voltage applications. High voltage probes can be used in the range of 1 to 5 KV. Large amount of insulation is required for such probes. They have high input impedance from 10 MΩ to 1000MΩ. Fig. 2.8.1.1 shows the diagram of a typical 1000 : 1 voltage probe.

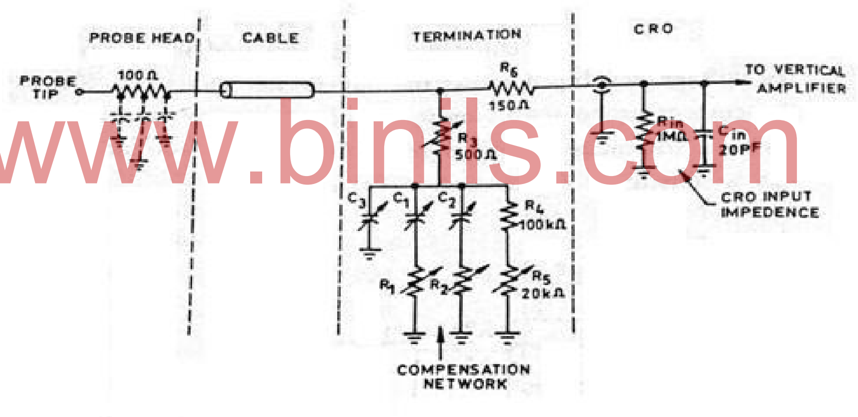


Fig 2.8.1.1 Voltage probe

2.8.2 Current probe:

The current probe consists of a sensor, coaxial cable and a termination circuit. Fig 2.8.2.1 shows a split core current probe.

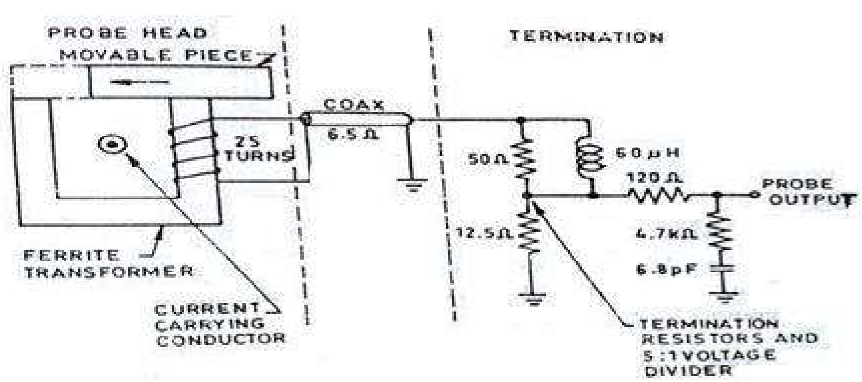


Fig 2.8.2.1 Current probe

This can be opened and clipped around a conductor whose current is to be measured. The current sensing device, current transformer is of split core design, consisting of a stationary U piece and a movable flat piece. A multi turn coil of about 25 turns is wound on one leg of the ferrite core to form the secondary transformer winding. The conductor under test is the single turn primary.

The input signal to the probe is the current in the conductor under test and the output is the voltage developed across the transformer secondary. Since the current probe senses only changes in current it can only be used for measuring ac signals.

2.8.3 Active probe:

The most widely used active probe is the FET probe shown in Fig 2.8.3.1

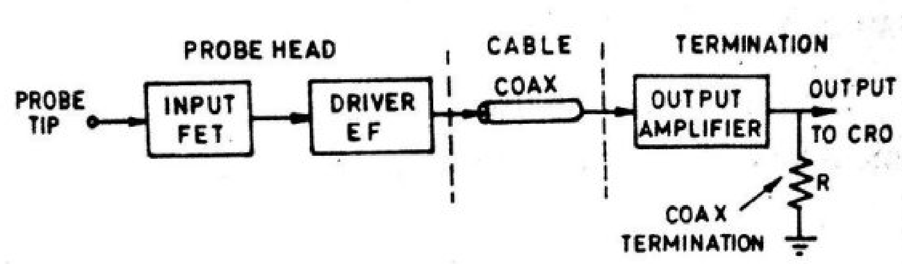


Fig 2.8.3.1 Block diagram of active probe

The field effect transistor is used in the source follower configuration, as the active input element. The FET probe also consists of three parts, the probe head, the coaxial cable and the termination. The probe head consists of a FET source follower along with emitter follower driver amplifier to drive the coaxial cable.

2.8.4 Passive probe

The most widely used passive probe is the compensated 10X probe shown in Fig 2.8.4.1

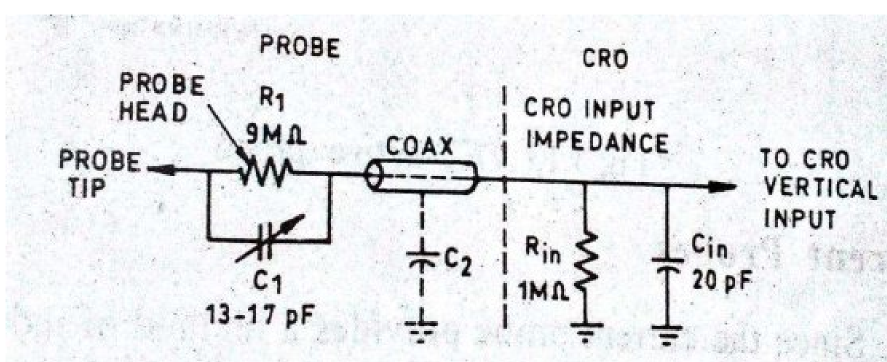


Fig 2.8.4.1 Passive probe

The probe head contains attenuating resistor R_1 shunted by a small variable capacitor C1 for probe compensation. When the 10X attenuator probe is first connected to the CRO, compensating capacitor C_1 must be adjusted for optimum frequency response of the probe, CRO combination. This adjustment is done by using a test 1 KHz square wave generator.

2.9 Applications of CRO:

CRO is used for

i) the measurement of frequency
ii) the measurement of phase of the waveform
iii) the measurement of voltage
iv) the measurement of current
v) studying waveforms

REVIEW QUESTIONS

PART – A (2 Marks)

1. Write the importance of bridge circuit
2. List the types of bridges
3. Write the balance equation for wheatstone and Maxwell bridge
4. Which bridge is used for the measurement of capacitance and inductance?
5. List the applications of schering bridge
6. Mention the applications of Maxwell bridge
7. What is the need for time base generator?
8. List the different modules of horizontal deflection system
9. What is CRO?
10. What is the use of trigger circuit?
11. What are the different parts of CRO probe?
12. List the types of CRO probe

PART – B (3 Marks)

1. List the advantages of using bridges
2. Compare ac and dc bridges
3. Give examples for ac and dc bridges
4. Mention the applications of wheatstone bridge
5. State the applications of wein bridge
6. Draw the block diagram of CRO
7. List the applications of CRO
8. Draw the circuit diagram of active probe

PART – C (10 Marks)

1. Explain the operation of wheatstone bridge
2. Write short notes on schering bridge
3. Discuss in detail about the operation of Maxwell bridge
4. Explain how an unknown frequency can be determined using wein bridge
5. Explain RLC meter with neat sketch
6. With neat sketch discuss in detail about the block diagram of CRO
7. Explain the working of cathode ray tube with neat sketch
8. Write short notes on Horizontal and vertical deflection system
9. Explain about current and active probes in detail
10. Write short notes on passive and voltage probes

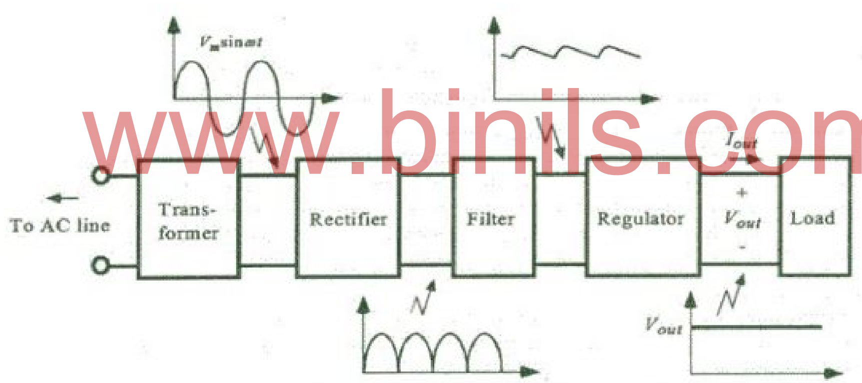
UNIT – III

TEST INSTRUMENTS

3.1. DC Power Supply

A DC power supply which maintains the output voltage constant irrespective of AC mains fluctuations or load variations is known as regulated DC power supply.

A regulated power supply consists of an ordinary power supply and voltage regulating device. The output of ordinary power supply is fed to the voltage regulator which produces the final output. The output voltage remains constant whether the load current changes or there are fluctuations in the input AC voltage.

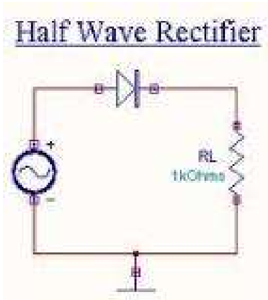


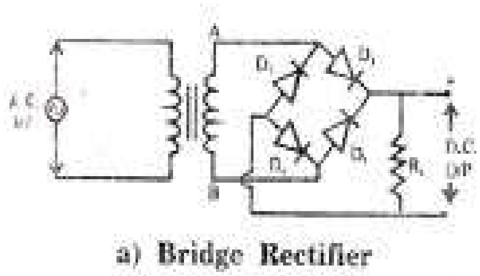
Components of a typical linear power supply

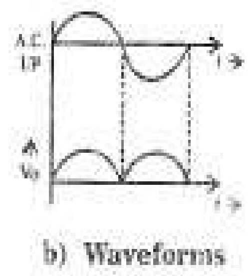
3.1.1. AC supply and transformer:

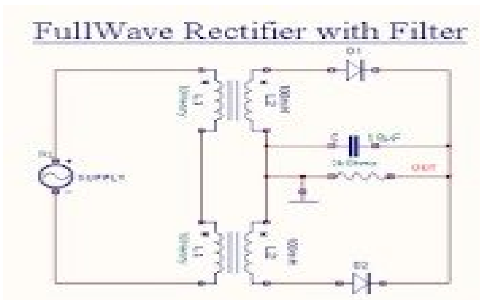
A power supply is used to provide the required amount of power at specific voltage from a primary source which can be ac mains or a battery. A transformer changes the ac mains (line) voltage to a required value. It is used to step the voltage up or down. In a transistor radio it may be a step-down transformer and in a CRT it may be a step-up transformer. Transformer provides isolation from the power line. It should be used even when any change in voltage is not necessary.

3.1.2. Rectifier:





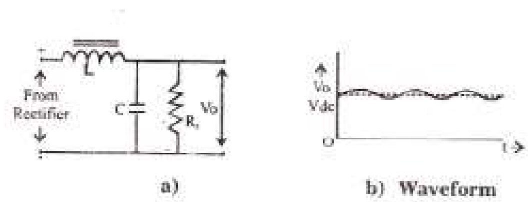




Full wave bridge rectifier circuit diagram

A rectifier converts ac into dc. It may be a half-wave rectifier, a full-wave rectifier using a transformer with centre-tapped secondary winding or a bridge rectifier. But the output of a rectifier may be fluctuating.

3.1.3. Filter:



LC filter

A filter circuit is used for smoothing out the ac variations from the rectified voltage. There are four types of filters: 1) Capacitor filter, 2) Inductor filter, 3) L-C filter and 4) R-C filter.

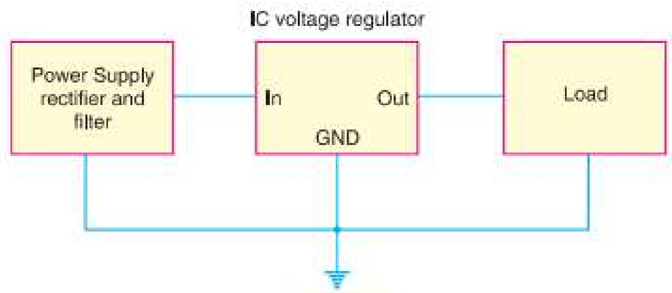
3.1.4. Voltage regulator:

A voltage regulator is necessary to maintain a constant output dc voltage by providing line regulation and load regulation. A zener -regulator, transistorized regulator or three terminal IC regulator can be used for this purpose. A switched mode power supply (SMPS) is used to provide large load current with negligible power dissipation in the series pass transistor.

IC Voltage Regulators

We can use integrated circuits (IC) to produce voltage regulators. One advantage of IC voltage regulators is that properties like thermal compensation, short circuit protection and surge protection can be built into the device. Most of the commonly used IC voltage regulators are three-terminal devices.

The following Fig. shows the schematic symbol for a three-terminal IC voltage regulator.



There are basically four types of IC voltage regulators viz.

(i) Fixed positive voltage regulators

(ii) Fixed negative voltage regulators

(iii) Adjustable voltage regulators

(iv) Dual-tracking voltage regulators

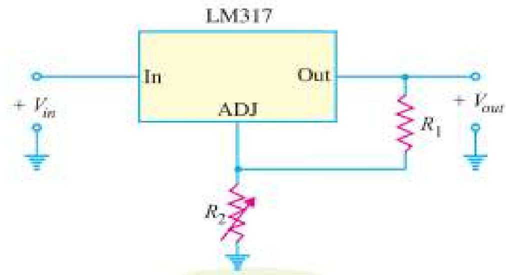
Fixed voltage regulators

The fixed positive and fixed negative IC voltage regulators are designed to provide specific output voltages. For example, LM 309 (fixed positive) provides a + 5V DC output (as long as the regulator input voltages are within the specified ranges).

Variable Voltage regulators

The variable voltage regulator can be adjusted to provide any DC output voltage that is within its two specified limits. The most popular three-terminal IC adjustable voltage regulator is the LM 317. It has an input terminal, output terminal and an adjustment terminal. An external voltage divider is used to change the DC output voltage of the regulator. By changing R2, a wide range of output voltages can be obtained.

Adjustable voltage regulator is the LM 317. It has an input terminal, output terminal and an adjustment terminal. An external voltage divider is used to change the DC output voltage of the regulator. By changing R2, a wide range of output voltages can be obtained.



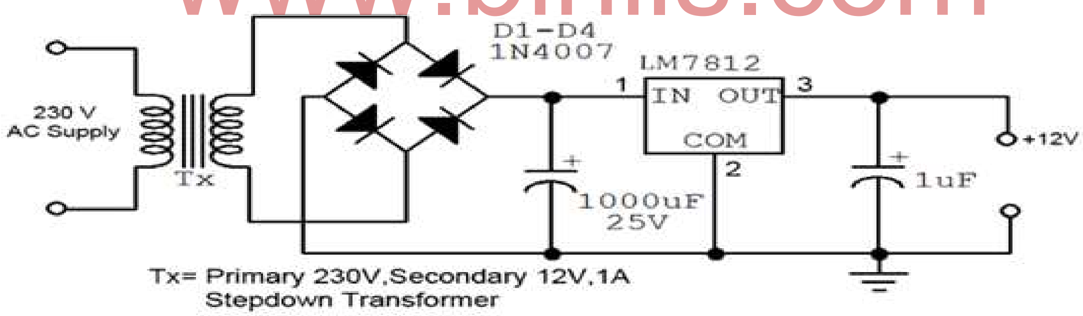
The LM 317 is a three-terminal positive adjustable voltage regulator and can supply 1.5 A of load current over an adjustable output range of 1.25V to 37V.

The data sheet of an LM 317 gives the following formula for the output voltage :

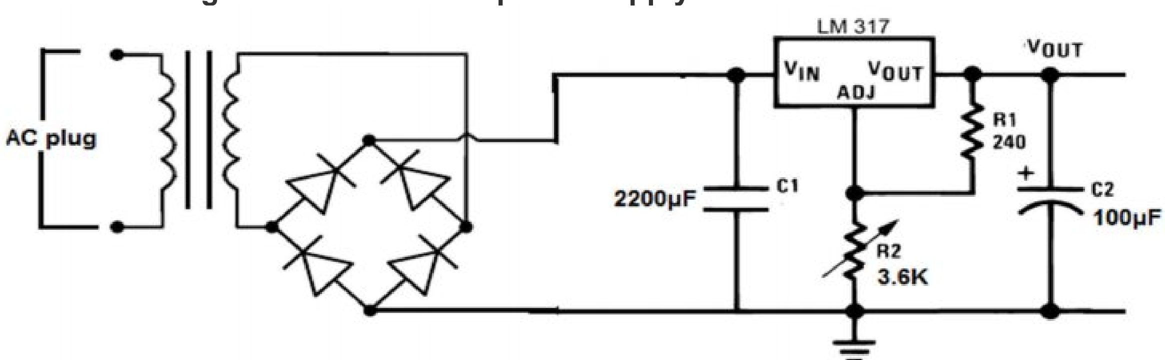
$$V_{out} = 1.25\left(\frac{R_2}{R_1}+1\right)$$

This formula is valid from 1.25 V to 37V.

3.15. Block diagram of Fixed DC power supply



3.1.6 Block diagram of Variable DC power supply:



APPLICATIONS:

- Used to supply DC voltage for electronics circuits.
- Mobile Phone power adaptors
- Regulated power supplies in appliances
- Various amplifiers and oscillators

3.2 SIGNAL GENERATORS

3.2. INTRODUCTION

Signal Generator are used as very important electronic equipment in, the research laboratories. It is used as a signal source for testing, maintaining, trouble shooting and development of electrical and electronic equipments. It is used to provide a variety of waveforms, including sine wave, square wave, triangular wave and as well as amplitude modulated waveforms.

The oscillator is the basic element of all signal sources and it provides only a sinusoidal output signal, but Generator provides several types of waveforms. In an oscillator, no energy is created, it is simply converted from a DC source into an AC energy at some specific frequency.

3.2. a). Definition:

The Signal Generator is a source of sine-wave voltage with an appreciable range of frequency and amplitude, both of which are known to a high degree of accuracy.

3.2. b) Applications of signal Generator

(a) Checking of gain and frequency response, and

(b) Checking of alignment in receivers.

3.2. c) Requirements of a signal Generator: (characteristics)

a) Frequency of the signal should be known and stable.
b) Amplitude should vary from very small to relatively large values and
c) The signal should be distortion free

The above characteristics (or) requirements of a signal generator are varying for special signal generator such as function generators pulse and sweep generators.

3.2. d) Classification of signal Generator :

The signal Generators are classified as

A. Radio Frequency (RF) signal generators and

B. Audio Frequency (AF) signal generators

3.2. e) The Band limits and frequency range of AF and RF signal Generators:

Band limit	Frequency range
Audio Frequency (AF)	20Hz to 20KHz
Radio Frequency (RF)	> 30KHz
Very Low Frequency (VLF	15 to 100KHz
Low Frequency (LF)	100 to 500KHz
Broadcast Frequency	0.5 to 1.5 MHz
Video Frequency	DC to 5MHz
High Frequency (HF)	1.5MHz to 30MHz
Very High Frequency (VHF)	30MHz to 300M Hz
Ultra High Frequency (UHF)	300M Hz to 3000MHz
Microwave Frequency	Above 3000 MHz

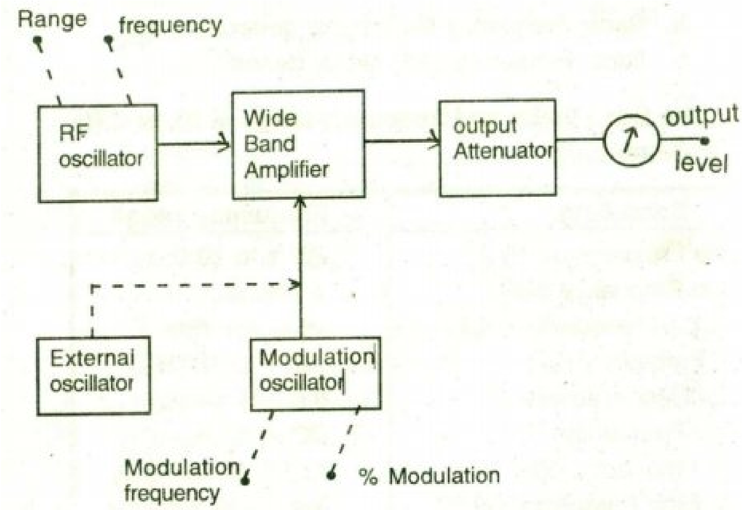
3.2.1. STANDARD SIGNAL GENERATOR

Standard Signal Generator is a source of sine wave Voltage with an appreciable range of frequency and amplitude both of which are known to a, high degree of accuracy.

Block diagram of standard signal Generator :

The basic block diagram of standard signal generator is shown in figure 3.2.1. It consists of various parts. They are,

a. RF oscillator .
b. Modulation oscillator
c. output attenuator
d. External oscillator
e. Wide band amplifier
f. output level meter



a) *RF oscillator :* A very stable RF oscillator is used to generate the carrier frequency using an LC tank circuit, having a constant output over any frequency range.

(b) *Modulation oscillator :* Modulation oscillator is the internal oscillator (fixed frequency oscillator), which is used to provide amplitude modulation.

(c) *Output Attenuator:* The output Attenuator used to attenuate the signal depends on the modulated carrier and it is made set.

(d) *External oscillator :* External oscillator is used to provide amplitude modulation, externally which is a fixed frequency oscillator.

(e) *Wide Band Amplifier:* In wide Band Amplifier, the *modulation is* done. This amplifier delivers its output that is modulation carrier to an attenuator.

(f) *Output level meter :* The output level meter is used to read the output Voltage and the attenuator output setting.

3.2.1. ii) Principle of operation of standard signal Generator

The carrier frequency is generated by a very stable RF oscillator using an LC tank circuit, having a constant output over any frequency range. The frequency of oscillations is indicated by the frequency range control and the venire dial setting. Amplitude Modulation (AM) is provided by an internal sine wave generator or from an external oscillator.

Modulation is done in the wide band amplifier circuit. This amplifier delivers the output that is modulation carrier to an attenuator. The output voltage is read by an output level meter.

Frequency stability is limited by the LC tank 'circuit and the instrument must be given time to stabilize at the new resonant frequency. In high frequency oscillators, isolation is necessary to avoid the effect on oscillator frequency, amplitude and distortion characteristics.

3.2.1, iii) Applications of standard signal Generator:

(I) standard signal Generator is used as power source for the measurement of gain, signal to noise ratio *(SNR),* Bandwidth, standing wave ratio(SWR) and other properties

(ii) Extensively used in testing of radio receivers and transmitters.

3.2.3. HETERODYNE TYPE AUDIO GENERATOR:

Heterodyne Type Audio generator, is used for generating audio frequency signals up to 20 KHz. Heterodyning principle (combination of two frequency outputs from the different oscillators) is used in this type. This type of Audio generator is also called as Beat-frequency oscillator (BFO)

3.2.3. i) Block diagram of Heterodyne Type Audio Generator:

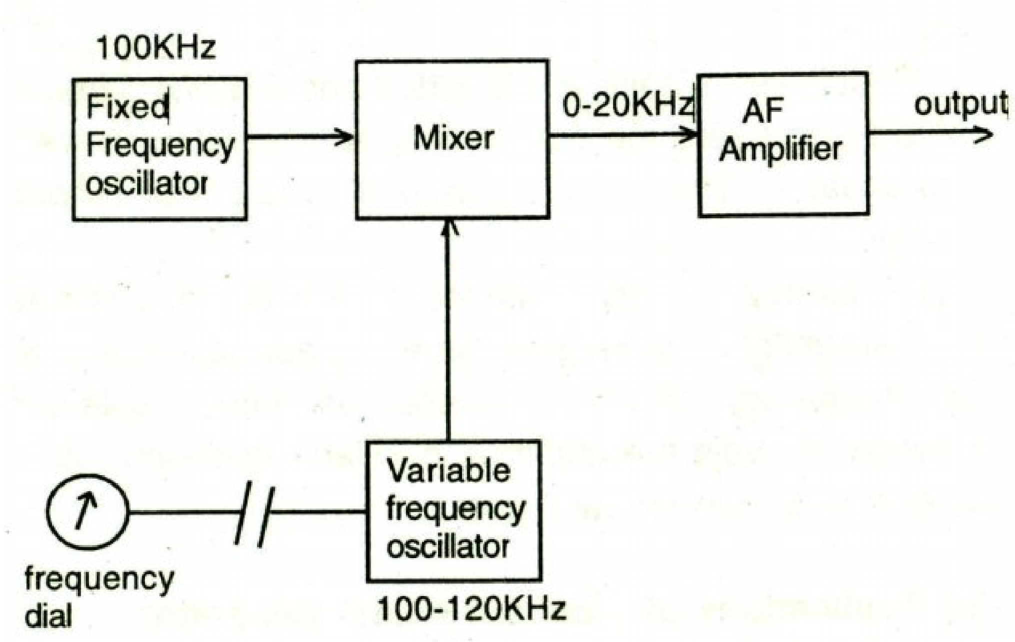
The block diagram of heterodyne type audio generator is shown in the figure 2.2. This audio generator consists of various parts. They are

a. Fixed frequency oscillator

b. Variable frequency oscillator

c. Mixer

d. AF amplifier



(a) *Fixed frequency oscillator:* Fixed frequency oscillator, generates fixed frequency and it is fed to the Mixer stage. It generates a frequency of 100KHz.

(b) *Variable frequency oscillator:* Variable frequency oscillator generates a variable frequency range, ranges from 100 KHz to 120KHz. It is fed to the mixer stage.

c) *Mixer:* The Mixer stage gives the sum and difference output of its two input frequencies. One is fixed frequency from the fixed frequency oscillator and other one is variable frequency from the variable frequency oscillator.

(d) *AF Amplifier :* AF amplifier is the Audio frequency Amplifier which is used to amplify the signal coming from the Mixer stage.

3.2.3. i) Principle of operation of Heterodyne type Audio Generator:

The voltages obtained from the two RF oscillators (fixed frequency oscillator and variable frequency oscillator) operating at slightly different frequencies are combined and applied to a mixer circuit. The Mixer gives the sum and difference of frequencies as output, which is fed to a suitable filter to select the desired signal.

Thus if the fixed frequency oscillator generates a frequency 100KHz the variable frequency oscillator generates a frequency range of 100KHz to120KHz. Then the output frequency varies between 0 to 20KHz. The signal is amplified by an AF amplifier. The output will be normally a sine wave with amplitude of 5V RMS in 400 ohms. .

3.2.3. iii) Advantages of .Heterodyne type Audio Generator

a) Accurately calibrated
b) Switching band is not required
c) Better output
d) Stable and accurate frequency output.

3.2.3 iv) Applications of Heterodyne type Audio Generator

a) Used for testing Radio transmitters
b) Used for TV Transmitters and Receivers

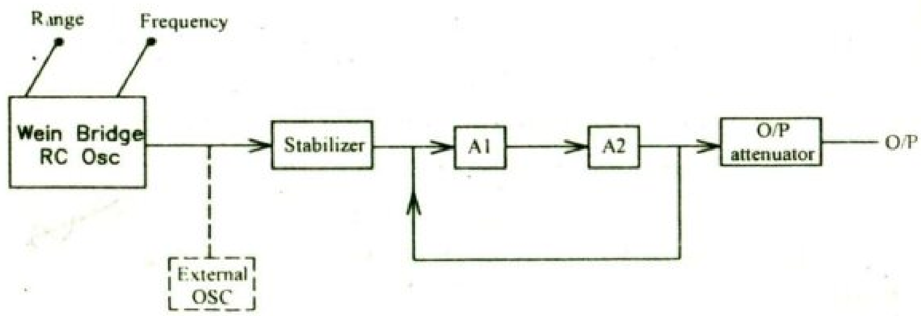
3.2.4. AUDIO SIGNAL GENERATOR

The Audio signal Generator has been designed extremely wide coverage of low frequency signals, covers the audio frequency range between the limit of 20Hz with low distortion and high level output over the full range.

3.2.4.i) Block diagram of Audio signal Generator :

The block diagram of Audio signal Generator is shown figure. It consists of

a) Wien Bridge oscillator
b) Stabilizer
c) External oscillator
d) AF amplifier
e) Output attenuator
f) Negative feedback



(a) *Wien bridge oscillator:* Wien Bridge oscillator is used to provide oscillations. It produces clear sine waves. It is the heart of audio signal generator.

(b) *Stabilizer:* Stabilizer is used to provide stabilized output voltage. It provides excellent regulation and stability with very low ripple.

(c) *External oscillator:* External oscillator is used to generate the required oscillations in addition to the oscillations provided by Wien Bridge oscillator.

(d) *AF Amplifier:* The stabilized output voltage is amplified by using Audio frequency (AF) Amplifier stages. The output of this AF Amplifier stage is distorted and unstable.

(e) *Output Attenuator:* Attenuator used in the output, may be varied between microvolt's to volts range with an overall accuracy of ± 2db.

(f) *Negative feedback network:* The negative feedback network, is used for stable frequency and stable output voltage level with negligible distortion.

3.2.4. ii) Principle of operation of Audio signal Generator

The Wien bridge oscillator produces a clear sine wave. The stabilizer is provided to get stabilized output voltage. The output of stabilizer is given to audio frequency amplifier stages, Where the audio signals are amplified. The output of this amplifier stage is distorted and unstable. Hence a portion of the amplified output is fed back at 180° phase shift using the negative feedback network. This negative feedback improves the stability and reduces distortion. The available audio signal is taken as the output from the output attenuator.

3.2.4. iii) Advantages of Audio signals Generator :

a. Reduced Distortion and noise

b. increased stability

c. increased Bandwidth

d. more reliable and accurate

e. available in different waveforms

f. low cost

3.2.4. iv) Applications of Audio signal Generator :

a. used for testing radio receivers

b. used for TV transmitters and receivers

3.2.5. RF SIGNAL GENERATOR

In RF signal Generator, modulated RF signal is generated. The frequency varies from 30KHz onwards. It provides a sinusoidal output voltage whose frequency varies smoothly and continuously over and entire frequency band. It is also called as sweep Generator.

3.2.5.i) Block diagram of RF signal Generator

The block diagram of RF signal generator is shown in the figure. This RF signal generator consists of various parts. They are

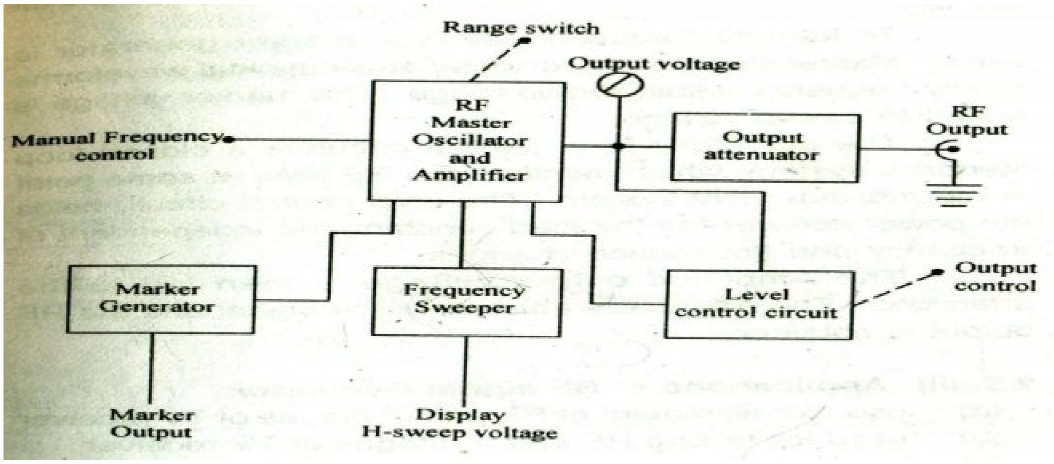
a. Marker Generator

b. RF Master oscillator and Amplifier

c. Frequency sweeper

d. level control circuit

e. Attenuator



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(a) Marker Generator': The Marker generator provides half sinusoidal waveform at any frequency within the sweep range. It is used to identify the frequency interval.

(b) 'RF Master oscillator and Amplifier: RF Master oscillator and Amplifier, is the Heart of the RF signal Generator. It provides a number of frequency bands.

(c) Frequency sweeper: The frequency sweeper provides a variable modulating voltage and makes the change in master oscillator. It provides varying sweep voltage for synchronization.

(d) Level control circuit: Level control circuit, is automatic closed loop feedback system, which monitors the RF level at some point in the measurement system.

(e) Attenuator: Attenuator is used to attenuate the amplified Signal and given to the output.

3.2.5. Ii) Principle of operation of RF signal Generator

The frequency sweeper provides a variable modulating Voltage, which causes the capacitance of the master oscillator to vary. A manual control allows independent adjustment of the oscillator resonant frequency. The frequency sweeper also provides a varying sweep voltage for synchronization to drive the horizontal deflection plates of CRO.

To identify frequency interval, marker generator is used. Marker Generator provides half sinusoidal waveforms at any frequency within sweep range. The marker voltage is added to sweep voltage.

The automatic level control circuit is a closed loop feedback system, which monitors the RF level at some point in the measurement system. The level control circuit holds the power delivered to the load constant and independent of frequency and impedance changes.

The Amplified output voltage is then fed to the attenuator.
The Attenuator attenuates the signal and the RF output is obtained.

3.2.5. iii) Applications of RF signal Generator

(a) Used for alignment of RF and IF stages of TV receiver

(b) Used for testing RF and IF 'stages of TV receiver

(c) Used for measurement of gain and Bandwidth.

3.2.6. RF MARKER GENERATOR

RF Marker Generator is essentially an RF signal Generator in the VHF and UHF bands, with much higher accuracy than the other signal Generators.

The drawback of the RF signal generator is, that it does not give any precise information of the frequency on the traced curve. This drawback of RF signal generator is rectified by using a separate RF generator called a "Marker Generator".

3.2.6. i) Block diagram of RF Marker Generator:

The block diagram of RF Marker generator is shown in fig.2.5. It consists of various parts. They are,

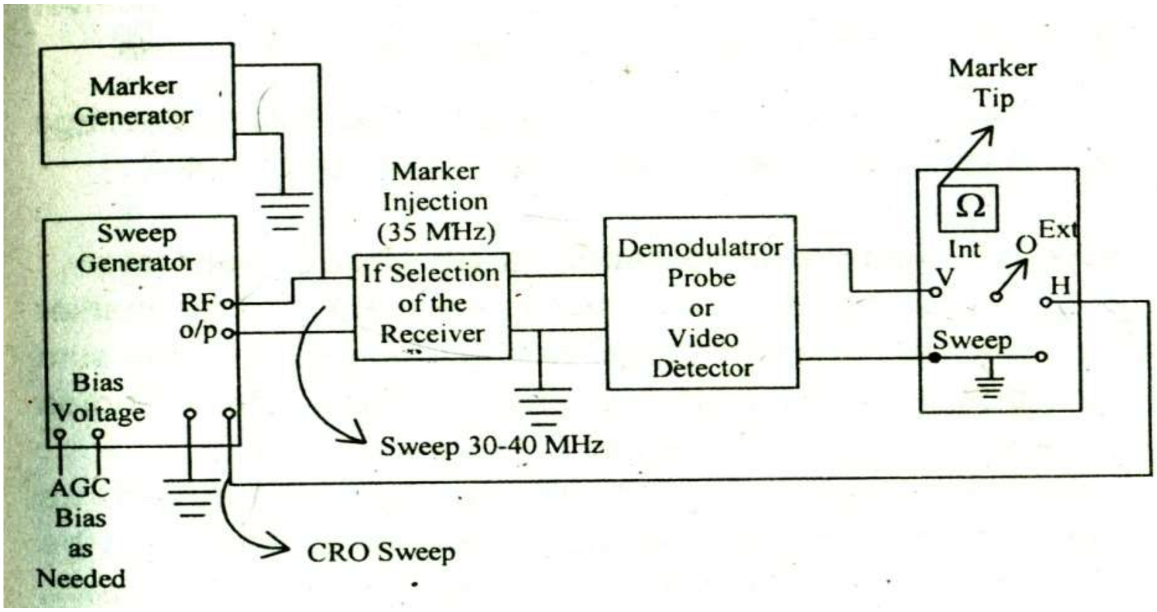
a. Sweep Generator

b. Marker generator

c. **IF** section of Receiver

d. Demodulator probe

e. Screen



(a) *Sweep Generator:* Sweep generator is a RF signal generator. It is one of the generators, used to provide RF output for heterodyning.

(b) *Marker Generator:* Marker generator is also a type of RF signal generator, which generates RF signal output and fed for the heterodyning process. The output of this marker generator is set at the desired frequency within the pass-band of the circuit under test.

(c) *If section of the Received* In this Intermediate Frequency (IF) section, the two RF outputs from the sweep generator and marker generator are mixed (heterodyned) to produce the sum and difference of the frequencies.

(d) *Demodulator Probe:* Demodulator probe (or) the vide detector, is used to detect the IF frequency of the receive and fed to the vertical and sweep section of the screen.

(e) *Screen.'* The screen is provided by the detected voltage and displays the low frequency output of the detector.

3.2.6. ii) Principle of operation of RF Marker Generator

The output from **the** sweep generator and the marker generator are mixed together, to produce outputs at the sum and difference of two frequencies. These frequencies appear at the detector output.

When no difference frequency is produced, no vertical deflection is produced on the screen. As the frequency approaches and just crosses the marker frequency, a curve on the screen along the trace is generated by the low frequency output of the detector. To get a sharp curve, a suit- able capacitor is shunted across the vertical input terminals of the GRO.

The Marker generator is provided with dial controlled frequency. It has the provision to generate crystal controlled fixed frequency output at several important frequencies.

3.2.6.iii) Applications of RF Marker Generator

a) used to identify the frequencies on the sweep frequency scale.,

b) used for alignment of receivers.

(c) used for more accurate calibration of sweeps

3.2.7. i) FUNCTION GENERATOR

A function Generator is an instrument, that delivers different waveforms of adjustable frequency over a wide range. The most common output waveforms are the sine, square, triangular and saw tooth waves, whose frequencies may be adjusted from a fraction of a Hertz to several Hundreds of Kilo Hertz.

The special features and the capabilities of the function generators are

(a) Various outputs are available at the same time

(b) It can be phase locked to an external source

(c) One function generator may be used to phase lock a second function generator and the two output signals can be displaced in phase, by an adjustable amount.

(e) By adjusting the phase and amplitude of the harmonics, almost any waveform may be generated.

3.2.7. i) Block diagram of function Generator

The block diagram of function generator is shown in the figure. It consists of various parts. They are

(a) Frequency control network

(b) Upper constant current source

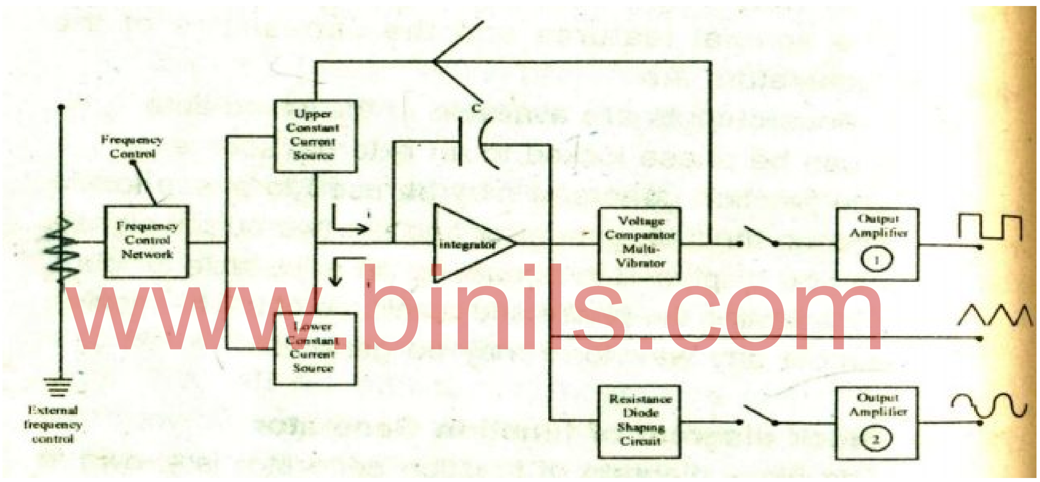
(c) Lower constant current source

(d) Integrator

(e) Voltage comparator multivibrator

(f) Resistance-diode shaping circuit

(g) Amplifiers



(a) *Frequency control network :* Frequency control network is used to control the frequency, by varying the magnitude of Current which is used to drive the integrator.

(b) *Upper constant current source :* The upper constant current source, supplies current to the integrator, whose output voltage changes linearly with time.

(c) Lower constant current source: The lower constant current source, supplies a reverse current to the integrator, to decrease the integrator output.

(d) *Integrator:* The Integrator output varies linearly with time according to the Formula $E_{out} = -1/c \int i \, dt$

(e) *Voltage comparator Multivibrator:* The voltage comparator multivibrator, changes its states at a pre-determined maximum level of the integrator output voltage.

(f) Resistance-diode shaping circuit : The Resistance diode shaping circuit, changes the slope of the triangular wave and produces a Sine wave.

(g) Amplifier: Amplifier is used to amplify the signals coming out from the voltage comparator Multivibrator and Resistance diode shaping circuit. There are Amplifiers, for each output.

3.2.7. ii) Principle of operation of Function Generator:

The frequency is controlled by varying the magnitude of current, which drives the integrator. This function gene rater produces, sine, square and triangular waveforms with a frequency ranging from 0.01 Hertz to 100KiloHertz.

The frequency controlled network, regulates two current sources. The upper current source supplies constant current to the integrator, whose output voltage increases linearly with time. An increase or decrease in the current increase or decreases, the slope of the output voltage and hence the frequency is controlled.

The voltage comparator Multivbrator, changes the states at a pre-determined maximum level of the integrator output voltage. This change cuts off the upper current supply and made it to switch on the lower current supply. The lower current supply, supplies reverse current to the integrator, so that its output decreases linearly with time.

The output of the integrator is a triangular waveform. The comparator output delivers a square wave voltage of same frequency, The resistance - diode network alters the slope of the triangular wave as its amplitude changes and produces a sine wave with less than 1% distortion. The amplifier in the output, amplifies the signal.

3.2.7. iii) Applications of function Generator

1) The different waveforms generated are used in Labs
2) Used to analyze the performance of characteristics of networks.
3) Used to generate several harmonic frequencies by phase locked loop systems
4) Unknown wave forms can be compared.

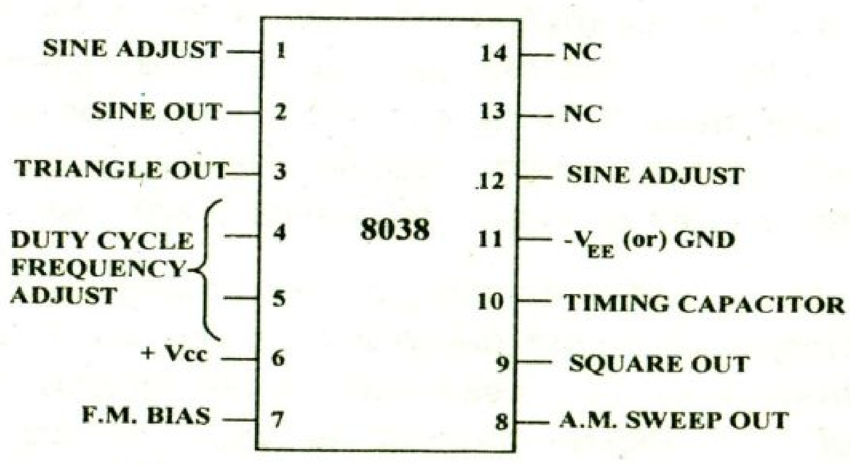
3.2.8. FUNCTION GENERATOR USING IC 8038

The Basic principle of the function generator, is linear charging and discharging of a capacitor in the integrator circuit. This generator produces triangular waveform, from which the square and sine waveforms are generated.

The IC 8038 is used to generate the various waveforms. The features of IC8038, are

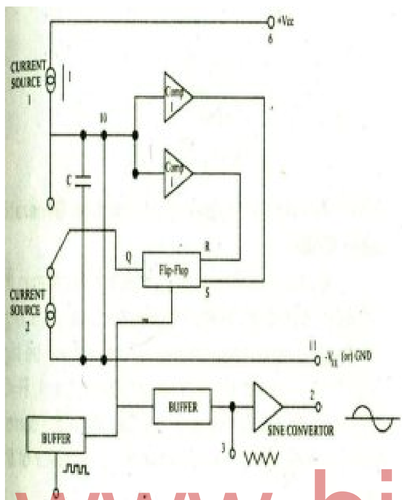
(a) It has low distortion
(b) It requires very few external components
(c) It can provide sine, square and triangular waves simultaneously.
(d) It has low frequency drift with temperature.

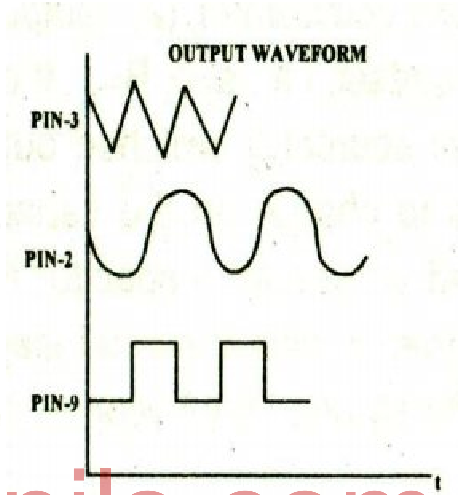
The pin details of the IC 8038 are shown in fig.2.7. It is of 14 pin DIP IC.

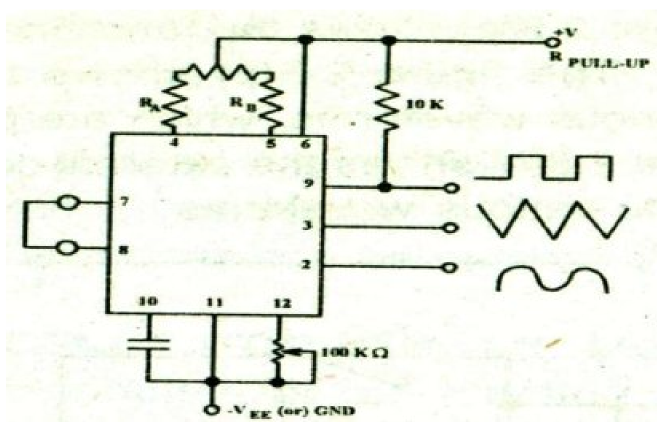


3.2.8 Functional Block diagram of IC 8038

The figure 1 shows the functional block diagram of IC8038. The figure 2 shows the relationship between the various waveforms, which are generated by IC8038. The figure 3 shows the external connections of IC8038 to generate various waveforms







3.2.8.ii) Principle of operation of Function Generator using IC8038

The two current sources, charges and discharges the capacitor alternatively. When the current source (1) is high (i.e. above reference level) comparator - I output will be high (logic-1). Now SR flip flop is in set condition (i.e. s=1, R=O Then the output of flip flop is '1'. i.e Q=1 when the current source(2) switched ON, it will discharge the capacitor of the same rate.

When the triangular wave level is below the negative reference level, the comparator (2) output becomes high Now the flip-flop is reset, i.e., s=O, R=1, therefore Q=O. This makes the current source(2) switched out and the current source begins to charge up the capacitor again. The voltage developed across the capacitor is given to buffer stage.. It is then' given to sine converter stage. The output of the flip-flop is buffered and so it becomes the square wave.

3.3. MEGGER:

Insulation resistance quality of an electrical system degrades with time, environment condition i.e. temperature, humidity, moisture and dust particles. It also get impacted negatively due to the presence of electrical and mechanical stress, so it's become very necessary to check the IR (Insulation resistance) of equipment at a constant regular interval to avoid any measure fatal or electrical shock.

3.3.1.Types of Megger

This can be separated into mainly two categories:-

1. Electronic Type (Battery Operated)
2. Manual Type (Hand Operated)

Advantages of Electronic Type Megger

1. Level of accuracy is very high.
2. IR value is digital type, easy to read.
3. One person can operate very easily.
4. Works perfectly even at very congested space.
5. Very handy and safe to use.

Disadvantages of Electronic Type Megger

1. Require an external source of energy to energies i.e. Dry cell.
2. Costlier in market.

Hand Operated Megger

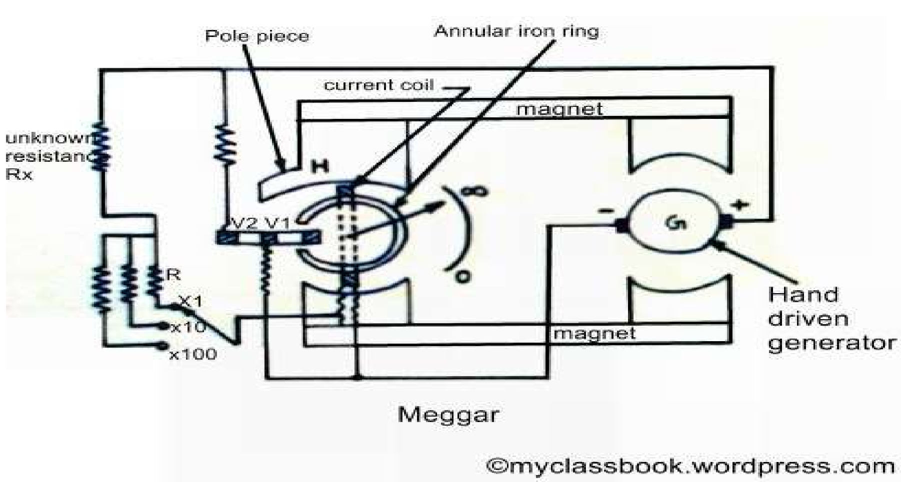
Advantages of Hand Operated Megger

1. Still keeps important in such high-tech world as it's an oldest method for IR value determination.
2. No external source required to operate.
3. Cheaper available in market.

Disadvantages of Hand Operated Megger

1. At least 2 persons required to operate i.e. one for rotation of crank other to connect megger with electrical system to be tested.
2. Accuracy is not up to the level as it's varies with rotation of crank.
3. Require very stable placement for operation which is a little hard to find at working sites.
4. Unstable placement of tester may impact the result of tester.
5. Provides an analog display result.
6. Require very high care and safety during use of the same.

3.3.2. With a neat sketch explain the Construction and working principle of a Meggar.



Meggar is an instrument used for measuring insulation resistance.

1. The Moving system consists of two coil called control coil and deflecting coil.
2. These are fixed at an angle of 90 degree
3. The compensating coil in series with a control coil and protection resistance is connected across a generator.
4. The coils move in the air gap of permanent magnet.
5. Control coil is in series with CCR.
6. Deflecting coil is in series with DCR and the resistance under test.
7. The guard rings by passes the leakage current.

Working:

1. The unknown resistance is connected between the terminal L&E.
2. The generator handle is turned at uniform speed.
3. When the resistance value is small, the current through the deflecting coil is high, so deflecting torque is also high.
4. Hence the pointer will move to clockwise and shows '0' or very low resistance
5. When the resistance is high, the current through the deflecting coil is low
6. The pointer will move to the anti clock wise direction (ie) infinity

Application of megger:

1. The device enable us to measure electrical leakage in wire
2. Megger is used for verifying the electrical insulation level of any device such as motor, cable, generator winding etc.

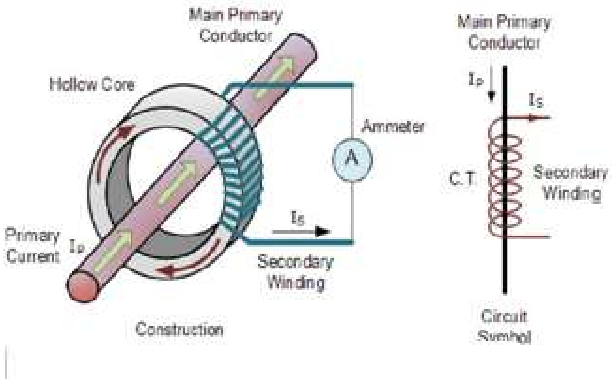
3.4. Constructional details of Current Transformer and Potential Transformer.

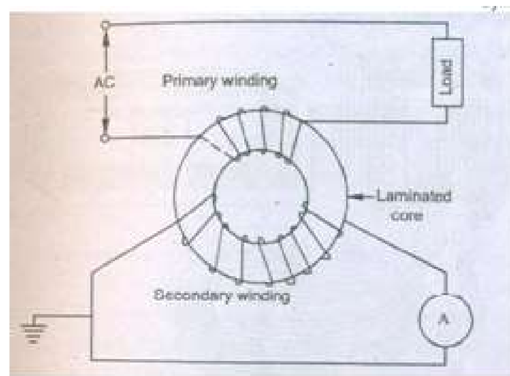
3.4.1. Current Transformer

The **Current Transformer** (**C.T.**), is a type of "instrument transformer" that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary.

Current transformers reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer.

3.4.2. Block diagram of Current Transformer





There are three basic types of current transformers: **wound**, **toroidal** and **bar**.

Three main part of current transformer:

1.Core

2.Winding

3. Insulation

a. Core:

There are three forms of cores

i) Rectangle form

ii) Shell form

iii) Ring form

(i) Rectangle form:

It is built up of ‘L’ Shaped punching suitable for high voltage winding are placed on the shorter limb.

(ii)Shell form:

Windings are placed in the central limb difficult to build up

(iii) Ring form:

It provides joint fewer cores suitable for large current. Winding is uniformly distributed around the ring .metal cores are commonly used now.

b. Winding:

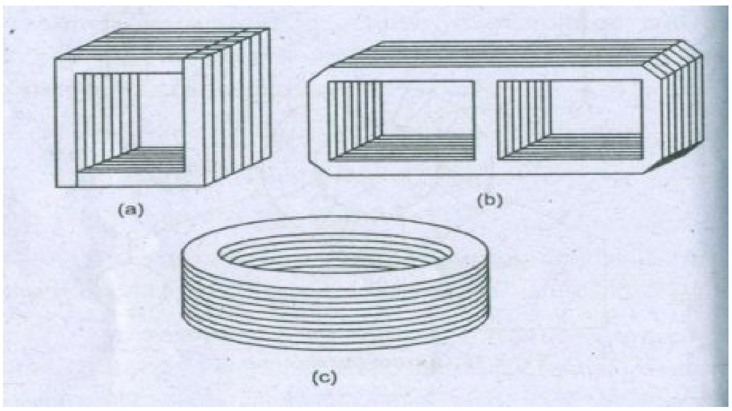
The primary winding consists of one or more turns connected in the series with the circuit. The secondary winding has more turns than primary winding and directly connected to the instrument.

c. Insulation:

The primary and secondary winding are separately wound. They are insulated by tape and varnish for low voltage.

Oil immersion or compound filling is done for high voltages.

Porcelain tubes are as used insulation in high voltage.



3.4.3. Working of CT:

$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$ $\frac{N_1}{N_2} = \frac{I_2}{I_1}$ $N_1 I_1 = N_2 I_2$ $I_1 = \frac{N_2 I_2}{N_1}$

Primary winding carries the load current (I1) secondary current is less.

3.5. Potential Transformer:

Potential transformer or **voltage transformer** gets used in electrical power

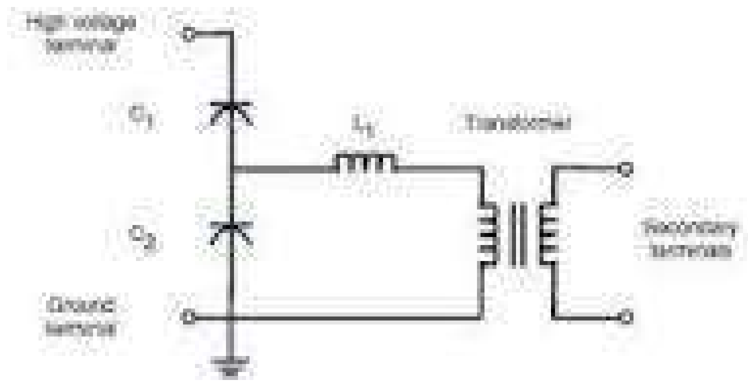
system for stepping down the system voltage to a safe value which can be fed to low ratings meters and relays. Commercially available relays and meters used for protection and metering, are designed for low voltage. This is a simplest form of

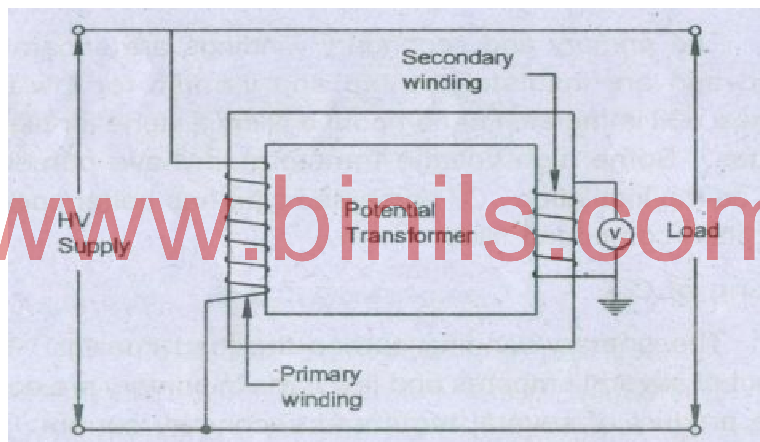
3.5.1. Voltage Transformer or Potential Transformer

A voltage transformer theory or potential transformer is just like a general purpose step down transformer. Primary of this transformer is connected across the phase and ground. Just like the transformer used for stepping down purpose, potential transformer i.e. PT has lower turns winding at its secondary.

The system voltage is applied across the terminals of primary winding of that transformer, and then proportionate secondary voltage appears across the secondary terminals of the PT.

3.5.2. Block diagram of Potential Transformer:





Potential transformer is used for measurement of high voltage by means of low range voltmeter. The potential transformer is a step down transformer. The meter is connected to the low voltage secondary winding.

Core:

Core may be of shell type, shell type is normally used for low voltage. metal and silicon steel are used for making the core.

Winding:

Primary winding consist of more number of turns. It is connected across the circuit. The secondary winding consists of few turns. It is shorted through a Voltmeter.

Insulation :

Cotton type and varnished camphor used as insulation for coil constructions

3.5.3. Working of PT:

Primary winding is connected across the line.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} \qquad \frac{N_1}{N_2} = \frac{V_1}{V_2} \qquad N_1V_2 = N_2V_1 \qquad V_1 = \frac{N_1V_2}{N_2}$$

The normal secondary voltage rating is 110v.

3.6. Recorder :

Recorder is a measuring instrument that records electrical and non-electrical quantities as a function of time.

3.6.1. Types of recorders :

1.Analog recorder

2.Digital recorder

Analog recorder is classified into

- X-Y recorder.
- Strip-Chart recorder.

3.6.2. XY RECORDER

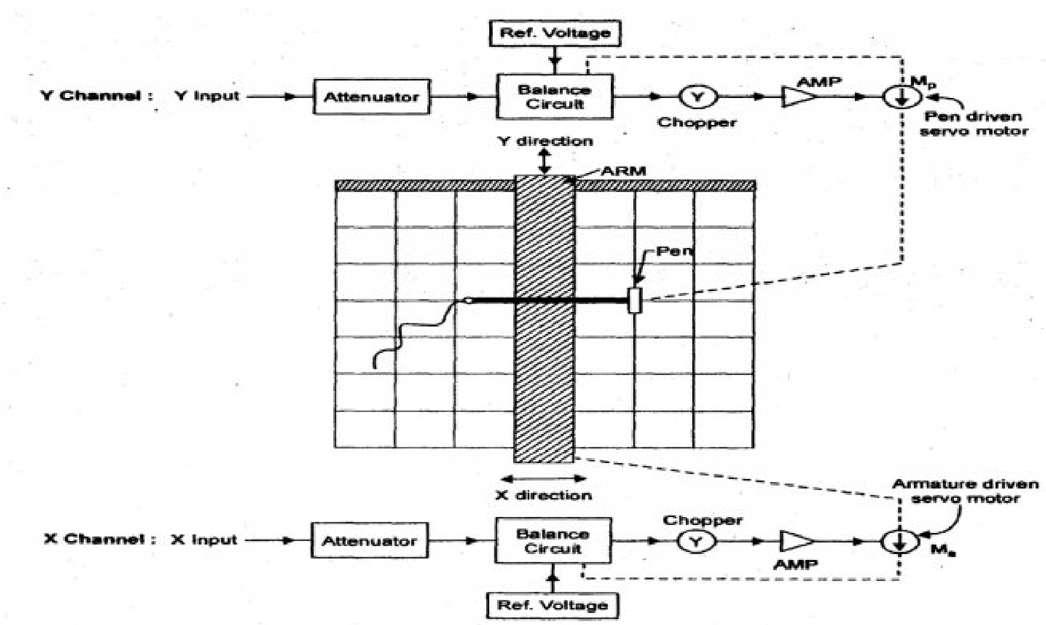


Fig. 22

BLOCK DIAGRAM OF XY RECORDER:

In XY recorder one circuit moves in X direction and another circuit moves in Y direction.

CONSTRUCTION:

Various blocks of XY recorder are

1. Attenuator
2. Balance circuit.
3. Chopper.
4. Amplifier
5. Servo motor.

Attenuator:

Two inputs (XY) are attenuated to the range of the recorder.

Balance circuit:

In balance circuit attenuated error signal is compared with the reference signal.

Chopper:

The error signal is given to the chopper. Chopper converts DC error signal to AC

Amplifier:

AC error signal is amplified here.

Servo motor:

Servomotor is used to move the pen in proper direction.

OPERATION:

X-Y inputs are given to attenuator.

- Attenuator reduces the input signal to the range of recorders.
- Then the attenuated signal is compared in the balanced circuit.
- The error signal from balanced circuit is given to the chopper.
- The DC error signal is converted into AC by Chopper.
- Since the AC error signal is low it is amplified by amplifier to drive two servomotors.
- One Servomotor drives the pen and the other moves the arm.
- Pen and arm moves over the fixed graph paper.
- Hence a record of one physical quantity with respect to another physical quantity is obtained.

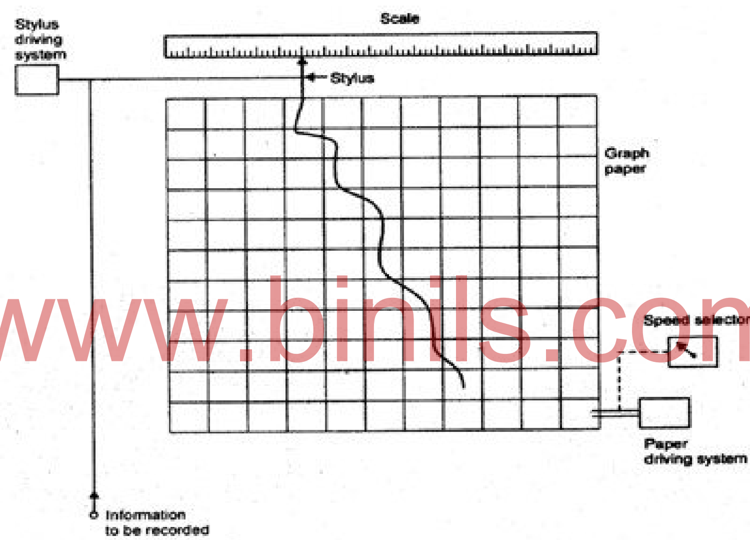
ADVANTAGES:

1. Even a complicated curve can be drawn.
2. Related electrical or non electrical quantities can be recorded.

APLLICATION OF XY RECORDER:

1. To draw VI characteristics of Zener diode, transistor, Vacuum tubes.
2. To plot Stress-Strain curves.
3. To draw regulation curves of power Supply.
4. To draw Speed –Toque characteristics of Motor.

3.6. 3. STRIP CHART RECODER:



Construction:

- Strip chart recorder is a recorder which records the data on a moving chart paper.
- It is also called XT recorder.
- A Strip chart recorder consists of a long role of graph paper.
- This graph paper moves at constant Speed .
- There is a stylus pen to make marks on moving graph paper.
- The stylus moves horizontally and also depend upon the quantity to be recorded.
- A Pointer is attached to the Stylus which moves over a scale.
- Pointer shows the value of quantity to be recorded.
- It consists of speed selector switch and range selector switch.

Operation:

- A paper driving system moves the chart paper at constant speed.
- According to the quantity to be recorded, the stylus moves over the chart.
- Stylus draws a graph and the pointer moves over the scale.
- When there is no signal applied to Stylus pen, it is stationary.
- At this time the paper moves and a straight line will be marked on the paper.
- When the input is given, the pen moves over the chart paper according to the variation of input signal.

APPLICATION:

1. Heat treatment furnaces.
2. Sugar processing plants.
3. Water and waste water treatment.
4. Textile and dye processes.
5. Tire and Rubber processing
6. Diary pasteurization plants
7. Pharmaceuticals.

3.6.4. COMPARE STRIP CHAT AND XY RECORDER:

STRIP CHART RECORDER	XY RECORDER
• It is an XT recorder. • It records variation of quantity with respect to time. • Sensitivity – 0.4 V/mm. • Self balancing potentiometer	• It is an XY recorder. • It gives graphic record between two quantities. • Sensitivity - 10 V/mm. • Two potentiometer is used.

REVIEW QUESTIONS

PART – A (2 Marks)

1. What is DC power supply?
2. List out the application of variable dc power supply.
3. What is the definition of signal generator?
4. What is RF generator used for?
5. Mention types of Megger.
6. Define and Potential Transformer.
7. What is the use of current transformer?
8. Writ the application of Strip chart recorder.

PART – B (3 Marks)

1. What is difference of fixed and variable dc power supply?
2. Write the application of Audio generator.
3. Write short notes on megger.
4. What is the difference between current transformer and Potential Transformer.
5. What are the advantages of X-Y recorder?
6. Compare Strip chart and X-Y recorder

PART – C (10 Marks)

1. Explain each block of the variable DC power supply with neat diagram
2. Discuss the Audio Generator working principle with neat diagram.
3. Explain the working principle of Hetrodyne type audio generator with neat block diagram
4. With a neat sketch explain the Construction and working principle of a Meggar.
5. Explain the constructional details of Current Transformer
6. Illustrate the working of X-Y recorder with relevant diagram.

UNIT - IV

Digital Instruments

4.1 Introduction:

Analog instruments are used to measure various quantities like current voltage power continuously. Digital instruments are used to measure various quantities like analog instruments, but the output will be displayed in numbers.

Digital VS Analog		
S.No	**Analog**	**Digital**
1.	Low precision	High precision
2.	More flexibility	Limited flexibility
3.	Not convenient for read out	Very convenient for read out
4.	Errors due to friction. tension may come	No such errors
5.	Parallax error in read out	No such error
6.	Continuous and simple output	Numerical output
7.	Frequency response is good	Frequency response is very good
8.	Not compatible for direct connection with PC, MC.	Compatible with PC, MC,PC.

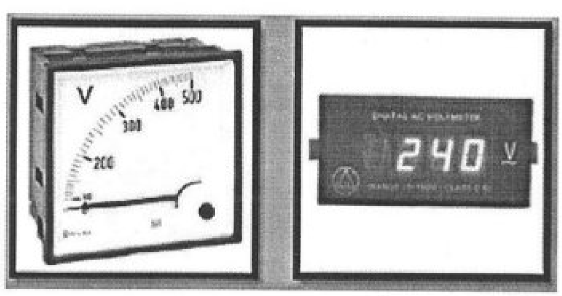


Figure 1: a) An analog voltmeter and b) a digital voltmeter

4.2 Digital Voltmeters [DVM] :

DVM is nothing but Digital Volt meter. Digital voltmeters are the measuring instruments which convert analog voltage signals into a digital readout. The digital output is displayed on the front panel.

DVM can also measure analog dc voltage. We can measure ac voltage, resistance dc, ac current, temperature and pressure using proper signal conditioners before giving then input to DVM. The DVM displays ac & dc voltages as discrete numbers.

DVM's are classified in the following ways by

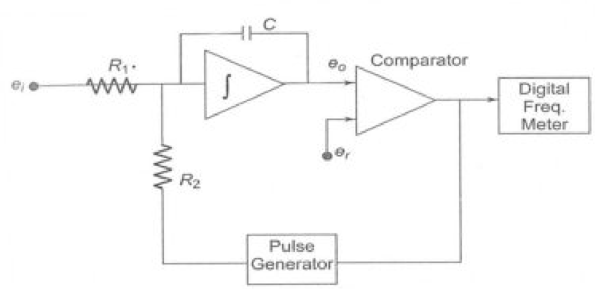
1. Number of digits.
2. Number of Measurements.
3. Accuracy.
4. Speed of reading.
5. Digital output of various types.

Characteristics of DVM's:

1. Accuracy is ± 0.005% of the total reading.
2. Resolution is 1 part in million.
3. Input resistance is 10 MΩ, capacitance is 40 ρf.
4. Input range is from +1.000 v ton +1000 v with automatic ranges selection.

4.2.1 Integrated Type DVM:

The principle of this type of DVM is the output frequency is proportional to the input voltage. A constant output voltage is integrated and the slope of output is proportional to the input voltage. When the output reaches to a particular value it is discharged to zero and another cycle begins.

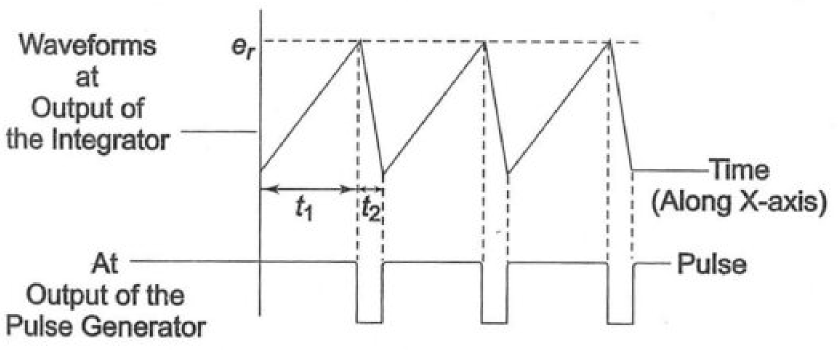


Block Diagram of integrating type DVM

Working:

The input voltage produces a charging current which charges the capacitor 'C' to the reference voltage e_r.If e_r is reached the comparator charges its state to trigger the precision pulse generator.

The pulse generator produces a pulse which rapidly discharges the capacitor. The charging rate and discharging produces a signal frequency which is directly proportional to e_i.



Waveform

The voltage to frequency conversion is of dual slope type.

$$ei = \frac{e_r t_2}{t_1}$$

If e_r, t_2 are constants, Let $K_2 = e_r.t_2$

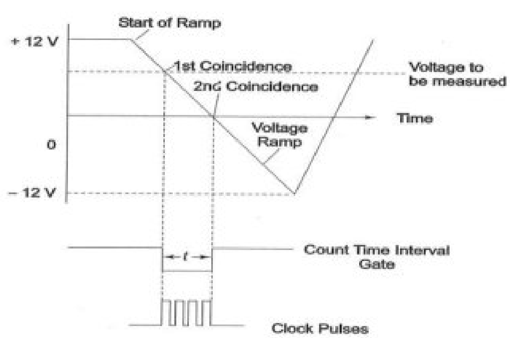
$e_i = \frac{K.1}{t_1} = K_2 . f_0$ $\quad [\therefore \, ^1/_{t_1} = f_0]$

The output frequency is proportional to the input voltage e_i.

4.2.2. Ramp type DVM:

Principle:

Based on the time taken by a linear ramp to charge the input level to ground level or vice-versa.



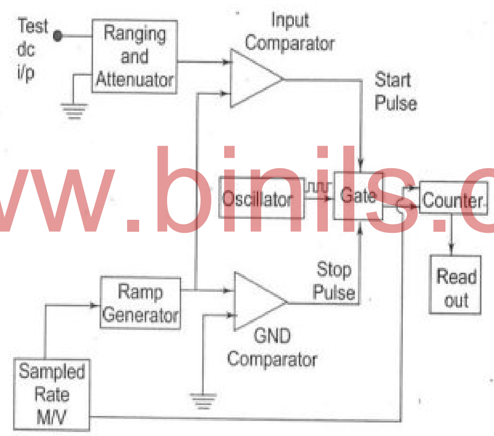
Voltage to time conversion

The ramp can be either positive or negative. The ramp voltage is initiated to start the measurement. The ramp voltage is compared with the voltage which is measured.

When two voltages are equal a coincidence circuit generates a pulse to open a gate. The ramp continues to go until the second comparator senses the ramp has reached zero. The ground comparator compares the ramp with ground.

When the ramp reaches zero the ground comparator generates stop pulse, and closes the gate. In between the time interval of start and stop pulse the gate opens the oscillator circuit which drives the counter.

The count magnitude indicates the input voltage magnitude which is displayed by the read out. The voltage is converted into time and its count represents the voltage magnitude.\



Block diagram of ramp DVM

Advantages:

1. Easy to design.
2. Operating cost is low.

Disadvantages:

1. Errors are maximum.
2. Noise is also more.

4.2.3 Successive approximation DVM:

Principle:

The values are approximated successively until we reach a near perfect value.

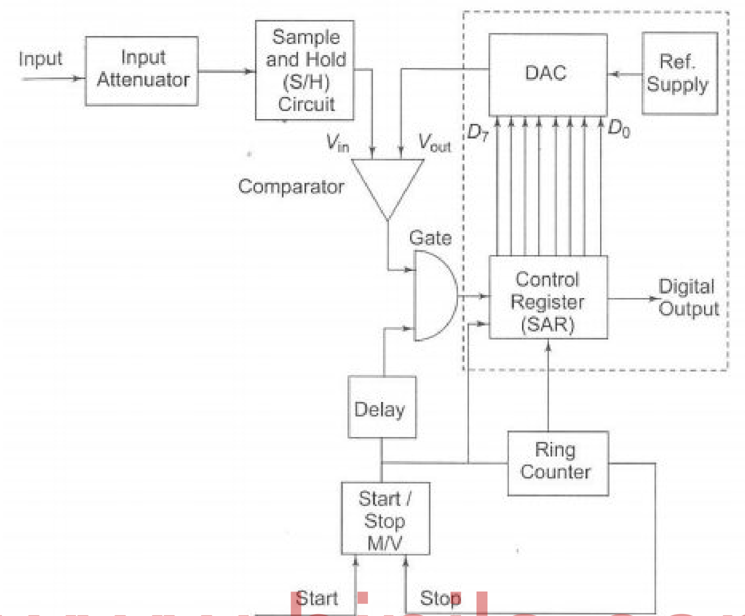


Fig. 5.10 Successive approximation DVM

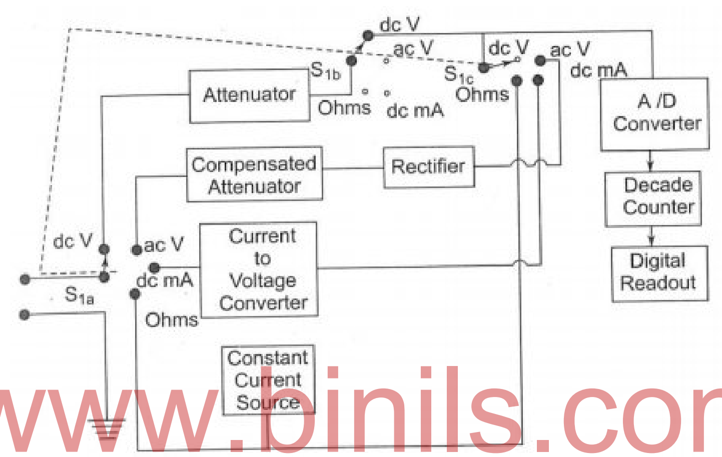
The start pulse activates the control circuit to clear successive approximation register (SAR). If the output of SAR is 00000000, Volt of the D/A converter is zero. If VIN > VOUT comparator output is positive and VIN < VOUT the comparator output is negative. During the first clock pulse the control circuit sets D_7 as 1 and volt reaches 50% of reference voltage the SAR output is 10000000. If volt is greater than VIN, the comparator output is zero and the control circuit resets D7. If VIN > VOUT, comparator output is positive and the control circuit keep D_7 set. Similarly the rest of the bits begins from D_7 to D_0 are set and started.

At starting a start pulse is applied to start / stop multi vibrator. This sets the MSB of control register as I and others are zero. The value will be 10000000. The output of D/A is ½ V. This output is compared to the unknown input by the comparator output is high. The control register retains the 1.

The ring counter advances one count by shifting 1 to second MSB and output becomes 11000000. The process continues until the ring counter reaches its final count. Then the measurement cycle stops and the digital output of the control register represents the final approximation of the unknown input voltage.

4.3 Digital Multimeter :

Digital Multimeter has high input impedance with high accuracy. They are small in size.



Block diagram of a basic digital multimeter

A basic digital multimeter is made up of many A/D converters with attenuation circuits. The current to be measured is applied to summing junction at input of operational amplifier. The current at input is zero because of high input impedance.

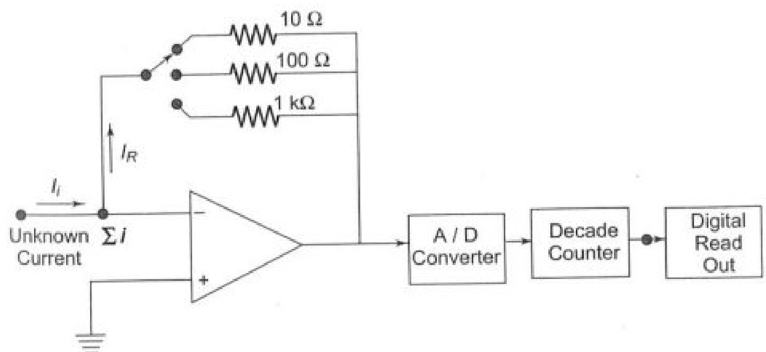
The current I_R nearly equal to I_i causing a voltage drop across the resisters. The voltage drop is the input to A/D converter, which gives a reading value proportional to unknown current.

To measure a resistance a known current from a constant current source is passed to that resistor. The voltage drop across the resistor is applied to the A/D converter. The A/D converter indicates the value of unknown resistance.

Digital Meters have the capabilities of displaying half digits. A full digit display displays all numbers from 0 to 9.A half digit display displays only the number 1.The half digit is always the first digit shown.

A 3.5 digit display has four segments with 3 full digits and one half digit.It will read maximum of 1999.For example if we like to display 10 KV on 3.5 digit meter we use the leading half digit. We have four digits resolution. Placing the decimal point properly the reading would be 10.00.KV will be displayed in front panel overlay.

A 4.5 digit display has 5 segments. 4 full digits with one half digit. Maximum display capability is 19999.If we like to display 10 KV on 4.5 digit meter we use the leading half digit. We use five digit resolutions. The final reading is 10.000.KV is displayed on front panel overlay.



Current to voltage converter.

4.3.1 Auto Ranging :

The aim of automatic ranging is to get optimum resolution in all circumstances. The instrument will be switched to more sensitive range to measure all type of values from very minimum to maximum.

The range of the instrument is automatically switched over to the appropriate range for near perfect measurements.

4.3.2 Auto Zeroing :

Automatic zeroing eases the operation of an instrument. After a measurement is made successfully the instrument comes back to zero zeroing offers optimum accuracy for low valued reading.

4.3.3 Auto Polarity :

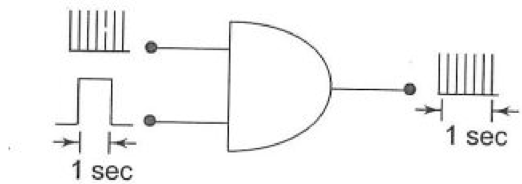
The polarity indication is obtained from analog to digital converter. The polarity is measured at the end of the integration period. The output of the integrator sets the polarity of the flip-flop. The output made at last will be there in the memory until a new measurement is made.

4.4.4 Digital Frequency Meter:

This type of mater is effectively used to measure the frequency and displays the measured frequency.

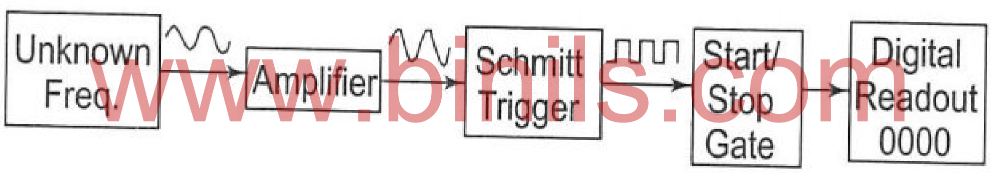
Principle of Operation:

The signal is converted into trigger pulses and applied to an AND gate Continuously. If pulse of I's is applied to other terminal and the number of pulses are counted for this period. The count indicates the frequency.



Principle of Frequency measurement

4.4.1 The Block Diagram of Digital Frequency Meter



Basic circuit of digital frequency meter

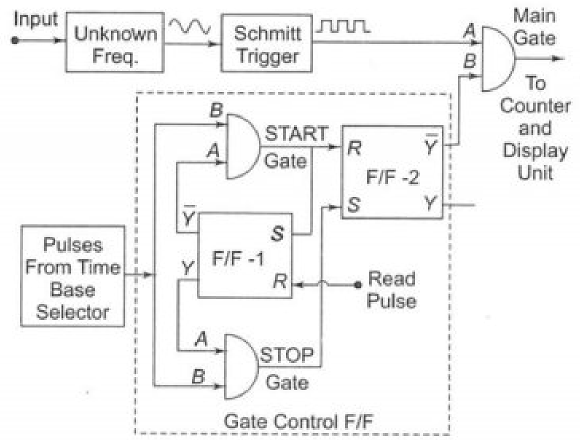
The unknown frequency signal is amplified before applying to Schmitt trigger. The Schmitt trigger converts the input signal into a square wave, as train of pulse.

The Schmitt trigger's output is given to Start / Stop gate. When the gate is enabled the input pulses pass through this gate and directly fed to electronic counter. The counter counts the number of pulses.

When the gate is disabled the counter stops counting the incoming pulses. The counter displays the number of pulses which are passed through the START/STOP time unknown frequency.

4.4.2 CIRCUIT DIAGRAM FOR DIGITAL FREQUENCY COUNTER

The basic circuit diagram for frequency measurement is shown below.



The basic circuit for measurement of frequency

The unknown frequency is applied to the Schmitt trigger produces positive pulses at the output. The pulses are present at point A of the main gate. The positive pulses from time base sector are present at point B of the START and STOP gates.

Initially the flip-flop 1 (F/Ff1) o is at logic 1 state. The voltage from Y is applied at point A of stop gate and enables the gate. The logic (zero stage at $\bar{Y}$ of F/F 1 is applied to input A of the START gate disables the gate.

The stop gate is enabled, the positive pulses from stop gate sets (S) input of the F/F-2 and sets that F/F-2.

The output 0 from of $\bar{Y}$ F/F-2 is application terminal B of the main gate. No pulses can pass through the main gate.

To start the Operation Positive pulse is applied to reset input of F/F-1, $\bar{Y}$=1, Y=0, STOP get is disabled and START gate is enabled. The same read pulse is applied to reset the input of all decade counters. The counters are set to Zero and the counting can start.

When next pulse arrives it passes through START gate to reset F/F-2, then F/F-2 output charges to 1 from Zero. $\bar{Y}$ changes from 0 to 1. $\bar{Y}$ signal is the gating signal, applied to input B of main gate and enables the gate.

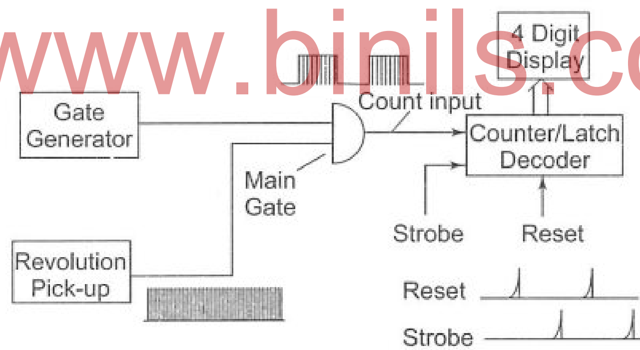
The pulses from unknown frequency source passes through the main gate of the counter which starts to count. The pulse from START gate is applied to F/F-1 changes its state from 0 to 1. This disables the START gate and enables the STOP gate. The unknown frequency will pars through main gate until it is enabled.

The next pulse from time base selector passes through the enabled STOP gate and set the input terminal of F/F-2 changer the output back to 1, and Y=0 So the main gate is disabled, and disconnects the unknown frequency signal from the counter.

The counter counts the number of pulses occurring between two successive pulses. If the time interval between two successive pulses is 1 second, the number of pulses counted in this interval of unknown frequency source is in Hz.

4.5 Digital Tachometer :

Digital Tachometer is used to measure the speed of a rotating shaft. This is similar to the Principle of Digital frequency counter.



Basic block diagram of a digital tachometer

Let us take the rpm of rotating shaft is R. P is the number of pulses produced from one revolution of the shaft.

In one minute the number of pulses picked up is RXP. Frequency is RXP/60 (Number of Pulses/Second). T is the gate period means the pulse counted is (RXPXT)/60. The counter counts R pules. (ie)

$$\frac{RxPx60}{60xP} = R$$

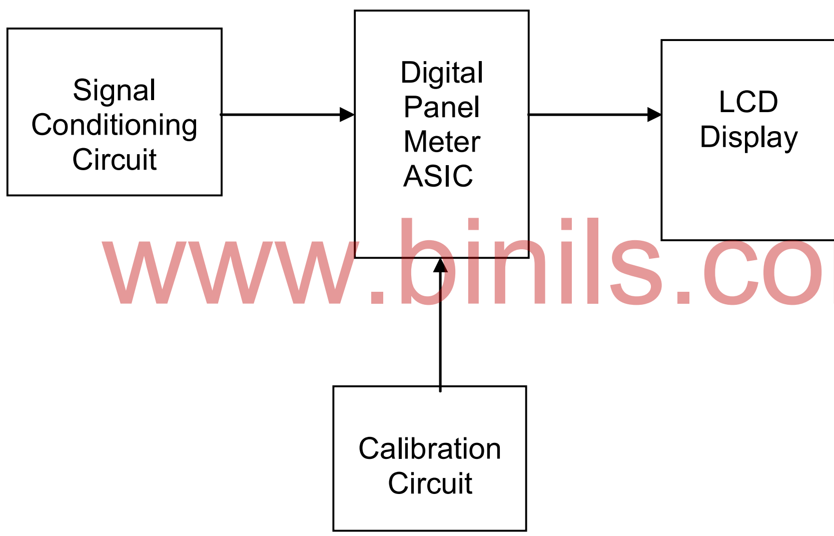
The rpm of the shaft is read directly. If we fix gate period T as one second (T=IS) The revolution pickup will produce 60 pulses per revolution.

4.6 Digital Panel Meters

Digital Panel Meters are mounted is Industrial Control Panel to measure Physical quantities like temperature, Pressure, Voltage, current power and speed. These meters take an electrical signal which is proportional to the measured physical quantity. The value will be displayed.

The digital panel meters are linear and more accurate. The They use LED or LCD display. An ASIC is nothing but Application Specific Integrated Circuit.

Block diagram



ASIC based digital panel meters

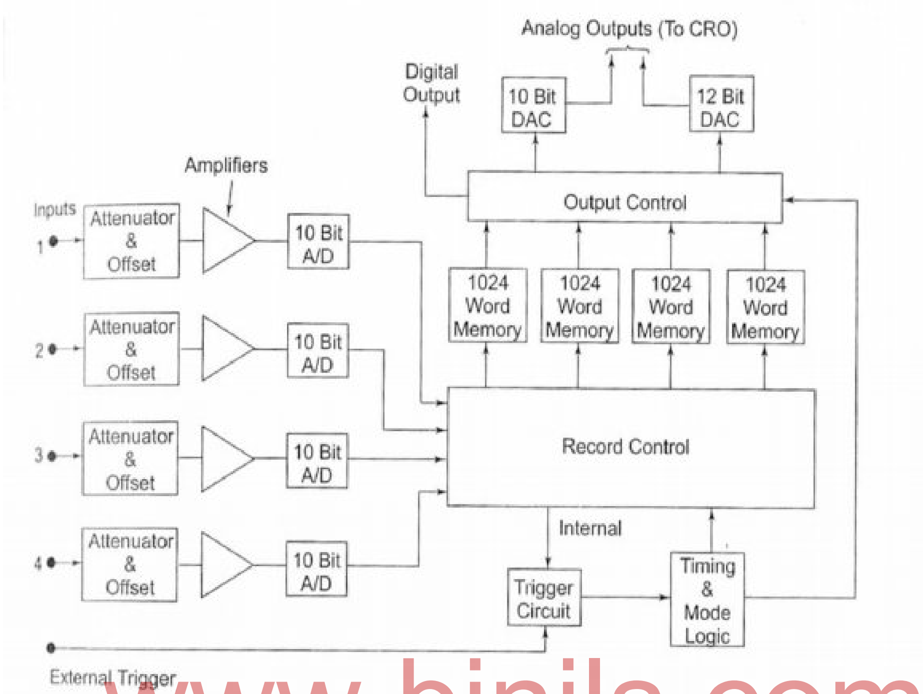
Application specific ICS and Application specific products for digital panel meters integrate the ADC' S and the display driver in a single device.

The Signal conditioning circuit varies based on the range and physical quantity.

4.7. Digital Storage O Oscilloscope (DSO)

Digital Storage Oscilloscope is an instrument which is used to measure the various types of signals and displays to the signal parameters in Digital format. This is available in two types 1) Processing 2) Non Processing .

The processing type has built in computing capability which given all data in digital format. The non processing digital scopes are used as storage and non storage types.



Digital Storage Oscilloscope.

The analog voltage input is digitized in a 10 bit A/D converter. The memory storage capacity is 4096 for single channel and 2048 for two channels, and 1024 for four channels.

The analog input voltage is sampled at variable rates and stored into the memory. After the sampled record is captured in memory we can do various manipulations in that. The digital memory can be read directly. Pre triggering recording allow the input signal before the trigger points to be recorded. The DSO records continuously, until the trigger signal is received. An adjustable trigger delay allows the Operator control of stop point. The trigger may occur near the beginning, middle or the end of stored information.

Advantages

1)Storage Capability is high
2) We can change the voltage and time scale display after the recording.
3) 0.25% resolution is possible with 0.1% accuracy.

4.8 Mixed Storage Oscilloscope (MSO):-

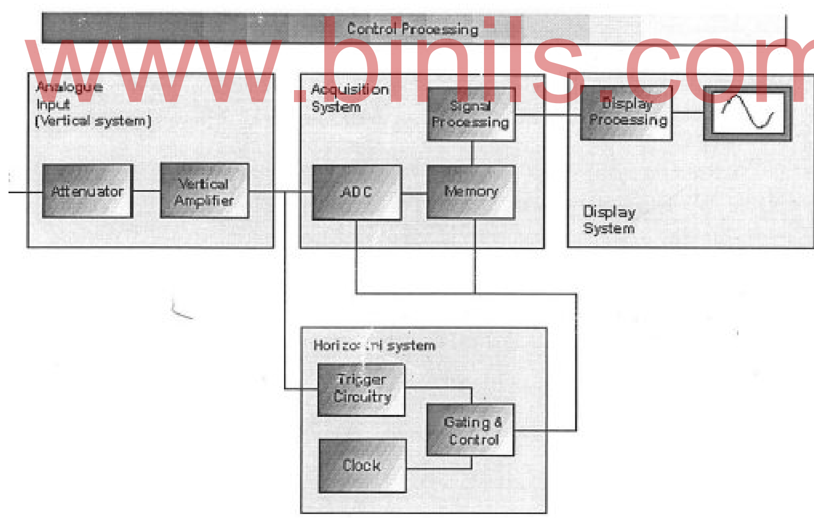
This has two kinds of inputs.

1) Small number of analog channels

2)Large number of digital channels

The measurements are acquired with a single time base and can be viewed on single display.

The mixed storage Oscilloscope works like a Digital Storage Oscilloscope with some measuring capabilities of a logic analyzer. They are used is analog to Digital converter, Digital to analog converter, Control Systems debugging.



The input to MSO is either analog or digital. The MSO has Horizontal System, vertical amplifier, acquisition system and display system with control processing.

Advantages:-

1) Digital or analog signals can be used
2) High flexibility
3) Easy read out.

REVIEW QUESTIONS

PART – A (2 Marks)

1) Write short notes on Digital Instrument
2) Write short notes on Digital Voltmeter
3) Mention the types of Digital Voltmeter
4) Write short notes on Digital Multimeter
5) What is auto ranging?
6) What is auto Zeroing?
7) What is auto polarity?
8) What is digital frequency meter?
9) Write short notes on digital Tachometer?
10) What is digital panel meter?
11) What is digital storage Oscilloscope?\
12) What is mixed storage Oscilloscope?

PART – B (3 Marks)

1) Compare analog & Digital Instruments
2) Mention the merits of digital Instruments
3) Draw the block diagram of digital frequency meter
4) What is digital Tachometer? Mention its advantages
5) Compare Digital Storage Oscilloscope with analog Oscilloscope
6) What is mixed storage Oscilloscope? Mention its advantages

PART – C (10 Marks)

1) Explain Integrated type Digital Voltmeter with neat diagram
2) Explain Ramp Type Digital Voltmeter with neat diagram
3) Explain successive approximation Digital Voltmeter with neat diagram
4) Explain Digital multi meter with a neat diagram
5) Explain Digital frequency meter with a neat back diagram
6) Explain Digital Tachometer with a neat diagram
7) Explain Digital Panel meter with a neat diagram
8) Explain Digital Storage Oscilloscope with a neat diagram
9) Explain Mixed Storage Oscilloscope with a neat diagram

UNIT - V

OP-AMP APPLICATIONS

5.1. INTRODUCTION

An operational amplifier (Op-Amp) is a special type of high gain amplifier which consists of one or more cascaded differential amplifier stages.In general IC 741 is used as an operational amplifier.

Characteristics of Op-Amp:

1.Infinite Voltage Gain

2.Infinite Input Resistance

3.Zero Output Resistance

4.Infinite bandwidth

5.Infinite Common Mode Rejection Ratio (CMRR)

6.Infinite Slew rate

Applications of Op-Amp:

1.Can be used as an Instrumentation Amplifier

2.Summing Amplifier

3.Differential Amplifier

4.Comparator

5.Integrator

6.Differentiator

A Signal generator produces a time dependent voltage or current wave form of prescribed characteristics such as frequency, amplitude, Shape and duty cycle. A voltage controlled oscillator (VCO) is a special signal generators whose frequency is externally controlled.

There are two categories of signal generators

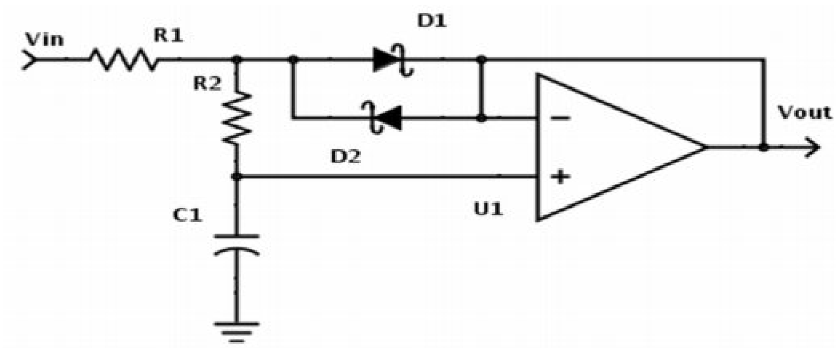
1. Tuned Oscillators
2. Relaxation Oscillator

Tuned Oscillator Produces Sinusoidal oscillations for this purpose either use is made of feedback amplifier using LC tuned circuit or RC phase shift network in the feedback loop.

Relaxation Oscillators employ bistable devices such as switches. Schmitt triggers, logic gates and flip flop to repeatedly charge and discharge a capacitor. Typically wave forms obtainable with this method are Ramp, Triangular, Square Saw tooth and pulses wave.

5.2 Ramp Type generators:

5.2.1 Ramp generator using op-amp

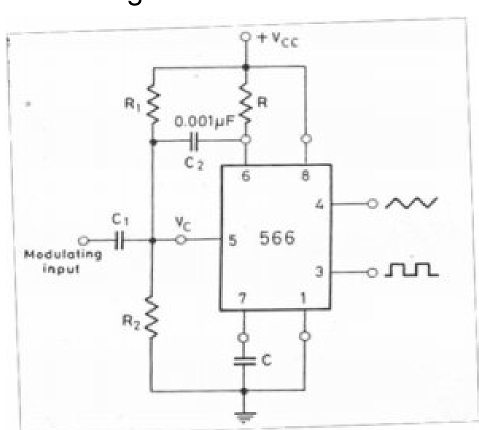


The op-amp is wired as a voltage follower, with D1 & D2 clamping the input to one diode drop above or below the output. When the input step-changes by a volt or more, the diodes will keep the voltage across R2 at a nearly constant 0.3V (because the output will follow any change on C), creating a constant slew rate at the output of 0.3V/R2C1 V/s. The output will slew to within 0.3V of the input and then follow an RC ((R1+R2)C1) curve until reaching a final value equal to Vin. For best results, R2 should be larger than R1, preferably by factor of ten or more. This simple circuit gives best results with fairly large steps, where the slow settling time won't be objectionable.

5.2.2 Ramp generator using VCO 566

There are two types of Ramp generators one is positive ramp and negative ramp using VCO 566.

Typical connection diagram for 566 device in this fig 5.1



External connection for 566 VCO

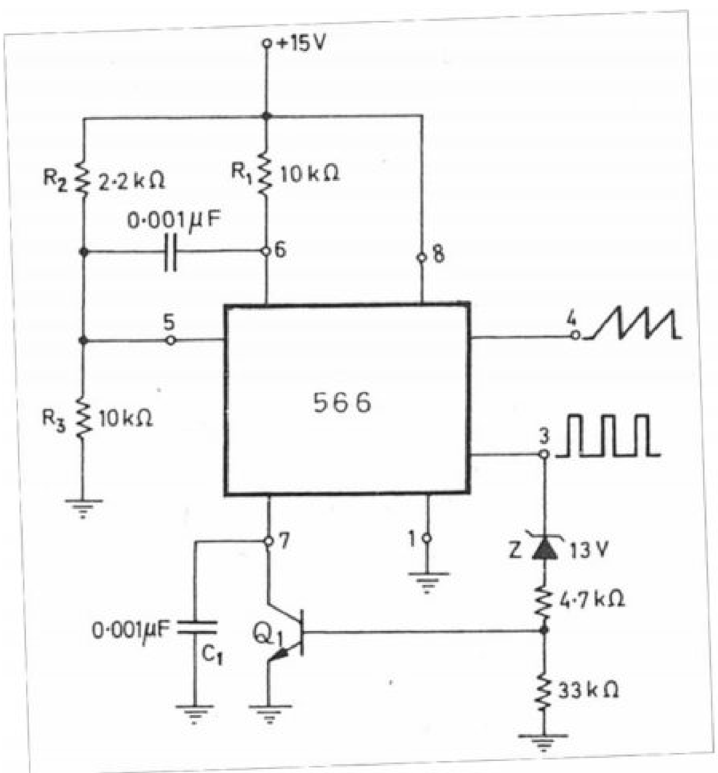
In this arrangement, the RC Combination determines the free running frequency and the control voltage Vc at terminal 5 is set by the voltage dinder R1, R2.

The modulating Signal is a c coupled with the capacitor C_1 and must be less than 3 V.

The f_0 can be varied over a 10:1 range as described above. The maximum output frequency is 1 MHz. A small capacitor, C2of 0.001 Micro farad is connected between pin 5 and pin 6 to eliminate possible oscillations in the control current source.

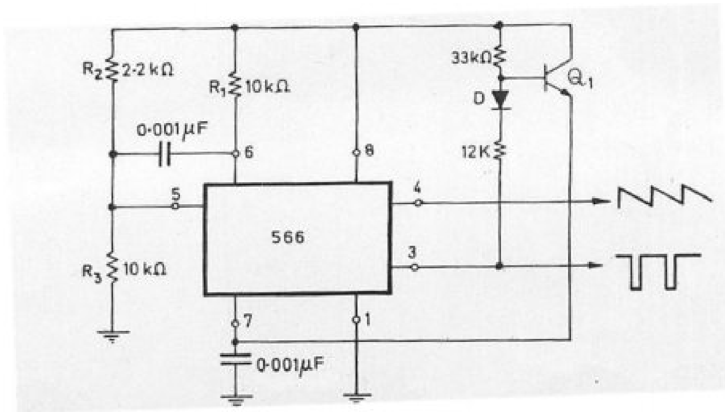
The amplitude of the output waveform is dependent upon supply voltage VCC. Which can be varied in the range of 10 to 24V. The square wave output is taken from pin 3 and ramp output pin 4.

Positive ramp generator.



Positive ramp generation using IC 566

Negative Ramp generation



Negative Ramp generation using IC 566

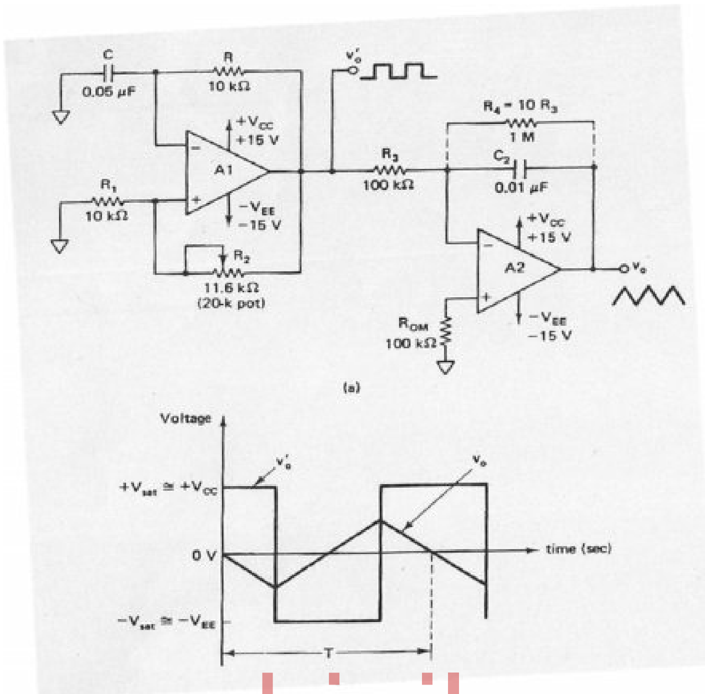
The 566 VCO can be conveniently used produce ramp output. This can be done by connecting external transistor. The transistor Fig 5.3 is used to discharge and charge rapidly the timing capacitor. This mechanism Transforms the triangular output available at pin 4 into a positive or negative going ramp. This circuit modification necessary for positive going ramp is shown in fig 5.2 Note that the square wave output at pin 3, 4 changed to a positive going pulse. A circuit which is modified to produce negative going ramp and negative going pulse is shown fig above.

5.3 Triangular wave generator:

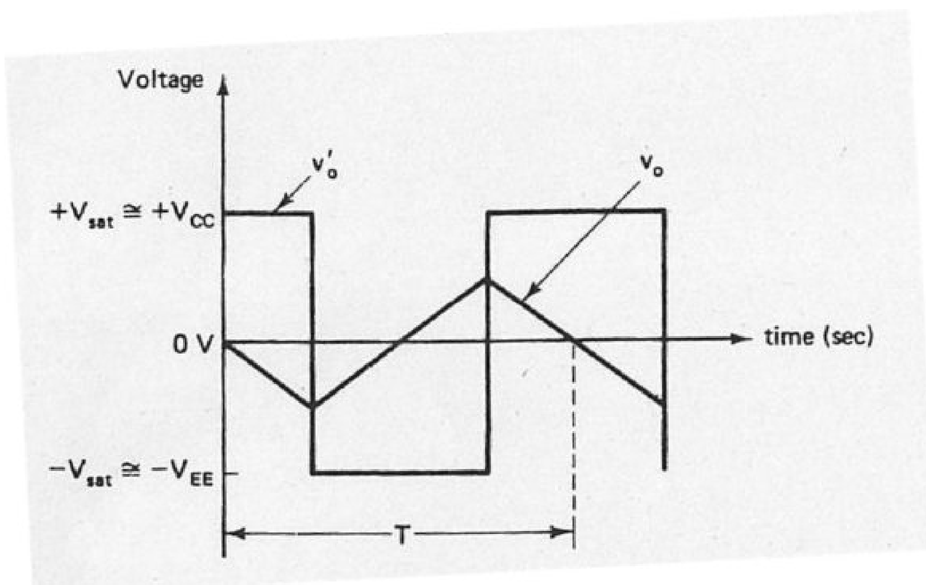
The output waveform of the integrator is triangular if its input is a square wave. This means that a triangular wave generator can be formed by simply connecting an integrator to the square wave generator of given fig.

This circuit requires of dual op-amp, two capacitors, and at least five resistors. The frequencies of the square wave and triangular wave are the same. For fixed R1, R2, and C values, the frequency of the square wave as well as triangular wave depends on the resistance R. The resistor R is increased or decreased, the frequency of the triangular wave will decrease or increase. respectively Although the amplitude of the square wave is constant ($\pm$V sat); the Amplitude of the triangular wave decrease with an increase in its frequency and vice versa.

The input of integrator A_2 is square wave, while its output is a triangular wave, However, for the ouput of A_2 to be triangular wave requires that 5 $R_3 C_2 > T/2$. Where T is the period of the square wave input. As a general Rule, R_3C_2 should be equal to T.



Triangular wave generator.



Output Wave form

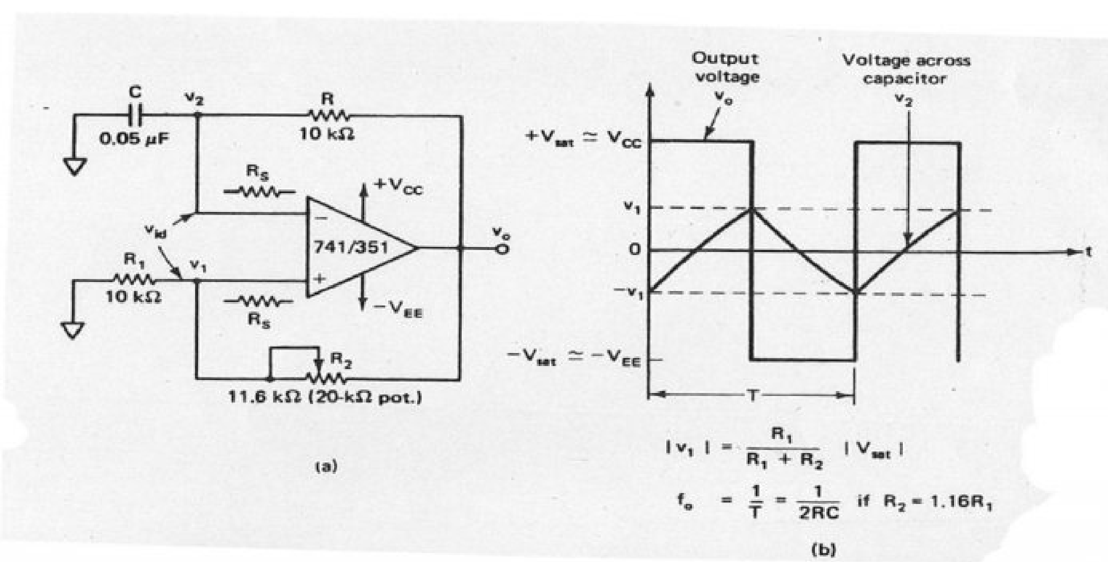
To obtain a stable triangular wave, it may also be necessary to shunt the capacitor C_2 with resistance R_4 and connect an offset voltage. Compensating network at the non inverting terminal of A_2. As with any other oscillator, the frequency of the triangular wave generator is limited by the slew rate of the op-amp. Therefore high-slow rate op-amp such as LM301 should be used for the generation of higher frequencies.

The frequency of oscillation can be given as

$$fo = \frac{1}{T} = \frac{R3}{4R_1C_1\,R_2}$$

5.4 Square wave generator:

In square wave outputs are generated when the op-amp is forced to operate in the saturated region. That is, the output of the op-amp is forced to swing respectively. between positive saturation + V sat (~+ V_{CC}) and negative saturation -Vsat (~V_{EE}). This square wave generator is also called a free running or astable multi vibrator.



Square wave generator **Output Wave form**

Assume that the voltage across capacitor C is zero volts at the instant the dc supply voltages $+V_{CC}$ and $-V_{EE}$ are applied. This means that the voltage at the inverting terminal is zero initially. At the same instant, however, the voltage V_1 at the non-inverting terminal is a very small finite value that is a function of the output offset voltage Vout and the value of R_1 and R_2 resistors. Thus the differential input voltage Vid is equal to the voltage V_1 at the non inverting terminal. Although very small, voltage V_l will start to drive the op-amp into saturation. Since initially the capacitor C acts a short circuit, the gain of the OP-amp is very large. Hence V_1 drives the output of the OP-amp to its positive saturation $+V_{sat}$. With the output voltage of the OP-Amp at $+V_{sat}$. The Capacitor C starts charging toward +Vsat through Resistor R.However the voltage V_2 across capacitor C is slightly more positive than V_1. the output of the OP-Amp is forced to switch to a negative saturation. -Vsat. with the OP-Amp's output voltage at negative saturation -Vsat. The voltage V_1 across R_1 is also negative. Since

$$V1 = \frac{R1}{R1 + R2} (-V_{sat})$$

Thus the net differential voltage Vid = V_1-V_2 is negative the output of the OP-Amp in negative saturation. The output remains in negative saturation until the capacitor C discharges and then recharges to a negative voltage slightly higher than $-V_1$. The capacitor's voltage V_2 becomes more negative than - V_1, the net differential voltage Vid becomes positive and hence drives the output of the OP-amp back to its positive saturation +Vsat. This complete one cycle with output at +Vsat, Voltage V_1 at the non-inverting input is

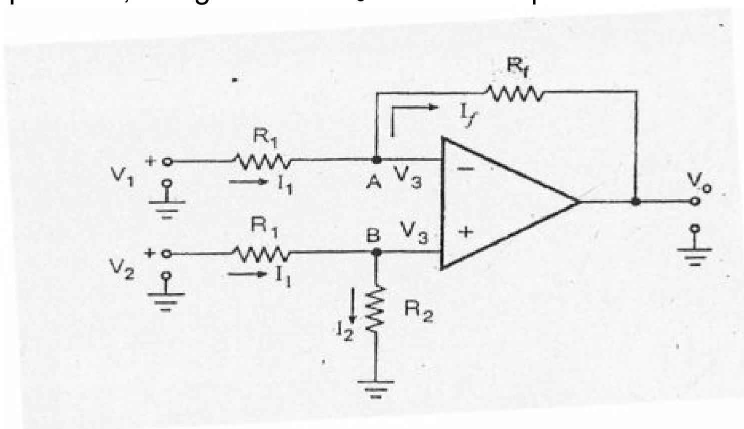
$$V1 = \frac{R1}{R1 + R2} (+ V_{sat})$$

The time period T of the output waveform is given by

$$T = 2 \text{ Rc ln} \left(\frac{2R1 + R2}{R2} \right)$$

5.5 Differential Amplifier:

The Subtraction of two input voltages is possible with the help of OP-Amp circuit called subtractor on difference amplifier circuit. This type of amplifier is very useful in instrumentation circuit. A typical circuit is shown in fig below. Since the differential voltage at the input terminals of the OP-Amp is zero. Mode A and B are at the same potential, designated as V_3 the nodal equation at A



Differential Amplifier

Node 'A' $\dfrac{V3 - V1}{R_1} + \dfrac{V3 - Vo}{R_2} = O \quad (1)$

Node 'B' $\dfrac{V3 - V2}{R_1} + \dfrac{V3}{R_2} = O \quad (2)$

Rearranging We get

$$\left[\frac{1}{R1} + \frac{1}{R2}\right] V3 - \frac{V2}{R1} - \frac{V0}{R2} = 0 \longrightarrow (3)$$

$$\left(\frac{1}{R1} + \frac{1}{R2}\right) V3 - \frac{V1}{R1} = O \longrightarrow (4)$$

Subtracting equation (4) and (3)

$$\frac{1}{R1}(V1 - V2) = \frac{VO}{R2}$$

$$VO = \frac{VO}{R2}(V1 - V2)$$

5.6 INSTUMENTATION AMPLIFIER:

The physical quantities are usually measured with the help of transducers. The output of transducer has to be amplified so that it can drive the indicator (or) display system. This function is performed by an instrumentation amplifier.

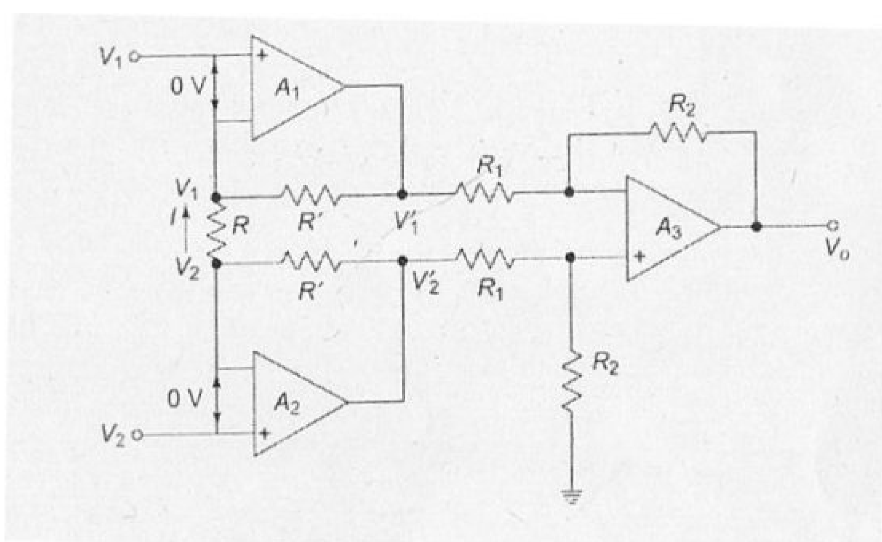
The instrumentation Amplifier is also called data amplifier and is basically a difference amplifier. The expression for its voltage gain is generally in the form.

$$AV = \frac{VO}{V2 - V1}$$

VO → output of the amplifier

V2 - V1 → Differential input which is to be amplified

The circuit diagram of instrumentation amplifier is shown in fig



Instrumentation Amplifier

The OP-amps A1 and A2 as shown in fig are voltage follower (or) buffer circuit acting as the input stage for each of the inputs V1 and V2. They have zero differential input voltage, Vid = O under such condition with common mode signal is zero and V1 = V2 the voltage across R is Zero.

The voltages at the inverting terminals of the buffers are equal to the input voltages. Since no current flows through the R and R^1 resistors, the output voltages are $V2^- = V2$ and $V1^- = V1$ respectively.

If V1 ≠ V2 them a current flows through the resistor R and R^-, and $(V2^- - V1^-) > (V2 - V1)$. Therefore the circuit will have more differential gain and CMRR.

The current flowing in the resistor

R is $I = \frac{(V1 - V2)}{R}$

Also Same current I will flow through the resistor R^-

The Voltage at the non inverting terminal of OP-Amp A3 is $\frac{R2V1^-}{R1 + R2}$

By using Super Position theorem, we get

$$VO = \frac{R_2}{R_1} V2^- + \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R2V1^-}{R_1 + R_2}\right)$$

Simplifying we get

$$VO = \frac{R2}{R1}(V1^- - V2^-) \rightarrow (1)$$

Since There is no current entering the OP-Amp, the current $I = \frac{(V1-V2)}{R}$,

Which flows through the Resistor R^-

$$V1^- = R^- I + V1 = \frac{R-}{R}(V1-V2) + V1$$

and

$$V2^- = R^-I + V2 = \frac{-R^-}{R}(V1-V2) + V2$$

Substituting the values of $V1^-$ and $V2^-$ in equ 1, Vo is given by

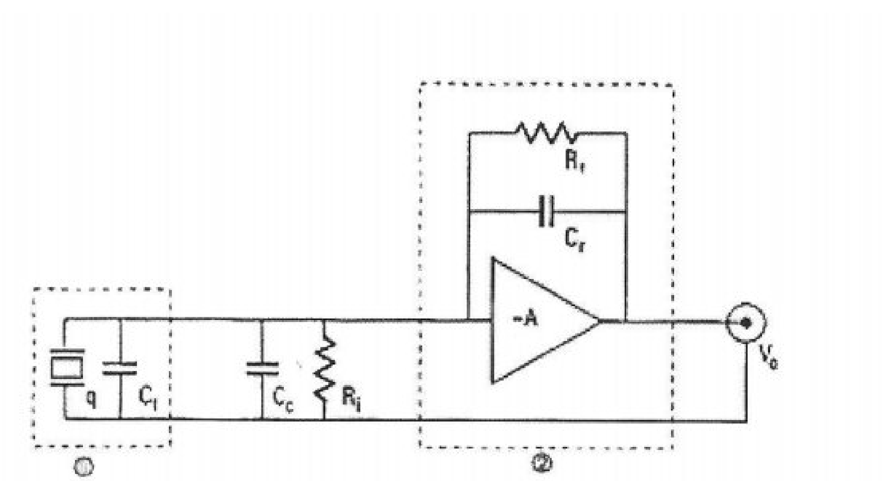
$$Vo = \frac{R2}{R1}\left(\frac{2R^-}{R1}(V2 - V1) + (V2 - V1)\right)$$

$$Vo = \frac{R2}{R1}\left(1+\frac{2R^-}{R}\right)(V2 - V1)$$

Features of Instrumentation Amplifier

5 High gain accuracy
6 High CMRR
7 High gain stability with low temperature co-efficient
8 low dc offset
9 low output impedance

4.8. Charge amp with Zero Electric Crystal

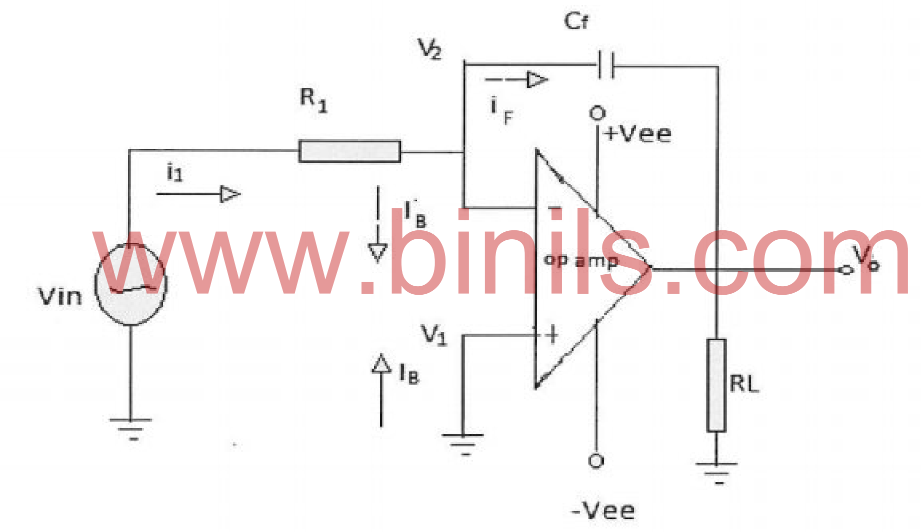


Charging amplifier with Crystal

The charge amplifier are usually constructed using an OP-Amp or other high gain semi conductor circuit with a negative feedback capacitor. The input current is offset by a negative feedback current flowing in the capacitor. Which is generated by an increase in output voltage of the Amplifier. The output voltage is dependent on the value of input current, it has to offset and the inverse of the value of the feedback capacitor. The greater the capacitor value, the less output voltage has to be generated to a particular feedback current flow.

The input impedance of the circuit is almost zero because of the miller effect hence all the stray capacitance are virtually grounded and they have no influence on the output signal.

Ideal Circuit

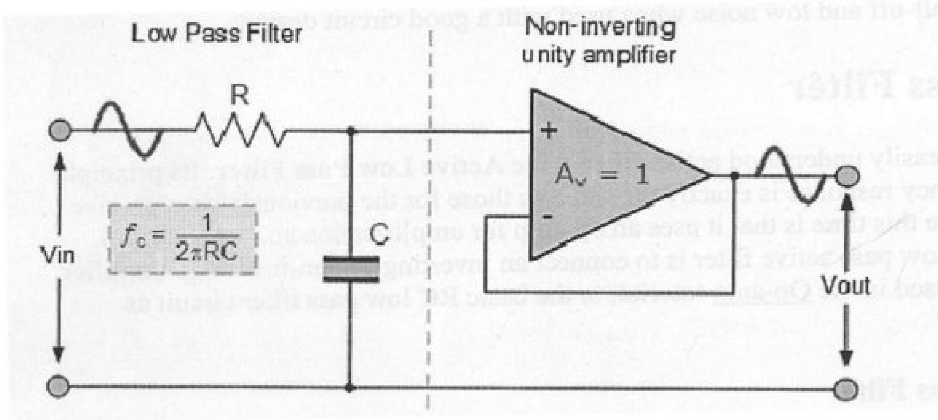


Ideal Circuit for analyzing charge Amplifier

4.9. Low Pass and High pass filter using OP-Amp:

The filter used in a PLL, may be either passive type (or) active type. Such as the Low pass Filter and high pass filters can be made using just a single resistor in series with a non polarized capacitor connected across a sinusoidal input signal.

Active Low pass filter



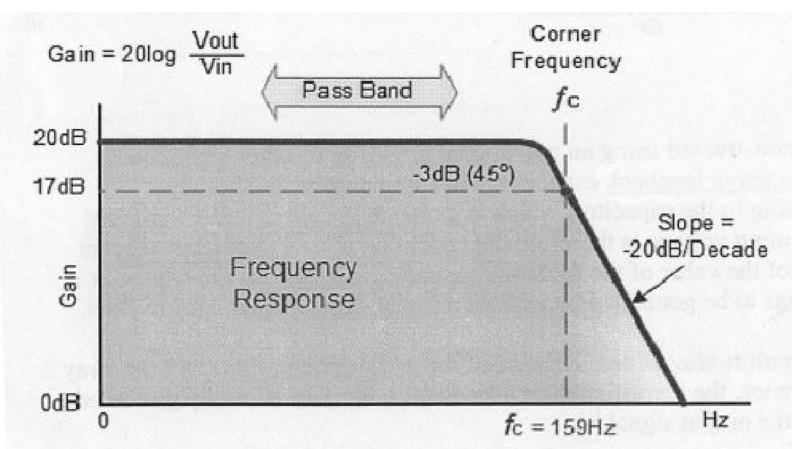
Active low Pass filter

The low pass filter not only removes the high frequency components and noise, but also control the dynamic characteristics of the PLL. These characteristics include capture and lock range, bandwidth and transient response. In filter bandwidth is reduced, the response time increases.

The main disadvantage of passive filters is that the amplitude of the output signal is less than that of the input signal. The gain is never greater than unity and that the load impedance affects the filter characteristics.

In Active filters contain active components such as OP-Amp, transistors (or) FET's within their circuit design. They their power from an external power source and use it to boost or amplify the output signal.

Frequency Response Curve



Frequency response curve.

The frequency response curve drawn between gain verses frequency. The cut of corner frequency calculated by the formula using.

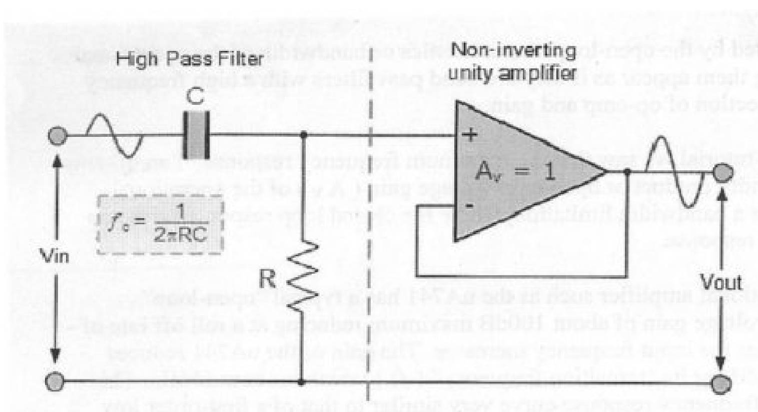
$$fc = \frac{1}{2\pi CR_2} Hz$$

While this configuration provides good stability to the filter, its main disadvantage is that it has no voltage gain above one. However the voltage gain is unity, the power gain is very high as its output impedance is much lower than its input impedance.

4.10. High pass filter

The basic operation of an active high pass filter (HPF) is the same as for its equivalent RC passive high pass filter design providing amplification and gain control.

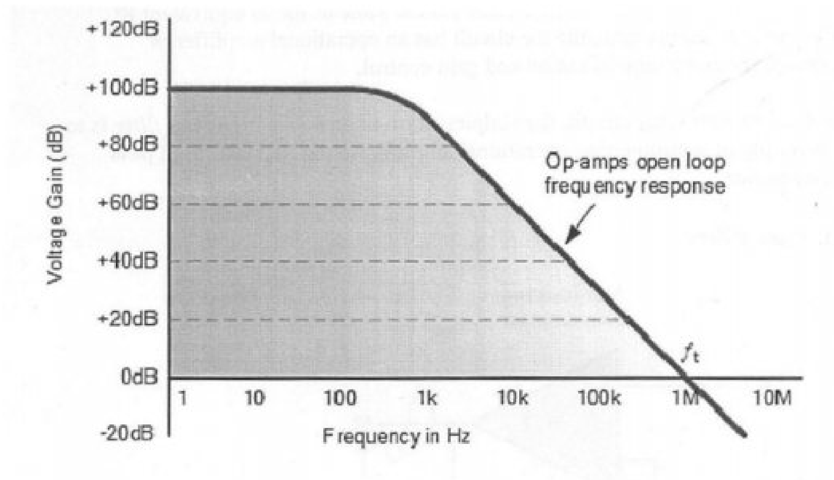
The previous active low pass filter circuit the simplest form of an active high pass filter is to connect a standard inverting (or) non inverting OP-Amp to the basic RC high passive filter circuit as shown.



Active high pass filter

The passive high pass filter is infinite frequency response, the maximum pass band frequency response of an active high pass filter is limited by the open-loop characteristics.

Frequency response curve for high pass filter :

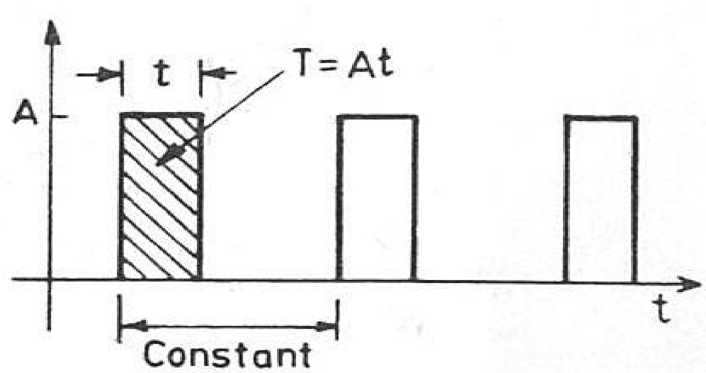


Frequency in HZ

This curve between gain verses frequency then the performance of high pass filer at high frequencies is limited by this unity gain crossover frequency which determines the overall Bandwidth of the open loop amplifier.

The OP-Amp based active filters can achiever very good accuracy and performance provided that low tolerance resistors and capacitors are used.

5.7 Pulse Height/Width Modulation:



Pulse height / width modulation

In the pulse width modulation / pulse amplitude modulation (PWM/PAM) multiplier, the pulse width of a repetitive train of pulse is made to be proportional to one input voltage and the pulse amplitude is mode to be proportional to the other input voltage.

‡ $V_x = K_x A$

$V_y = K_y t$

$V_z = K_z T$

Where Kx, Ky and Kz are scale factors

A = height (amplitude) of pulse

t = pulse width pulse

T = are of the pulse

‡ Vz is given by

$$V_z = K_z T = K_z At$$

$$= \frac{K_z}{K_x K_y} V_x V_y$$

To obtain the above result, the pulses are passed through an integrating circuit (or low pass filter). The output Vz will be proportional o the pulse area i.e, proportional to the product of two input voltages.

This method provided high Accuracy, and low switching speed.

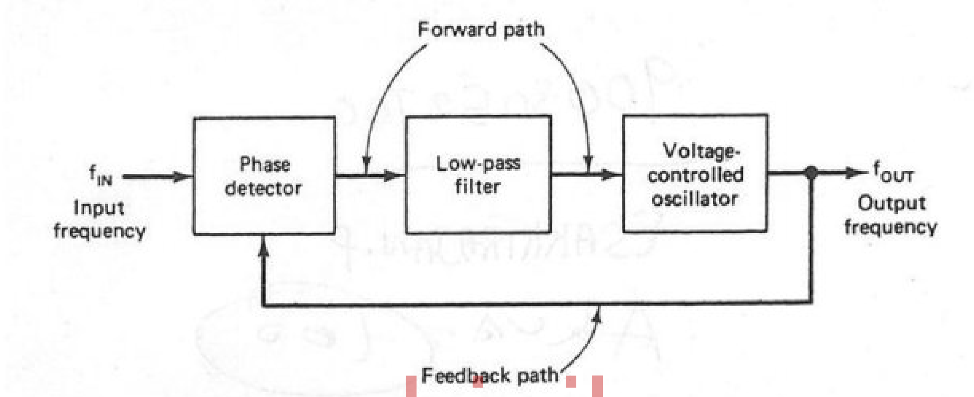
5.8 PLL [PHASE LOCKED LOOP]

The phase locked loop (PLL) is an important building block of linear systems. It is basically a closed loop system. PLL was first introduced in its discrete form in early 1930: when it was used for radar synchronization and communication Applications.

PLL is designed to lock the ouput frequency and phase of the input signal PLLs are available as inexpensive monolithic IC.

Basic principles of PLL:

The PLL is a circuit which causes a particular system to track with another one. That means, PLL synchronizes on output signal with an input signal in frequency as well as phase.



Block diagram of a Phase locked loop

The phase locked loop (PLL) in its basic form. As illustrated in this figure, the phase locked loop consists of (1) a phase detector, (2) a low pass filter and (3) a voltage controlled oscillator.

The phase detector, (or) comparator compares, the input frequency f_{IN} with the feedback frequency f_{OUT}. The output voltage of a phase detector is a dc voltage and therefore is often referred to as the error voltage. The output of the phase detector is then applied to the low pass filter, with removes the high frequency noise and produces a de level. This dc level, in turn, is the input to the voltage controlled oscillator (VCO). The filer also helps in establishing the dynamic characteristics of the PLL circuit. The output frequency of the VCO circuit is directly proportional to the input dc level. The VCO frequency is compared with the input frequencies and adjusted until it is equal to the input frequencies.

The phase locked loop goes through three states:

5.8.1 Free Running

5.8.2 Capture and

5.8.3 Phase lock (or) pull-in-time

Before the input is applied, the phase locked loop is in the free running state. once the input frequency is applied, the VCO frequency starts to change and the phase locked loop is said to be in the capture mode. The VCO frequency continues to change until it equals the input frequency and the phase locked loop is then in the phase locked state. When phase locked, the loop tracks any charge in the input frequency through its repetitive action

Applications:

1. FM frequency modulationStereo decoders
2. Motor speed control
3. Tracking filters.
4. Frequency synthesized transmitters and receivers
5. FM demodulators
6. Frequency shift key (FSK) decoders
7. Generation of local oscillator frequencies in TV and in FM tuners.
8. Used to generate ramp waveforms.

REVIEW QUESTIONS

PART – A (2 Marks)

1. Draw triangular waveform.
2. Draw square waveform.
3. What is operational amplifiers.
4. What is instrumentation amplifier.
5. Draw the diagram for low pass filter using OP-Amp.
6. Draw the diagram for High pass Filter using OP-Amp.
7. What is PLL?
8. What is capture range?
9. What is lock range?

PART – B (3 Marks)

1. Explain operational amplifier.
2. Explain Instrumentation amplifier and mention its advantages.
3. Compare low pass filter using OP-Amp with high pass filter.
4. Explain PLL?
5. Compare lock range with capture range.
6. Mention some applications of PLL.

PART – C (10 Marks)

1. Explain ramp generator with a neat diagram.
2. Explain saw tooth generation with a neat diagram.
3. Explain triangular generator with a neat diagram.
4. Explain instrumentation amplifier with a neat diagram.
5. Explain low pass filter with OP-Amp with a neat diagram.
6. Explain high pass filter with OP-Amp with a neat diagram.
7. Explain PLL with a neat diagram.