# UNIT – I

# Block Schematics of Measuring Systems

## and

# Measuring Instruments

# EM I    I-unit

→ The first scientific instruments from science is telescope, microscope, spectroscope.

→ The role of science is to discover the laws of nature and how ~~many~~ they operate in complex s/m's.

→ The role of Engineering is to apply the discoveries of Science to human needs.

- Scientists make discoveries that increase our understanding of world.

→ Engineers make inventions intended to increare our produtivity or ability to Survive.

→ Instrumentation is branch of engineering that serves not only science but also all branches of engineering & medcine.

→ The measurement of dimentions like temp, preasure, Voltage, Energ

current, impedence are important for science & Engineering.

→ Instrumentation is a collective term for measuring instruments ② used for indicating, measuring and recovering physical quantities.

→ ① Instrumentation is developement (or) use of measuring instruments for observation, monitering or control.

→ An instrument is a device that measures a physical quantity, flow, temp, distance, preasure.

→ Eg: Thermostat → which sences the temp of a s/m

↳ it is control unit for heating or controlling s/m. through setting the target temp.

→ Electronic measurements are → Amplifier
voltmeter
Ammeter
CRO
Sensor
Temp Controller.

→ measuring instrents are two types → Analog → .
Digital.

Energy meter is electrical measuring instrument → generates eletric bill → coil, disk rotate → numbers.

→ electronic measurements → chips → accuracy, portable.

→ pmmc is electrical instrument.

→ This subject dealing with measuring instruments.

① monitoring of process & operations

② Control of process and operations.

③ Experimental Engineering Analysis.

↳ ① Some measuring instruments have only monitering function

↳ for eg: Thermometer & Barometer. → They simply indicate the condition of environment & cannot control any function

↳ ② Home - Heating s/m using a thermostat control.

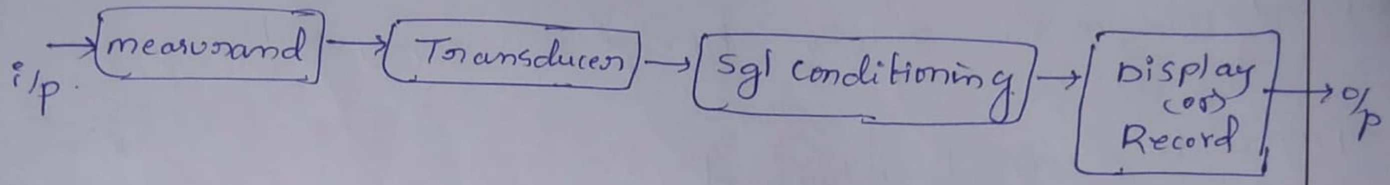
↳ ③ In research and developement work.

mechanical Instruments

Electrical Instruments

Electronic Instruments.

## → Basic block diagram of measuring s/m



① **measurand** : The quantity to measured is called measurand

② **Transducer** : A device that converts a physical quantity in to an electrical quantity.

③ **sgl conditioning** : Amplification , Filtering modulation , Demodulation A/D conversion.

④ **Display /Record** : The quantity is recorded using x-y strip chart.

# Block Schematic of Telemetry S/m

→ Telemetry is an automated Commⁿ process, by which the measurements and other data are collected at remote or at in accessable points and transmitted to receiving equipment for monitoring.

→ It is also called wireless data transfer mechanism using, radio, Infrared.

→ It consist a sensor, Txⁿ path, & display, recording, or control device

→ A Telemeter is a device used to remotely measure any quantity.

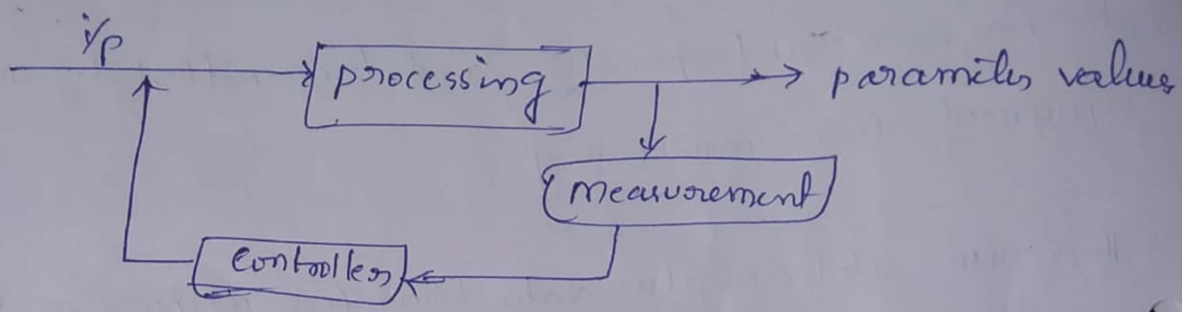
Telemeter is physical device in used in tele metry

**Applications:-**

1. meteorology
2. oil and gas industry for drilling.
3. motor Racing
4. Transportation
5. Space
6. Ships
7. Defense
8. Millitary
9. Flight testing
10. Health care

## Block schematic of control Instrumentation.

↳ Here we have a feedback loop b/w i/p & o/p to control the parameter to be measured.

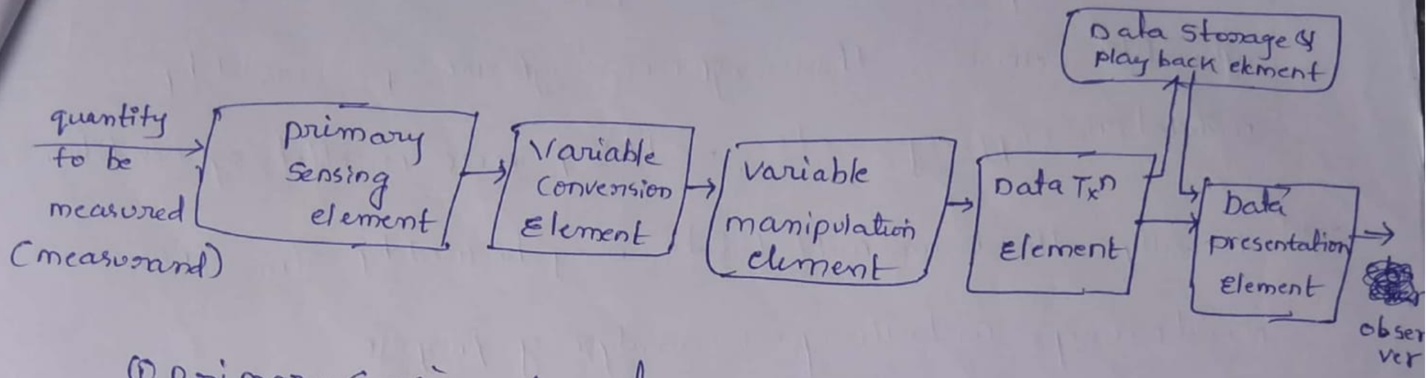


## Data process s/m :

→ In this digital control techniques are employed using µp and µc on a pc.

→ The analog sgl is converted to digital sgl by ADC and is processed by µp or µc on pc.

# Functional Elements of an Instrument



① primary Sensing element

② Data conditioning element

③ Data presentation element.

①.

→ In most of cases, a transducer follows primary sensing element which converts measurand into corresponding electrical sgl.

* In general, a transducer converts a physical quantity from one ~~for~~ form to other, but in case of Electrical & Electronic measurements, it converts physical quantity to be measured into an analog electrical sgl.

* analog to digital → variable conversion → if s/m requires digital dat

V.M.E

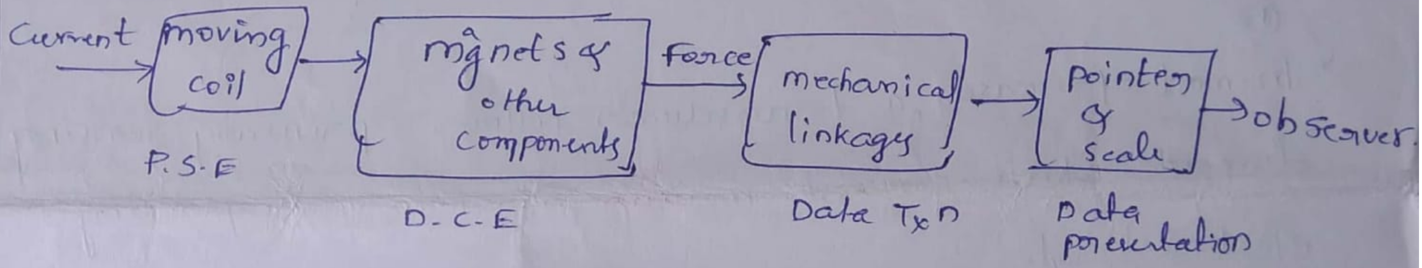
* The o/p from previous stage may not enough to drive the next stage so V.M.E manipulates the sgl, preserving the original nature of sgl.

For eg= amplifier. → amplify the sgl.
attenuator → to lower the sgl.

→ Sometimes o/p of transducer may get effected due to unwanted sgls like noise, . these ~~sgl~~ noise sgls are processed by modulation, clipping --etc. → this process is called sgl conditioning

→ Finally the transmitted data may be used by s/m, for monitoring, controlling or analyzing purpose

For eg: Block schematic of an ammeter.



→ Selecting the proper instrument for a particular type of measurand needs the knowledge of performance chara's. of an Instrument.

Performance char'cs :

③ The instrument design , testing , and evaluation are performed based on their parameters.

② ↳ The performance char'cs are devided in to two ~~to~~ categories.

i) Static char's

ii) Dynamic char'cs.

* The set of criteria defined for the instruments which are used to measure the quantities which are slowly varying with time or mostly constant, means do not vary with time is called static char'cs.

① Performance chara'c of an Instrument are important for selecting the most suitable instrument for specific measuring jobs.

* A static char'cs of an Instruments ~~which~~ are ~~used~~ ~~to measure~~ in general , considered for instruments which are used to measure an unvarying process condition.

Calibration : is a process of making an adjustment or making a scale so that the reading of an instrument agree with the accepte and certified standard.

→ Is the procedure for determinging the correct value of measurand by comparision with the measured or standard ones.

* when the quantity under measurement changes rapidly with time then we need to know dynamic relation b/w i/p & o/p. These relations are expressed with differential equations.

* The set of criteria defined based on such dynamic differential eqn is call Dynamic char'cs.

**Static char'cs:**

→ The various static char'cs are accuracy, precision, resolution, error, sensitivity, threshold, reproducibility, zero drift Repeatability, stability, linearity. -- etc.

**Instrument:** A device or mechanism used to determine the present value of quantity under measurement.

**Measurement:** The process of determinig, amount, degree, or capacity by comparision (direct or indirect) with accepted standards of s/m units being used.

**Accuracy:** The degree of closeness of a measurement compared to the expected (desired) value.

→ closeness of a measurement to the true value.

→ Indicates max error, which will not be exceeded, as assured by the manufacturer of instrument.

→ if Accuracy of a 100V voltmeter is ±1%. Then the max error for any reading will not exceed ±1V.

**Precision:** means sharply or clearly defined., it is measure of order of degree to which a particular parameter is measured.

↳ Digital Instruments are more precise than analog Instruments.

**Error:** The difference b/w measured value & the true value is called Error.

(or) Deviation of true value from desired value.

**Resolution:** It is the smallest change in the measured value to which the instrument can respond.

For eg: 100 V voltmeter may not be able to measure 100mV, only when min i/p is 0.5V.

↳ the smallest measurable i/p change.

**Sensitivity:** Capacity of instrument to respond truly to the change in the o/p.

(or) Ratio of magnitude response of o/p sgl to magnitude response of i/p sgl.

↳ Smallest change in measured variable to which the instrument responds $\frac{\Delta e_o}{\Delta e_i}$

**Repeatability:** It is defined as variation of scale reading when i/p is randomly applied, with time gaps.

**Reproducibility:** Degree of closeness with which, a given quantity may repeatedly measured.

↳ Scale of reading over a given period of time when the i/p is constantly applied.

eg: For a given voltmeter if 10V is applied as i/p and i/p is continously connected to instrument then the o/p reading of voltmeter must be 10 V. if it fluctuates, reading changes, then Reproducibility is poor.

→ 3 most common variations in the measured quantity are

① Step change.. In which the primary element is subjected to an instantaneous and finite change in measured variable.

Gross E
Sy. E
R. E

②. Linear change: In which the primary element is following a measured variable, changing linearly with time

③ Sinusoidal change: In which the primary element follows a measured variable, the magnitude of which changes in accordance with a sinusoidal function of constant amplitude.

## Dynamic characteristics .

**Fidelity** . It is quality of indication by the instrument with regard to changes in i/p .

**Speed of response** : It is rapidly with which an instrument responds to changes in the measured quantity

**Dynamic Error** :

↳ Error in the reading is diff b/w true value & measured value.

**Lag** : Speed of response. of instrument.

**Dead zone** : The max value of i/p to which the instrument does not respond.

**Threshold** : It is min value to which the instrument responds to when the i/p is gradually increased from zero value.

R→ smallest unit of measurement that can be indicated by an instrument

S→ " amount of difference in quantity that will change an instruments reading.

**Error:** difference b/w the indicated value and true value.

Ste

$e = A_t - A_m$ $A_t$ → measured value of quantity

└ Absolute error. $A_m$ → true value of quantity.

↳ The error 'e' also called <u>absolute error</u>. the absolute error does not indicate precisely the accuracy of measurements.

For eg: absolute error of ±1 V is negligible when voltage ~~range~~ to be measured is 1000V, but same error ±1 V becomes significant when the voltage under measurement is 5V

→ Then we consider relative error instead of absolute error.

↳ $e_r$ (Relative error) $= \frac{\text{Absolute error}}{\text{True value}} = \frac{\text{True value} - \text{Measured value}}{\text{True value}}$

$$= \frac{A_t - A_m}{A_t}$$

% of relative error is $\% e_r = \frac{A_t - A_m}{A_t} \times 100$.

↳ Accuracy is given by $\Rightarrow A = 1 - e_r$

↳ Relative accuracy.

$$A = 1 - \left| \frac{A_t - A_m}{A_t} \right|$$

% accuracy $\Rightarrow a = A \times 100\%$.

↳ The error can also be expressed as % of full scale reading

Error as a % of full scale reading $= \frac{A_t - A_m}{f.sd} \times 100$.

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**Stability:** The ability of an instrument to retain its performance throughout its specified operating life and storage life.

**Tollerance** The max allowable error in the measurement is specified interms of some value which is called tollerance

↳ Tolerance indicates the max allowable deviation of a manufactured component from a specified value.

**Range or span**

The min & max values of a quantity for which an instrument is designed to measure is called its range or span.

**Bias** The constant error which exists over the full range of measurement of an instrument is called bias. such a bias can completely eliminated by calibration

## Dynamic char'cs

↳ when instrument is subjected to rapidly varying i/ps, the relation b/w i/p & o/p becomes totally different than static or constant i/p. As the i/p varies from instant to instant ~~to~~ the o/p also varies from instant to instant. The behaviour of s/m under such conditions is called dynamic response.

→ The dynamic behaviour of measuring s/m is determined by applying some known & predetermined variations of i/p to sensing element.

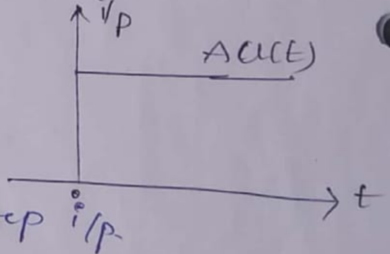
→ The dynamic behaviour of measuring s/m is expressed by differential eq^ns.

**Step i/p:** This represents sudden instantaneous and finite change in i/p

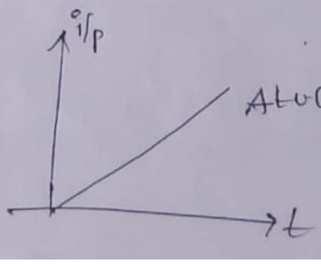
↳ The step i/p of magnitude A is denoted as $A\,u(t)$ its Laplace transform is

$$F(s) = \frac{A}{s}$$

when $A = 1$, it is called unit step i/p.



**Ramp i/p** This represents linear change in i/p. , the i/p is varies linearly with time. it changes at a constant rate with respect to time.



→ The ramp i/p of magnitude A is denoted as $A t u(t)$

↳ The Laplace Transform of ramp is

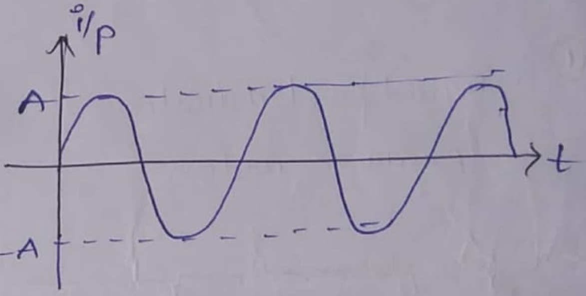
$F(s) = \frac{A}{s^2}$ , when $A=1$ , it is called unit ramp i/p.

Sinusoidal i/p: This represents an i/p which changes in accordance with sinusoidal function of constant amplitude. and freq is independent variable

↳ The sinusoidal i/p is $A\sin\omega t$, where 'A' is amplitude

↳ its laplace transform is

$F(s) = \frac{A\omega}{s^2+\omega^2}$



Lag: The delay in the response of s/m is called Lag.

① Retardation Lag: In this the response of s/m begins immediately after a change in the variable has occured.

② Time delay: In this, response begins after some time called dead time, after the application of i/p

## Instrument classification:

① Active/passive instruments
② Null/deflection type instrumentation.
③ Monitoring/control instruments
④ Analog/digital instruments.
⑤ Absolute/secondary instruments.

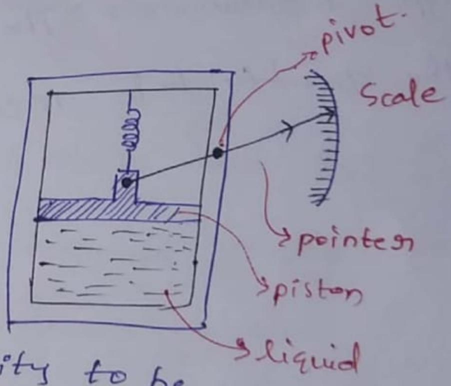
### ① Active/passive

↳ The instruments in which the o/p is produced entirely by the quantity being measured are called passive instruments.

eg: is preasure gauge.

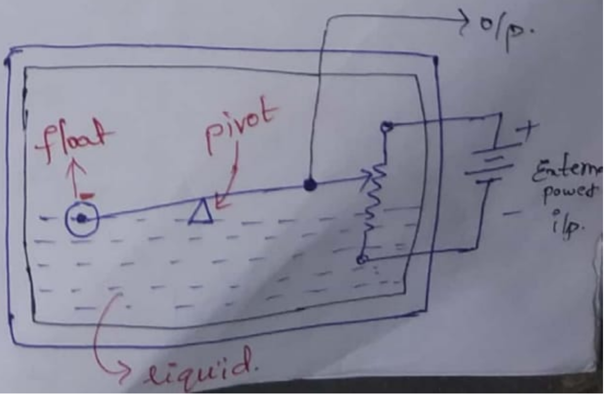
No other i/p energy source other than liquid preasure is used in this instrument.

↳ The resolution is less



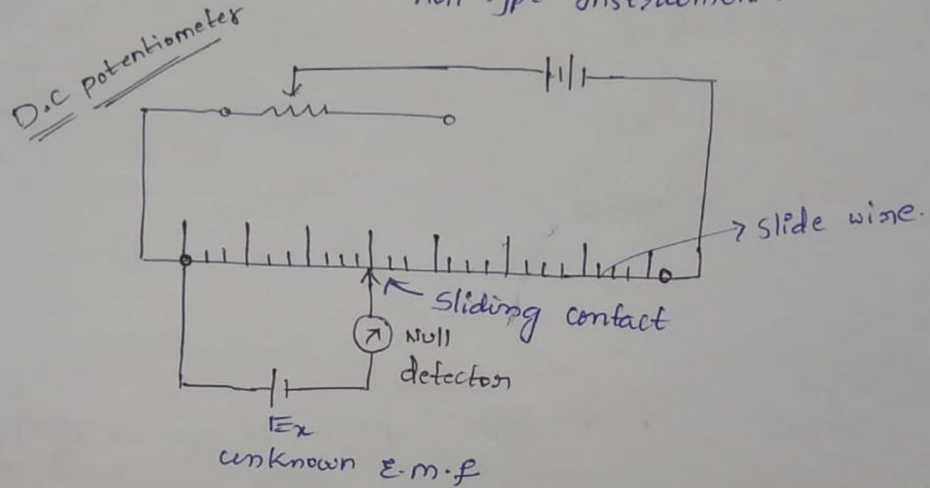
↳ The instrument in which the quantity to be measured just activates the magnitude of some external power i/p source which in turn produces the measurement are called active instruments.

eg: liquid level indicator

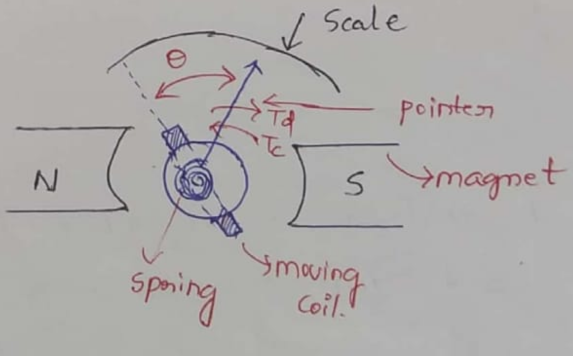


## ② Null / Deflection Type instruments:

↳ The Instruments in which a zero or null indication leads to the determination of the magnitude of the measured quantity are called null type Instruments.



↳ The instruments in which the quantity to be measured produces some effect due to which pointer deflects, are called deflection type instruments. The pointer deflection is proportional to the quantity to be measured.



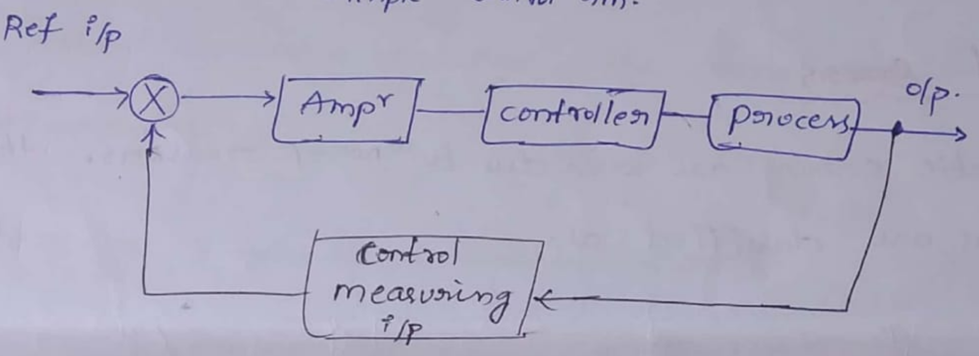
PMMC Ammeter.

## Monitoring /Control Instruments

↳ The instruments which are used to monitor the process, indicating the value or ~~po~~ condition of parameter under study are called the monitoring instruments. Such instruments. give as audio or visual indication of magnitude of quantity to be measured.

↳ The instruments which are used in automatic control S/ms are called controll instruments.

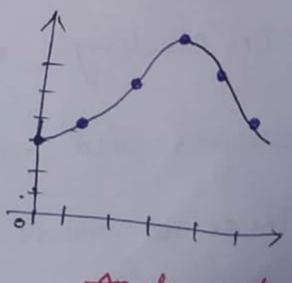
Simple Control S/m.



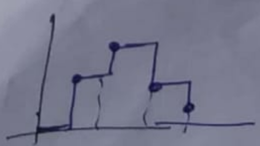
## Analog/Digital Instruments:

↳ The instrument which gives the o/p which varies in continous fashion as the quantity being measured changes, taking infinite no. of values in any given range is called "Analog Instrument"

↳ The instrument which gives the o/p which varies in descrete steps and thus take only finite different values in the given range is called Digital Instruments



Analog sgl.



## Absolute/secondary Instruments.

↳ The Instruments which gives the magnitude of quantity to be measured in terms of physical constants of the instrument, is called an absolute instrument.

↳ The instrument in which the reading shown by the instrument gives directly the measurement of the quantity to be measured is called secondary instrument.

## Types of Errors

↳ The static errors are arise due to no. of reasons. the static errors are classified as.

① Gross errors
② Systematic Errors
③ Random Errors.

### ① Gross Errors:

↳ These errors mainly occur due to carelessness or lack of experience of a human being, these are human mistakes in readings, recordings and calculating results. . These errors also occur due to incorrect adjustments of instruments

↳ These errors also called personal errors.

↳ The complete elimination of gross errors is not posible.

↳ But we can minimize them by

① Taking care while taking the reading.

② without depending on only one reading, Atleast 3 or more readings must be taken.

② ~~S~~ <u>Systematic errors:</u>

↳ These errors are mainly resulting due to the short comings of the instrument and the char'c of the material used.

↳ A constant uniform deviation of the operation of an instrument is known as Systematic error.

↳ There are 3 types of Systematic errors.

① Instrumental errors
② Environmental errors
③ observational errors.

① <u>Instrumental</u>: These errors b'coz of 3 reasons.

ⓐ <u>Short comings of instruments</u> → b'coz of mechanical structure of instruments eg: friction in bearings of various moving parts.

ⓑ <u>misuse of instruments</u>

ⓒ Loading effect.

② <u>Environmental</u>: due to conditions of external parameters.

↳ The various factors resulting these errors are temp changes pressure changes, thermal E.m.f, Stray capacitance

↳ we can reduce these errors using.

ⓐ using proper correction factors.

ⓑ Reducing effect of dust & humidity on components.

③ observational errors:

↳ while reading a meter, wrong scale selection, such as parallax error.

③ Random errors.:

↳ Some Errors are still occured, even though the systematic and instrumental errors are reduced.

↳ The cause of such errors are ~~kno~~ unknown.

↳ The only way to reduce these errors is by increasing no.of observations and using statistical methods for best results.

## Statistical Analysis of Random Errors

out of various posible errors, the random errors cannot be determined in the ordinary process of measurements, such random errors are treeted mathematically. this mathematical analysis of various measurements is called statistical analysis of data. In this same reading is taken no.of times.

## Arithmatic mean vs median :

↳ when the no. of readings of same measurement are taken

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \cdots - x_n}{n} = \frac{\sum_{n=1}^{n} x_n}{n}$$

$\bar{x} \rightarrow$ arithmatic mean

$x_n \rightarrow$ $n^{th}$ reading taken

$n =$ total no. of readings.

↳ The mean is very close to true value, if no. of readings is very large.

↳ But when no. of reading are large, calculation of mean is ~~calculated~~ complicated, In such case a median value is obtained, which is close to arithmatic mean. value.

eg : $x_1, x_2, x_3 \cdots - x_{11}$

$$x_{median} = x_{(n+1)/2} = x_6.$$

**Deviation from Mean:** it tells the departure of a given reading from the arithmatic mean of data set, this is denoted as 'd' & calculated for each reading is.

$$\boxed{d_i = x_i - \bar{x}}$$

$d_i \rightarrow$ deviation of $i_{th}$ reading

$x_i \rightarrow$ Value of $i_{th}$ reading

$\bar{X} \rightarrow$ Arithmatic mean.

**Average Deviation:** it is the sum of absolute values of deviations devided by no. of readings. (mean deviation).

$$\bar{D} = \frac{\Sigma|d_i|}{n}$$

**Standard Deviation:** It is also called root mean square deviation. It is defined as square root of the sum of individual deviations squared, devided by the no. of readings. denoted as 'σ'.

$$\sigma = \sqrt{\frac{d_1^2+d_2^2+d_3^2+---d_n^2}{n}}$$

$$\boxed{\sigma = \sqrt{\frac{\Sigma d^2}{n}}}$$

→ less the value of standard deviation, more accurate is the measurement

**Variance** It is mean square deviation, means it is square of standard deviation. denoted with 'v'

$$V = \sigma^2 = \frac{d_1^2+d_2^2+d_3^2+---d_n^2}{n}$$

## Gaussian Distribution

The freq distribution curve is called Gaussian Distribution curve, when the freq & magnitude ~~curve~~ of eqⁿs are related by the mathematical expression.

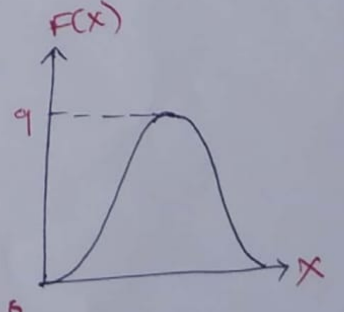
$$F(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{[(x-m)^2/2\sigma^2]}$$

x → value of reading

m → mean value.

Y-axis is freq of occurance of each measurement value denoted as F(x)

x-axis is magnitude



Freq distribution curve

# Measuring Instruments.

→ 3 basic quantities in the electrical measurements are current, voltage & power.

→ The measurement of these quantities is important as it is used for obtaining measurement of some other quantity or used to test the performance of some electronic ckts or components.

* necessary requirements for any instruments are

① The quantity to be measured should not get affected due to the instrument used.

② The power consumed by the instruments for their operation should be as small as possible.

→ The instrument which measures the current flowing in the ckt is called "Ammeter"

→ while the instrument which measures the voltage across any points of a ckt is called "Voltmeter".

→ But there is no fundamental difference ~~[illegible]~~ in the operating principle of analog voltmeter and ammeter.

→ The action of ~~al~~ almost all the analog ammeters and voltmeters depends on the deflecting torque produced an eletric current.

→ In ammeters such torque is proportional to the current to be measured.

→ In voltmeter this torque is decided by current which is proportional to the voltage to be measured.

→ All analog ammeters and voltmeters are basically current measuring devices.

→ The instruments which are used to measure power are called power meters.

## Classification of Measuring instruments.

a). Indicating Instruments
b). Recording "
c). Integrating "

ⓐ I.I: These instruments make use of dial and pointer for showing or indicating ~~[illegible]~~ magnitude of unknown quantity, eg: Ammeter, voltmeter.

ⓑ R. I: These instruments give a continous record of the given electrical quantity which is being measured over a specific period.

eg→are various types of recorders.

ⓒ I. I: These instruments measure the total quantity of electricity delivered over a period of time.

for eg: A house hold energy meter registers no. of revolutions made by disc to give total energy delivered.

## Essential requirements of an instrument.

→ In case of a measuring instruments, the effect of unknown quantity is converted into a mechanical force which is transmitted to the pointer which moves over a calibrated scale.

→ The moving s/m of such instrument is mounted on a pivoted spindle., and following s/ms are present in ~~any~~ an instrument.

① Deflecting s/m producing Deflecting Torque. Td.
② Controlling s/m producing Controlling Torque Tc
③ Damping s/m " Damping "

① Deflecting S/m:

→ In the most of indicating instruments the mechanical force is proportional to the quantity to be measured is generated. This force or Torque deflects the pointer.

→ The S/m which produces such deflecting torque is called "Deflecting S/m". & Torque is Td. and it overcomes

1) The inertia of moving S/m
2) The controlling torque provided by controlling S/m
3) The damping " " " damping "

↳ The deflecting S/m uses one of the following effects produced by current or voltage, to produce torque.

a) magnetic effect: when current carrying conductor placed in uniform magnetic field, it generates a force which causes to move it. This effect is mostly used in many instruments like moving iron attraction & repulsion type.

b). Thermal effect: The current to be measured is passed through a small element which heats it to cause rise in temp which is converted to an Emf by a thermocouple attached to it.

c) Electrostatic effect: when two plates are charged, there is a force exerted b/w them, which moves one of the plates. This effect is used in electrostatic instruments which are normally instruments.

d) Induction Effects: when a non magnetic conducting disc is placed in a magnetic field produced by electromagnets which are excited by alternating currents, an E.m.f is induced in it.

e) Hall Effect: If a semiconducting material is placed in uniform magnetic field., and if material carries current then E.m.f is produced b/w two edges of conductor.

② Controlling s/m: It produces a force equal and opposite to the deflecting force in order to make deflection of a pointer at a definite magnitude.

↳ If this s/m is absent, then the pointer will swing beyond its final steady position for the given magnitude and deflection will become indefinite.

↳ It brings moving s/m back to zero position, when the force which cause the movement of the ~~following~~ moving s/m is removed. It will never come back to its zero position in the absense of controlling s/m.

③ Damping s/m: The deflecting Torque provides Some deflection & controlling torque acts in the opposite direction to deflecting torque.

↳ So before coming to rest, pointer always oscilates due to inertia, about equilibrium position. unless pointer rests, final reading cannot be obtained.

↳ So to bring the pointer to rest with in short time damping s/m is required.

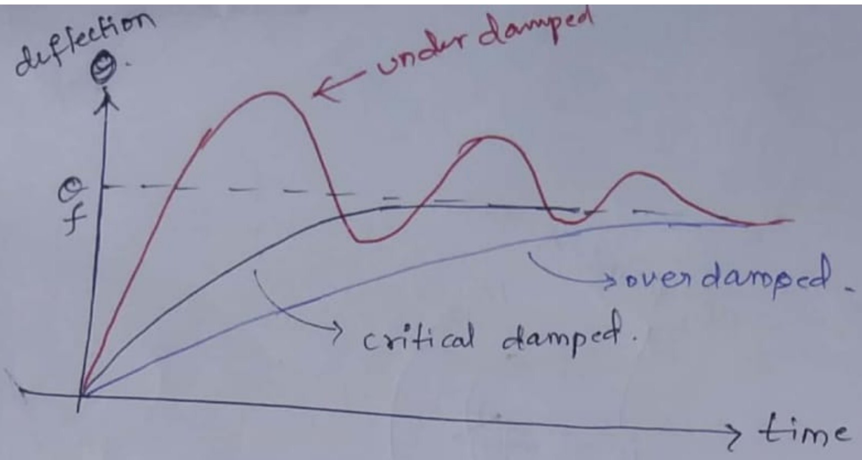
↳ The s/m Should provide a damping torque only when moving s/m is in motion.

↳ Damping torque is proportional to velocity of moving s/m.

→ The quickness with which the moving s/m settles to the final steady position depends on relative damping. if the moving s/m reaches to its final position rapidly but smoothly without oscillations, the instrument is said to "critically damped."

→ If the instrument is "under damped", the moving s/m will oscillates about final steady position with a decreasing amplitude and will take some time to come to rest.

→ while the instrument said to be "over damped" if the moving s/m moves slowly to its final steady position.


deflection
θ
θf
under damped
over damped.
critical damped.
time

## Type of instruments.

① pmmc
② moving Iron
③ Electrodynamometer
④ Electrostatic
⑤ Hot wire
⑥ Thermo couple
⑦ Induction type
⑧ Rectifier.

→ pmmc can be used for DC measurements only, & Induction ~~type~~ type for A.C measurements only. And other types can be used for both AC & DC measurements.

→ Pmmc is very accurate for DC measurements.

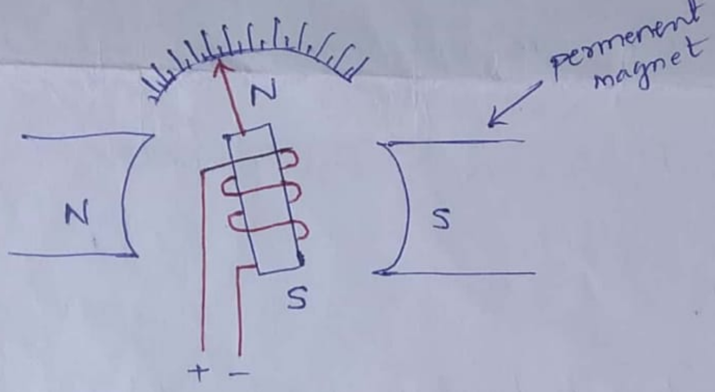
## Basic meter movement:

→ The action of dc meter is based on fundamental principle of motor. The motor action is produced by the flow of small current through a moving coil, which is positioned in the field of a permenant magnet. This basic moving coil s/m is called D'Arsonval galvanometer

→ This D'Arsonval movement has a spring-loaded coil through which the measurement ~~[illegible]~~ current flows.

- → The coil is in homogeneous field of a permenent magnet and moves in a rotary fashion.
- → The amount of rotation is proportional to the amount of current flowing through coil
- → A ~~coil is~~ pointer attached to the coil indicates the position of coil on a scale calibrated in terms of current or voltage.
- → It ~~Represents~~ responds to DC current only, and it is linear calibration

## PMMC



D'Arsonval principle.

## PMMC

- → pmmc instrument is most accurate for D.C measurements.
- → The working principle of this pmmc is same as D'Arsonval type of galvanometer.

→ The basic pmmc movement offers the largest magnet in a given space and is used when large flux is required in the air gap.

→ It provides low power consumption and low current required for full-scale deflection (fsd).

## Construction

→ The instrument consist of a permanent magnet of horse-shoe form with soft iron pole pieces attached to it.

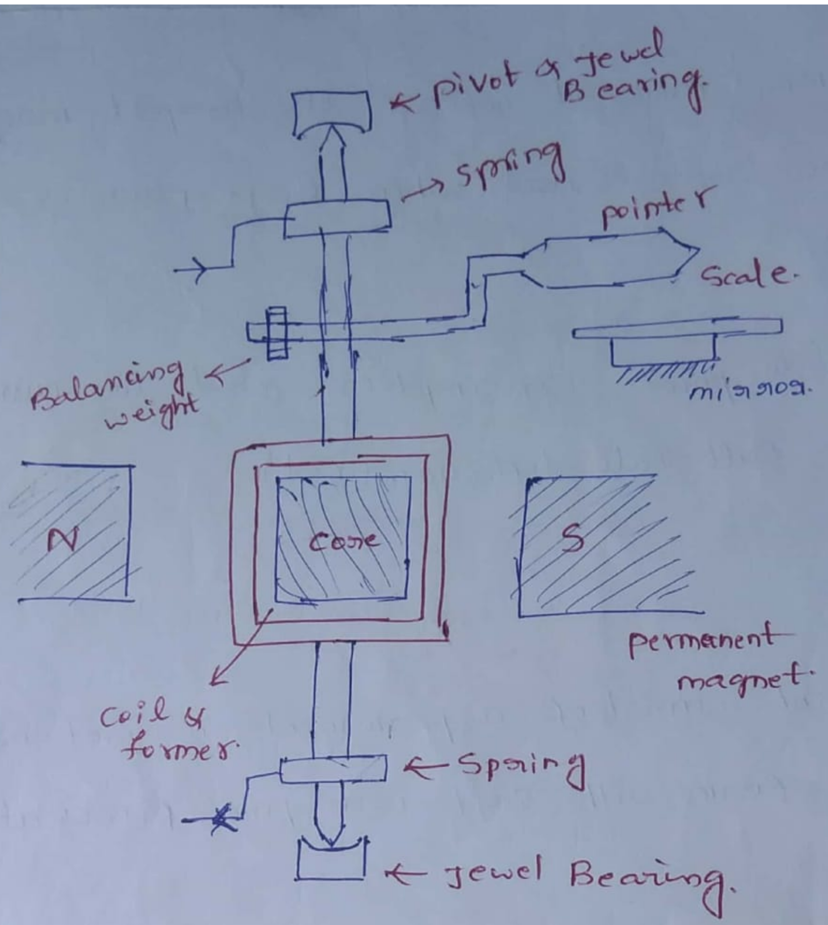
→ B/w pole pieces a cylinder of soft iron, which serves to provide a uniform magnetic field in the airgap b/w pole pieces and the cylindrical core.

→ Surrounding core is a rectangular coil of many turn

→ So it can rotate freely in the air gap.

→ A pointer attached to the coil moves over a graduated scale and indicates angular deflection of coil, which is proportional to the current flowing through it.

→ The aluminium metal frame not only provides support for the coil but also provides damping torque by eddy currents induced in it.



→ control of coil movement is provided by two phosphor-bronze hair springs, one above and one bellow.

→ The total moving s/m is ~~controlled corr~~ balanced ~~b~~ for deflection positions by 3 balance weights, The pointer, springs & pivots are fixed to the coil.

→ and entire coil supported by Jewel bearinge.

→ The Torque is directly proportional to coil current.

→ The basic pmmc is a linear-reading dc device.

## 1 principle and Deflecting Torque

→ when current flows in the coil, coil is rotating with generated electromagnetic torque.

→ Torque is balanced by the mechanical Torque of control Springs atached the coil.

→ The balance of Torque & angular position of movable coil is indicated by a ~~p~~ pointer against a fixed reference, ~~[illegible]~~ called Scale.

$T_d = B \cdot A \cdot I \cdot N$

B → flux density in airgap. (wb/m²)

A → effective coil Area. (m²)

I → current in the movable coil (amps).

N → Number of turns in the coil.

T → Torque (Newton-meter)

→ $T_c$ → opposing control spring Torque. ($T_c$).

$T_c \propto$ deflection, $\theta$

$T_c = K\theta$. → K is Spring constant.

in the find deflected position $T_d = T_c$

**Adv** ① low power consumption

② no hysteresis

③ They can modified with help of shunts & resistance to cover a wide range of currents & voltage

→ Disadv: ① errors due to ageing of control Springs. & permenent magnet.

② friction due to Jewel - pivot suspension

③ They can not be used for A-C measurements

Eg ① Amoving coil instrument has

$N = 100$

width of coil = 20 mm

Depth " " = 30 mm

$B = 0.1\ wb/m^2$

calculate deflecting Torque when carrying a current of 10mA. Also find deflection, if control spring constant is $2\times10^{-6}$ Nm/degr

An: The deflecting Torque Td is

$T_d = B.A.I.N$

$= 0.1 \times 30\times10^{-3} \times 20\times10^{-3} \times 100 \times 10\times10^{-3}$.

$= 60\times10^{-6}\ N/m$.

→ Restoring Torque.

$T_C = K\theta$.

$\Rightarrow$ As $\Rightarrow T_d = T_C$.

$T_C = 60\times10^{-6}\ N/m = K.\theta$.

$$\theta = \frac{60\times10^{-6} N/m}{K} = \frac{60\times10^{-6}}{2\times10^{-6}} = 30°$$

$\theta = 30°$

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→ An ideal voltmeter has infinite internal (meter) resistance, it should have no current going through it

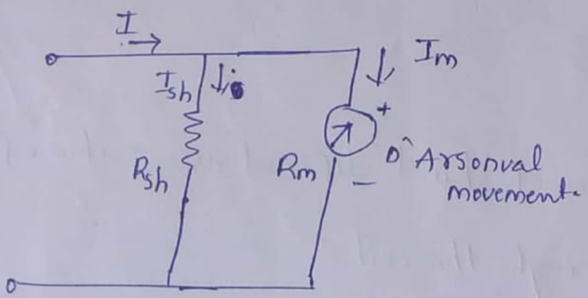
→ Ideal ammeter has zero internal resistance. An ideal ammeter Should not have voltage drop across it.

## D.C Ammeter :

→ The basic movement of a D.C ammeter is a pmmc galvanometer.

→ Since the coil winding ~~form~~ of a basic movement is small and light, it can carry only very small currents.

→ when large currents are to be measured, it is necessary to bypass a major part of the current through a resistance called shunt.



Basic D.C. Ammeter.

$R_m$ → Internal resis of movement (coil)

$R_{sh}$ → Resis of Shunt.

$I_m$ → Full scale Deflection current of movement

$I_{sh}$ → shunt current

I = Full scale current of ammeter

→ Since the shunt resis is in parllel with the meter movement the volt drop across the shunt and movement must be same

$$V_{sh} = V_m.$$

$$I_{sh} \cdot R_{sh} = I_m \cdot R_m \Rightarrow R_{sh} = \frac{I_m \cdot R_m}{I_{sh}}$$

$$I_{sh} = I - I_m \Rightarrow \boxed{R_{sh} = \frac{I_m R_m}{I - I_m}}$$

**eg:** A 1 mA meter movement with an internal resis of 100Ω is to be converted in to 0-100mA. find value of shunt resis.

Ans

$R_m = 100\,\Omega$

$I_m = 1\ mA$

$I = 100\ mA$

$$R_{sh} = \frac{I_m \cdot R_m}{I - I_m} = \frac{1 \times 100}{100 - 1} = \frac{100}{99}$$

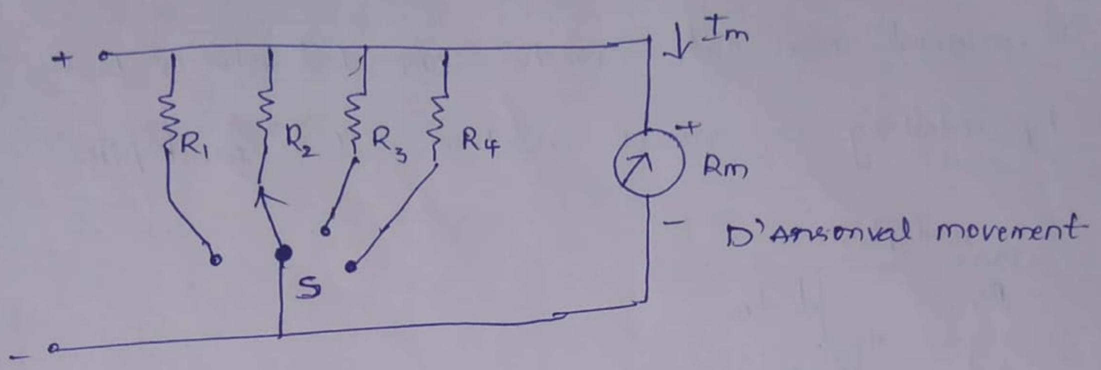
$$= 1.01\,\Omega \ //$$

$$R_{sh} = \frac{I_m \cdot R_m}{I - I_m}.$$

$m = \frac{I}{I_m}$ → multiplying power of shunt defined as ratio of total current to the current through the coil

$$R_{sh} = \frac{R_m}{\frac{I}{I_m} - 1} = \frac{R_m}{m - 1}$$

## → Extending the range of D.C. Ammeter.



→ The current range of the DC ammeter may be further extended by a numbers of shunts, selected by a range switch S.

→ Such meter is called a multirange Ammeter

→ It has 4 shunts $R_1$, $R_2$, $R_3$ & $R_4$ which are placed in parllel with the movement to give 4 different current ranges $I_1$, $I_2$, $I_3$, $I_4$.

$$R_1 = \frac{I_m \cdot R_m}{I_1 - I_m}$$ , for current range, $I_1$

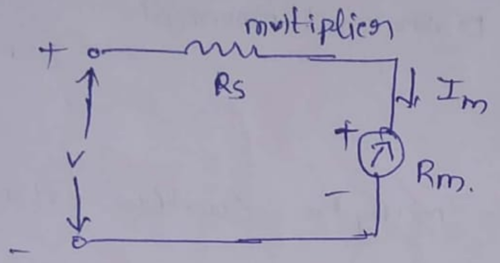
$$R_2 = \frac{I_m R_m}{I_2 - I_m}$$ , for current range $I_2$

$$R_3 = \frac{I_m R_m}{I_3 - I_m}$$ , for current range $I_3$

$$R_4 = \frac{I_m R_m}{I_4 - I_m}$$ for current range, $I_4$

## D.C. Voltmeter :

→ A basic D'Arsonval movement can be converted into a D.C voltmeter by adding a series resistor called "multiplier"



→ The function of multiplier is to limit the current through the movement so that the current does not exceed the full scale deflection value.

→ A D.C voltmeter measures the potential difference b/w two points in a dc ckt.

→ The value of a multiplier, required to extend the voltage range is

$$V = I_m (R_s + R_m)$$

$I_m$ → Full scale deflection current of movement ($I_{fsd}$)

$R_m$ → Internal resistance of movement.

$R_s$ → multiplier resistance

V → full range voltage of instrument

$$\boxed{R_s = \frac{V - I_m R_m}{I_m} = \frac{V}{I_m} - R_m.}$$

$V = I_m (R_m + R_s)$

$V = I_m R_m + R_s I_m$

$I_m R_s = V - I_m R_m$

$$\boxed{R_s = \frac{V - I_m R_m}{I_m}}$$

The multiplying factor for multiplier is the ratio of full range voltage to be measured and drop across the basic meter.

V = drop across basic meter = $I_m R_m$

m = multiplying factor = $\frac{V}{v}$

$$m = \frac{I_m(R_m+R_s)}{I_m R_m} = \frac{I_m R_m}{I_m R_m} + \frac{I_m R_s}{I_m R_m}$$

$$\boxed{m = 1 + \frac{R_s}{R_m}} \Rightarrow \frac{R_s}{R_m} = (m-1)$$

$$R_s = (m-1)R_m.$$

* Means to increase the range of voltmeter 'm' times the series resistance required is (m−1) time the basic meter resistance. This is nothing but extension of range of a voltmeter.

→ A moving coil instrument gives a full scale deflection with a current of 40 μA, while the internal resis of meter is 500 Ω, It is used as a voltmeter to measure a voltage range of 0 − 10V, find multiplier resis($R_s$)?

Ans

$R_m = 500\,\Omega$

$I_m = 40\,\mu A$

$V = 10\,V$

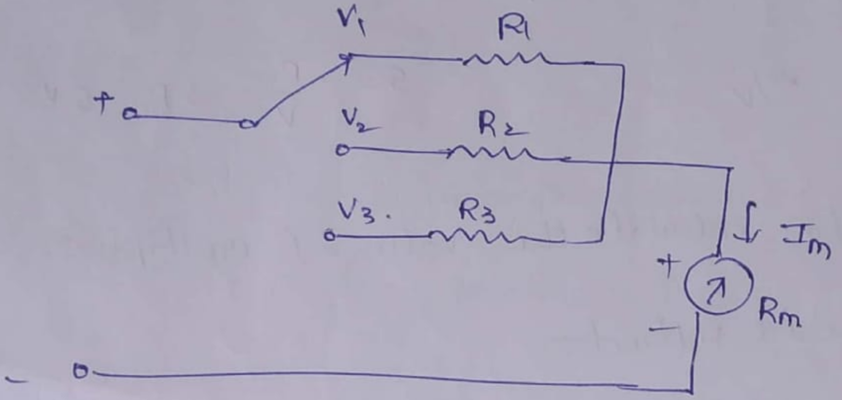
$$R_s = \frac{V}{I_m} - R_m$$

$$R_s = \frac{10}{40\times10^{-6}} - 500$$

$R_s = 249.5\,k\Omega.$

## Extending range of D.C voltmeter:

The addition of a number of multipliers along with a range switch provides the instrument with a greater no. of ranges.

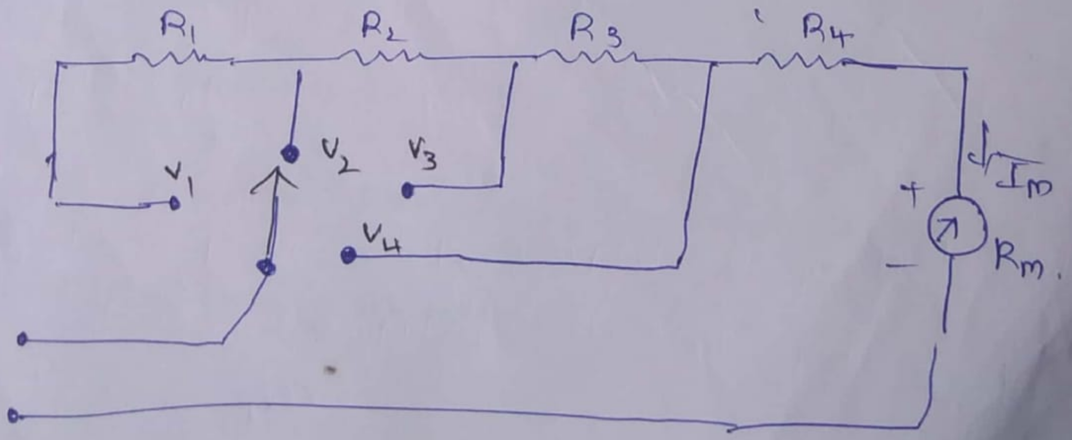


$R_1 = \frac{V_1}{I_m} - R_m$ for voltage range $V_1$

$R_2 = \frac{V_2}{I_m} - R_m$ for voltage range $V_2$

$R_3 = \frac{V_3}{I_m} - R_m$ for voltage range $V_3$

**multiplier connected in series.**



## Voltmeter Sensitivity

→ The sensitivity is the ratio of the total ckt resis $R_T$ to the voltage range.

→ It is the reciprocal of full scale deflection current of basic movement.

$$\therefore S = \frac{1}{I_{fsd}} \ \Omega/V \qquad S = \frac{R_T}{V} \Rightarrow R_T = S.V$$

↳ It can be used to calculate the value of multiplier resistors in a d.c voltmeter.

$R_s$ = Resis of multiplier.

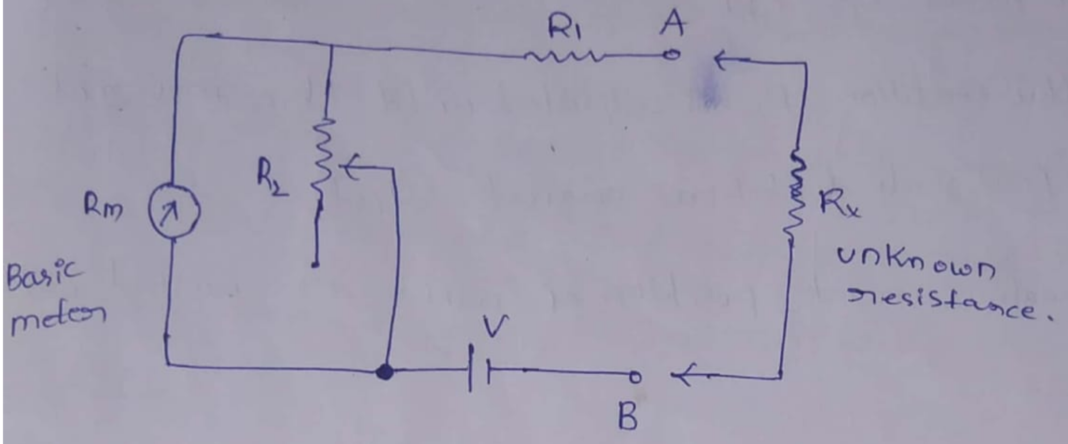
$R_T$ = Total ckt resis ($R_T = R_s + R_m$)

$R_m$ = internal resis of movement.

$R_S = R_T - R_m$ & $R_T = S \cdot V$.

$R_S = S \cdot V - R_m$.

# Series type ohmmeter:



↳ It consist a D'Arsonval movement connected in series with a resistance $R_1$ and a battery to a pair of terminals to which the unknow resistance is connected.

→ The current flowing through the movement then depend on the magnitude of unknown resistance.

→ Then the meter deflection is directly proportional to the value of unknown resistance.

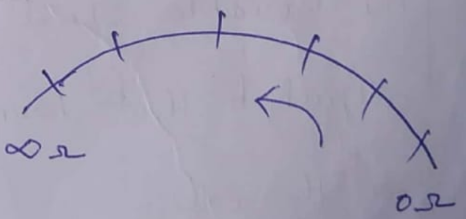
$R_1$ → current-limiting resistor.

$R_2$ → zero adjust resistor

V → Internal battery

Rm → Internal series of D'Arsonval movement.

Rx → unknown resistor.



→ whe $R_x = 0$ ⇒ terminals A & B shorted, then max current flows in ckt.

→ under this condition, $R_2$ is adjusted until the movement indicates full scale deflection current ($I_{fsd}$).

→ The full scale current position of pointer is marked "0Ω" on the scale.

→ when $R_x = \infty$ (A & B is open), the current in ckt is zero. and movement indicates zero current which is then marked ∞ on the scale.

→ The draw back in this series ohmmeter is the decrease in Voltage of the internal battery with time and age. due to this, the full scale deflection current drops and meter does not read '0' when A & B are shorted.

The variable shunt resistor, $R_2$ across the movement is adjusted that bringing the pointer back to '0' ohms on the scale.

→ It is also posible to adjust the full scale deflection Current without shunt $R_2$ in ckt, by varying $R_1$

to compensate voltage drop.

→ The internal resistance of coil $R_m$ is very low compared to $R_1$.

→ when $R_2$ is varied, the current through ~~$R_2$ is reduced, then~~ the movement is increased and current through the $R_2$ is reduced, then bringing the pointer to the full scale deflection position.

→ The Series type ohmmeter used for general Service work.

Design:

→ $R_h$ is half-scale position resistance. at this position the resis across terminals A & B is defined as $R_h$.

→ $R_1$ & $R_2$ can be determined from value of $R_x$ which gives half Scale deflection.

→ unknown resistance must be equal to total internal resis of ohmmeter.

$$R_h = R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

$$I_h = \frac{V}{2R_h}$$ → current needed to suply half Scale deflection.

The total current of ckt $I_t = 2I_h = \frac{V}{R_h}$

The shunt current $I_2 = I_t - I_{fsd}$
through $R_2$ is.

→ The voltage across the shunt ($V_{sh}$) is equal to the voltage across the meter.

$$V_{sh} = V_m$$

$$I_2R_2 = I_{fsd}\cdot R_m \Rightarrow R_2 = \frac{I_{fsd}\cdot R_m}{I_2}$$

But $I_2 = I_t - I_{fsd}$.

$$R_2 = \frac{I_{fsd}\cdot R_m}{I_t - I_{fsd}}$$ But $I_t = \frac{V}{R_h}$

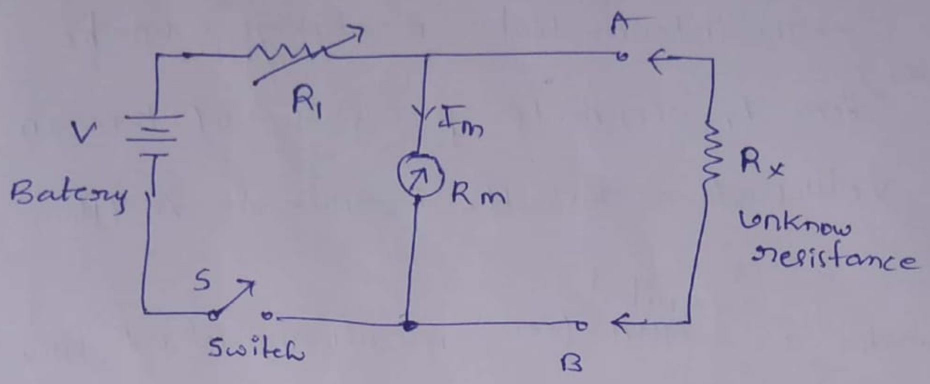
$$R_2 = \frac{I_{fsd}\cdot R_m}{\frac{V}{R_h} - I_{fsd}} \Rightarrow \boxed{\frac{I_{fsd}.R_m\cdot R_h}{V - I_{fsd}R_h} = R_2} \quad — ①$$

As $\boxed{R_h = R_1 + \frac{R_2 R_m}{R_2+R_m}}$

$$R_1 = R_h - \frac{R_2R_m}{R_2+R_m} \Rightarrow R_1 = R_h - \frac{\frac{I_{fsd}\cdot R_m\cdot R_h}{V - I_{fsd}R_h}\times R_m}{\frac{I_{fsd}\cdot R_m\cdot R_h}{V - I_{fsd}R_h} + R_m}$$

$$\boxed{R_1 = R_h - \frac{I_{fsd}R_mR_h}{V}} \quad — ②$$

## Shunt type ohmmeter:



→ It consist of a battery in series with an adjustable resistor $R_1$ and a pmmc meter. $R_x$ is

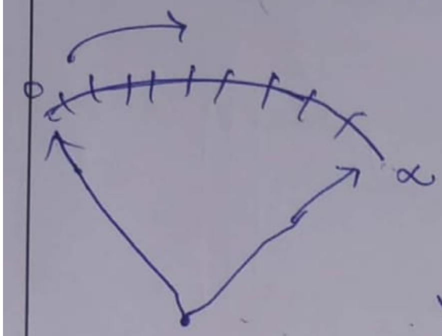
→ The switch is provided to disconnect the battery when instrument is not in use. unknown resis is connected in parallel with the meter. So it is called shunt type ohmmeter.

→ when the terminals A & B are shorted, then meter gets bypassed by short ckt. Hence entire current flows through the ckt and meter current is zero. This pointer position is marked as zero & $R_x = 0$.

→ when terminals A & B are open, $R_x = \propto$ then entire current flows through meter, Hence pointer deflects to maximum.

→ The Resis $R_1$ is then adjusted such that current through the meter is ~~zero. This pointer position.~~ is ~~marked~~ as ~~zero and $R_x = 0$~~ its full scale deflection current. this position of pointer is marked as $\propto$

→ Thus the scale is marked from 0 to ∞



→ The intermediate markings can be done by connecting res of known values ~~a~~ across the terminals A & B.

This type of ohmmeter is ~~used~~ suited for measurement of low res. hence this is used as a test instrument in laboratory.

→ when $R_x = \infty$

v → internal battery voltage

$R_1$ → current limiting resistor

Rm → internal res of PMMC.

$$I_{fsd} = \frac{V}{R_1 + R_m}$$

$$R_1 = \frac{V}{I_{fsd}} - R_m$$

For any value of $R_x$, connected across the meter terminals the meter current decreases & given by

$$I_m = \frac{V}{R_1 + \frac{R_m \cdot R_x}{R_m + R_x}} \times \frac{R_x}{R_m \cdot R_x}$$

$$= \frac{VR_x}{R_1 R_m + R_x (R_1 + R_m)}$$

At half scale reading of meter $(I_m = 0.5 I_{fsd})$, $R_x = R_h$

$$0.5 \, I_{fsd} = \frac{V \cdot R_h}{R_1 R_m + R_h (R_1 + R_m)}$$

where $R_h$ → external res of causing half scale deflection.

→ To find relative Scale values for a given value of $R_1$, the half scale reading may be found by .

$$R_h = \frac{R_1 R_m}{R_1 + R_m}$$

→ from that the $R_h$ is find by $R_1$ & $R_m$.

→ and $R_1$ is determined by $R_m$ & $I_{fsd}$.

## Megger :

↳ The megger is used to measure very high resistance (above 50 MΩ) such those found in cable insulation, b/w motor windings in transformer widings.

↳ The megger is a portable ohmmeter with built-in high voltage source. it has two main elements, a magnet type dc generator to supply current for making measurements and an ohmmeter which measures the resis value

→ The generator armature is turned by a hand crank, usually through step up gears, to produce an o/p voltage of 500V, when the crank is turned, the gears turn the generator at high speed to generate an o/p voltage that may be 500, 1000 or 2500V depending on model.

Multimeters:

also called voltage-ohm-meter.

→ The basic ckt vom includes balanced bridge d.c ampr.

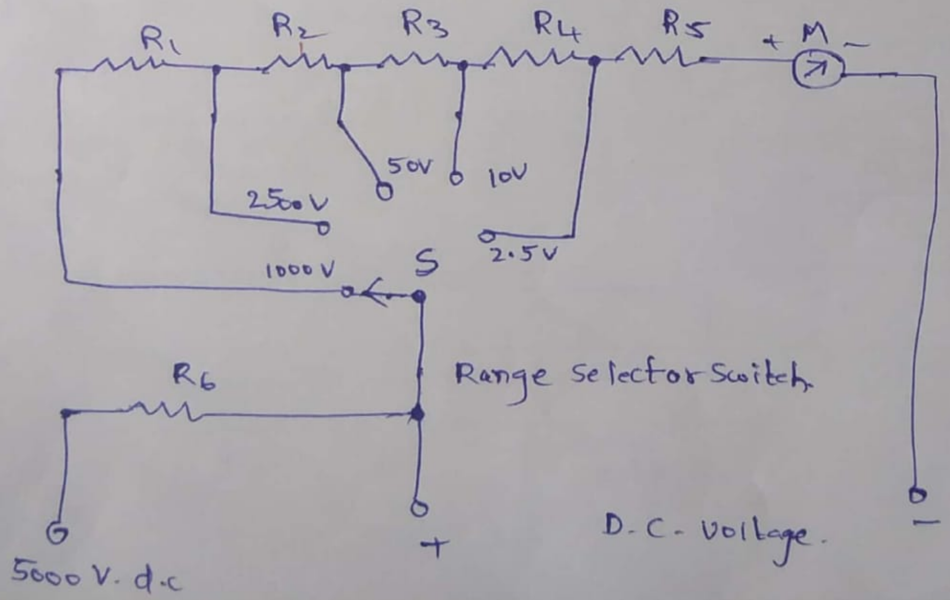
→ To limit magnitude of i/p sgl RANGE Switch is provided. by properly adjusting i/p attenuator i/p Sgl can be limited.

→ It is also includes rectifier section

→ The various parameters measurement is possible by Selecting required function using FUNCTION Switch.

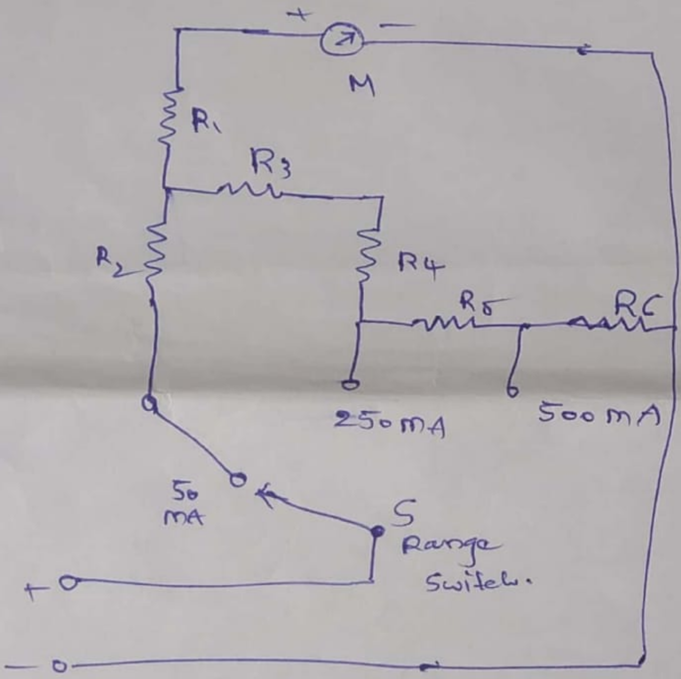
→ The measurement of various parameters is indicated with the help of Indicating meter.

Use of multimeter for D.C voltage measurement.



→ For getting diff range of voltages, diff series resistances are connected in series. we can get diff ranges to measure the d.c voltages by selecting the proper res in series with basic meter.

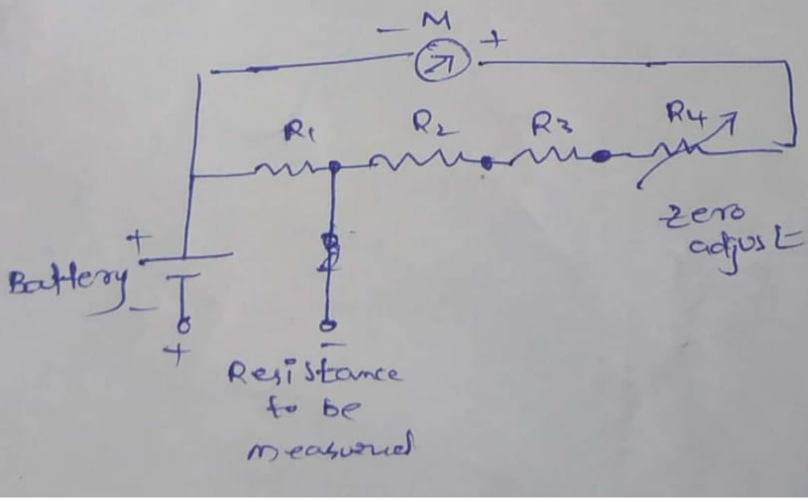
→ use of multimeter as an ammeter.



→ To get different current ranges, diff shunts are connected across the meter with the help of range selector switch.

→ The working is same as pmmc meter.

→ use of multimeter for resistance measurement



## Loading Effect:

→ While selecting a meter for a ~~multiplier~~ particular measurements, the sensitivity rating is very important.

→ A low sensitive meter may give the accurate reading in low resistiance ckt but will produce totally inaccurate reading in high resistance ckt.

→ The voltmeter always connected across the two points b/w. which the potential diff is to be measured. If it is connected across a low resistance then as voltmeter resistance is high, most of the current will pass through a low resistance and will produce the volt drop which will be nothing but the true reading. If voltmeter is connected across high resistance, due to two high resistances in parllel, current will devide in two paths. meter will record the voltage drop across high resis, which is much lower than the true reading

→ Thus the low sensitivity instrument when used in high resis ckt gives a lower reading than true reading. This is called loading effect of voltmeters., it is mainly caused due to low sensitivity instruments.

## Electronic voltmeters:

The voltmeters which use rectifiers, diodes, amplifiers and other electronic ckts to produce a current proportional to the quantity to be measured, are called Electronic voltmeters.

### Adv. of E.V.M

→ Low level sgl ~~conditioning~~ detection
→ low power consumption
→ Less loading effect
→ High sensitivity & High i/p impedance
→ High freq range.
→ Improved dynamic range
→ High accuracy

## Basic electronic voltmeter (Transistor voltmeter)

→ To measure the low voltage sgls, an ampr is used in the electronic voltmeters.

→ A D.C ampr with one or more sgls is used in D.C electronic voltmeter before basic pmmc meter.

→ The high i/p impedence can be achieved using FET at i/p.

→ The BJT $Q_2$ along with resistors forms a balanced bridge ckt.

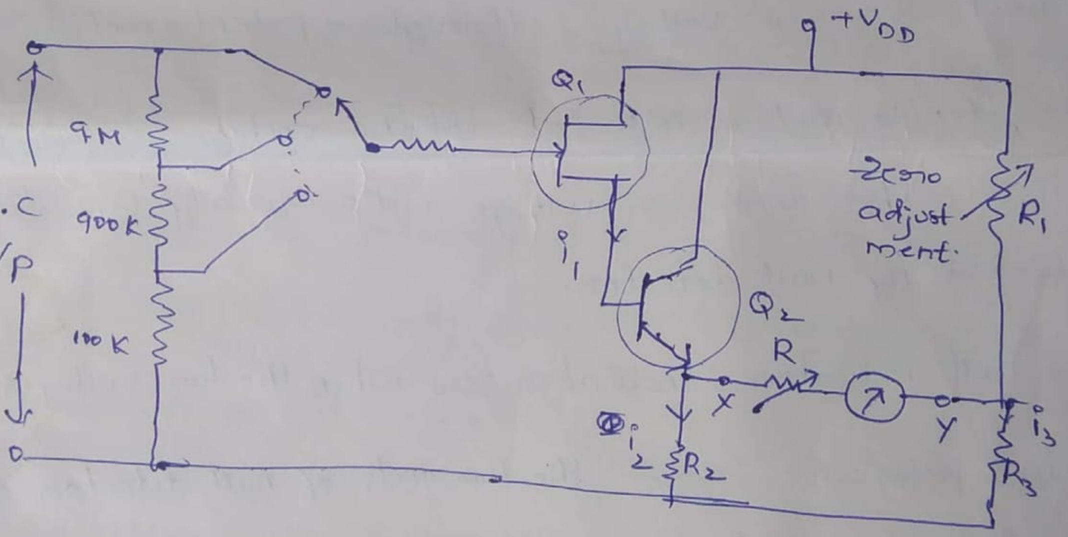
→ The FET $Q_1$ acts as a Source follower, which provides high i/p impedence.

→ Due to this, the meter ckt can be isolated from the ckt under measurement.

→ The i/p impedence of FET is greater than $10 M\Omega$

→ The bridge balance is obtained by zero adjustment resistor such that for zero i/p the pointer shows zero.

→ The bias on $Q_2$ is such that $i_1 = i_3$ when i/p is zero, under this condition, potential of point x, $v_x$ and potential of point Y ($v_y$) is same. No current flows through the meter ~~the~~ → $i_4 = 0$ for zero input.



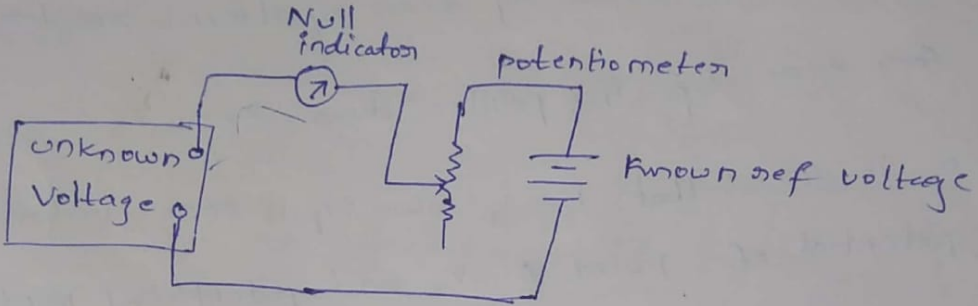
→ when i/p volt is applied, the bias on $Q_2$ increases, this causes $V_x$ to increase hence proportional current $i_4$ flows through the meter. Thus the deflection of meter is proportional to the i/p voltage, with in dynamic range of amplifier.

→ The value of i/p which causes max meter deflection is the basic range of the meter.

A.C //

## Differential voltmeter :

This voltmeter indicates the difference b/w known and unknown Voltages, by comparing unknown voltage with known voltage.



↳ The working is similar to potentiometer, also called potentiometric Voltmeters. it uses a null indicator which is connected b/w Unknown & known voltages. through a potentiometric devider.

→ The potentio meter is varied, till the voltage across it becomes equal to the unknown voltage. The equality condition is indicated by null detector.

* The null indicator indicates zero when the two voltages are same.

→ when 2 voltages are same, the two ends of null detector are at the same potential. Hence it does not draw any current, not from unknown voltage and not from reference source too. zero current indicates infinite impedence to the unknown voltage

→ under null condition the voltage across devider is function of known voltage and it can be measured, which is nothing but unknown voltage.

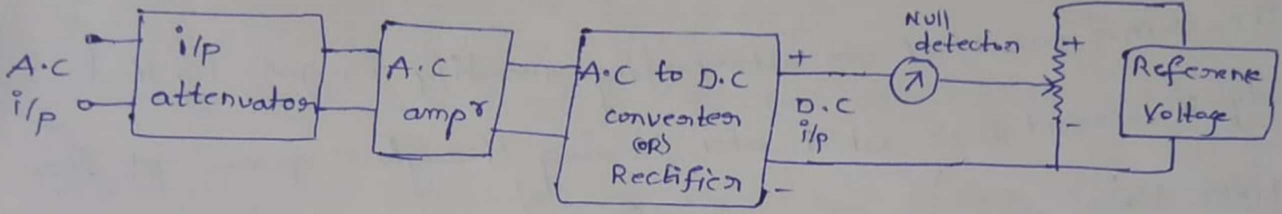
→ To detect very small voltages, the null detector must be very sensitive

→ The ref volt is usally 1 v d.c battery.

→ To measure the high volt known ref supply is required.

## A.C. Differential voltmeter:

→ To avoid the requirement of high ref supply the voltage deviders or attenuators are connected across the unknown i/p votage source.
potentiometer.



→ unknown voltage to be measured is applied at the i/p. this voltage is applied to attenuator, consisting of no. of resistors used in voltage devider mode.

→ Attenuator o/p is given to A.C ampr which amplifies small sgls. An amplified A.C voltage is then converted to D.C voltage, by using precision rectifier ckt.

→ once the D.C o/p, proportional to A.C i/p voltage is obtained, the remaining function of voltmeter is same as differential voltmeter.

## A.C Voltmeter using Rectifiers:

→ The pmmc movement used in D.C voltmeter can be effectively used in A.C voltmeters. The rectifier is used to convert A.C volt to be measured, to D.C voltage. and it is amplified if required and then given to pmmc meter.

→ The pmmc gives deflection proportional to the quantity to be measured.

→ The A.C meters are usually calibriated to read R.m.s value of an alternating quantity to be measured.

→ The r.m.s value of an alternating quantity is given by that Study current (D.c) which when flowing through a given ckt for a given time produces the Same amount of heat as produced by the alternating current which when flowing through the Same ckt for the Same value.

→ The rms value is calculated by measuring the quantity at equal intervals for one complete cycle. Then squaring each quantity, the avg of Squared values is obtained.

→ The square root of this avg value is r.m.s value.

→ The rms means, root-mean-square, i.e. Squaring, finding mean, i.e, avg and finally root.

→ If the wave-form is continous then instead of squaring and calculating mean, the integration used

$$\boxed{V_{rms} = \sqrt{\frac{1}{T}\int_0^T V_{in}^2\, dt}}$$

↳ For purely Sinusoidal quantity

$$\boxed{V_{rms} = 0.707 V_m}$$

$V_m$ → is peak value of Sinusoidal quantity.

→ Most of A.C Voltmeters are R.m.s responding or average responding type, with scale calibrated in terms of the r.m.s value of Sine wave.

→ The avg value is defined as that value which is obtained by averaging all instantaneous values over a period of half cycle.

→ For symmetrical A.C quantity the avg value over a complete cycle is zero as both +ve & -ve half cycles are exactly identical

→ If A.c quantity is continous the avg value can be expressed as

$$\boxed{V_{avg} = \frac{2}{T}\int_0^{T/2} V_{in}\,dt}$$

→ The interval $\frac{2}{T}$ indicates the avg value over a half cycle.

For purely sinusoidal quantity

$$\boxed{V_{avg} = \frac{2}{\pi}V_m = 0.636\,V_m.}$$

$V_m$ = Peack value of Sinusoidal quantity.

↳ The avg responding meter scale is also calibrated in terms of r.m.s Values. To achieve this a pure sine wave with r.m.s value of 1 V is applied. Then deflection of meter is adjusted to 1 V reading. for this a particular factor is required , that is called form factor.

↳ It is ratio of r.m.s value to the avg value. of an alternating quantity.

$$\boxed{K_f = \frac{\text{r.m.s value}}{\text{avg value}} = \text{form factor.}}$$

↳ for purely ,Sinusoidal waveform the $K_f = 1.11$

→ while calibrating avg responding meter interms of r.m.s values the markings are actually corrected by a factor of 1.11

$$\boxed{\text{Avg value} = \frac{\text{r.m.s value}}{K_f}}$$

→ Some meter Scales are calibrated in terms of peak value of the i/p. In such cases another factor relating Peak value and the r.m.s value becomes important. This factor is called Peak Factor or Crest factor.

→ It is ratio of peack (max) value to r.m.s value of an alternating quantity.

$$\boxed{K_p = \frac{\text{max value}}{\text{r.m.s value}}}$$

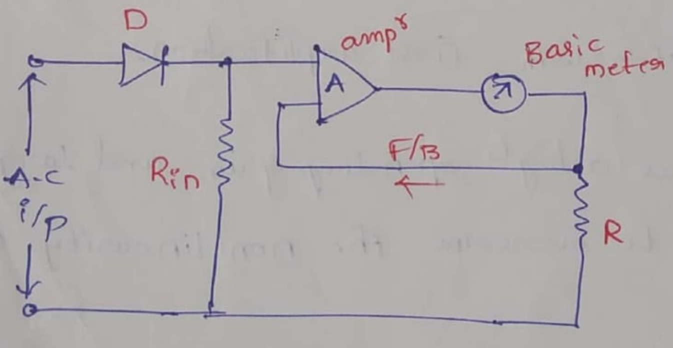
↳ For purely Sinusoidal A.C. quantity the crest factor is 1.44

→ why to use these factors to correct the readings by measuring avg ~~an~~ & peak values, when the true r.m.s voltmeter can give direct r.m.s reading, reason is that the avg & peak responding meters are less in cost and very simple in construction as compared to True r.m.s voltmeters.

*⇒ A.C. Voltmeters can be designed in two ways.

i) First Rectifying the A.C. sgl and then amplifying.
ii) First amplifying the A.C sgl and the rectifying

## ① First rectifying and then Amplifying A.C sgl.



A.C. voltmeter with first rectification

↳ The A.C i/p volt if first rectified using the diode D. This rectified sgl is then applied to the amp^r of gain A. the amplified sgl is then given to basic PMMC meter to obtain deflection.

→ This approch ideally requires a d.c amp$^r$ with zero drift char'cs and d.c meter movement with high sensitivity. Rin is i/p resis of meter.

## ② First Amplifying and then Rectifying A.C Sgl.

↳ The A.C i/p sgl, which is small sgl is amplified first and then rectified after the sufficient amplification.

↳ The A.C sgl is applied to an amp$^r$ ~~and hence~~

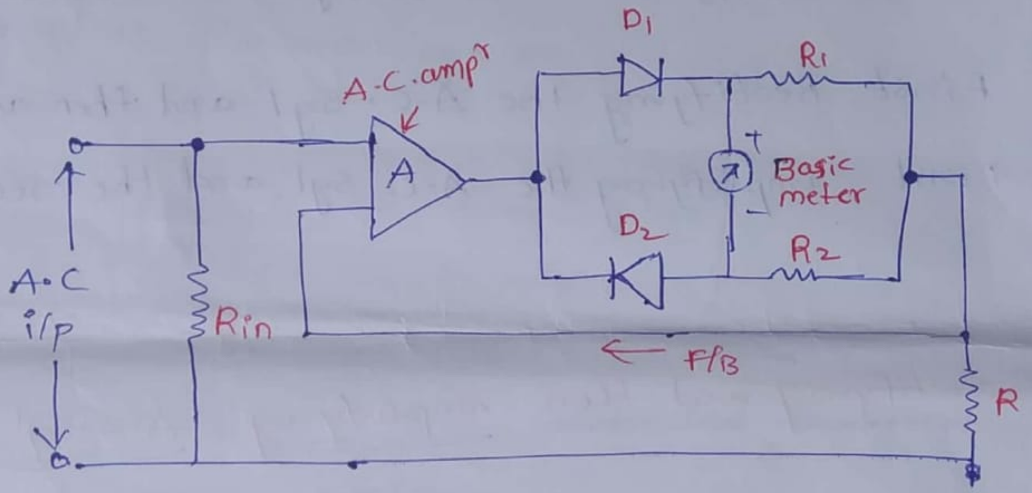


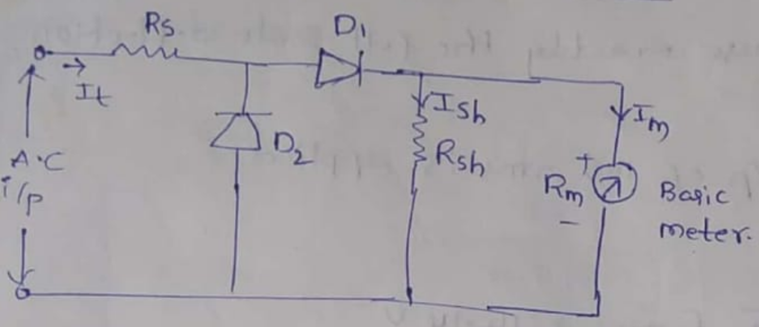
fig: Voltmeter with first amplification.

↳ The A.C amp$^r$ requires a high open loop gain and large ~~of~~ amount of -ve f/b to overcome the non linearity of rectifier diodes.

→ The amp$^r$ o/p is applied to full wave rectifier consisting of diodes $D_1$ & $D_2$

→ The diodes are non linear devices at low values of forward current.

## Basic Rectifier type A.C. voltmeter



↳ The diodes $D_1$ & $D_2$ used for rectifier ckt

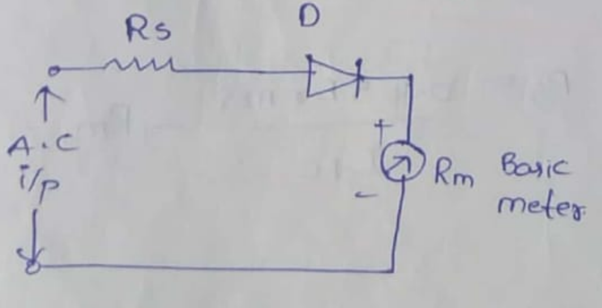
↳ The diodes show the non-linear behaviour for low currents hence to increase the current through diode $D_1$, the meter is shunted with reris $R_{sh}$.

↳ when A.C. i/p is applied, for +ve half cycle, the $D_1$ conducts and causes the meter deflection proportional to the avg value of half cycle.

↳ For −ve half cycle, the diode $D_2$ conducts & $D_1$ R.B. the current through the meter is in opposite direction hence meter movement is bypassed.

↳ Due to diodes, the rectifying action produces pulsating D.C and the meter indicates the avg value of i/p.

## A.C. voltmeter using Half wave Rectifier.



→ The diode 'D' conducts only during +ve half cycle

↳ The sensitivity of D.C. voltmeter is → $\boxed{S_{d.c} = \frac{1}{I_{fsd}}}$

→ A.C. voltmeter less sensitive than D.C. voltmeter.

↗ series mult

↳ Let $I_{fsd} = 1mA$ ⇒ $S = 1 k\Omega/V$ , $R_s = 10 k\Omega$ hence the 10 v d.c i/p would cause exactly the full scale deflection,

↳ Let pure sinusoidal i/p of 10V rms is applied.

$E_{rms} = 10V$

$E_p$ = peak value = $\sqrt{2}\ E_{rms}$ = 14.14 V.

↳ Now rectified D.C. is pulsating D.C, hence meter will deflect proportional to the avg value.

$E_{avg} = 0.636\ E_p = 8.99V.$

↳ But diode conducts only for half cycle and meter movement is bypassed for another cycle. Hence it responds to half the avg value of A.C. i/p.

$E_{avg} = \frac{8.99}{2} \simeq 4.5V$.

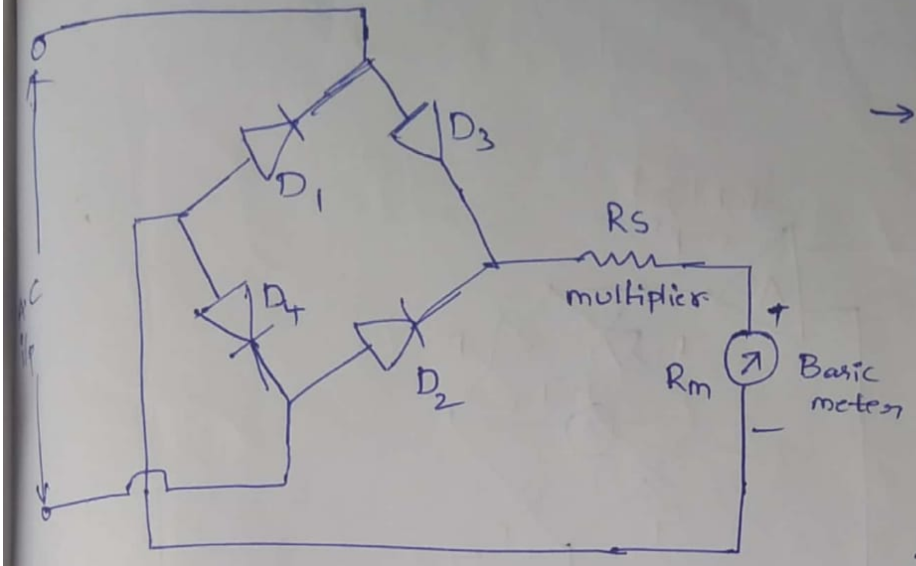
↳ Thus pointer will deflect for full scale if 10V d.c is applied & 4.5V when 10V r.m.s sinusoidal i/p is applied.

↳ Thus the A.C. voltmeter is less sensitive than d.c. voltmeter

$E_{dc} = 0.45\ E_{r.m.s.}$

$\boxed{R_s = \frac{E_{d.c}}{I_{dc}} - R_m}$ ⇒ $R_s = \frac{0.45 E_{r.m.s}}{I_{dc}} - R_m.$

# A-C Voltmeter using Full wave rectifier.



→ It is achieved by using Bridge rectifier, consist 4 diodes

→ Let 10V r.m.s purely Sinusoidal i/p be applied

$$\therefore E_{rms} = 10V$$

$$E_p = 14.14V$$

$$E_{avg} = 0.636\,E_p = 8.99V$$

$$= 9V.$$

↳ This meter uses full wave rectifier and hence the avg value of o/p over a Cycle is same avg of i/p over a cycle i.e 9V.

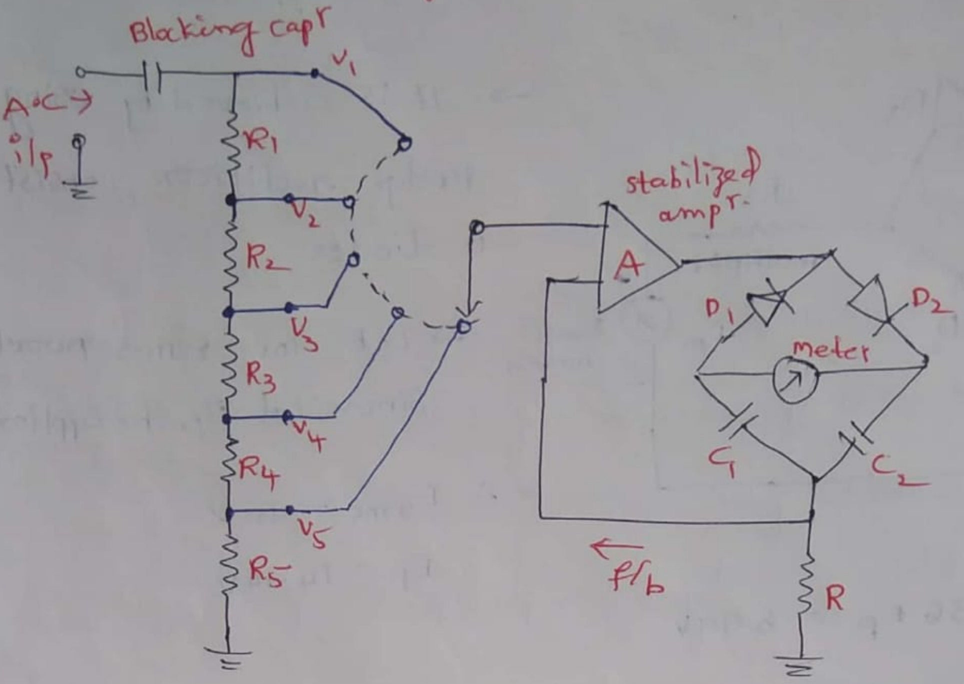
↳ Thus the 10V r.m.s voltage is equal to 9V d.c for full Scale deflection. thus pointer will deflect to 90% of full scale

$$\boxed{\text{sensitivity (A-C)} = 0.9 \times \text{sensitivity (d.c)} \text{ for full wave.}}$$

↳ The multiplier resis can be obtained as

$$\boxed{R_S = \frac{E_{dc}}{I_{dc}} - R_m = \frac{0.9\,E_{rms}}{I_{dc}} - R_m}$$

# Average Responding Voltmeter



→ The A.C i/p applied is first amplified with help of high gain stabilized amp^r, up to a req^d level. This volt is then rectified using the diodes D1 & D2. The rectified volt is fed to a D.C milliammeter used as a measuring meter.

→ The current obtained from rectifier, is averaged by using a filter to produce a steady deflection of the meter pointer.

→ The blocking capacitor used at the i/p side blocks any d.c component in the i/p voltage. Large amount of -ve f/b is used for amp^r to ensure stability for measurement accuracy. It is also increases the freq range of instrument. The effect of diode non linearity is minimised by including the meter in f/b path.

→ The capacitor C1 & C2 in rectifier ckt act as storing capacitors or filter capacitors. This capacitors also act as coupling capacitors in f/b path. The -ve f/b compensates any changes in meter impedence

→ The D.C millimeter is calibrated in terms of r.m.s value of i/p volt. As rectifier current is averaged using the filter, the meter responds to avg reading of i/p, hence called avg responding meter.

# Peak responding volt meter

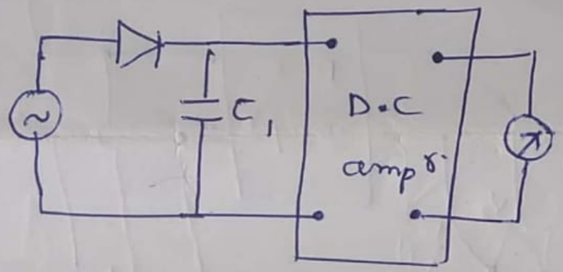
→ This meter responds to peak value of A.C i/p sgl. The diff b/w avg responding meter and this meter is use of storage capacitors with rectifying diode.

→ The storage capacitor charges through diode up to peak value of A.C i/p sgl. The D.C amp$^r$ then amplifies this sgl & provides the necessary current for the meter movement proportional to the peak value of i/p.

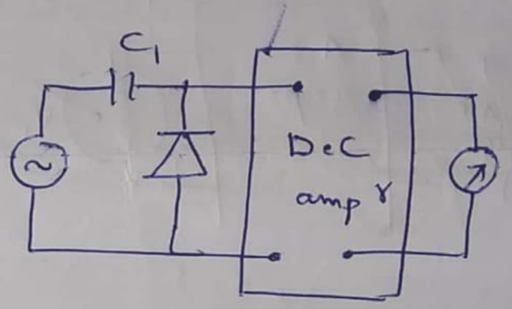
↳ 2 types of peak responding voltmeters

i) D.C coupled peak responding voltmeters

ii) A.C coupled peak responding voltmeters.



ⓐ D.C. coupled P.R.M



ⓑ A.C. coupled P.R.M

→ In D.C coupled voltmeter, C$_1$ charges to total peak voltage above the ground ref. In this case presence of D.C with A.C i/p effects the meter reading.

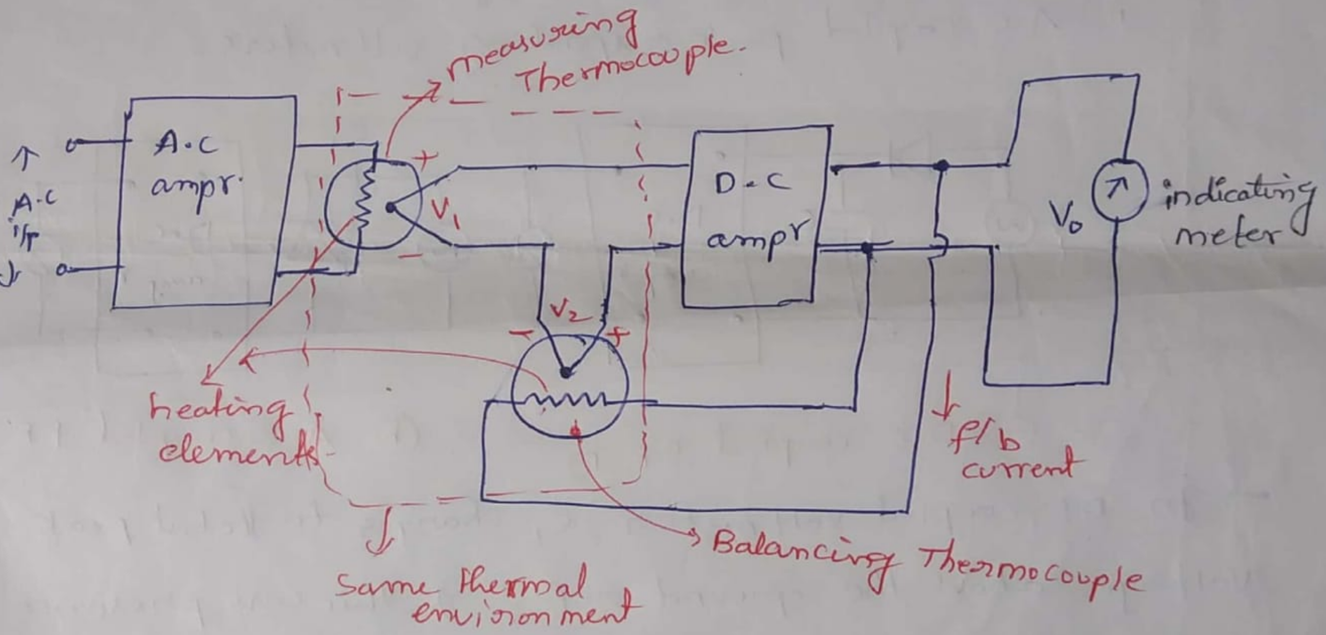
→ In A.C coupled peak reading voltmeter, the position of diode & cap$^r$ are interchanged. The cap$^r$ still charges to the peak value of A.C i/p.

→ In both meters D.C amp$^r$ has very high i/p impedence is used. due to this, the discharging of cap$^r$ takes place very slowly. Thus negligible amount of current is supplied by the ckt under test. This keeps capacitor charged to peak value of A.C i/p. The D.C ampr provides the necessary meter current required for the deflection.

## * True R.M.S Responding Voltmeter.

→ The r.m.s value means root-mean-square value. it is obtained by squaring the i/p sgl & then calculating square root of its avg value.

→ The r.m.s value is also called effective value. It compares heating effect produced by A.C & D.C



→ The True Rms responding voltmeter produces a meter deflection by sensing the heating power of waveform

→ This heating power is proportional to square of i/p r.m.s value. The measurement of heating power is achieved by the use of thermocouple.

→ The i/p volt to be measured is applied to heater the heating effect of heater is sensed by a thermocouple attached to heater. The thermocople generates corresponding voltage.

→ The A.C i/p is amplified & then given to the heater element to achieve enough heating so that the thermocouple can generate enough level of voltage to cause meter deflection

* The o/p Volt is proportional to r.m.s value of A.C i/p

$$\text{power} = \frac{E^2_{rms}}{R_{heater}}$$

$$E_0 \propto \text{heat} \propto \text{power}$$

$$E_0 = \frac{K \cdot E^2_{rms}}{R_h}$$

$E_{rms}$ = R.M.S value of A-C i/p

$E_0$ = o/p Volt of thermocouple

K = constant of proportionality

→ The value of k depends on the distance b/w heater & the thermocouple & also on the materials used in heater & thermocouple.

→ The i/p thermocouple is called "Measuring Thermocouple", & thermocouple in f/b path is called "Balancing thermocouple" these two thermocouples forms a balancing bridge in i/p ckt of D.C ampr.

→ when A.C i/p is applied, the measuring thermocouple produces the volt $v_1$ which upsets the balance of bridge. The D.C ampr amplifies the unbalanced volt. this amplified volt is f/b to the balancing thermocouple, which heats heater element to produce $V_2$, such that the balance of bridge is re-established.

→ Thus the d.c f/b current is the current which is producing same heating effect as that A.C i/p current i.e the d.c current is nothing but r.m.s value of i/p current. The meter deflection is thus proportional to r.m.s value of A.C i/p.

$V_o = A(V_1 - V_2)$ ∵ A → high gain of D.C. ampr

$V_1 - V_2 = \frac{V_o}{A} \simeq 0$

for balanced condn of bridge & as A is very high.

$V_1 = V_2$

∵ $V_1 \Rightarrow$ o/p of Measuring thermocouple

∵ $V_2 \rightarrow$ o/p " Balancing "

$\boxed{V_1 = K.E^2_{rms}}$

$\boxed{V_2 = K.V_o^2}$

$E_{rms}$ = R.M.S value of i/p

$V_o \rightarrow$ o/p of D.C Volt

As K is same due to same thermal environment used for two thermocouples

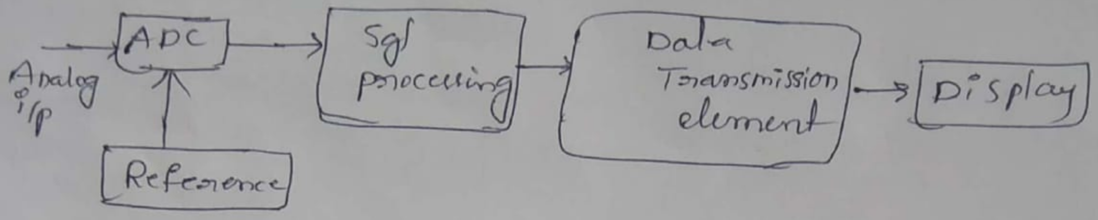
$E^2_{rms} = V_o^2$

$\boxed{V_o = E_{r.ms}}$

So, the Voltage measured by meter is r.m.s value of A.C i/p.

**Adv**: The non linear behaviour is avoided by using 2 thermocouples placed in same thermal environment.

## Basic block diagram of DVM. (Digital voltmeters)



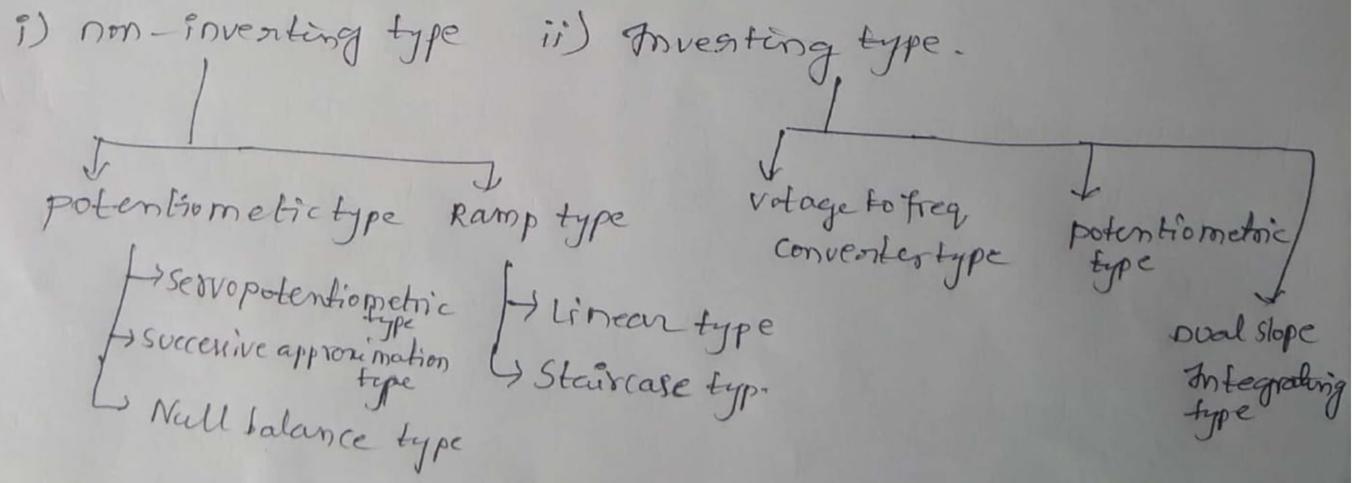
→ Any digital instrument requires analog to digital converter at its i/p.

→ Every ADC requires a reference. The ref is generated internally & ref. genr ckt'y depends on type of ADC technique used.

→ The o/p of ADC is decoded & sgl is processed in decoding stage. such decoding is necessary to drive the seven segment display. The data from decoder is then transmitted to the display.

→ The data transmission element may be latches, counters. as per requirement. A digital display shows necessary digital result of measurement

## classification of Digital voltmeters



# UNIT -II

# Signal Analyzers
# and
# Signal Generators

M.Ganesh.

# Signal Analyzers. II - unit → part-1

→ A sgl consist of a D.C component or complete A.C component (Sine wave).

→ A complex waveform is made up of a fundamental freq & its components is called harmonics.

→ A complex wave form can be split in to individual components
  ↳ fundamental freq
  ↳ no. of harmonic freqs.

→ Harmonics means it describes the distortion of Sine wave.

→ A Sinewave have only 1 harmonic.

→ * It is necessary to measure the distortion in sgls. It is also required to measure the amplitude of each harmonic or fundamental freq. The device used to measure the distortions are called "Sgl analyzers".

→ Any sgl can be analyzed in either 'Time domain' or "Freq domain".

→* The Time domain analysis of sgl can be carried out by using CRO

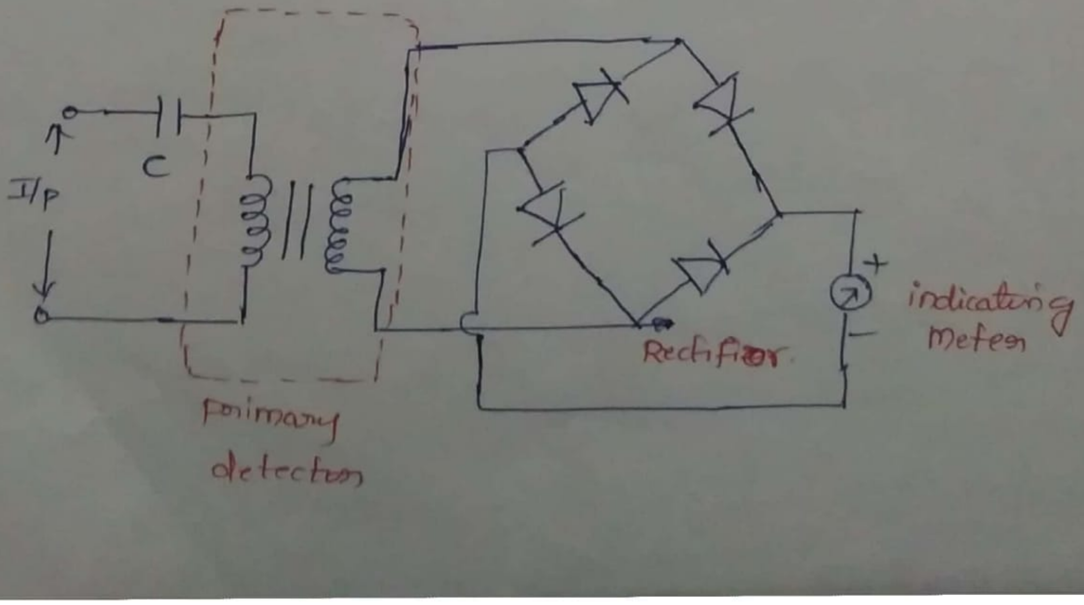
→ The freq domain analysis of sgl can be carried out by using spectrum analyzer, FFT analyzer, Vector analyzer.

* Wave Analyzer is an instrument designed to measure relative amplitude of a single freq component in complex waveform.

* Any periodic waveform can be represented as the sum of a D.C component and a series of sinusoidal harmonics. Analysis of waveform includes the determination of amplitude, freq & phase angle of harmonic components.

## Basic wave Analyzer :

↳ It consist of a primary detector which is a simple LC ckt. It is adjusted for resonance at the freq of particular harmonic component to be measured.



→ The Fullwave rectifier is used to obtain the avg value of the i/p. The indicating meter is simple d.c Voltmeter, calibrated to read peak Value of the Sinusoidal i/p Voltage.

→ The LC ckt passes only for which it is tuned. It rejects all other freq's.

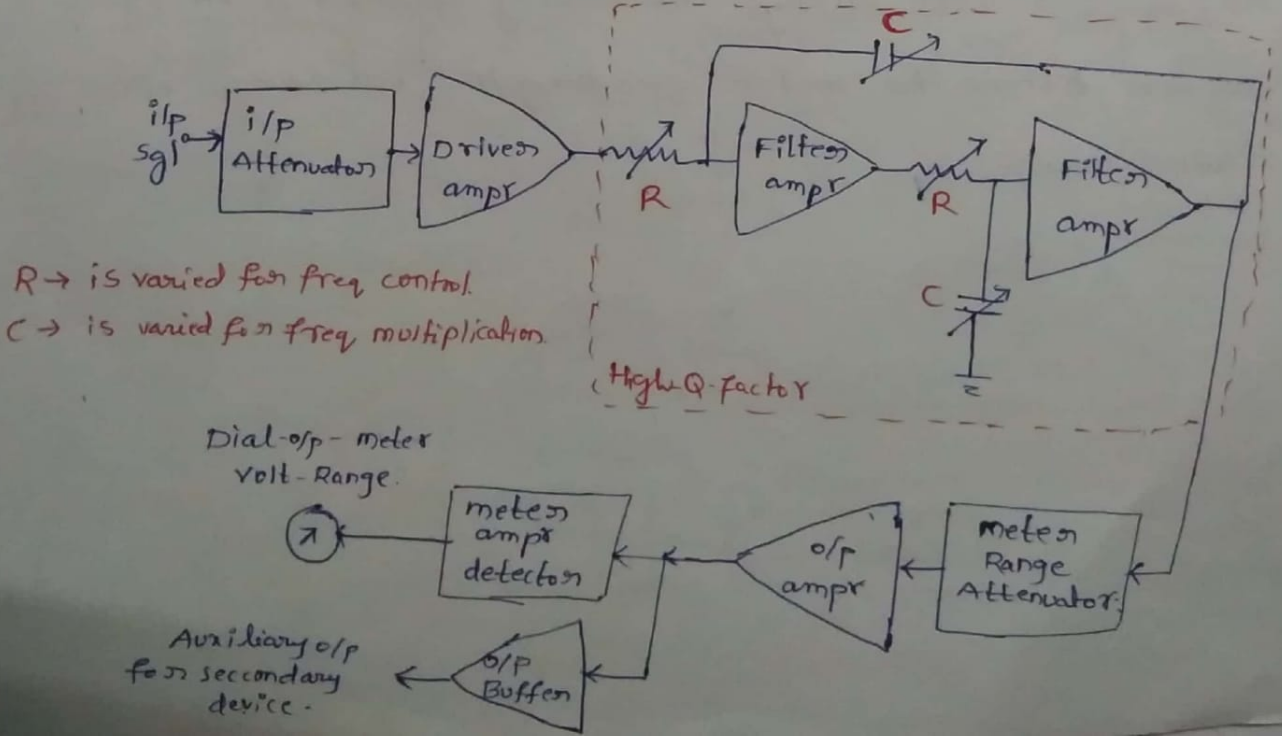
* There are two types of wave analyzers

i) Freq Selective wave Analyzer
ii) Heterodyne wave analyzer.

## ① Freq Selective wave Analyzer

→ This is used in the measurement of Audio freq range i.e from 20 Hz to 20 kHz.

→ The w.A, used for analyzing the sgls are of AF range is called Freq Selective w.A.



R → is varied for freq control.
C → is varied for freq multiplication.

The AF sgl is given to i/p attenuator.

**input Attenuator:** The AF sgl is given to i/p attenuator. if the sgl amplitude is too large, then it can be attenuated.

**Driver ampr:** It amplifies i/p sgl if required.

**High Q-filter:** It is used to select desired freq and reject unwanted freq's. It consist two RC sections & two filter amp^rs & these are cascaded with each other, we can vary capacitance values for changing the range of freq's & we can vary the resistance to change freq with in selected range.

**meter Range Attenuator:** it gets selected AF sgl as an i/p & produce an attenuated o/p when required.

**output ampr:** It amplifies the selected AF sgl if need.

**output Buffer:** It is used to provide the selected AF sgl to o/p devices. To drive the o/p devices (recorders, counters).

**meter ckt:** It displays the reading of selected AF sgl we can choose the meter reading in volt range or decibel range.

## Heterodyne wave Analyzer (RF or HF wave Analyzer)

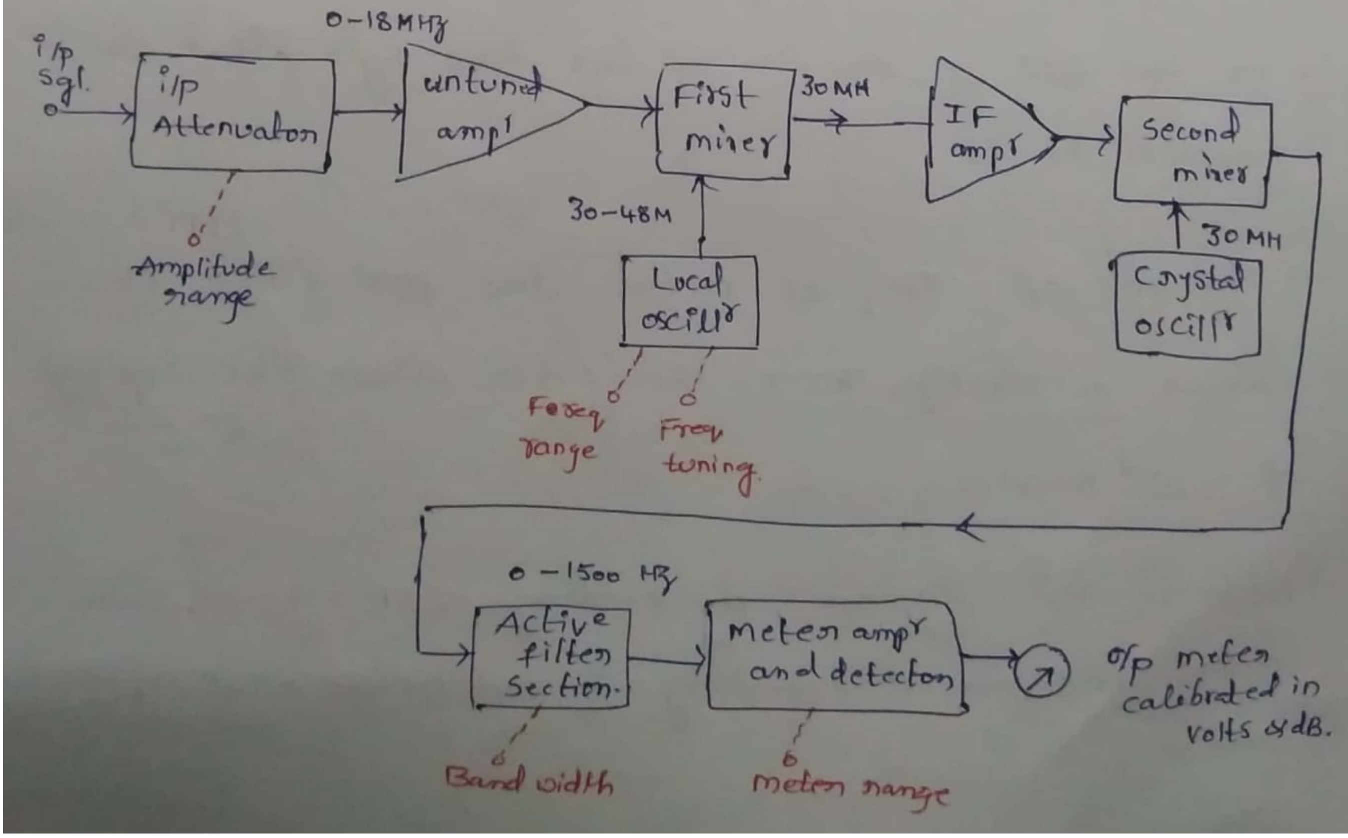
→ The w.A used to analyze the sgls of RF range or (high freq range) is called "Heterodyne wave Analyzer".

→ The RF range Analyzer works on principle of mixing. means Heterodyning.

→ Heterodyning means mixing the i/p sgl with localoscillʳ freq.

→ In this i/p sgl is heterodyned to a Higher Intermediate freq (IF) by an internal local oscillator.

→ The RF sgl, which is to be analyzed is applied to i/p attenuator



→ untuned amp^r amplifies the RF sgl whenever required and it is applied to first mixer.

→ The freq range of RF sgl & o/p of Local oscill^r are 0-18 MHZ & 30-48 MHZ. So first mixer produces an o/p which has freq of 30 MHZ. This is diff of freq's of two sgls that are applied to it

→ IF amp^r amplifies the Intermediate freq sgl. i.e the o/p of first mixer. The amplified IF sgl is applied to second mixer.

→ The freq's of amplified IF sgl & o/p of crystal oscil^r are same and equal to 30 MHZ so, the 2^nd mixer produces an o/p, which has freq of 0 HZ. This is the diff of freq's of the two sgls that are applied to it

(LPF)

→ The cut of freq of active low pass filter is choosen as 1500 HZ. Hence, this filter allows the o/p sgl of 2^nd mixer

→ meter ckt displays the reading of RF sgl. we can choose the meter reading in volt range or decibel range.

# Applications of wave Analyzer

→ To measure the harmonic distortion of an ampr.

→ It can be used to seperate and display about 50 harmonics

→ To measure relative amplitudes of single freq components in a complex waveform.

→ To measure the amplitude in the presence of noise and other interfering sgls.

→ To measure sgl energy with well defined B.W.

→ To carryout complete harmonic analysis.

→ To obtain fine spectrum analysis to display various discrete freq's & resonances, related to the motion of machines.

## Spectrum Analysis:

→ The oscilloscope is the most common device used to display the sgls, with time as x-axis, ~~it is called~~ such sgls which require time as x-axis to display them are called time domain sgls.

→ Some time it required to display the sgls in freq domain

→ Such freq domain display of sgl consist of information of energy distribution of sgl.

→ The analysis of such freq domain display of sgls is called spectrum analysis of sgl.

→ The study of energy distribution across freq spectrum of a given sgl is defined as spectrum analysis.

→ The instrument which graphically provides the energy distribution of a sgl as a function of ~~energy~~ freq on its CRT. is called "spectrum analyzer"

* The spectrum analysis of a sgl provides the information about following things.

i) The measurement of freq & its response
ii) The component levels
iii) Bandwidth
iv) Freq stability
v) Harmonic & intermodulation distortion.

(vi) special purity

(vii) modulation index and attenuation

→ The spectrum Based on instrumentation limitations the spectrum analysis is devided into two types

i) Audio Freq (AF) analysis

ii) Radio freq (RF) analysis.

↳ The RF Spectrum analysis covers a freq range of 10 MHZ to 40 GH. used in Radar, Navigation, comm$^n$, & Indutrial instrumentation freq bands.

## Spectrum Analyzer:-

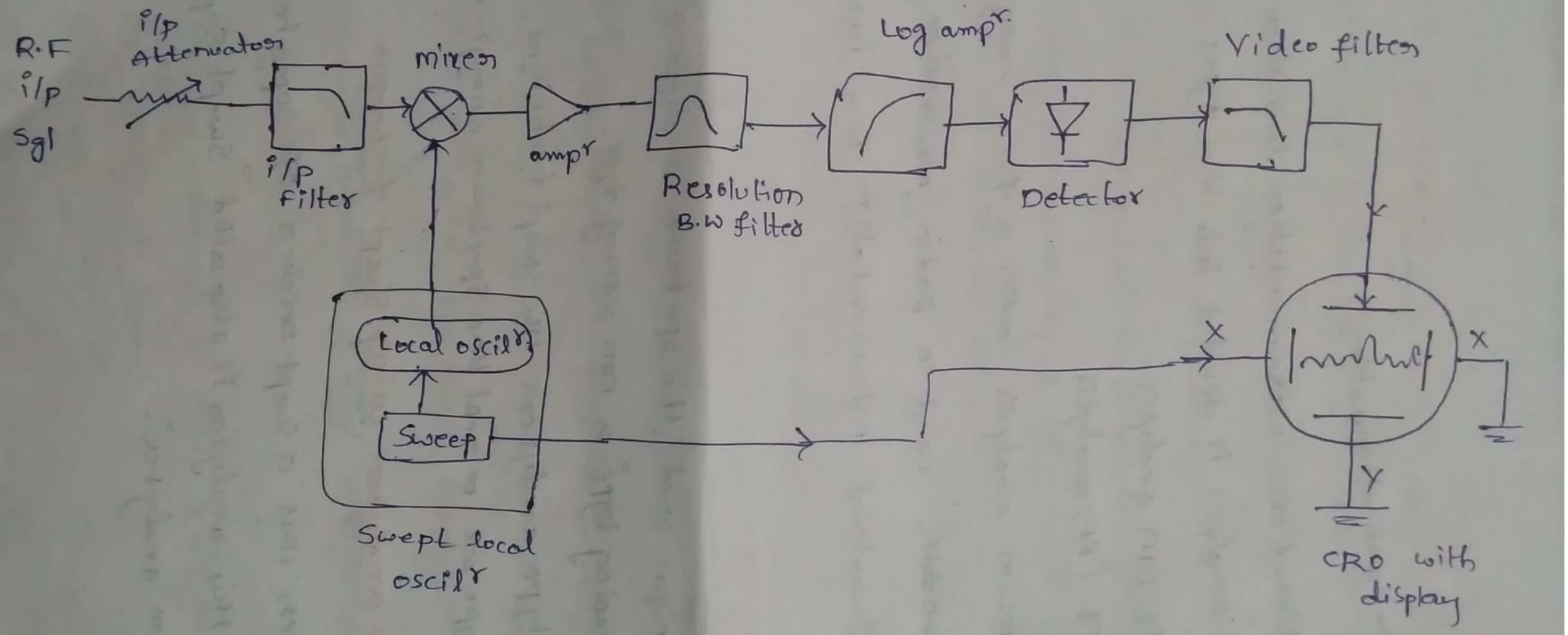
↳ Based on technique used, the spectrum analyzers can be classified as "scaning type" & non scaning type.

→ The scaning type analyzers use swept technique, & non scaning type are real time Spectrum analyzers.

## Basic spectrum analyzer using swept technique

→ This analyzer uses a Swept receiver of super heterodyne type hence this analyzer is also called "Swept Superhetero-dyne spectrum analyzer".

→


R.F
i/p
Sgl
i/p
Attenuator
i/p
Filter
mixer
ampr
Resolution
B.W filter
Log ampr.
Detector
Video filter
Local oscilr
Sweep
Swept local
oscilr
X
X
Y
CRO with
display

The basic blocks of this Swept superheterodyne SP-A. are

① wideband i/p mixer

② Swept local oscill^r driving wideband mixer

③ Resolution B.w filter, deciding intermediate freq.

④ Detector and video filter

⑤ Display.

→ The RF i/p is applied to an i/p attenuator

→ The i/p attenuator decides the level of i/p sgl, as to Keep it with in operating range of other blocks of instrument.

→ power handling range of i/p attenuator is 0.5 to 1W and this limits max i/p level.

→ The i/p filter is used to reject unwanted sgls.

→

→ The wide band i/p mixer multiplies the i/p sgl from filter and local oscil^r sgl. It provides 2 sgls at the o/p which are proportional in amplitude to the i/p sgl

- But having freq's which are sum and diff of freq's of i/p sgl and local oscil$^{r}$ sgl. This is b'coz i/p filters rejecting unwanted sgls are difficult to realize in practice.

Intermediate freq Section:

→ The stage function is to provide a wide ~~range~~ selection of resolution B.W filters. these filters are described by their 3-dB B.W. these filters decide the resolving power of analyzers.

→ Generally the filters are tuned to a narrow band of 2 GH & the i/p sgls which are seperated from the local oscill$^{r}$ freq 2 GHz only are converted to the IF band.

→ The o/p of filter given log amp$^{r}$. It process the incoming sgl in a logarithmatic fashion. it allows a large incoming sgls to be measured and compared.

→ The detector used in the analyzer is a linear envelope detector. this is similar to the detectors used in A.M. radios

→ The detector receives a sgl from log amp$^{r}$ which is compressed one. This releases the large linear range requirement of detector.

→ The detector o/p is given to video filter. These filters are used to post filtering the detector o/p. The B.W setting of video filter is same or larger than resolution B.W filter.

→ If sgl is along with noise, avg'g is need & Avg'g removes the random noise and pure sgl remains.

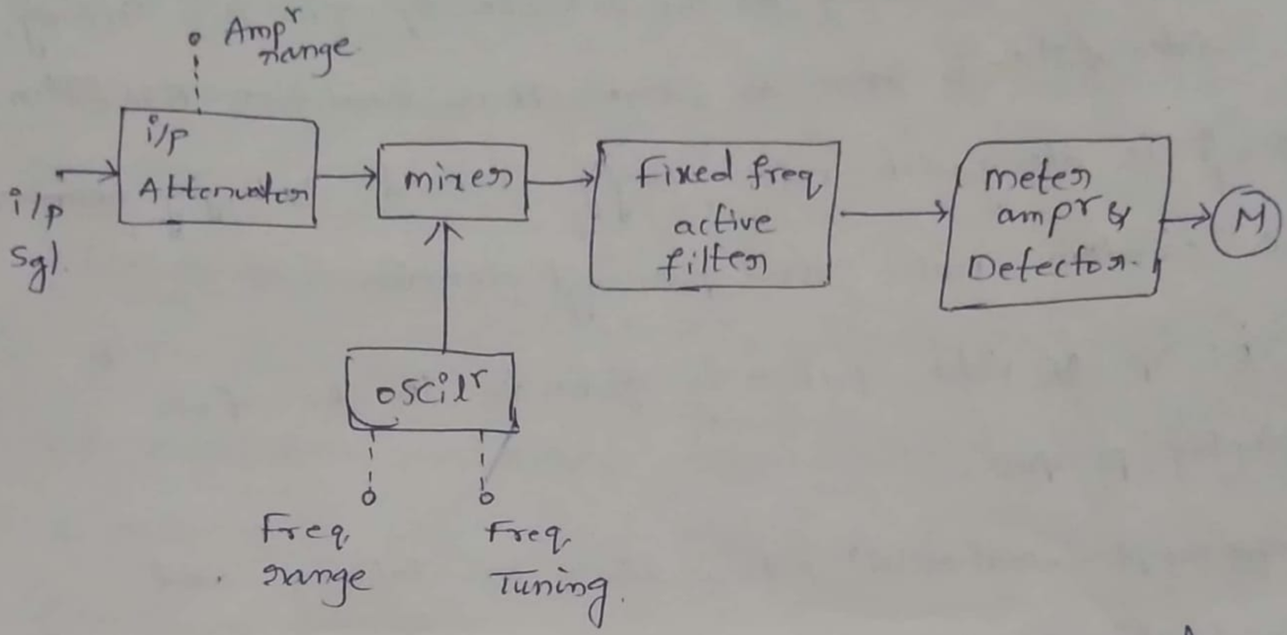
→ The o/p of video filter is given to the CRO for display purpose.

→ The swept local oscill^r puts a limit on Stability and Spectral purity in many Performance areas

→ The ideal local oscill^r is exactly Stable without freq Modulation

→ The stability of local oscill^r is set using no. of methods such as discriminator loops, phase locked loops, and freq locked loops

# Heterodyne Harmonic Distortion Analyzer.



→ In this Highly Selective, fixed freq filter is used.

→ The variable freq oscilr o/p is mixed with each harmonic of the i/p sgl, with the help of balanced mixer, either sum or diff freq is made equal to the freq of the filter.

→ The quartz crystal type highly selective filters can be used as each harmonic freq is converted to a constant freq. this allows to select constant freq sgl related to a particular harmonic and pass it to the metering ckt.

→ The balanced mixer consist of a balanced modulator & it eliminates original freq of the harmonic.

→ Generation of low harmonic distortion is the adv of the balanced modulator. In some cases the meter reading is calibrated directly interms of voltage, in some cases, the ~~meter reading~~ harmonics are compared with a ref volt, which is rep^n of fundamental component.

→ They are also called freq selective voltmeters

→ These instruments are also called carrier-freq voltmeters & Selective level voltmeters.

→ It calculate the total harmonic content of a Sinwave with some distortion

## Distortion Analyzer :

→ The application of purely sinusoidal i/p sgl to an amp^r should result in purely sinusoidal sgl at o/p . But practically o/p waveform is not exact replica of the i/p

→ This is because of presence of various types of distortions (due to inherent nature of amp^r or nonlinear char's of various components used).

→ The distortion caused due to non linear behaviour of the ckt elements is called "Harmonic distortion"

→ In case of sinewave which is harmonically distorted, it consist of a fundamental freq f & harmonic multiples of fundamental freq 2f, 3f -- etc

→ The distortion repd by particular harmonic is is ~~so~~ the ratio of the amplitude of harmonic to the amplitude of fundamental freq

$$D_2 = \frac{B_2}{B_1} \quad , \quad D_3 = \frac{B_3}{B_1}$$

$$D_n = \frac{B_n}{B_1}$$

$D_n$ → distortion of $n^{th}$ harmonic

$B_n$ → amplitude of " "

$B_1$ → " " fundamental freq component.

"Total harmonic distortion" or distortion factor is

- $$T.H.D = \frac{\left[\Sigma (\text{Harmonics})^2\right]^{1/2}}{\text{fundamental}}$$

$$T.H.D = \frac{\sqrt{B_2^2 + B_3^2 + \cdots}}{B_1} = \sqrt{\left(\frac{B_2}{B_1}\right)^2 + \left(\frac{B_3}{B_1}\right)^2 + \cdots}$$

$$T.H.D = \sqrt{D_2^2 + D_3^2 + D_4^2 + \cdots}$$

⇒ using fundament suppression Distortion Analyzer we can find total distortion, and not individual distortion components.

→ using Heterody Harmonic distortion analyzer we can find individual distortion components

## Standing wave ratio: (SWR)

→ It is important term related to the transmission line, it is important design parameter in the design of antena, as most of antena's are fed by the $T_x^n$ lines.

→ $T_x^n$ line is considered as a chain of symmetrical N/w's connected in cascade. The important property of such symmetrical N/w's is the charic impedence $(Z_0)$.

→ The SWR is defined as the ratio of max amplitude of voltage or current to the min amplitude of voltage or current

$$SWR = \left|\frac{V_{max}}{V_{min}}\right| = \left|\frac{I_{max}}{I_{min}}\right|$$

→ The ratio of max amplitude of Volt to min amplitude of volt is called "Voltage Standing wave Ratio" (VSWR).

$$VSWR = \left|\frac{V_{max}}{V_{min}}\right|$$

→ The ratio of max amplitude of Current to min amplitude of current is called "Current Standing wave ratio" (ISWR)

$$ISWR = \left|\frac{I_{max}}{I_{min}}\right|$$

→ If $P_f$ is forward power from the i/p side to the o/p side & $P_R$ is power reflected back from o/p side to i/p side, then SWR is given by

$$SWR = \frac{1+\left(\frac{P_R}{P_F}\right)^{1/2}}{1-\left(\frac{P_R}{P_F}\right)^{1/2}}$$

→ The SWR in terms impedence

$$SWR = \frac{Z_0}{Z_L} \quad (\text{if } Z_0 > Z_L)$$

$$= \frac{Z_L}{Z_0} \quad (\text{if } Z_0 < Z_L)$$

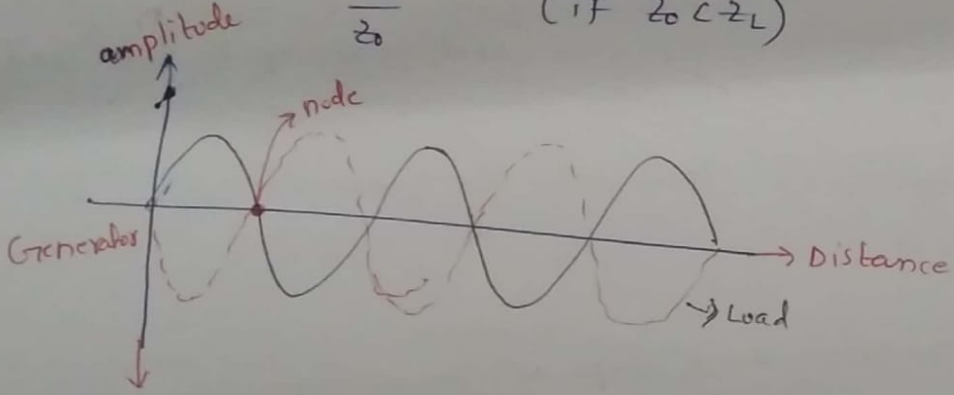
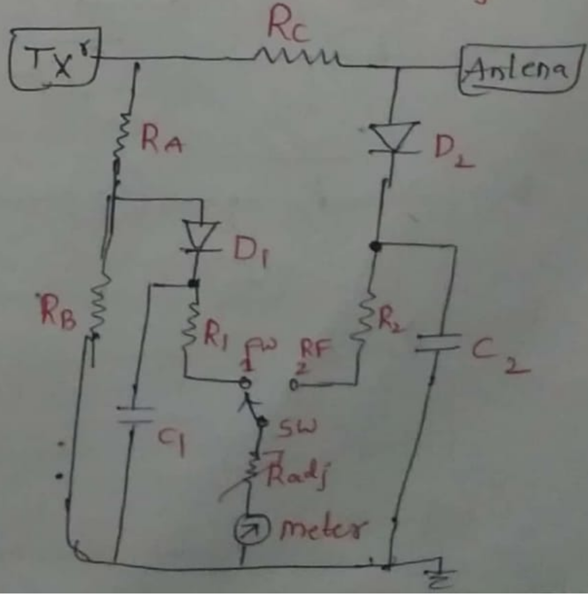


fig: Formation of standing waves

→ In Radio Engineering & Telecomm^ns, SWR is a measure of impedence matching of loads to the charc^s impedence of Tx^n line or wave guide.

fig Bridge type SWR using wheatstone bridge



## Power Analyzer :

→ In modern industrial applications, the no. of electronic appliance are connd to the A.c line, b'coz of no. of appliance connected to single A.C. line, the i/p connected to every device clean study of sinusoidal with constant amplitude.

→ Hence when any device does not work properly, it is necessary to check the quality of i/p power supplied to that device.

→ IEC-1000-3-standard deals with allowable interference level caused by an electrical appliance that works up to 16A load.

→ IEC-1000-3-2 standard deals with the harmonic currents caused by appliance.

→ This standard provides indication of power problems caused by the appliance.

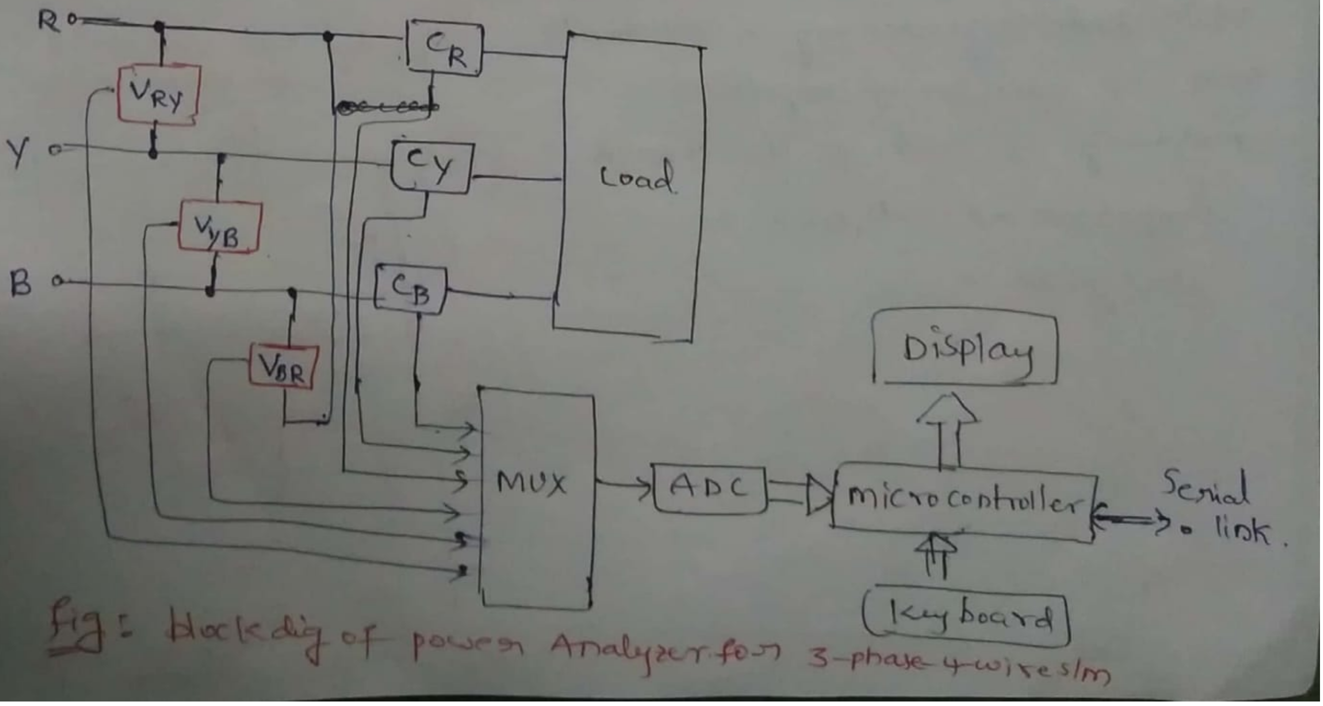


fig: block dig of power Analyzer for 3-phase 4-wire s/m

→ It is a 3-phase - 4-wire s/m of supply.

→ In each line, line voltages are sensed using sensors

→ The line currents are sensed by using sensors $C_R, C_Y$ & $C_B$ while the line voltages are sensed by using sensors $V_{RY}, V_{YB}, V_{BR}$. These - sensed currents & voltages are selected sequentially by mux. The mux combines all above analog sgls in to a ~~signal~~ single channel.

→ The o/p mux is connected to the analog to Digital converter (ADC)

→ The ADC gets converted to digital sgl. Such digital sgl is given to microcontroller.

→ According to program stored in memory of micro controller desired computations & calculations are done by micro controller.

→ The calculated quantities are displayed using display unit

→ The power analyzer measures all line currents & line voltages at set sampling rates, it can also calculates power & related quantities & can carryout harmonic analysis of voltages & currents

→ According standards the supply freq ~~mo~~ may be 50H or 60HZ

→ most commonly used power supply is 3-phase, 4-wire s/m

→ for each s/m, 3-lines currents, 3-line voltages are sensed

→ for 3-phase - 3-wire s/m → 2 line currents, 2-line voltages are used

→ for single phase power analyzer & only one current & one voltage line is sufficient for analysis

## Features of power Analyzer

→ It can be used in either single phase ckt or 3-phase ckt

→ when P.A used in A.C ckts, the most commonly used voltage & current sensors are potential transformers & current transformers.

→ The Current Transformers are used with 5A rating.

→ According to the requirement, the normal voltages of 110V, 220V, 440V can be used in different application areas.

→ The power analyzer can be analyze up to almost 50th harmonic with 50H supply. so the highest freq that can be accomodated is 2500HZ. Hence as freq of measurement increases, the no. of harmonics decreases

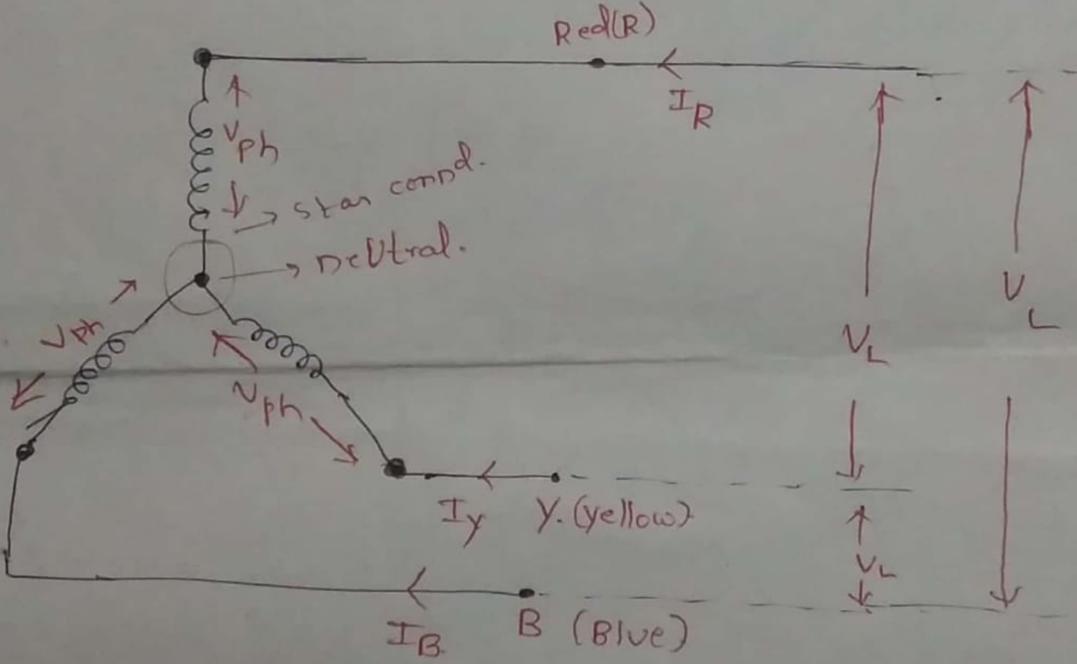
## capacitive Voltage Analyzers (C-V Analyzers).

The C-V Analyzers are specially used to measure & analyze the capacitance Vs voltage (C-V) and capacitance vs time (C-t) char's of special Semiconductor devices like p-n Jn diodes, shottky diodes, FET's, memory cells, (CCDS) charged-coupled devices.

→The char'cs of such devices can be tested using a high freq sgl of 100k or 1mH.

→Using C-A (or) meter, the C-V & C-t char'cs are obtained for the semiconductor devices, can be used to determine the s.c device doping profiles, oxide, char'cs density of mobile ions, Threshold Voltage.

## 3-phase-4-wire star connected system (power Analyzer)



→ Nutra point carries no current to balance the s/m.

→Sum of all currents $I_R + I_y + I_B = 0$

→$V_{ph}$ → is volt across the individual winding → phase volt
is volt b/w one phase & nutral point.

* Line volt b/w two lines = 3 times of phase volt

$V_L = 3 V_{ph}$

→ In star connection the line volt b/w two line terminals is 3 times of phase voltage.

* $I_R = I_y = I_B = I_L$

$I_L$ → line current → current flowing through any line.

$V_{Ry} = V_{YB} = V_{BR} = V_L$ (line volt) → volt b/w two lines.

# SIGNAL GENERATORS

II-unit

→ "sgl generator" provides variety of different sgls for testing various electronic ckts at low powers.

→ "sgl generator" is an instrument which provides several different o/p waveforms including sine wave, square wave, triangular wave, pulse train & amplitude modulation wave form.

→ In different instrumentation s/ms, the sgl at audio freq as well as at Radio freq are required.

→ In general the sgl at particular freq is generated using an oscillator, which provides fixed freq sgl.

→ The oscilr provides only sinusoidal o/p sgl with either fixed or variable freq, & the sgl generator can be described as an instrument capable of providing different types of o/p sgl such as sinesoidal, square, trianguelar, modulated waveforms.

→ Eventhough such instrument is called generator, no energy is created but only the d.c sgl is converted to A.c sgl. at required freq.

→ The AF & RF sgl generators are providing the sgl s for general test ~~process~~ purpose. These two are generally designed to cover a wide freq band from few Hz to several GHz.

## * freq Band limits:

| Band | Range: |
|---|---|
| Audio freq (AF) → | 20Hz – 20 kHz |
| Radio Freq (RF) → | Above 30 Hz |
| Very Low freq (VLF) → | 15 – 100 KHz |
| Low freq (LF) → | 100 – 500KHz. |
| Broad cast → | 0.5 to 1.5 MHz |
| Video → | 0 – 5 MHz |
| High freq (HF) → | 1.5 – 30 MHz |
| Very High freq (VHF) → | 30 – 300 MHz |
| Ultra High freq (UHF) → | 300 – 3000 MHz |
| Micro wave → | Beyond 3GHz |

## Requirements of Laboratory type sgl generator:

→ The o/p freq of sgl generator should be very stable.

→ The amplitude of o/p sgl must be stable.

→ The ~~o/p o~~ harmonic of o/p contents in the o/p should be as low as posible. The o/p sgl should be distortion free.

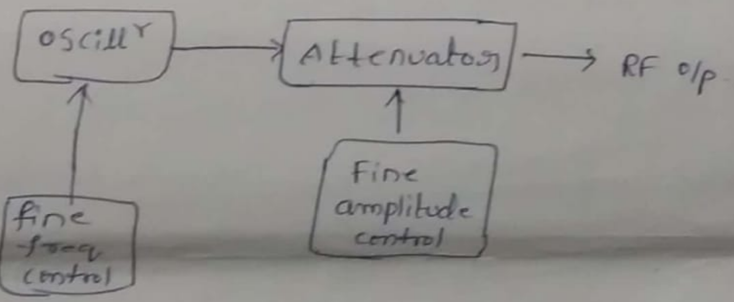
→ The sgl generator should provide low spurious o/p, means effect of noise, jitter & modulation should be negligible

## Standard Sgl generator:

→ most of measurement & instrumentation s/m s , the i/p sgl is required is sinusoidal sgl. ~~A~~ such sgl is generated by using an oscillator.

→ An oscil$^{r}$ is a ckt that generates a sinusoidal sgl with constant amplitude & constant desired freq using positive f/b

→ So oscil$^{r}$ is acts a sgl generator, which generates o/p using +ve f/b



→ It consist two main blocks → ① oscillator
① Attenuator.

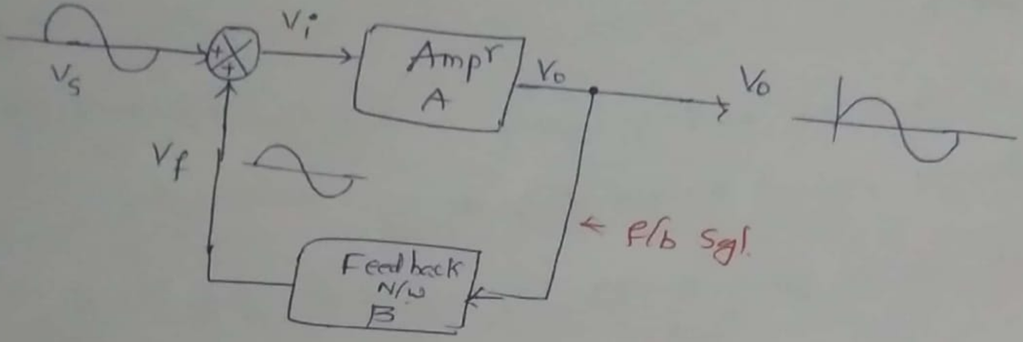
→ oscillator uses active operational amp$^{r}$ , the o/p of amp$^{r}$ is feed back in phase with i/p. , this +ve f/b causes regenerative action resulting an oscillator

→ Attenuator provides amplitude control , which reduces or attenuates the power level of sgl

→ The proper functioning of Sgl gener$^{r}$ depends on performance of an oscil$^{r}$ & attenuator.

# Basic Theory of oscillator:

→ consider non-inverting ampr with the voltage gain 'A'



positive f/b

→ The i/p sinusoidal sgl (voltage) $V_s$ is applied to the ckt

→ As ampr is non inverting, the o/p volt $V_o$ is in phase with i/p sgl $V_s$. the part of o/p is fed back to i/p with help of f/b N/w, how much part of o/p is to be fed back, gets decided by f/b N/w gain β.

→ Hence the f/b volt $V_f$ is in phase with the i/p sgl $V_s$, As phase of f/b sgl is same as i/p applied, the f/b is called "positive f/b"

→ ~~The gain~~ The ampr gain 'A' → it amplifies its i/p $V_i$, A times to produce o/p $V_o$.

$$\Rightarrow A = \frac{V_o}{V_i}$$ → This is called open-loop gain of ampr.

The gain $A_f = \frac{V_o}{V_s} \rightarrow ①$

↳ The f/b is +ve & voltage $V_f$ is added to $V_s$ to generate i/p of ampr $V_i$. So

$$V_i = V_s + V_f \quad —②$$

↳ And the $V_f$ is depends on f/b element β, So

$$V_f = \beta V_o$$

$$V_i = V_s + \beta V_o \rightarrow ③$$

$$V_s = V_i - \beta V_o \longrightarrow ④$$

from eqn ① $A_f = \frac{V_o}{V_s} = \frac{V_o}{V_i - \beta V_o}$

$$A_f = \frac{V_o/V_i}{\frac{V_i - \beta V_o}{V_i}} = \frac{V_o}{1 - \beta \cdot \frac{V_o}{V_i}}$$

But we know

$$A = \frac{V_o}{V_i}$$

$$\boxed{A_f = \frac{V_o}{1 - A\beta}}$$

↳ The above eqn shows, the gain with f/b increases as the amount of +ve f/b increases.

~~Types of oscillators~~

→ This indicates that ckt can produce o/p without external i/p ($V_s = 0$), just giving the part of the o/p as its own i/p.

→ Thus without an i/p the o/p will continue to oscillate whose freq depends on f/b N/w or ampr or both. . Such ckt is called oscillator.

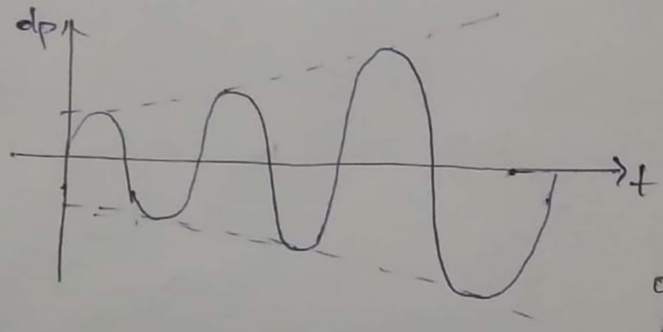
→ The β is always a fraction & hence $\beta < 1$.

→ So the f/b N/w is an attenuation N/w. To start with oscillations $A\beta > 1$, but the ckt adjusts itself to get $A\beta = 1$, when it produces sinusoidal oscillations while working as an oscillator.

## Types of oscillations:

### ① Growing type oscillations:

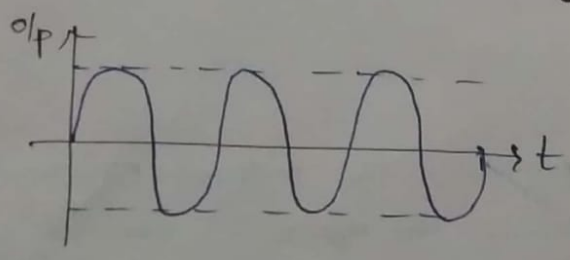
$|A\beta| > 1$



→ when total phaseshift around loop is 0° or 360° & $|A\beta| > 1$ then o/p oscillates but oscillations are growing type. the o/p oscillations are goes in increasing.

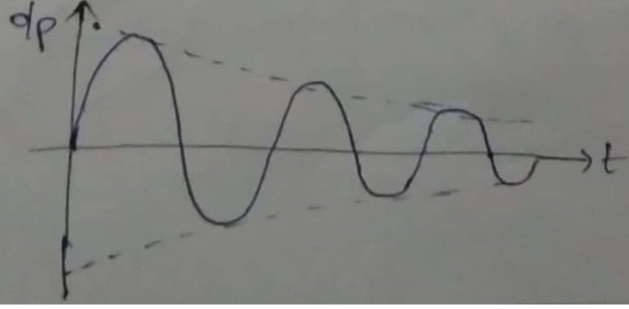
### ② Sustained oscillations:

$|A\beta| = 1$



→ when total phaseshift around loop is 0° or 360° then oscillations are with constant amplitude & constant freq.

### ③ Exponentially decaying oscillations: $|A\beta| < 1$



→ when total phase shift around loop is 0° or 360°, then total oscillations are decaying type.

→ amplitude is decreasing exponentially.

## A.F. Signal Generators :

→ The sgl generators which provides sinusoidal waveform in the freq range of 20H - 20KH are called A.F. sgl. gen$^{r}$s.

→ Depending on load the o/p impedence is select either 50Ω or 600Ω

→ In practical to generate A.F sgls RC f/b oscil$^{r}$s are used.

→ The most commonly used RC f/b oscil$^{r}$s are wien Bridge oscil$^{r}$ & RC phase shift oscil$^{r}$

### ① wein Bridge oscillator: (W.B.O)

→ In general in the oscill$^{r}$, an amp$^{r}$ provides 180° phaseshift & f/b N/w provides additional 180° phaseshift to obtain a phase shift of 360° (2π) around loop. This is req$^{d}$ condition for any oscil$^{r}$.

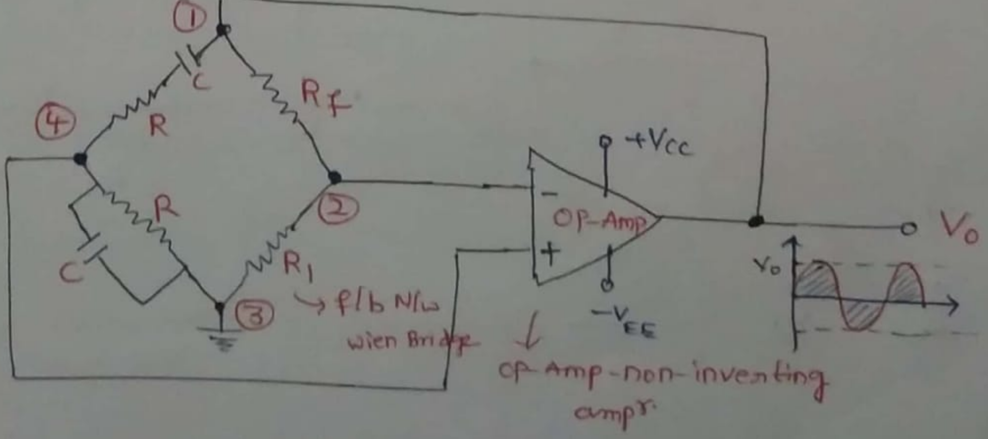
→ But W.B.O uses non-inverting amp$^{r}$ & hence does not provide any phase shift during amp$^{r}$ stage. As total phase shift reqd is 0° or 2π radians, in W.B.O$^{r}$ types no phase-shift is necessary through f/b, thus total phase shift around loop is 0°

Adv ① The o/p is perfect sine wave

② low distortion & good freq stability

③ Has wide freq range

④ diff freq ranges can be obtained easily.



→ The gain of amp^r is adjusted by using $R_f$ & $R_1$ ⇒ $A = 1 + \frac{R_f}{R_1}$

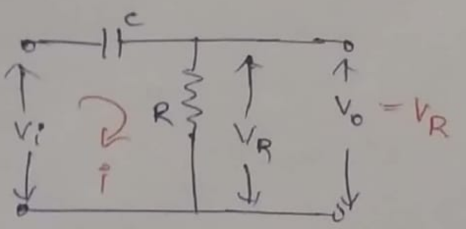
* sp

## Rc phase shift oscillator :

→ Rc phase shif oscil^r basically consist of an amp^r & f/b N/w. ~~Amp^r &~~ f/b N/w consist of Resistors & capacitors arranged in laden fasion

→ To understand the operation of this oscil^r first we know the "Rc ckt."

① Rc ckt :

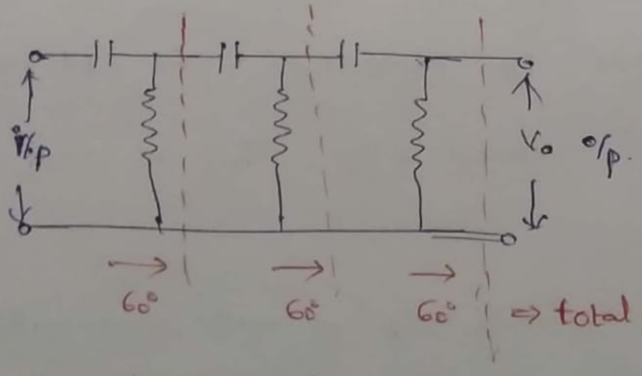


$$X_C = \frac{1}{2\pi f_c}$$

$$V_o = V_R = IR$$

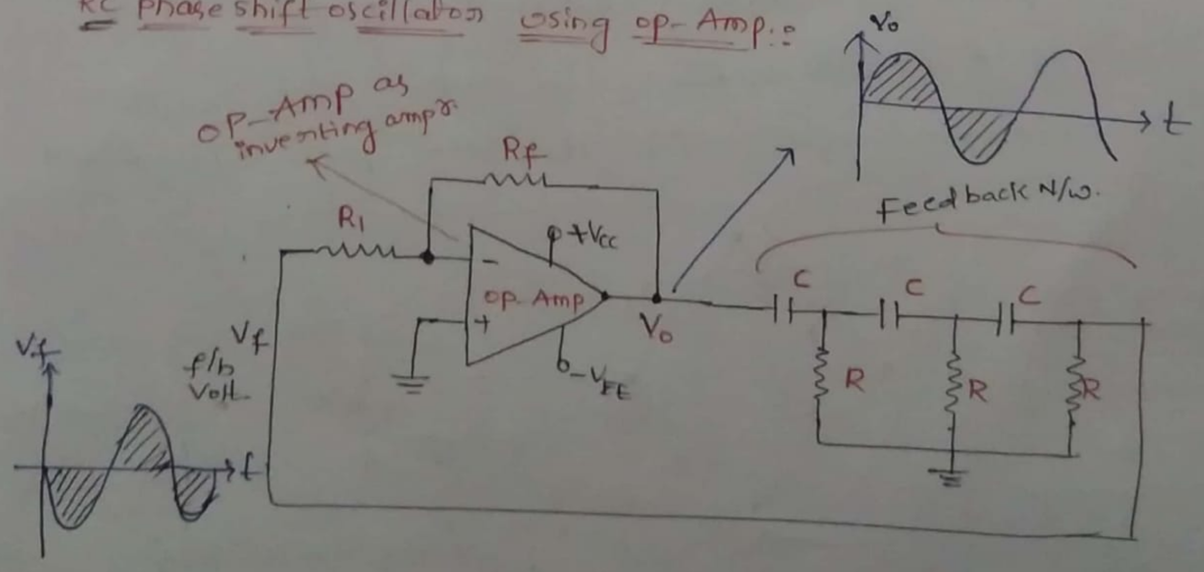
$$V_C = I \cdot X_C$$

② f/b N/w in RC phase shift oscil^r :



⇒ total = 180° phase shift

## Rc phase shift oscillator using op-Amp :



## Heartly oscill$^r$s

③

→ RC phase shift oscil$^r$ using op-Amp uses op-amp amp$^r$ in inverting mode

→ Thus it gives 180° phase shift b/w i/p & o/p

→ The F/B N/w consist 3 RC sections, each producing 60° phaseshift → Total = 180° phase shift

→ The o/p amp$^r$ is given to F/b N/w.

→ The o/p of feedback network drives the amp$^r$.

→ The total phase shift around loop is 180° of amp$^r$ & 180° due to 3 RC sections. thus 360°.

→ this satisfied reqd condition for +ve f/b & ckt acts as an oscil$^r$.

$$f_0 = \frac{1}{2\pi\sqrt{6}RC}$$

**Adv** → ckt is simple to design.

→ it is a fixed freq oscil$^r$.

## Specifications of A.F. sgl gen$^r$s.

① freq range from 10H - 1MH, freq is Variable over 10K. continously

② The amplitude of Sine wave o/p can be Varied from 5mv - 5V (rms)

③ The amplitude of square wave o/p can be Varied from 0 - 20V (peak).

④ The square wave symmetry is adjustable from 30% to 70%.

⑤ At 220 V, 50 HZ, AF sgl gen$^r$ requires 7w power

⑥ The o/p is taken from pushpull amp$^r$ with low o/p impedence of 600 Ω

## Radiofreq (RF) Sgl generators

→The sgl generators which provide sinusoidal waveforms above 20KH are called R.F. sgl generators.

→ The main diff b/w A.F sgl gen^rs & R.F. sgl gen^rs is, that the elements used in the f/b N/w.

→ In A.F sgl gen^r, oscil^r uses RC f/b N/w, while R.F sgl. gen^r uses LC F/b N/w.

↳ The oscil^r which use elements L & C to produce oscillations are called LC oscil^ns.

→ The ckt using elements L & C are called Tank ckt (or) oscillatory ckt (Resonating ckt or tuned ckt).

→ These oscil^rs are used for high freq range from 200K - GHz

## Basic form of LC oscil^r ckt:

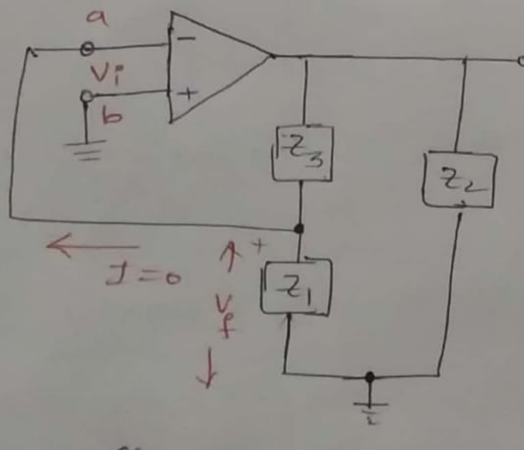


Fig: Basic ckt

→ LC tuned ckt forms the f/b N/w while an op-amp, FET or BJT can be active device in the amp^r stage.

→ gain of amp^r is Av.

→ The amp^r o/p feeds the N/w consisting impedences $Z_1, Z_2$ & $Z_3$.

## Heartly oscil$^{r}$ :

→ This LC oscillator uses two inductive reactances & one capacitive reactance i.e $X_1$ & $X_2$ and inductive $X_3$ capacitive in the tank ckt which acts as a f/b ckt

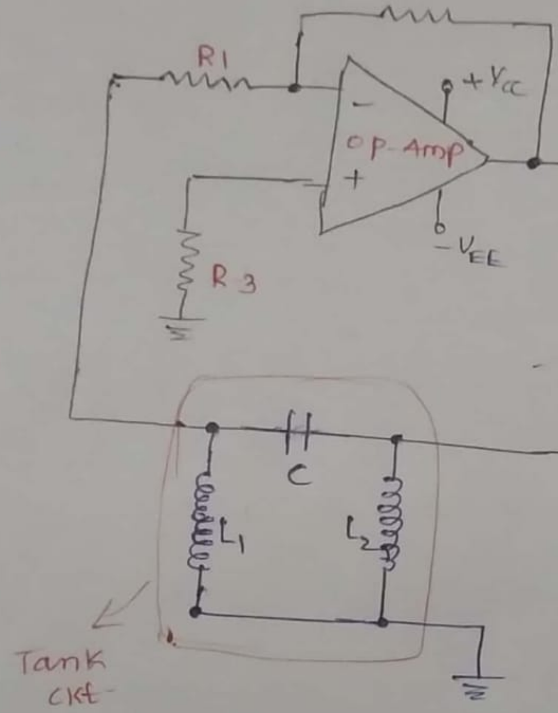


Fig : Heartly oscil$^{r}$ using op-Amp.

$$\boxed{f = \frac{1}{2\pi\sqrt{C L_{eq}}}}$$

$$L_{eq} = L_1 + L_2$$

or

$$\boxed{L_{eq} = L_1 + L_2 + 2M}$$

Amp$^{r}$ gain $A_V = \frac{L_1}{L_2}$

## Colpitts oscil$^{r}$ :

→ An LC oscil$^{r}$, which uses 2 capacitive reactances & one inductive reactance in f/b n/w is called "coll pits oscil$^{r}$"

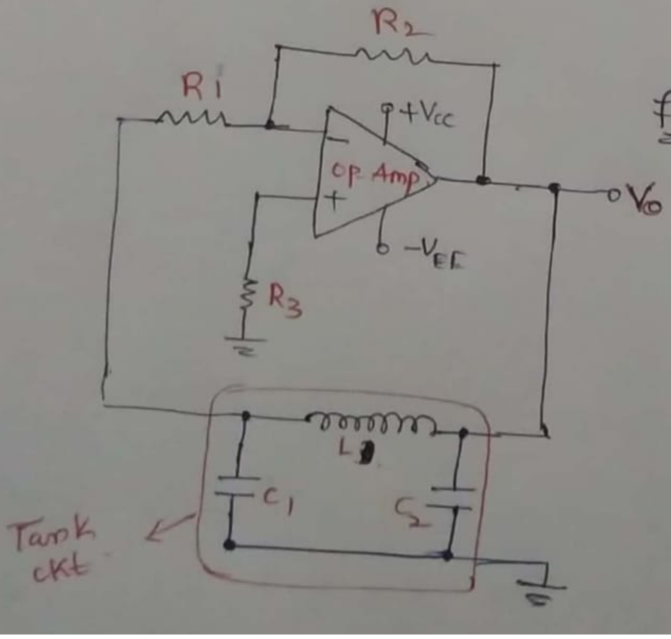


fig : collpits oscil$^{r}$ using op-Amp.

$$\boxed{f = \frac{1}{2\pi\sqrt{L C_{eq}}}}$$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

## ∴ Audio Freq (A.F) Sine & Square wave generator :

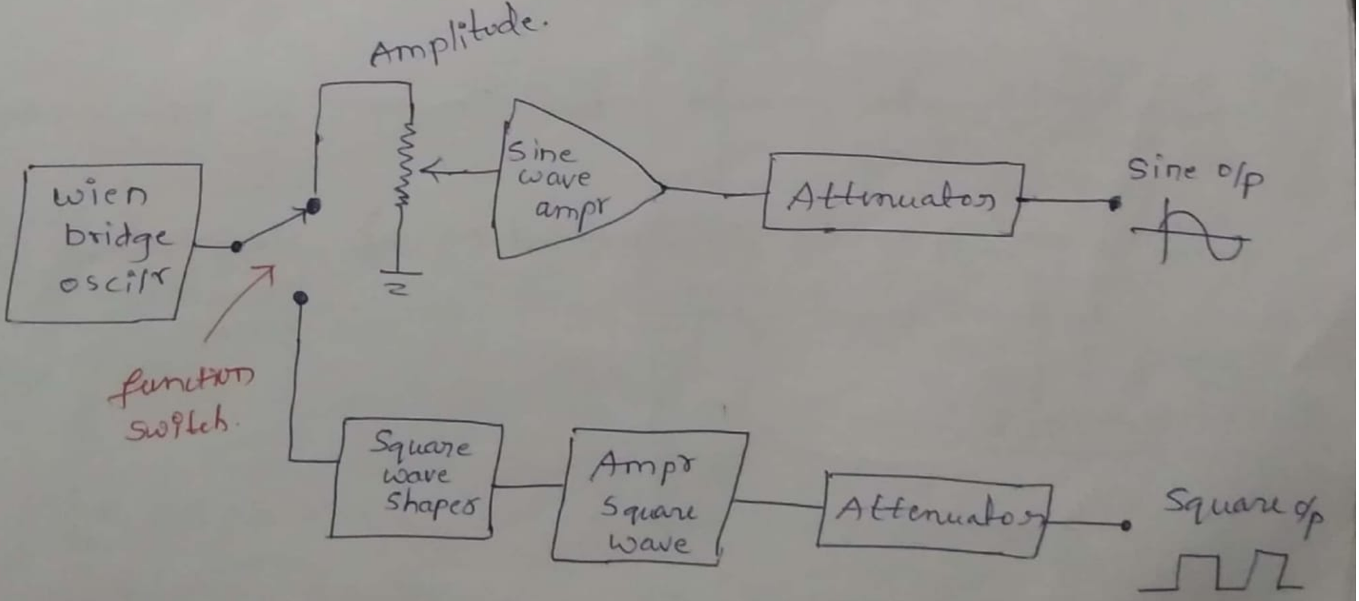
→ In this we have wien-Bridge oscill^r is used.

→ The wein bridge oscil^r is the heart of an AF sine-square wave generator.

→ Depending on the position of switch, we get o/p as square wave o/p or Sinewave o/p.

→ Depending on the position of switch, it is switched to ckt.

→ In the square wave generation section, the o/p of wien bridge oscill^r is fed to square wave shaper ckt which uses schmitt trigger ckt.



→ The attenuators in both the sections are used to control o/p sgl level. Before attenuation, the sgl level is made very high using sine wave ampr & square wave ampr.

## front panel controls:

① Freq Selector: Selecting freq in diff ranges.

② Freq multiplier: it selects the freq range ~~from~~ more than 5 decades from 10 Hz – 1MHz
10k

③

③ Amplitude multiplier: it attenuates sine wave

④ Variable Amplitude: it attenuates the sine wave amplitude continously

⑤ Symmetry control: it varies the Symmetry of Square wave from 30% to 70%.

⑥ Amplitude: It attenuates square wave amplitude continously

⑦ function switch It selects mode required either sine wave o/p or square wave o/p.

⑧ o/p variable: It provides actual sine wave or square wave o/p

⑨ Sync: It provides synchronisation of the internal sgl with external sgl

⑩ ON-OFF Switch:

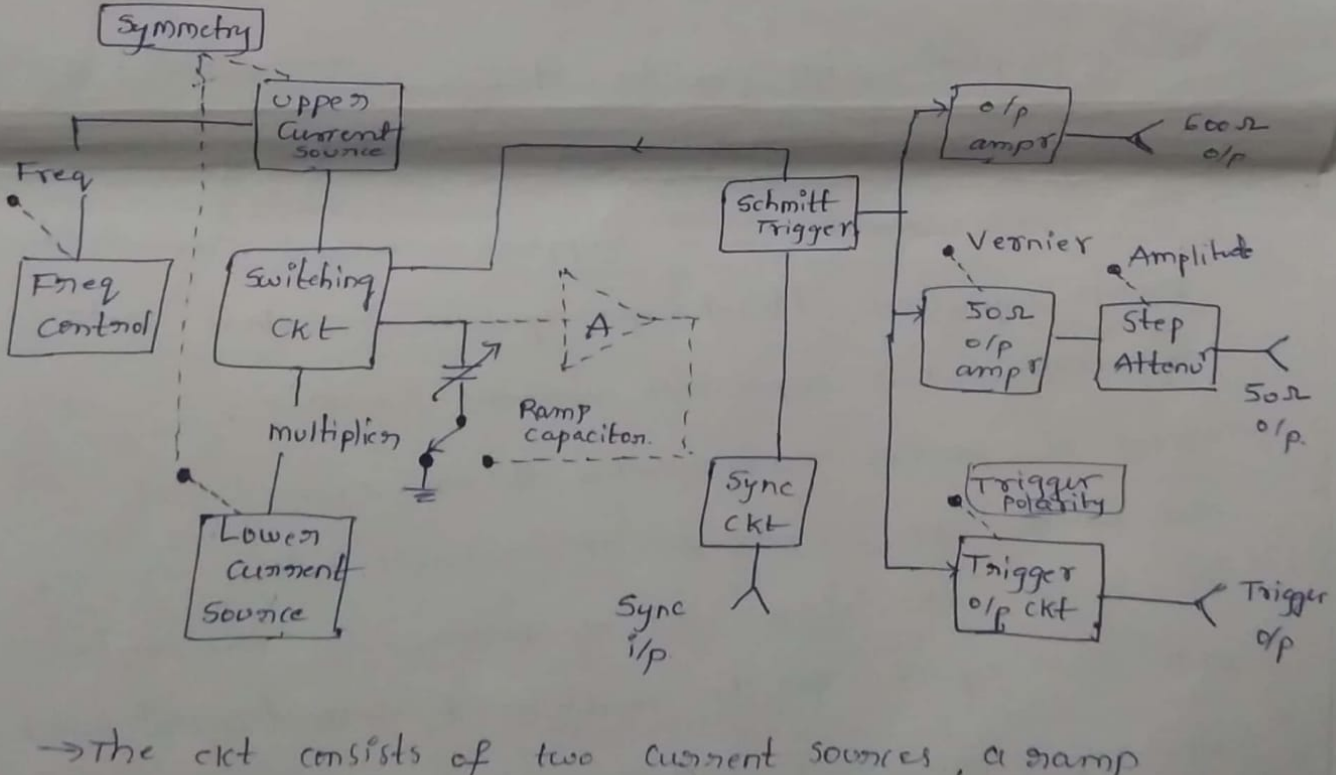
∴ Square and pulse generator.

→ The generators are used as measuring devices in combination with a CRo.

→ The fundamental diff b/w a pulse generator and a square wave generator is in the duty cycle

$$\text{Duty cycle} = \frac{\text{pulse width}}{\text{pulse period}}$$

→ A square wave generator has a 50% duty cycle.



→ The ckt consists of two current sources, a ramp capacitor, & schmitt trigger ckt & current switching ckt.

→ The current sources provide a constant current to a ramp capacitor for charging & discharging.

→ The ratio of these charging & discharging current is determined by setting of Symmetry control.

→ The Symmetry control determines duty cycle of of o/p waveform.

→ In the current Source, an appropriate control voltage is applied to current control transistors which controlls the freq. i.e sum of two currents.

→ The multiplier Switch provides decade Switching control o/p freq

→ The upper current source supplies a constant current the ramp capacitor, this charges capacitor at constant rate as voltage across capacitor increases linearly.

→ when the positive ramp reaches the max upper limit set by the ckt components, the schmitt trigger changes its state. the trigger ckt o/p becomes -ve. the trigger ckt -ve o/p changes the Condition of current control Switch. Now capacitor starts discharges linearly.

→ The discharge rate is linear & it is controlled by the lower current source.

→ when negative ramp reaches lower limit the schmitt trigger comes back to its original state. this provides positive o/p.

→ This changes condition of current control switch again by cutting off the lower current source while turing ~~on~~ ON the upper current source. this gives one cycle of operation.

→ This process is repetative giving positive & negative pulses at constant rate.

→ The o/p of Schmitt trigger is passed to the trigger o/p ckt and 50Ω & 600Ω ampʳs.

→ The Trigger o/p ckt differentiates square wave o/p, inverts resulting pulse & provides positive trigger pulse.

→ The 50Ω ampʳ is provided with Step attenuator which allows a control of sgl o/p voltage.

## Specifications

→ The freq range is from 1H to 10MH

→ The duty cycle can be varied from 25% to 75%.

→ Two independent o/p are available

* 50 Ω Source supplying pulses with 5 ~~sec~~ nsec rise and fall times at 5V peak amplitude.

* 600Ω Source supplying pulses with 70 nsec rise and fall

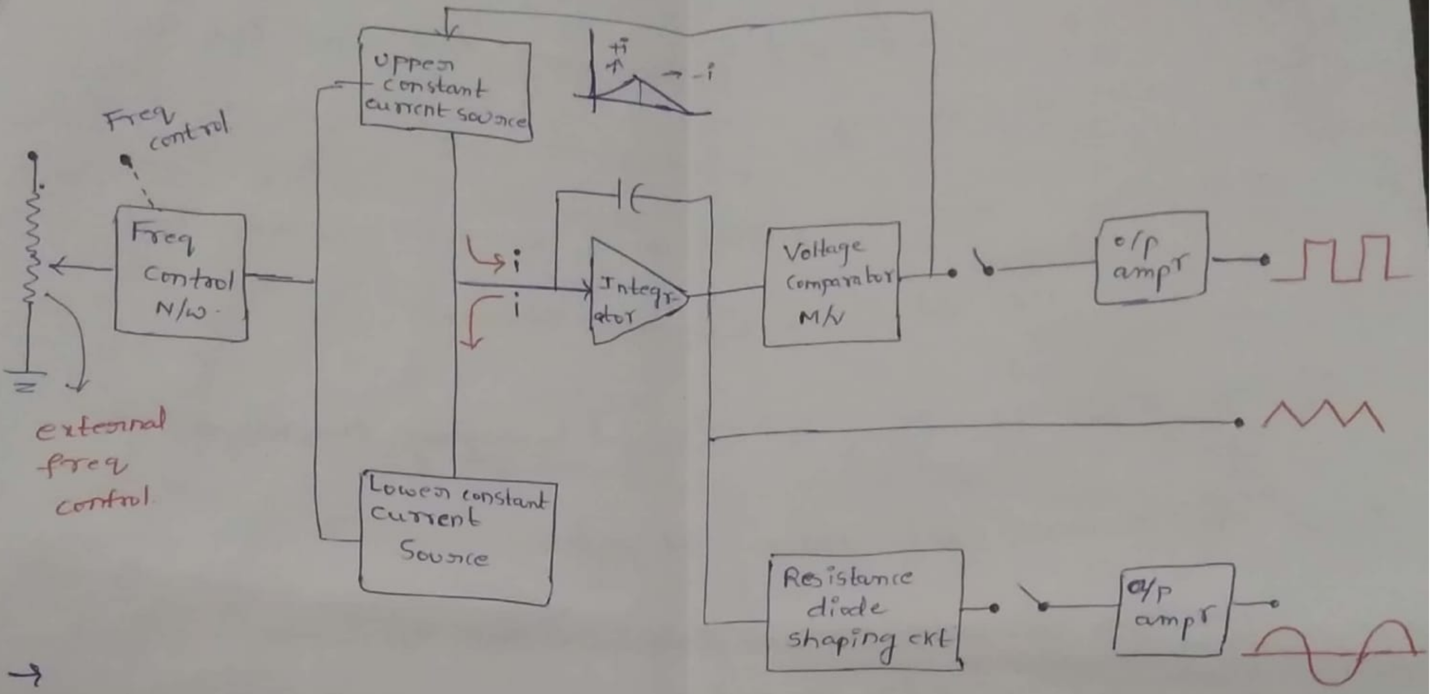
times at 30V peak amplitude.

→ The generator can be operated as free running generator

→ This can be synchronized with external sgl

→ To synchronise external ckts, trigger o/p pulses are available.

# Function Generator



→

→ F.G is an instrument which generates diff types of waveforms.

→ The freq of these waveforms can be varied over wide range

→ The most common reqd waveforms are sine, square, triangular, sawtooth.

→ Square → for testing linearity measurements in audio s/m.

→ Sawtooth → This o/p drives horizontal deflection ampr of an oscilloscope, which gives visual display of measurements.

→ F.G can be phase locked to an external sgl source.

→ The F.G can supply o/p sgls at very low freq's.

→ The freq is controlled by varying the capacitor in LC ckt or RC ckt.

→ But lower freq is posible using RC ckts is limited, So diff method is used to control freq.

→ In F.G the freq is Controlled by varying the magnitude of current which drives integrator.

→ The F.G generates sinewave, Triangular wave, Square wave varying from 0.01H to 100KHZ.

→ The freq controlled Volt is used to regulate 2 current Sources, that are upper current Source & Lower Current Source. (L.C.S)

→ The U.C.S supplies constant Current to integrator

→ The o/p Volt of integrator then increases linearly with time.

→ If the current, charging the capacitor increases or decreases the slope of o/p Volt increases or decreases, hence this controles freq.

→ The Volt comparator multivibirator ckt changes the state of N/w when the o/p volt of integrator equals the max predetermined upperlevel.

F G

→ Then b'coz of this change in state the ~~uppr~~ U.C.S is removed & L.C.S is switched ON.

→ This L.C.S supplies opposite current to the integrator ckt. the o/p of integrator decreases linearly with time

→ when this o/p volt equals to max predetermined lower level on negative side, the volt comparator m.v again changes the condition of N/w by switching OFF the L.C.S & switching ON U.C.S.

→ The o/p volt of integrator is triangular waveform.

→ To get square wave, the o/p of integrator is passed through comparator.

→ The volt comparator delivers square wave o/p volt of same freq as i/p triangular waveform.

→ The triangular wave is synthesised into sine wave using diode resis N/w.

→ The two o/p amp's provide two simultaneous, individually selected o/p s of any of waveform functions.

→ The F.G generates sgl's of known amplitude and known freq. –

→ The sgl generators are used to supply sgl level at very low levels ~~at~~ for the testing of receivers. So attenuators are used in ~~for~~ F.G's

→ The attenuator reduces the power of an i/p such that the ratio of i/p power to o/p remains constant.

$$A\ (\text{in dB}) = 10 \log_{10}\left[\frac{P_{in}}{P_{out}}\right]$$

→ In general we have two switches for attenuator such as 20 dB & 20 dB. if we press either of a switch we can get fixed attenuation of 20 dB.

→ Hence the total attenuation in dB of two casecaded attenuators is the sum of the decible attenuation of each attenuator. (40 dB).

### Features of F.G

① The freq range is 0.01 H – 100 KH

② can produce various wave forms such as sine, square, triangular, sawtooth & -

③ The accuracy is with in ±1 % in low freq range.

④ The distortion is less than 1% for sine wave.

⑤ can be phase locked to another external sgl source.

⑥ can be phase locked to standard freq, so all the o/p waveforms of generator will have same accuracy & stability as that of standard source.

⑦ A continous adjustable d.c offset is available b/w -5V to +5V.

### Specifications of FG

① Freq range → 0.001H to 20MH ③ freq stability 0.05%.

② Distortion: -55 dB bellow 50 KHZ, -40 dB above 50 KHZ

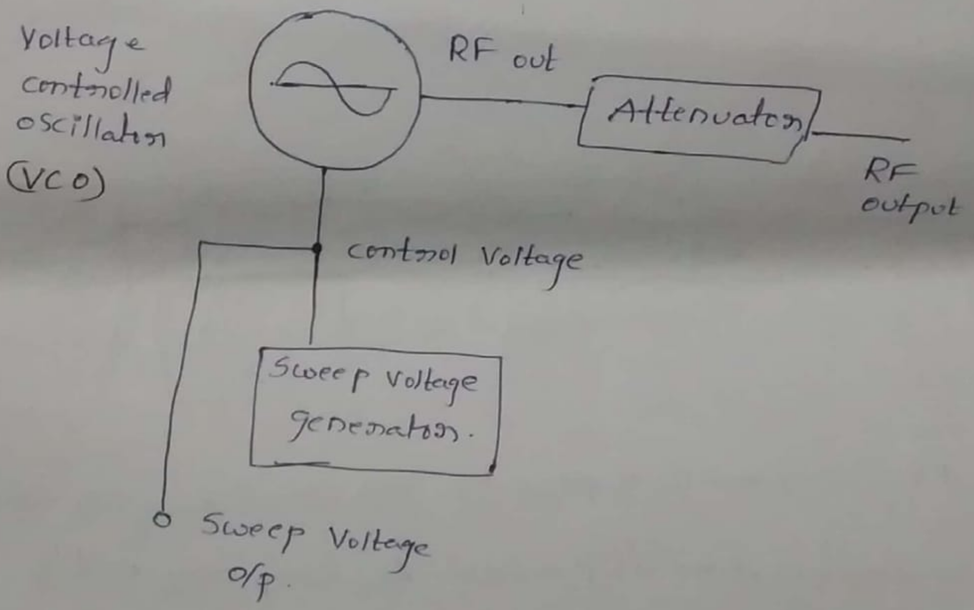
④ o/p amplitude: 10Vp-p, impedance: 50Ω

## Sweep generator

→ The sine wave generator generates o/p voltage at a known constant & stable freq.

→ But in some applications such as measuring freq response of amp$^{r}$s, filters & other N/w's, a variable freq source is required. In such cases sweep freq generators are used.

### Simple sweep freq generator:



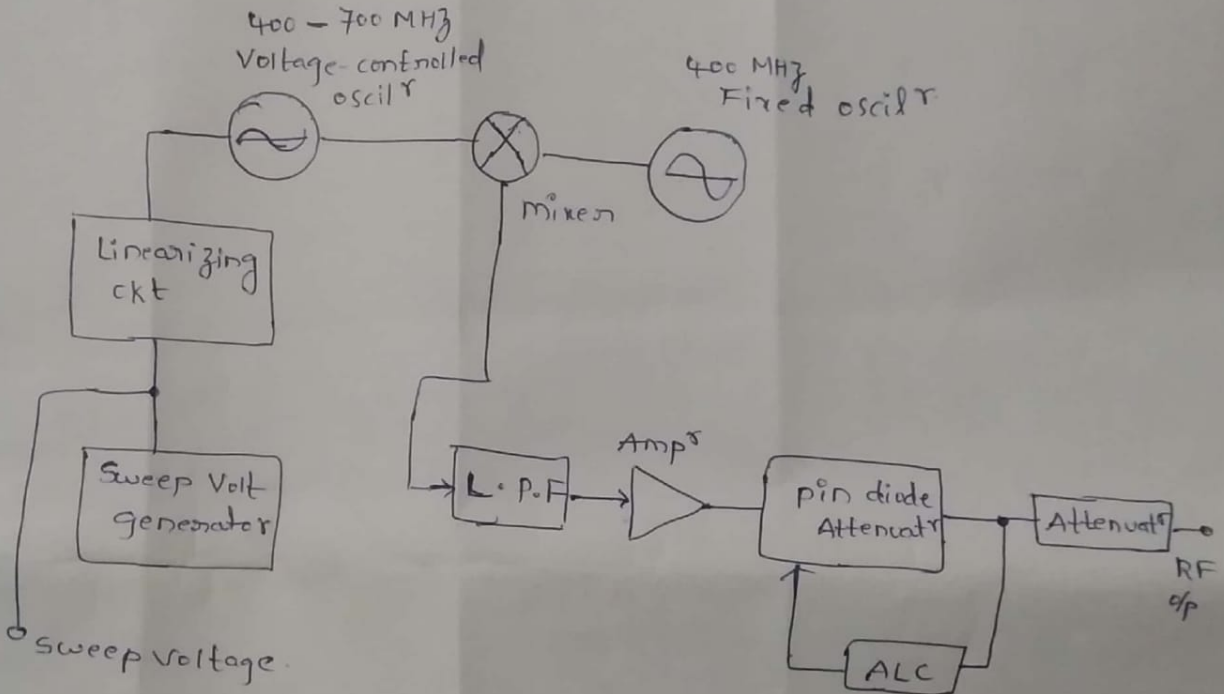
→ The sweep sgl gen$^{r}$ is very much similar to the simple sgl gen$^{r}$.

→ In the simple sgl gen$^{r}$, an oscill$^{r}$ is tuned to fixed single freq.

→ In the sweep generator, an oscil$^{r}$ is electronically tuned & by using voltage controlled oscil$^{r}$, variable freq is obtained.

→ A Sweep Volt gen$^r$ provides Voltage, known as control volt, to the VCO. The function of VCO is to provide various freq sweeps according to volt provided by Sweep Volt generator.

## wide band sweep generator:



→ The relationship b/w sweep volt & freq is non linear, To obtain linearity, a compensation is provided b/w sweep freq volt & oscil$^r$ tuning voltage. The compensation ckt is called "Linearizing ckt".

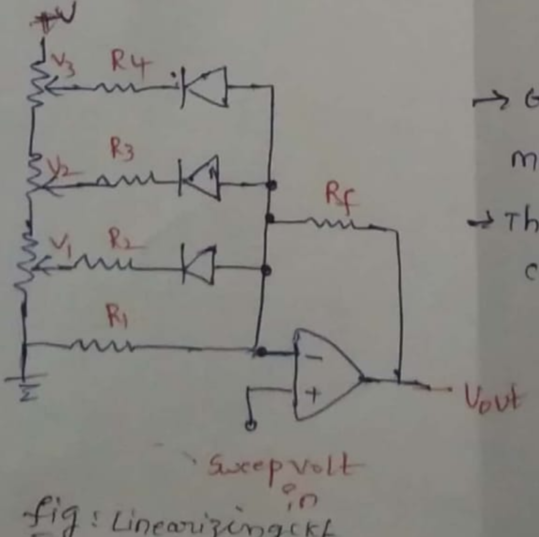


fig: Linearizing ckt

→ Generally there is a limit of 2:1 of max to min freq of any sweeping oscil$^r$.

→ This ckt used to match the transfer char$^{cs}$ with an oscil$^r$.

→ The gain of ckt is fun$^n$ of f/b resistor $R_f$ & net resis of parllel combinations of $R_1$ through $R_4$

→ initially when i/p ~~sweep~~ volt is very low the diods are can't conduct & gain of op-amp is → $(1+\frac{R_f}{R_1})$

→ when sweep volt approches $V_1$, the first diode conducts & gain of amp increases & it is $1+\frac{R_f}{R_A} \Rightarrow 1+\frac{R_f}{R_1 || R_2}$

→ when sweep volt i/p reaches $V_2$, $D_1$ & $D_2$ both conducts & gain increases to $(1+\frac{R_f}{R_B})$ where $R_B = R_1 || R_2 || R_3$

→ when sweep volt i/p reaches to $V_3$, the gain still increases & becomes $(1+\frac{R_f}{R_C})$, where $R_C$ is parllel combination of $R_1$, $R_2$, $R_3$ & $R_4$.

## wide band sweep generator:

→ To maintain sweeping freq ratio 2:1, the operating freq of sweeping osci/r is selected well above the widest sweep width. In this case, 0-300 MHz sgl is generated by mixing a 400-700 MH oscil/r with a fixed oscil/r giving 400 MHz freq. The o/p freq covers 0Hz up to 300MHz while max to min freq ratio is well bellow two.

→ It is very difficult to mix sgls which are at very high freq (MHz), filter the diff o/p, amplify it and maintain resultant amplitude within few decibles. ALC is used to (Automatic level control) adjust amplitude of resultant automatically

→ The wide band sweep gen/r also requires a linearizing ckts.

Adv:

Adv ① very popularly used to determine the freq response of amplifiers & other S/ms.

② A wide range of freq's can be generated.

Disadv :→ Linearizing ckt is reqd. → ALC is reqd → complicated in design.

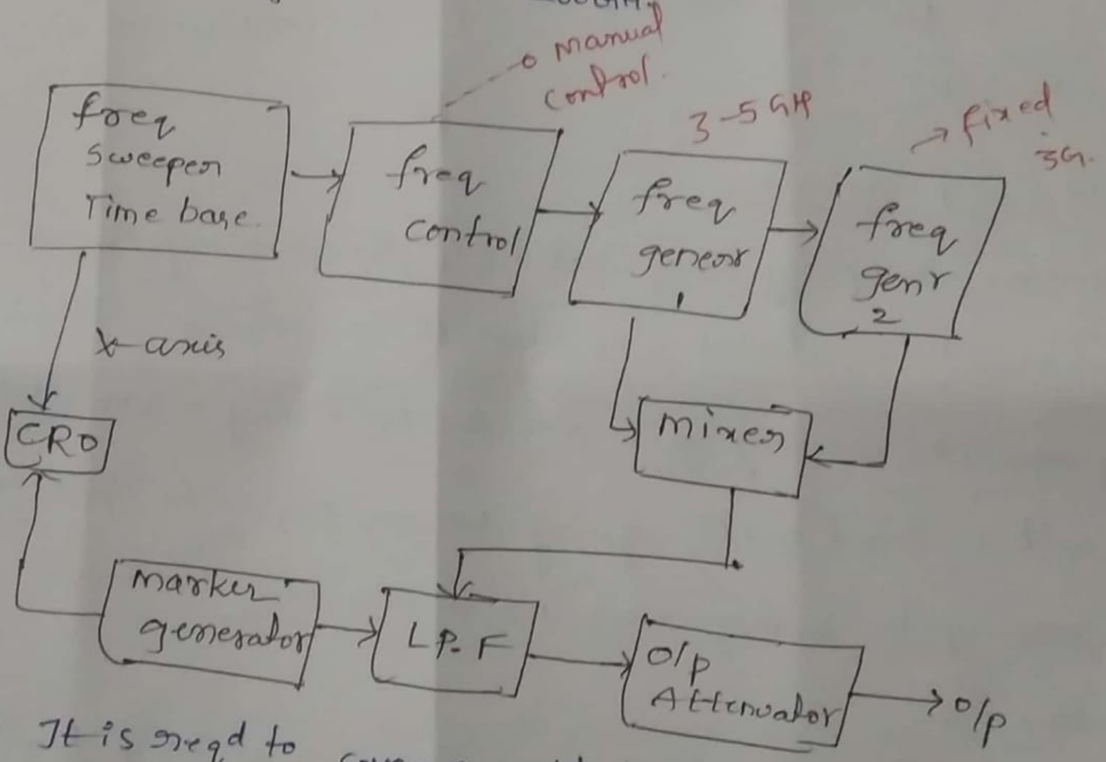
## Swept freq generator using Heterodyne freq generator

→ The range of Sweep freq genr is in 3 bands

① A.F range : 0.001 H – 100 K

② R.F. range : 100 K – 1500 K

③ Microwave range : 1 GH – 200 GH.



→ It is reqd to cover a wide band of freq's using a single instrument

→ for this 3 approches are used in in this freq genr.

① Manual Switching
② Stacked Switching
③ Heterodyne control.

→ In first approch "manual switching b/w diff freq range is used.

→ In this the problem occurs when specified freq range lies b/w two freq bands.

→ In 2n approch, "Stacked Switching" using electronic switch is used.

→ with the electronic switches the freq range is automatically selected. so whole range of genr is sweeped as one continous band.

→ The 3rd approach uses "Heterodyne control", where two high freq sgls are mixed together to generate lower freq sgl equal to the diff b/w 2 high freq's.

→ Let the sgl o/p of genr 1 varies in b/w 2GH to 4GH & if the o/p of genr 2 is with fixed freq of 2GH. then mixer produces the o/p in the range of 0.001GH ⇒ 0.1MH - 2GH as the diff in two freq's.

→ In this genr the o/p genr 2 is with fixed freq, while genr 1 varies over a freq range.

→ Let o/p genr 1 varies b/w 3GH- 5GH & genr 2 is with fixed freq 3GH, then the mixer will generate o/p with freq Varying from 1-2000 MHZ.

→ The genr has good linearity b'coz the tuning range is small as compared with wide o/p variation.

→ But non-linear mixer is used to mix two freq's along with req^d freq's many other unwanted freq's are produced

→ The o/p amplitude level is controlled by using level controls

→ The o/p of R.F. sgl is compared with standard sgl with req^d amplitude

→ Using CRO, the freq of o/p sgl can be calculated.

→ But many times it is difficult to properly obtain the freq of the o/p. To ~~observe~~ overcome this, the marker gen^r is used in the instrument

→ It generates series of known freq markers which are generally used as reference. to obtain these markers, the o/p of stable crystal oscil^r is passed through harmonic gen^r. this harmonic gen^r produces the series of pulses at every harmonic interval. Now this pulses are mixed with R.F. o/p from sweep gen^r. then mixer produces series of low freq o/p sgl.

→ These are shaped, amplified and then mixed with sgl from the device under test. this gives composite freq response of device under test & marker freq's.

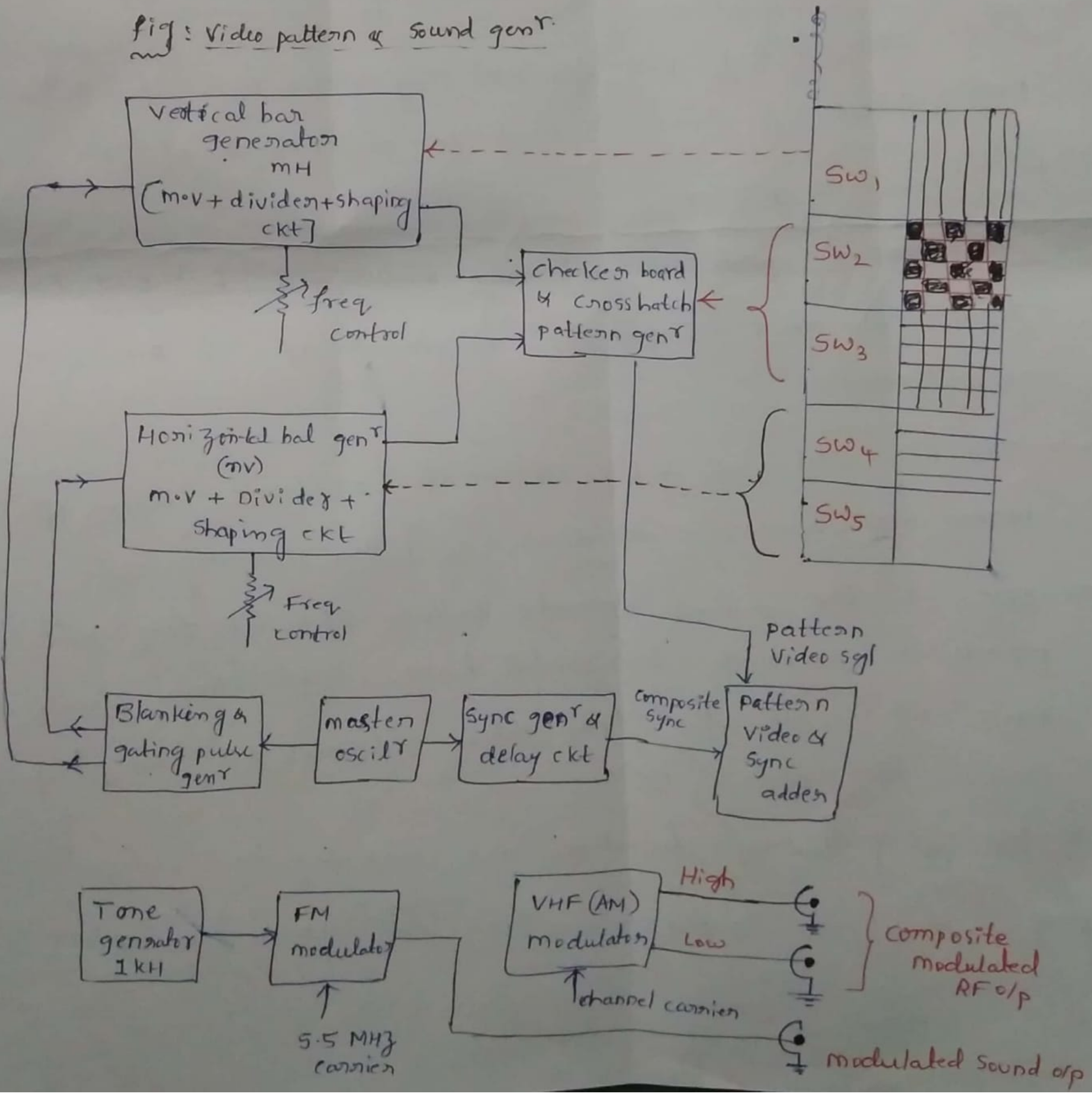
# Video Signal (pattern) Generator.

→ A Video pattern generator is very important type of sgl generator in Television S/m's for testing & Serviceing of T.V receivers.

→ A V.P.G generates video sgl either directly or with radio freq modulation.

→ It is important for alignment of T.V. receiver, testing of T.V receiver & Servicing of T.V receiver.

fig: Video pattern & sound genr.



→ In the video pattern generator (V.p.g) design at o/p side has the geometric patterns such as Horizontal ~~bars~~ bars, Vertical bars Cross-hatch, dots, checker boards are produced.

→ V.S.g is a device which produces Video wave forms, alongwith that some other sgls are also called to Stimulate faults.

→ The important factor which effects Video image on T.V is synchronization

→ The pattern of diff geometric shapes are most imp for the adjustment of linearity & Video ampr charlcs.

→ The ~~Video~~ V.p.g provides not only video sgls, but also FM sound sgl which is used for alighnment of TV Receivers Sound Section.

→ The V.p.g provides not only video sgls, but also FM Sound sgl which is used for alignment of TV Receivers sound Section.

→ The basic ckt'y of V.p.g consist of 2 stable chains of multivibrators' devideors & pulse shaping ckts.

→ one of the chains operate bellow the line freq & it produces series of horizontal bars, while other chain of basic ckt works at freq above 15625 KH to produce series of vertical bars

→ The Sgl with long duration are converted to short pulses

→ This modified pulses are then fed in video Section

The pulses in accordance with sync pulse train produces fine lines on TV screen

→ The switches provided in b/w sgl paths of both the m·v produces different patterns. if both mH & nV switch off a blank white raster is produced.

→ when mH Switch is only ON, vertical bars are produced while horizontal bars are produced with only nV switch is ON.

→ But when both Switches are ON, cross-hatch pattern is generated.

## Digital Signal generators.

→ we have 3 categories.

① Arbitary wave form Generator.

② Arbitary function generator: → use full in the applications where variations in the waveform is required for unit under test with fast response.

③ Data or pattern Generator: It provides a stream of binary data with specific timing char'cs & timing information stored.

## Arbitary waveform generator:

→ The A.W.G generates a periodic waveform for which the user defines the shape of the period. (in the form of set of sample points).

→ A.W.G are a device that generates arbitary streams of digital information. these wave forms donot have any fixed shape

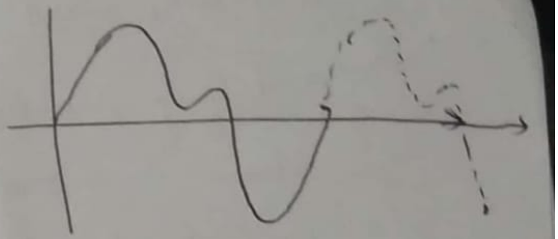
→ To simiulate a S/m with a complex wave form

→ is Digital based sgl Source capable of generating any wave form with in given limits of B.W, freq range accuracy & o/p level.

→ To create non Standard waveforms for Simulating complex s/m i/ps. if i/p ckt'y is not available.

→ A.w.g is the use of digital sgl generation in Instrumentation

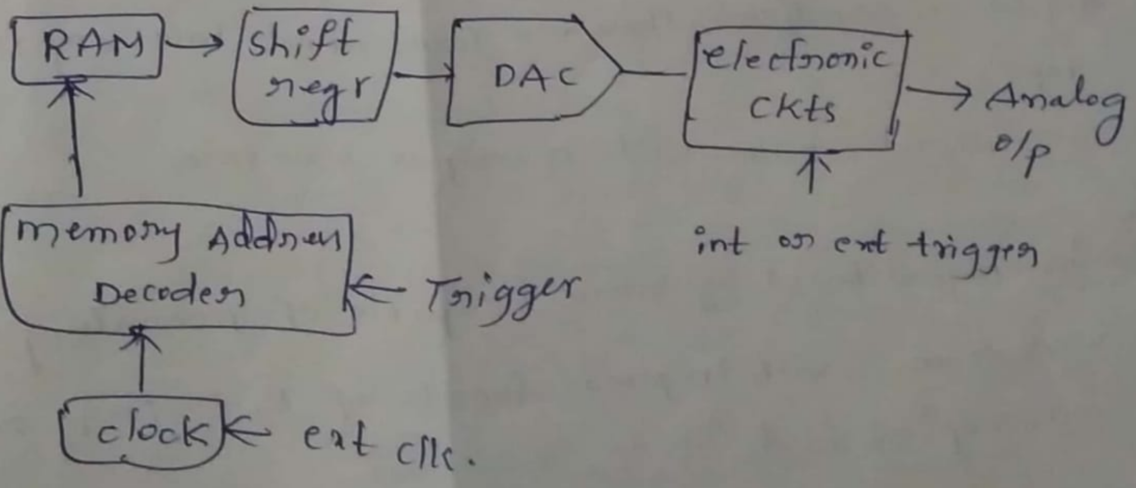
→ The user can define various samples with graphical editing capability such as display screen & a mouse



→ The more complex wave form can be generated using it provided that more sample points are supplied

→ The user can also control the freq & amplitude once a set of sample points is loaded in the memory of gen$^r$, an electronic ckt'y generates a wave form passing smoothly and repeatatively through the set

→ Basically it is a ~~a~~ play back S/m which generates a waveform based on digital data stored in RAM of instrument.



→ The sampling of stored data can be done either by using graphical, mathamatical tech's or by measuring wave form with oscilloscope.

→ The regenerating the waveform, the memory locations are read & fed to the digital to Analog converters

→ In this the Sampling freq must be seluted at ~~last~~ least the twice of that of the ~~sg~~ highest freq component of Sampled sgl.

→ To produce desired wave form, the sample points must be sufficiently large enough.

Parameters of Arbitary wave form generator:

→ The important parameters of A.W.G. are

① vertical resolution: The resolution of A.W.G is expressed as the resolution of DAC expressed in bits

→ So if the no. of bits is more, the resolution of DAC is higher.

→ while the general purpose AWG offers 12 or 14 bits

→ The AWG with 8bit resolution provides 256 sample levels over full volt range.

② memory depth:

The flexibility of AWG is decided by memory depth

# UNIT – III

# Oscilloscopes
# and
# Special Purpose Oscilloscopes

# III-unit Oscilloscopes

① CRT
② CRO
③ Time Base ckts
④ Lissajous figures
⑤ CRO probes
⑥ High freq CRO considerations.
⑦ Delay lines
⑧ Applications
⑨ measurement freq, Time period.
⑩ Specifications.

→ The device which allows the amplitude of periodic or non periodic sgls to be displayed primarily as a function of time is called CRO.

→ The CRO gives visual representation of time varying sgls.

→ It is a universal instrument or tool for developement of electronic ckts & s/ms.

→ The oscilloscope is like a voltmeter, instead of mechanical deflection of a metalic pointer as used in the normal voltmeter, the oscilloscope uses a movement of ē beam against a flourscent screen, which produces a movement of visible spot.

→ The movement of such spot on screen is proportional to varying magnitude of sgl.

→ The ē beam is deflected in 2 directions ① Horizontal (x-axis) ② Vertical (y-axis)

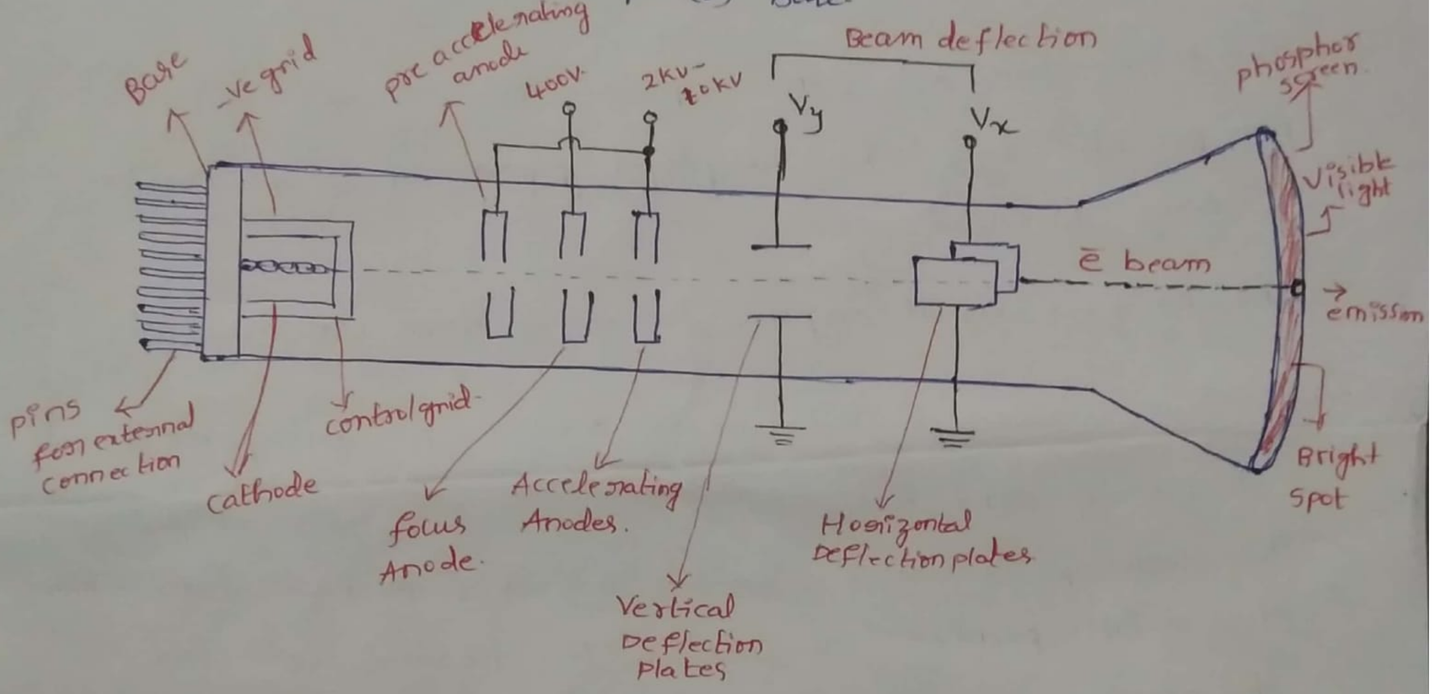
→ So an ē beam producing a spot can be used to produce 2-dimentional displays.

## Cathode Ray Tube: (CRT)

→ It is heart of CRO, it generates $\bar{e}$ beam, accelerates the beam, deflects the beam & also has a screen where beam becomes visible as a spot. The main parts of CRT are

i) Electron gun ii) Deflection s/m iii) Fluorscent screen

iv) Glass tube (or) envolope (V) Base.



① <u>Electron gun</u>:: → it provides sharply focused $\bar{e}$ beam directed towards screen (Fluorscent-coated). This section starts from thermally heated cathode, emitting the $\bar{e}$s.

→ The control grid is given -ve potential w.r.t cathode.

→ The grid controls no. of $\bar{e}$s in the beam, going to screen.

→ The momentum of $\bar{e}$s determines the intensity or brightness of the light emited from screen.

→ B'coz of the $\bar{e}$ are -vely charged, a repulsive force is created by applying a -ve volt to ~~cathode~~ control grid. (Variable -ve volt).

* A more -ve volt results in less no. of ē s in the beam & hence decreased brightness of beam spot.

→ b'coz of -ve charge → repulsion force → ē repel each other

→ To compensate this respulsion force, an electro static field is created b/w focus anodes.

→ The Variable +Ve volt on the 2$^{nd}$ anode is used to adjust focus or Sharpness of bright beam spot

→ The high +Ve potential is given to pre-accelerating anodes (P.A.A) & accelerating anodes (A.A) for req$^{d}$ acceleration of ē s.

→ These two P.A.A & A.A anodes are conn$^{d}$ to a common +Ve high voltage (2KV - 10KV varies).

→ The focus anode connected to low +Ve volt of 400V - 500V.

## Deflection S/m:

→ when ē beam is accelerated, it passed through the deflection s/m (with which beam can be positioned any where on the screen).

→ It has 2 pairs of parllel plates. ① Vertical deflection plates
② Horizontal " "

→ one of the plates in each set is connected to gnd. (0V).

→ To the other of each set, an external deflection Volt is applied through an internal gain amp$^{r}$ stage.

→ The ē beam is passes through these plates.

→ A +ve volt is applied to Y i/p terminal ($V_y$) causes beam to deflect vertically upward (due to attraction forces), while

Fluo

-ve Volt is applied to ~~y~~ y i/p will cause the ē beam to deflect vertically down ward (due to repulsion force.)

→ Similarly a +ve volt is applied to x- i/p terminal($V_x$) will cause the ē beam to defflect Horizontally to right, while -ve voltage → ē beam deflect Horizontally to left of screen

→ The amount of Vertical or Horizontal deflection is directly proportional to the applied Voltage.

→ Horizontal deflection (x), $V_x$ is deflection voltage.

$$x \propto V_x \Rightarrow \boxed{x = KV_x}$$ $K_x$ is constant.

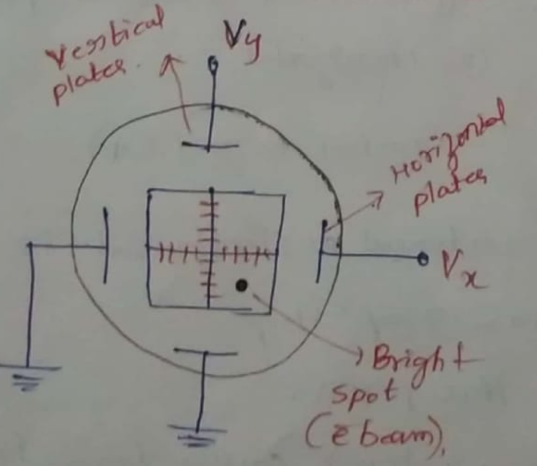
$$K_x = \frac{x}{V_x}$$ ⇒ $K_x$ → is Horizontal Sensitivity.

→ similarly Vertical deflection(y), $V_y$ is deflection Voltage

$$y \propto V_y \Rightarrow \boxed{y = K_y V_y} \Rightarrow \boxed{K_y = \frac{y}{V_y}}$$

$K_y$ → Vertical Sensitivity.

arrangement of plates in CRT



→ The bright spot of ē beam can trace (or plot) the x-y relationship b/w two volt's $V_x$ & $V_y$.

## Fluorescent screen.

→ The light produced by screen does not disappear immediately when sgl becomes zero. the time period for which the trace remains on screen after sgl becomes zero is called "persistence", it may be short as few microsec. or it s' long as 10 sec or minutes.

→ medium persistance traces mostly used for general purpose applications

→ Long persistance traces are used in study of transients.

→ short " " " " " high speed phenomena.

→ The screen is coated with fluorescent material (phosphor) which emits light when attack by ē s.

## Glass Tube

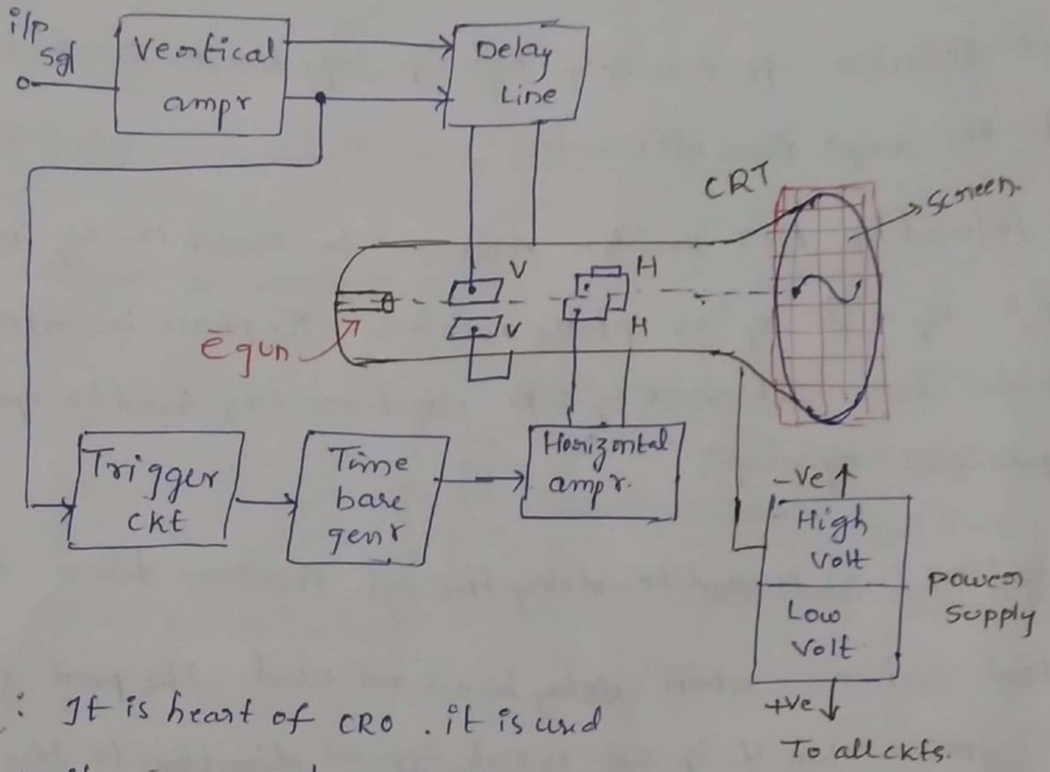
→ All components of CRT are enclosed ~~with~~ in a evacuated glass tube called envelope. this allows emited ē s to move freely from one end to other of tube.

## Base

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

## CRO (cathode Ray oscilloscope.)

↳CRO consist of ① CRT ② Vertical ampr ③ Delay line ④ Trigger ckt ⑤ Time base genr ⑥ Horizontal ampr ⑦ power supply ⑧ Graticules. ⑨ front panel controls.



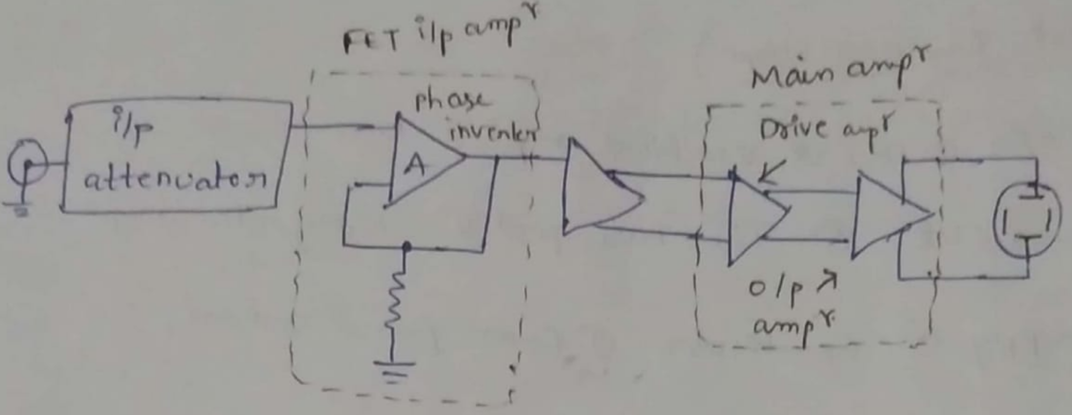
**CRT :** It is heart of CRO . it is used to emit ēs reqd to strike the phosphor screen to produce the spot for visual display of sgls.

**Vertical ampr:**

→ it is used to amplify the i/p sgls (when sgl is not strong)

→ the ampr stage used are wide band amprs.

→ It is also contains attenuator, used when high volt sgls to be examined, to get proper range of operation.



→ The i/p stage consist of an attenuator followed by FET Source follower. It has very high i/p impedence reqd to isolate the ampr from attenuator.

→ It is followed by BJT Emitter follower to match the o/p impedence of FET o/p with i/p of phase inverter. The phase inverter provides two antiphase o/p sgls which are required to operate the push-pull o/p ampr.

Delay Line : It is used to delay the sgl for some time in the vertical sections. when delay line is not used, the part of sgl gets lost. Thus the i/p sgl is not applied directly to the vertical plates, but it is delayed by some time using Delay line.ckt

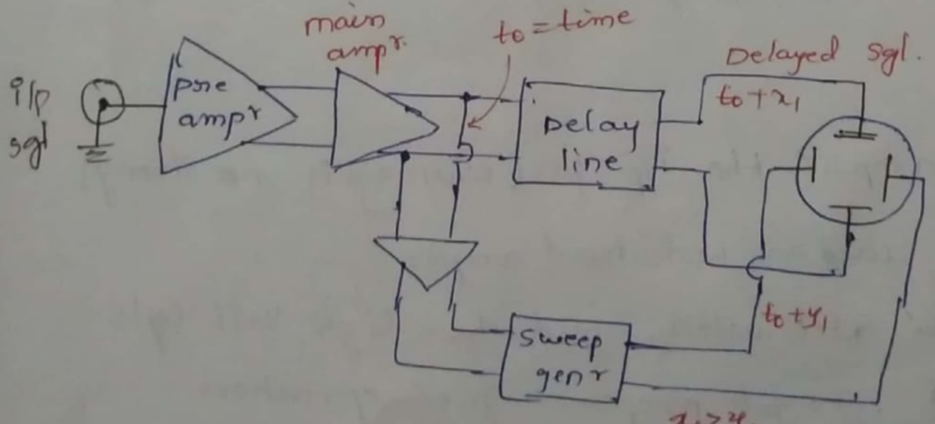


fig: Delay line ckt.

As the sgl delayed the sweep genʳ o/p gets enough time to reach to the horizontal plates before sgl reaches the Vertical plates.

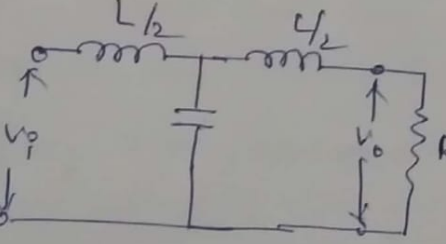
→ ~~If~~ trigger pulse is picked off at $t = t_0$, after the sgl has passed through the main ampʳ then sgl is delayed by $x_1$ nsec, while sweep takes $y_1$ nsec to reach.

→ There are two types of delay lines used in CRO.

i) Lumped parameter delay line

ii) Distributed parameter delay line

i) Lumped parameter Delay line:



T-filter section.

→ it consist no. of cascaded Symmetrical LC N/w s called ~~Tees~~. T-sections. Each section capable of delaying the sgl by 3 to 6 nsec.

$$f_c = \frac{1}{\pi\sqrt{LC}}$$

→ $V_i$ consist of freq's much less than Cut-off freq, o/p sgl $V_o$ will be same as $V_i$, but delayed by time

$$t_s = \frac{1}{\pi f_c} = \sqrt{LC}$$

$t_s$ → delay for single T-N/w., $t_d = n t_s$, $t_d$ → total delay

n → no. of T-sections.

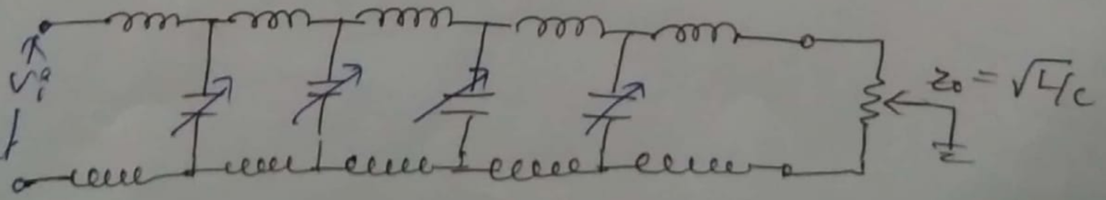


fig practical delay Line.

ii) Distributed paramdter Delay line:

→ It is a transmission line constructed with a wound helical coil on a m

→ It is manufactured with co-axial cable with high inductance per unit length.

→ ~~And~~ The inductance can be increased by winding the helical inner conductor on ferromagnetic core.

→ This increase the impedence Zo & delay line.

→ Typical parameters for helical

$Z_0 = 1000\,\Omega$. $t_d = 180$ nsec/m

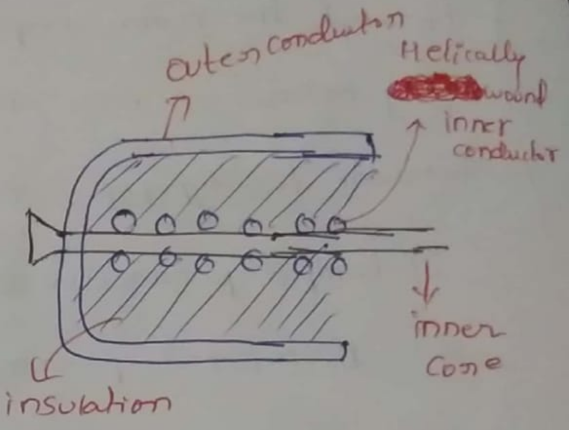


Fig: Helical distributed Delay line

④ Trigger ckt:

→ To Synchronize Horizontal deflection with vertical deflection a synchronizing or triggering ckt is used.

→ It converts the incoming sgl into the triggering pulses, which are used for synchronization

⑤ Time base generator: It is used to generate Sawtooth Voltage, reqd to deflect the beam in the Horizontal section

→ This volt deflects the spot at a constant time dependent rate.

**Horizontal amp^r** → The saw tooth volt produced by the time base generator may not sufficient strength. Hence before giving it to the Horizontal deflection plates, it is amplified using the Horizontal amp^r.

⑦ **Power supply:** → It provides ~~power sup~~ volt req^d by CRT to generate & accelerate an ē beam & voltages req^d by other ckts of the oscilloscope like Horizontal amp^r, vertical amp^r.

↳ High voltage section (HV) (1000 - 1500V)

↳ Low voltage section

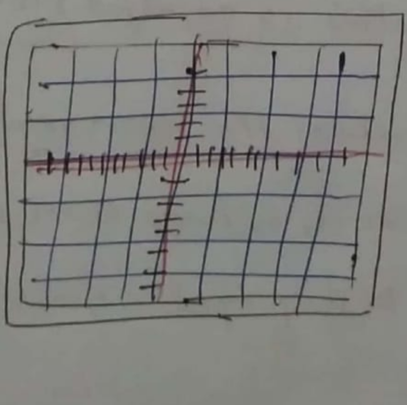
⑧ **Graticules:** The CRo has some sort plastic screen infront of the cathode ray tube. This screen has a grid engraved on it, giving it an appearance similar to that of graph paper. This is called graticule.

↳ 3 types of graticules used.

① external graticule:

② Internal "

③ projected ".



## Front panel controls:

① Basic controls

② vertical section

③ Horizontal section

④ Z-axis intensity control

## Time Base circuits:

Time base generator: The generator which generates a wave form which is responsible for the movement of spot on screen horizontally is called "Time base generator" or "Sweep gen$^{r}$."

→ The sweep ckts along with the display gating functions are called time bases.

→ The linear sweep moves the spot from left to right, while the movement of spot from right to left is not visible.

→ This portion of waveform is generated by time base is called "flyback" or "Retrace". During this time the CRT is blanked.

→ The time base gen$^{r}$ also controls the rate at which the spot moves, across the screen. This is adjusted from front panel control.

*. The Sweep generator produces the movement of spot on Screen such that it acts as a time axis or time base for the waveforms to be displayed. Hence it is called "Time base gener"

The 2 front panel controls which are used to control rate and duration of time base wave form are
i) Time /division ii) Time variable control

## Basic principle of Time Base Generator.

→ A use charging char'cs of capacitor to generate linear rise time Voltages. linearly increasing ramp which becomes zero within very short duration of time, means the spot is visible from left to right & visible from right to left.

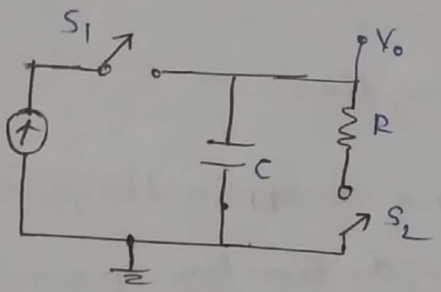
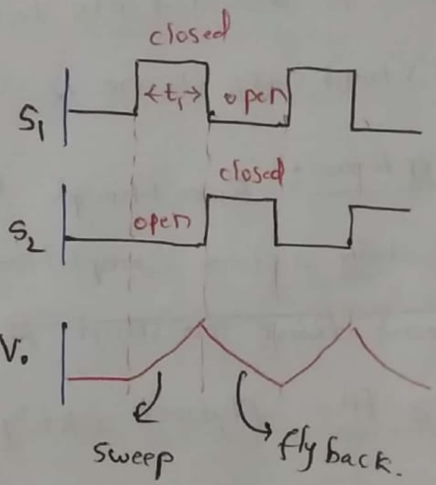


Fig: cap$^r$ charging from constant current source.



→ when switch $S_1$ is closed, $S_2$ is open & cap$^r$ charges to produce linear ramp at the o/p. The swee rate controlled by changing the value of cap$^r$ (or) charging current.

→ After reaching max value of ramp volt, $S_2$ is closed & $S_1$ is open. then cap$^r$ gets discharged through 'R'. This is called "flyback" (or) "retrace".

→ $t_1$ is called "Sweeptime". → The ckt is a relaxation oscil$^r$ which generates Sawtooth waveform.

→ During sweep time, the spot moves from left to right.

→ During retrace, the screen is blanked & spot comes back to its starting level but its movement from right to left is invisible.

→ The Trigger ckt associated with time base gen$^r$. This ckt generates a trigger pulse, which activates time base gen$^r$ to produce a ramp.

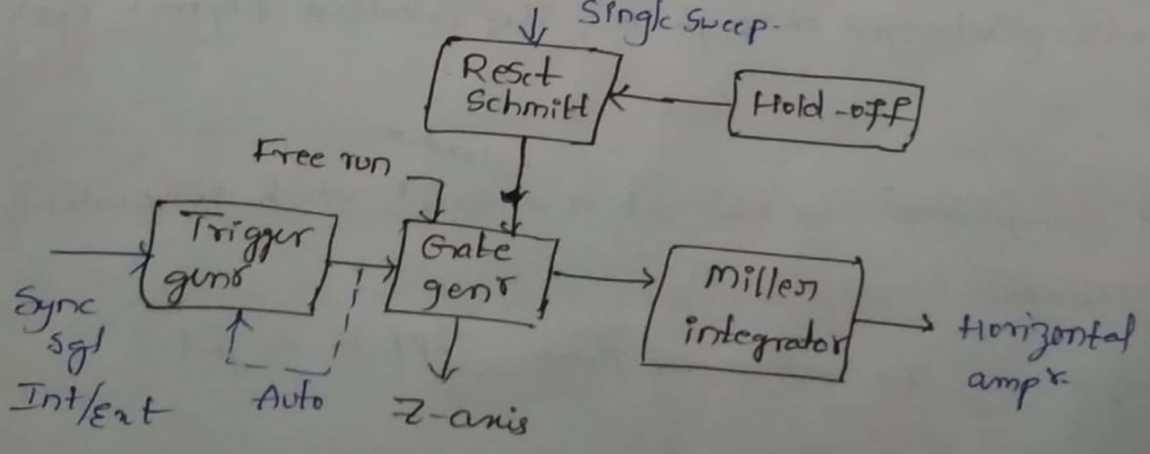
→ when one cycle, sweep & retrace is completed then the time base generat$^r$ takes certain time to start the next cycle. This time is devided into two-

i) Hold-off time & ii) waiting time

Hold off time: Even though the trigger ckt applies the pulse immediately after completion of cycle, the time base generator takes some time to start the ramp. this time is req$^d$ to stabilize the flyback ckt'y. This time is called 'Hold-off time'

Waiting time: when trigger pulse is generated by trigger ckt, the pulse has to cross certain reference level, so as to activate the time base gen$^r$. This ref level is called "Trigger threshod".

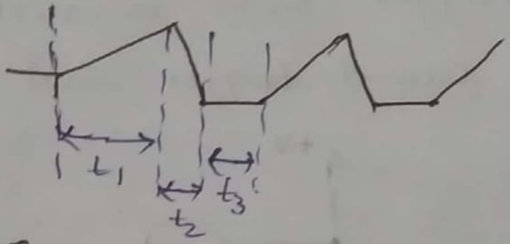
## Time base Block diagram



→ The miller integrator is the basic time base genʳ ckt.

→ This ckt has flexibility of choice of capʳ & resistor in f/b loop. The capʳ can changed from 10pF to 1uF, and resistor from 100kΩ to 50 MΩ.

→ Trigger genʳ to generat trigger pulses (The i/p applied to Vertical plates to generate trigger pulse or it uses some external sgl to generate trigger pulse



$t_1$ → Sweep time
$t_2$ → flyback time
$t_3$ → Hold-off time

Fig: sweep output

→ This trigger genʳ activates gate genʳ which in turn starts the miller integrator ckt.

→ The hold off time is reqᵈ to stabilize the miller integrator ckt when swee cycle is completed.

→ The reset schimitt is reqᵈ which sends a sgl to gate genʳ whenever the hold-off time is completed.

→ This ckt work in 3 modes.

i) Free run mode: In this mode miller integrator is starts immediately after hold off time, without waiting for the trigger pulses to cross the trigger threshold.

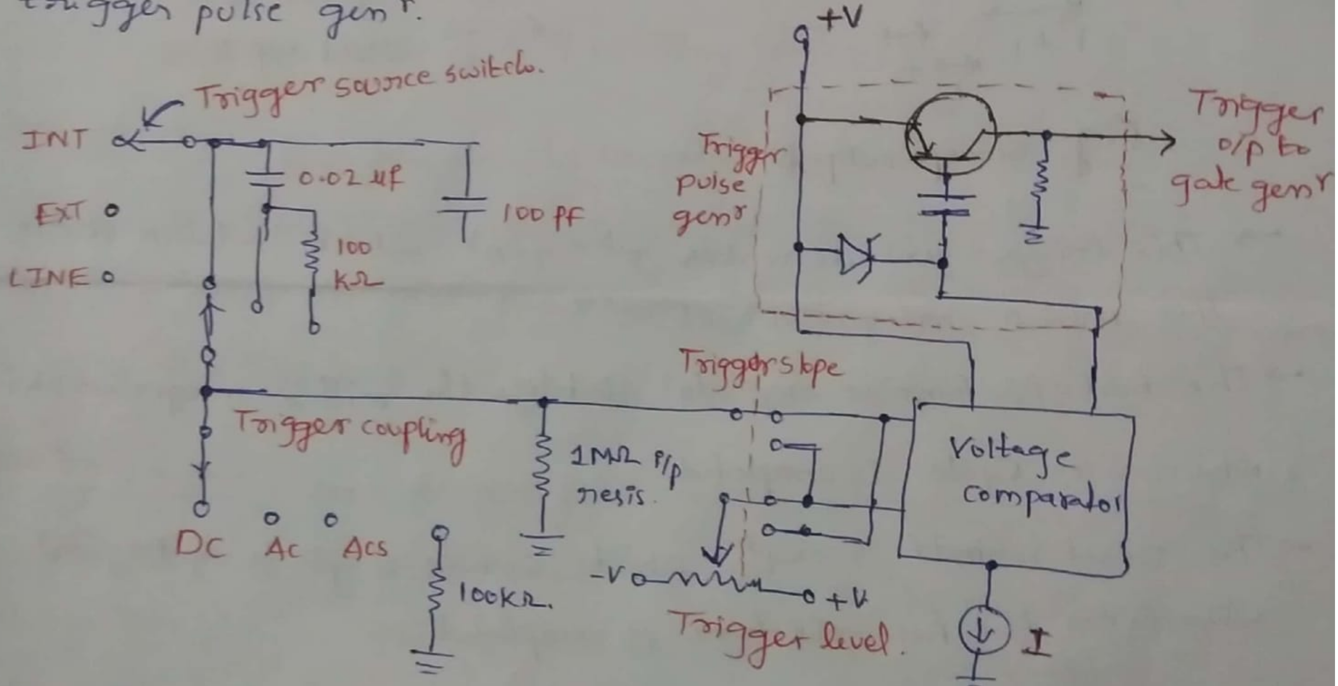
ii) Auto mode It sensens the length of time after a sweep occures & automatically provides a trigger pulse if no sgl comes ~~after~~ either from INT or EXT, after 20 msec

iii) **Single sweep mode:** The sweep runs only once from a trigg pulse after which the gate gen$^{r}$ is not reset until the operator desires.

## Trigger generators

→ The ckt which is responsible for starting the sweep at the desired point on a waveform is called trigger gen$^{r}$.

→ The trigger gen$^{r}$ includes trigger source, a variable ~~capacitor~~ comparator to set desired trigger level & a trigger pulse gen$^{r}$.



→ Three trigger sources are

i) INT ii) EXT iii) LINE

↳ it provides replica of sgl applied to the vertical amp$^{r}$.

ii) Ext → it is external source & it is derived from an external i/p sgl.

iii) Line → It is derived from . power line having 50Hz freq.

**Beam speed:** it is decided by velocity of ēs which are accelerated by anode voltage . if anode volt is $V_a$.

Velocity $v = \sqrt{\frac{2qV_a}{m}}$ m/s

$q \rightarrow$ change on ē $= 1.6 \times 10^{-19}$c

$m =$ mass of each ē $= 9.1 \times 10^{-31}$kg

$V = 5.94 \times 10^{5} \sqrt{V_a}$ m/s.

→ eg ① what is acclerating anode volt in CRT if $l = 2$ cm, $L = 30$ cm & deflection for 50V is 1cm on screen. The plates are seperated by 1cm

Sol: $l = 2$ cm , $L = 30$ cm, $V_d = 50$V , $D = 1$ cm , $d = 1$ cm

$S = \frac{D}{V_d} = 2 \times 10^{-4}$ m/v , $S = \frac{lL}{2dV_a}$

$V_a = 1500$V.

## CRO Measurements:

→ using CRO we can measure voltage, current, period, freq, phase, amplitude, peak to peak value, duty cycle .

### Voltage measurement:

amplitude $V_m = \frac{V_{P-P}}{2}$

$V_{P-P} =$ (no. of divisions or units) $\times \frac{\text{volts}}{\text{divisions}}$

$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{V_{P-P}}{2\sqrt{2}}$ (for sine sgls)

## Period & freq measurement

→ In this the wave form is displayed on screen, one complete cycle is visible on screen.

$$T = (\text{no. of divisions occupied by 1 cycle}) \times \frac{\text{Time}}{\text{division}} = \text{Time period}$$

$$f = \frac{1}{T}$$

## * Lissajous figures

→ The Lissajous pattern method is the quickest method of measuring the freq. In this method, the standard known freq sgl is applied to Horizontal plates & unknown freq sgl is applied to vertical plates.

→ Such patterns obtained by applying simultaneously two diff sine wave to horizontal & vertical deflection plates are called "Lissajous figures" or "Lissajous patterns"

→ The shape of this figure depends on

① Amplitude of two waves

② phase diff b/w two waves

③ Ratio of freq's of two waves.

→ consider two sgls applied, having same amplitude & freq & having phase diff of $\phi$ b/w them.

$e_1 = E_m \sin\omega t$

$e_2 = E_m \sin(\omega t + \phi)$

- The phase diff $\phi$ produces the Various patterns, which Vary from Straight diagonal line to the ellipse.

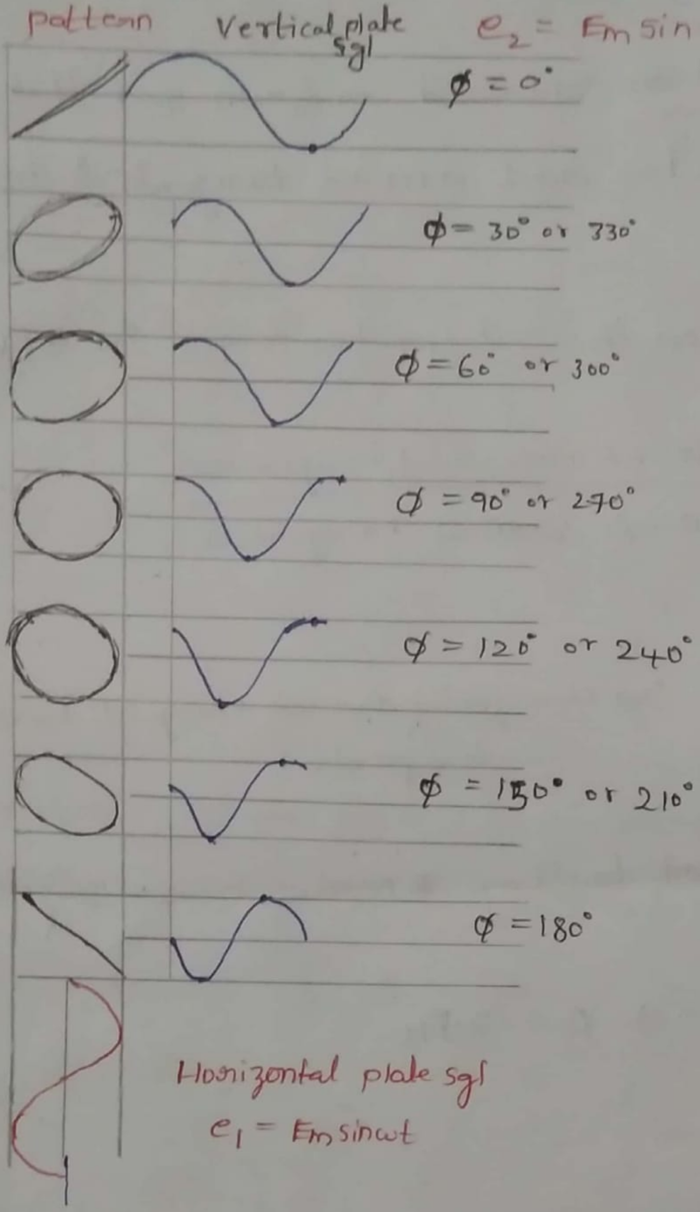


fig: Lissajous patterns for same freq diff phase shifts.

## Measurement of freq:

- → To measure unknown freq, the sgl with unknown freq is applied to Vertical deflection plates called $f_V$.
- → Then sgl applied to horizontal deflection plates is obtained from a variable freq oscill^r of ~~k~~known freq $f_H$.

ⓐ

$f_H$ = freq of sgl applied to horizontal plates (known)

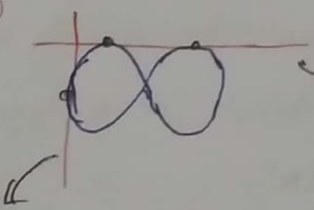
$f_V$ = " " " " " Vertical " (known)

→ The Lissajous pattern obtained on screen such that to to the fig vertical & horizontal axes are tangential to one or more points.

→ The patterns depends on the ratio of two freq's $f_H$ & $f_V$

i.e. $$\frac{f_V}{f_H} = \frac{\text{No. of Horizontal tangencies}}{\text{no. of vertical tangencies.}}$$

Eg: ①

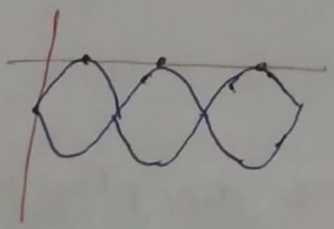


→ Horizontal axes (or) trangent touching two points

Vertical tangent touching 1 point.

$$\frac{f_V}{f_H} = \frac{2}{1} \Rightarrow f_V = 2 \cdot f_H.$$

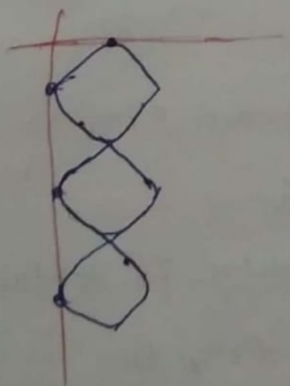
②



→ Vertical = 1
Horizontal = 3

$$\Rightarrow \frac{f_V}{f_H} = \frac{3}{1} \Rightarrow f_V = 3 \cdot f_H$$

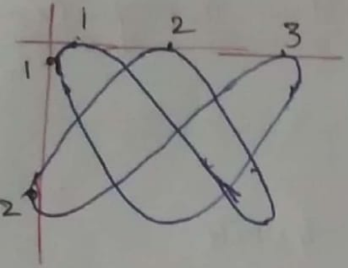
③



⇒ Vertical = 3
Horizontal = 1

$$\frac{f_V}{f_H} = \frac{1}{3}$$

eg ④



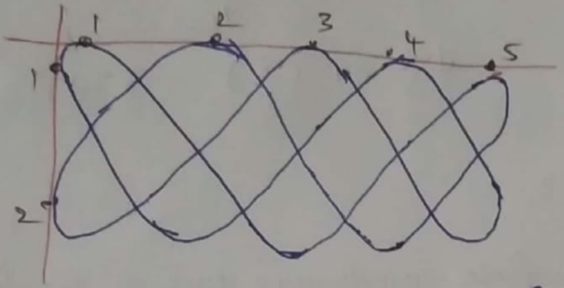
vertical = 2

Horizontal = 3.

$\frac{f_V}{f_H} = \frac{3}{2}$

$f_V = \frac{3}{2} f_H$.

eg ⑤



Vertical tangents = 2

Horizontal tangents = 5

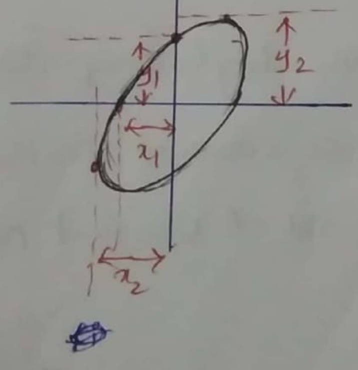
$\frac{f_V}{f_H} = \frac{5}{2}$

## Measurement of phase diff:

→ consider Lissajous fig, with an unknown phase diff & freq & amplitude of two waves is same.

→ The parameters $x_1, x_2$ (or) $y_1, y_2$ can be measured as

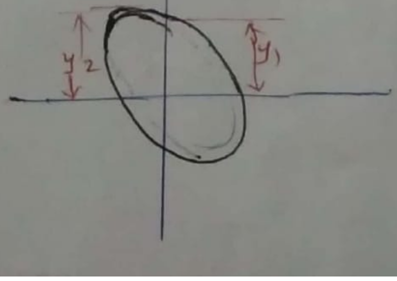
fig: ⓐ.



→ The phase angle is

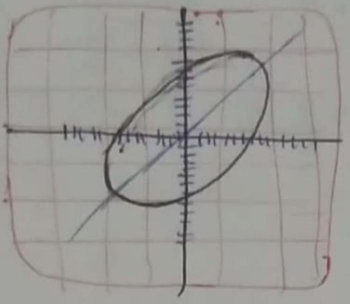
⇒ $\phi = \sin^{-1}\frac{y_1}{y_2} = \sin^{-1}\frac{x_1}{x_2}$.

fig. ⓑ



⇒ $\phi = 180° - \sin^{-1}\frac{y_1}{y_2}$

eg: The Lissajous fig obtained on CRO is shown in fig - find phase diff b/w two waves applied.



Sol: $y_1 = 8$ units
$y_2 = 10$ units.

$$\phi = \sin^{-1} \frac{y_1}{y_2}$$

$$\phi = \sin^{-1}\left(\frac{8}{10}\right) = 53.13^\circ$$

## * High freq CRO considerations:

→ The low freq general purpose oscilloscope uses a single set of vertical deflecting plates. If a very high freq sgl is used in such oscilloscope shows some limitations. i.e

- ↳ The ē beam does not get the sufficient time to pick up levels of i/p sgl.
- ↳ The intensity of an ē beam reduces at high freq's.
- ↳ The no. of ēs striking the screen in a given time also reduces at high freq's.

* So for this to avoid this limitations high freq oscilloscopes are used. this is done by using a series of vertical deflecting plates instead of one set of vertical plates.

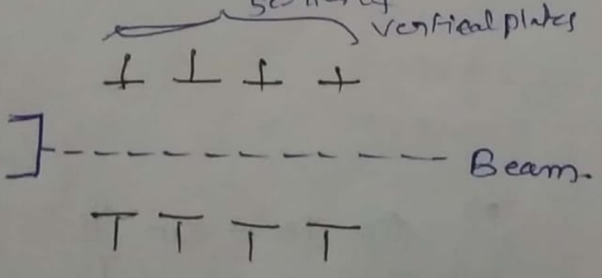


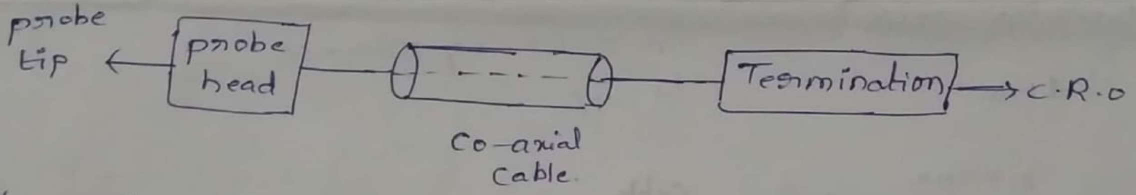
fig: HF oscilloscope tube

These plates are used to increase brightness of the trace So that the limitations of low freq oscilloscope can be completed eliminated.

→ Due to high freq it is necessary that an ē beam should get an additional deflecting force ~~in proper~~ such an additional deflecting force in proper time sequence is provided by properly Shaped & Spaced Series of vertical deflecting plates.

## CRO probes :

→ It is used with oscilloscope to connect the test ckt to the oscilloscope. while connecting the test ckt, the probe does not disturb the ckt and sgl conditions to the analysed. for the probe should have high impedence. the probe B.W should be as high as posible.

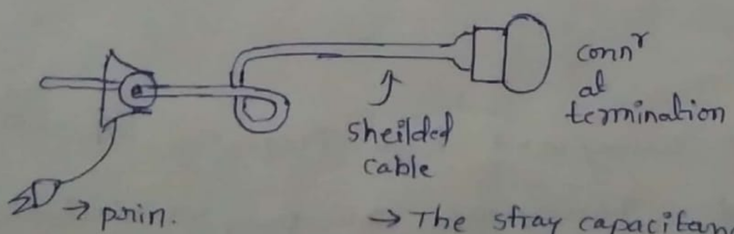


→ The probe tip is sgl sensing ckt. it may pasive or active.

→ The various types of probes are.

① Direct probes ② High impedence probes ③ Active probes ④ Current probes ⑤ Differential probes

### ① Direct probes

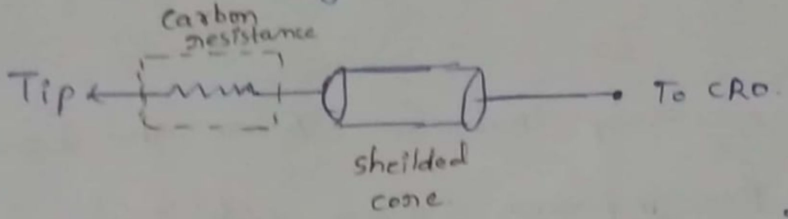


→ it uses a Shielded co-axial cable.

→ ~~[illegible]~~ it used for low freq sgls.

→ The stray capacitance of probe adds with the capacitance of oscilloscope, hence at high freq's total i/p reactance becomes low.

→ The shunt capacitance effect of such probe at high freq's can reduced by placing a carbon resistor in series with test leads



→ But even though such modification also there is small reduction in amplitude, change in shape of i/p. to avoid this we go for High impedence probes.

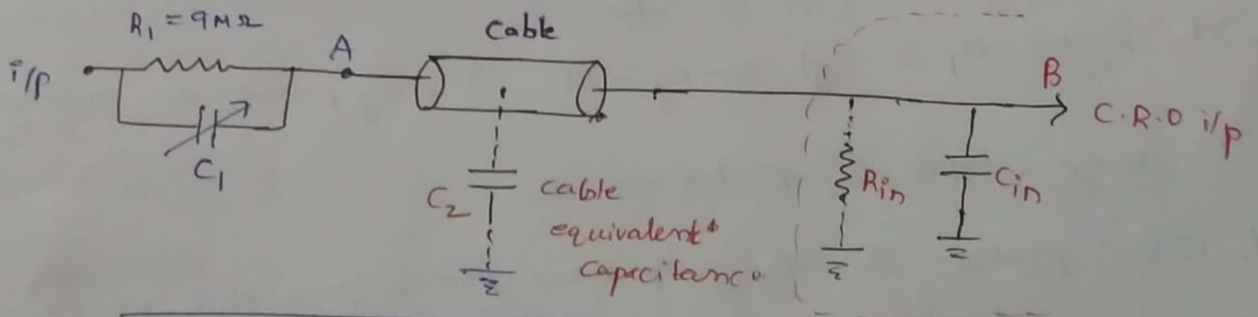
## ② High impedence probes:

→ This is called "passive voltage probe". The funⁿ of this probe is to increase i/p impedence & reduce the effective i/p capacitance of an oscilloscope. This probe head used as a resistor & capʳ combination. $C_1$ is called compensating capʳ.

$C_2$ → probe cable equivalent capacitance.

$R_{in}$ → i/p resis, ↳ 1MΩ.

$C_{in}$ → CRO capacitance. ↳ 20pf

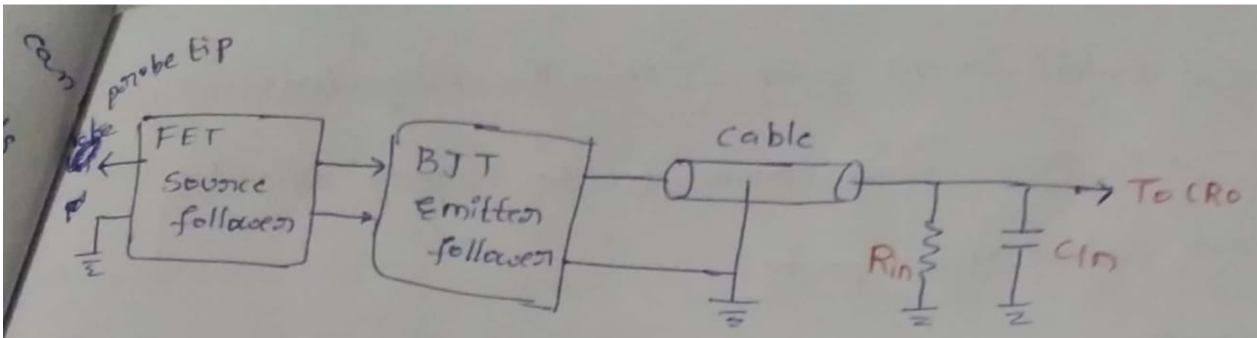


$$\boxed{R_1C_1 = R_{in}(C_2+C_{in})}$$

→ The limitation of this probe is sgl attenuation take place

## ③ Active probes:

→ For connecting fast rising and high freq sgls the active probes are used. These probes are very use full for small sgl measurements as their attenuation factor is very small.



→ This probe consist active element like FET Source follower ckt, & BJT as emitter follower
↳ to amplify Sgls.

→ In this no. sgl attenuation, so small sgls can be measured.
→ provides high i/p impedence, reducing loading effect.
→ capacitance of such prob is very low (2-3 pf)
→ High freq, fast rise time sgls can be clearly measured.

* The need of D.C supply makes such probes more expensive than passive probes.

* Another limitation is → it handle sgls which are less than few volts.

## ④ Current probes:

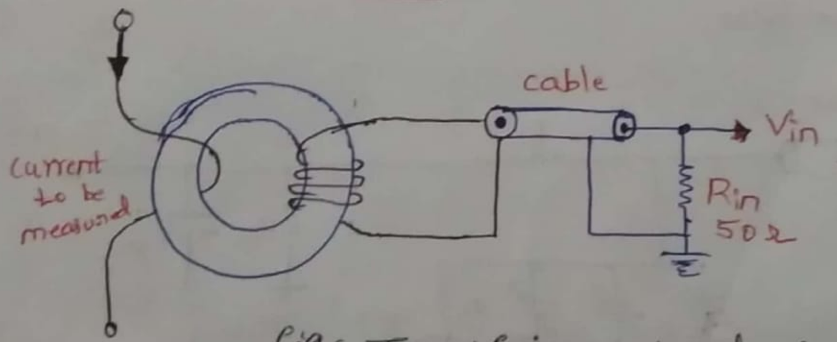


fig: Transformer based current probe.

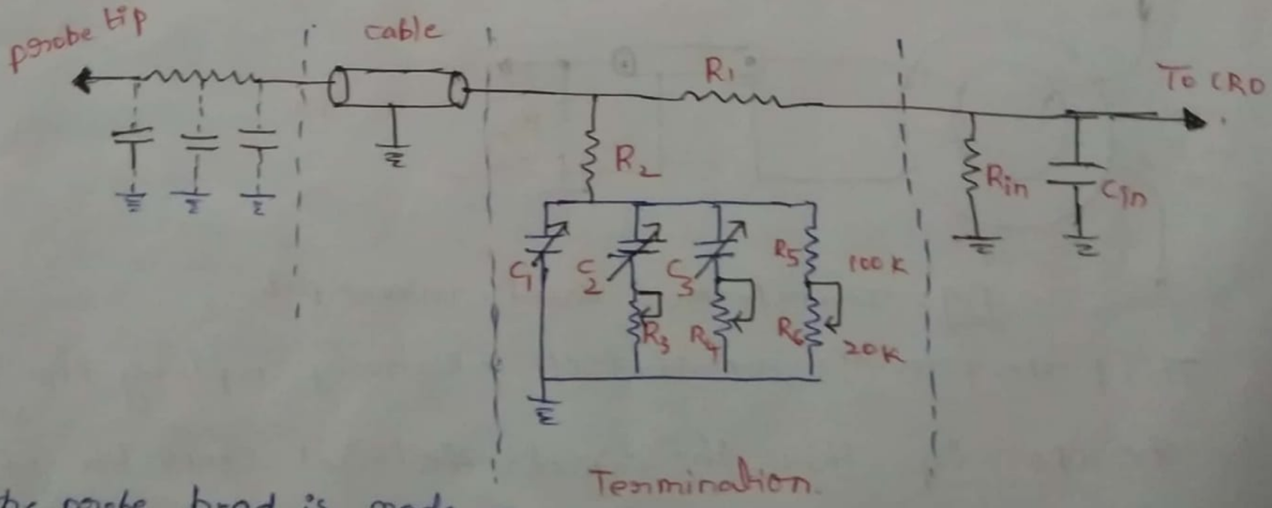
This probe provides a method of inductively coupling the sgl to the CRO i/p. thus the direct electrical connection to the test ckt is not necessary. This probe can be clamped around a wire carying an electrical current without any physical contact to the probe. Thus the magnitude of current with freq range from d.c to 50 MHz can be measured using this probe.

→ A magnetic core with a removable piece is used as coupling element for current probe. The wire carrying current to be measured in centre of magnetic core and acts as a primary of a transformer.

→ B'coz of electromagnetic induction principle, whenever current flows through primary, the e.m.f gets induced in seccondary. This is fed to C.R.O i/p via termination circuitary.

## ⑤ High Voltage current probes:-

↳ These are used to measure very high voltages in the range of kilovolts. It provides voltage division ratio of 1000 to 1 or more also.



→ The probe head is made up of high impact strength thermo-plastic material which provides security against electric shock hazards to user.

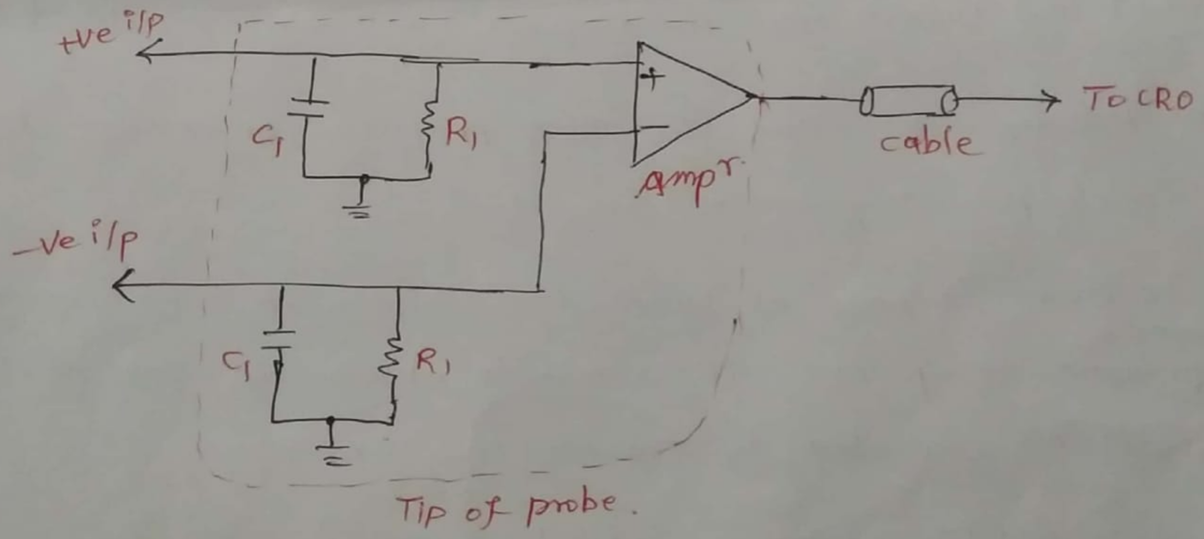
This probe head consist of high i/p resis of 100 MΩ A special cable connects head to the termination.

→ limitation in this probe is requirement of large isolation, big size & not Scuitable for high freq..

⑥ **Differential probes:**

→ it is a type of active probe. it has two i/ps, a positive & a negative. It has a seperate ground lead and it drives single terminated 50Ω cable to transmit its o/p to one oscilloscope channel.

→ This o/p volt sgl is proportional to diff b/w voltages appearing at two i/p terminals.



→ The B.W up to 1 GH can be achieved in this

→ High values of CMRR (Common mode Rejection Ratio).

→ It can handle less volt sgls.

## Applications of CRO:

→ It is used to measure A.C & D.C Voltages & currents, used to calculate the parameters of the voltages as peak to peak value, r.m.s value, duty cycle e.t.c.

→ In lab to measure freq, period, phase relationships b/w sg^l & to study periodic & non-periodic sgls.

→ In radar, it is used for giving the visual rep^n of target such as aeroplane, ship

→ In radio applications, it is used to trace & measure a sgl through out the RF, IF & AF channels of radio & TV Rx^rs.

→ In medical applications, it is used to display the cardiograms, which are usefull for the diagnosis of heart of patient.

→ In Industry it is used for many purposes, to observe B-H-Curves, P-V diagrams & other effects.

→ To study response of various transducers, which measure strain, pressure, temp etc. it is used to observe the radiation pattern generated by transmitting antena.

→ It is used to determine modulation char's & detect standing waves in transmission line.

→ To measure capacitance, inductance & also to check diods.

# III-unit Sepecial purpose oscilloscope. :

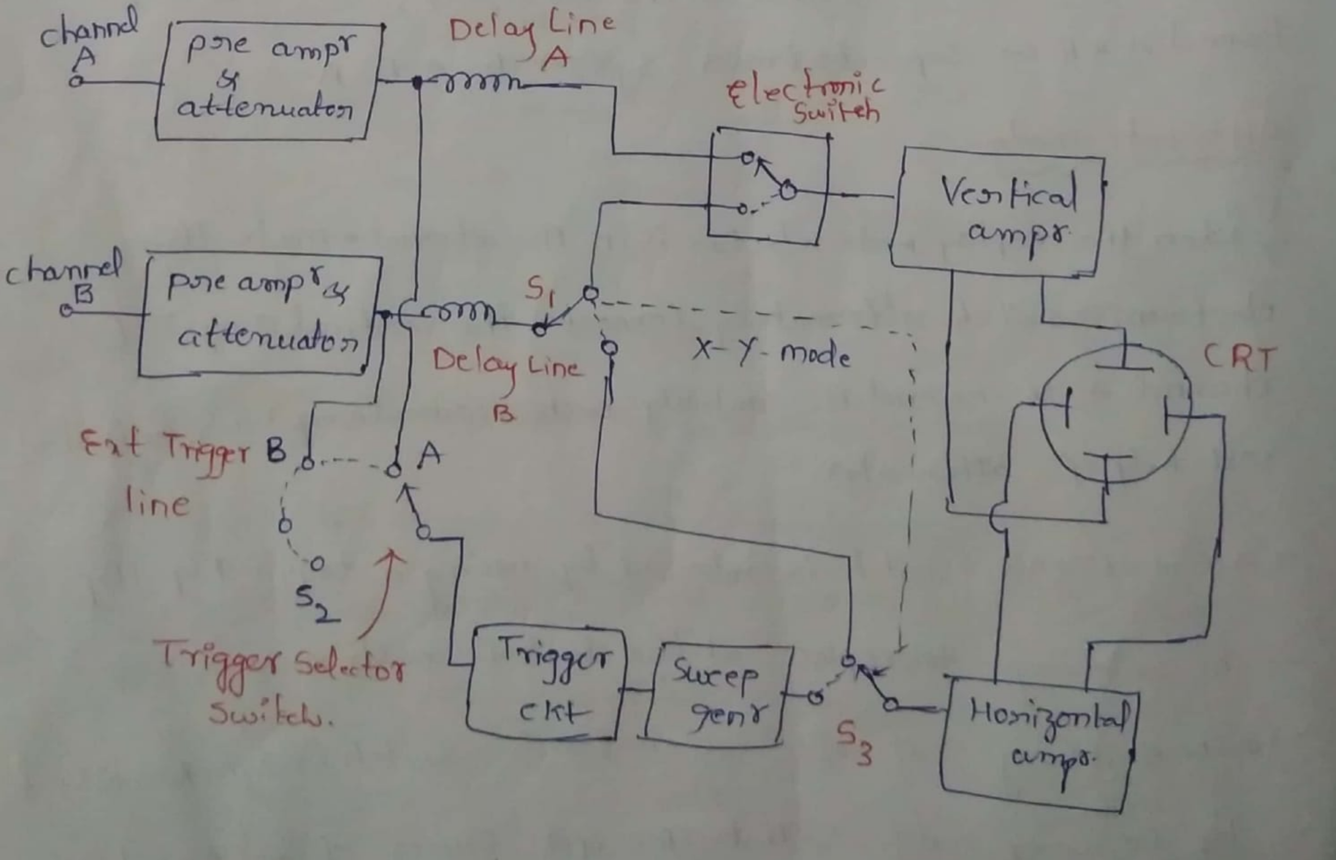
## Dual Trace oscilloscope:

→ The comparision of two or more voltages is very much necessary in the analysis & study of many electronic ckts & S/ms.

→ This is posible by using more than one oscilloscope at the same time. A common and less costly to solve this problem is to use Dual trace or multitrace oscilloscope.

→ In this method, the same ē beam is used to generate two traces which can be deflected from two indipendent vertical sources.

→ The two methods are used to generate two independent traces which are ① ~~At~~ Alternate sweep method ② chop method.



→ There are two seperate ~~Vertual~~ Vertical i/p channels A & B each channel has seperate preamp$^r$ & attenuator stage hence amplitude of each i/p can be individually controlled.

→ After preamp$^r$ stage, both sgls are given to an electronic switch, the switch can pass one channel at a time via delay line to the vertical amp$^r$.

→ The time base ckt uses a trigger selector switch $S_2$, which allows ckt to be triggered on either A or B channel.

→ The Horizontal amp$^r$ is fed from the sweep gen$^r$ or the B channel through $S_1$ & $S_3$

→ The x-y mode means, the oscilloscope operates from channel A as the vertical sgl & channel B as Horizontal sgl.

→ Depending on the selection of front panel controls several modes of operation can be selected as channel A only, channel B only, channel A & B as seperate traces, sgls A+B, A-B, B-A.

## Alternate mode:

→ when the display mode selector is in the altrnate mode the electronis switch alternately connects the vertical amp$^r$ to channel A & channel B. Initially each verticalamp$^r$ is adjusted with help of attenuator.

→ An electronic switch is controlled by using a toggle Flip-flop

→ The switching takes place at the start of each new sweep

→ The switching rate of an electronic switch is synchronised ~~by~~ the to sweep rate, so that CRT spot traces chanel A sgl on one sweep ~~&~~ channel B sgl on the next sweep. thus two channels are alternately connected to vertical ampr.

→ The change over flyback period of Sweep.

→ During flyback, the ē beam is invisible & change over is also invisible. Thus alternate mode displays one vertical channel for a full sweep and the next vertical channel for next sweep.

→ The time relation in this mode of dual trace CRO is given in fig.

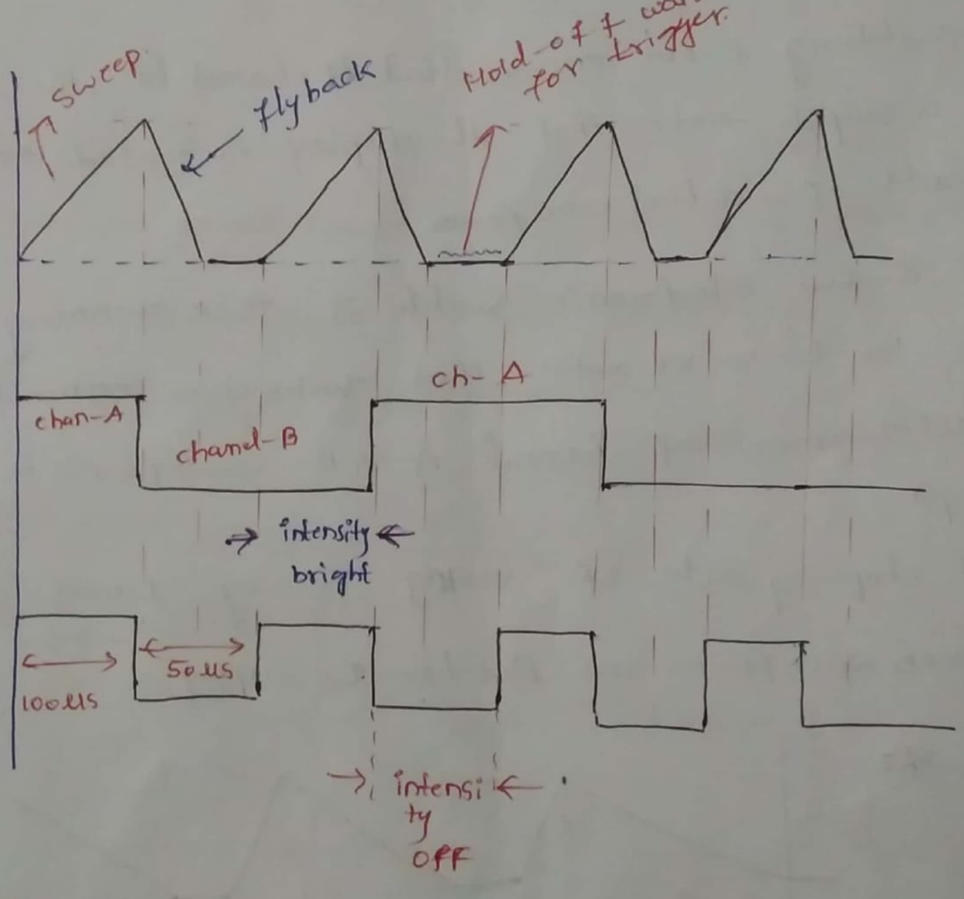


Fig: Time Relation in alternate mode.

→ The sweep ~~sgl~~ trigger sgl is available from channels A or B & trigger pick-off takes place before the electric switch. This technique maintain correct relationship b/w A & B sgls.

→ It has one limitation in display. The sgl are displayed as if they were existing at ~~to~~ two different times. Similarly the alternate mode can't used for displaying very low freq sgls.

## Chop mode

→ In this, switching from one vertical chanel to other, many times during a single sweep.

→ This switching from one vertical ~~to~~ chanel to other is at such a rapid rate that the display is created from small segments of actual wave form.

→ The ~~E swi~~ electronic switch is free running oscillator at 100 to 500KH rate, thus switch can connects the small segments of channel A & B wave forms to the main ampr

→ At choping rate of 500KHz, for eg 1 usec segments of each wave form are fed to the display.

~~If the~~

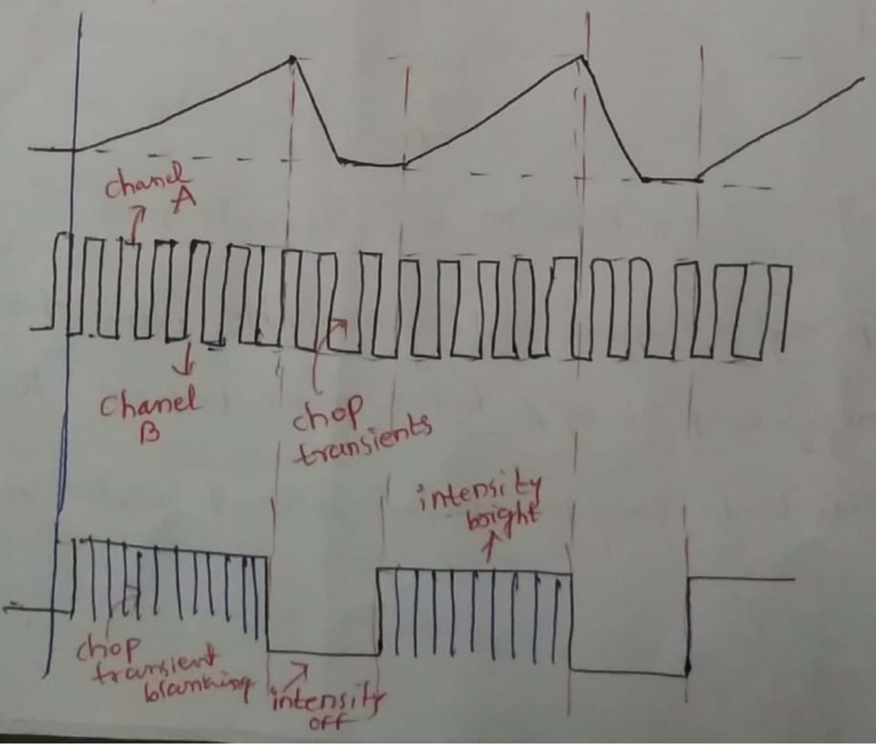


Fig Time Relations in chope mode.

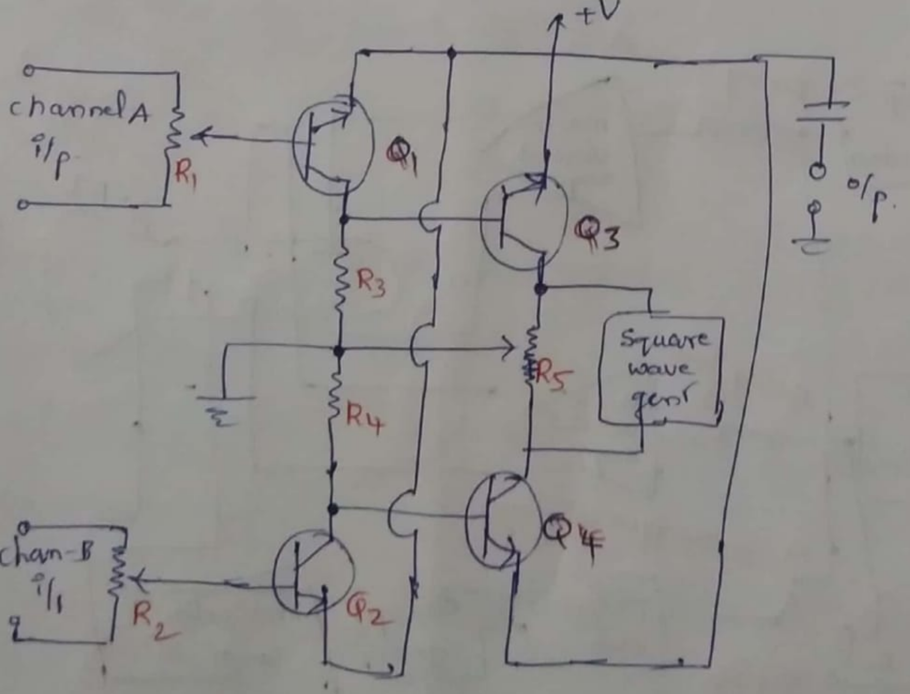
→ if the chopping rate is faster than horizontal sweep rate, then the individual little segments fed to the vertical amp$^{r}$ together reconstitute the original A & B waveforms on the CRT Screen, without any visible interruptions.

→ The little chopped segments merge to appear continous eye.

→ * If the chopingrate is Small, the continuity of the display is lost. in such cas it better to use alternate mode

## Electronic Switch:

↳ it is used in dual trace oscilloscope. it ~~controlles~~ enables two sgls to be displayed simultaneously on the screen by single gun CRT.



→ Each ~~switchits op.~~ sgl is applied to seperate gain control and gate stage.

→ The resis $R_1$ & $R_2$ adjust the amplitude of chan-A & B sgls.

→ $Q_1$, $Q_2$ are amplifiers.

→ $Q_3$ $Q_4$ are switches.

→ i/p from ch-A is applied to $Q_1$ after proper gain control by $R_1$.

→ " " " B " " " $Q_2$ " " " " $R_2$

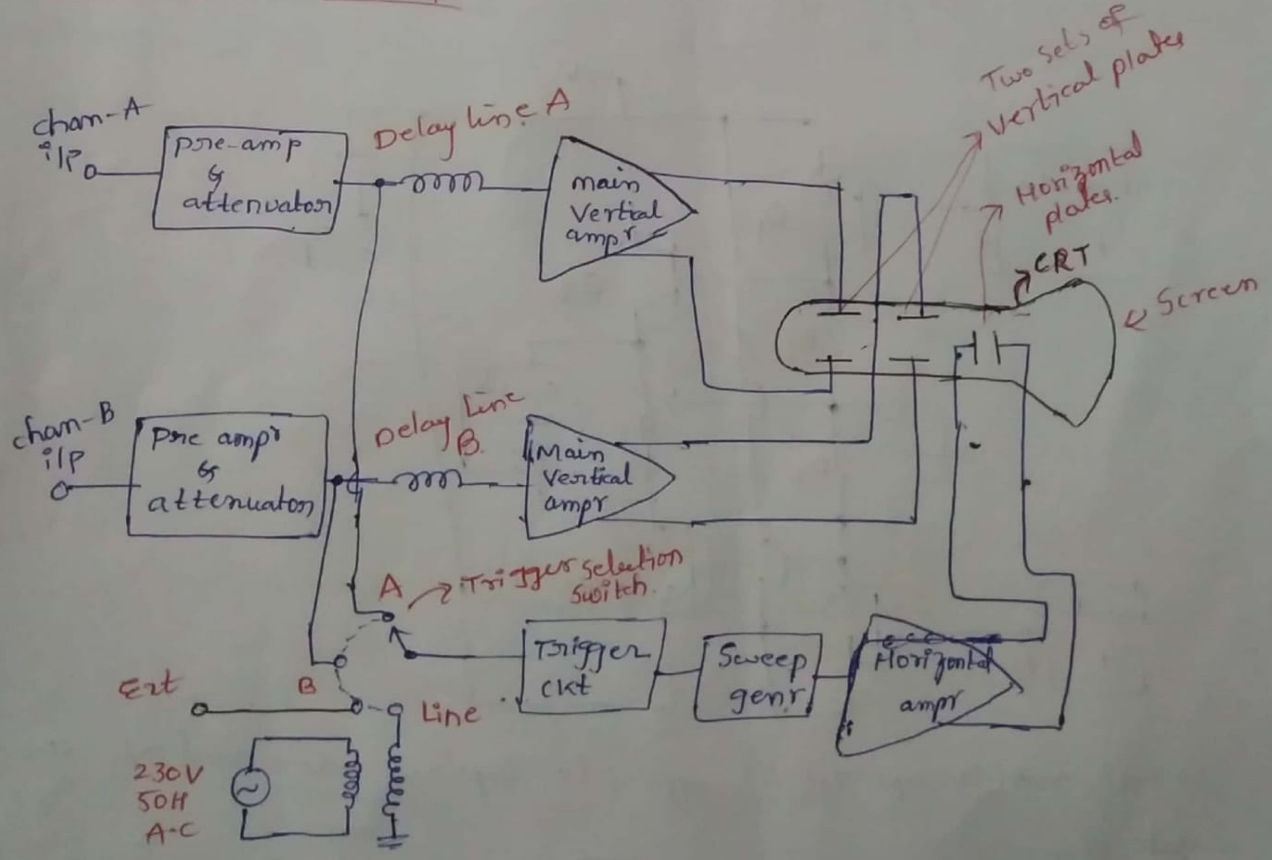
→ The square wave genr provides alternate biasing sgl to $Q_3$ & $Q_4$.

→ when $Q_3$ is conducting, $Q_4$ is OFF & vice-versa.

→ when $Q_3$ is cut-off, $Q_4$ sends chanel-B sgl to o/p, while when $Q_4$ is OFF, $Q_3$ " " A " " " .

→ $R_5$ controls position.

## Dual beam oscilloscope



7. Another method of studying of two voltages simultaneously on screen is to use special cathode ray tube having two seperate ~~ebeam~~ electron guns generating two seperate beams.

→ Each ē beam has its own vertical deflection plates.

→ But two beams are deflected horizontally by the common set of horizontal plates.

→ The time base ckt may be same or different. such oscilloscope is called "Dual beam oscilloscope"

→ The oscilloscope has two vertical deflection plates & 2 seperate channels A & B for two seperate i/p sgls. Each channel consist of a preampr & and attenuator.

→ A delay line, main verticalampr & a set of vertical deflection plates together forms a single channel.

→ There is a single set of horizontal plates & single time base ckt.

→ The sweep genr drives the horizontal ampr which inturn drives the plates.

→ The horizontal plates sweep both the beams across the screen at the same rate.

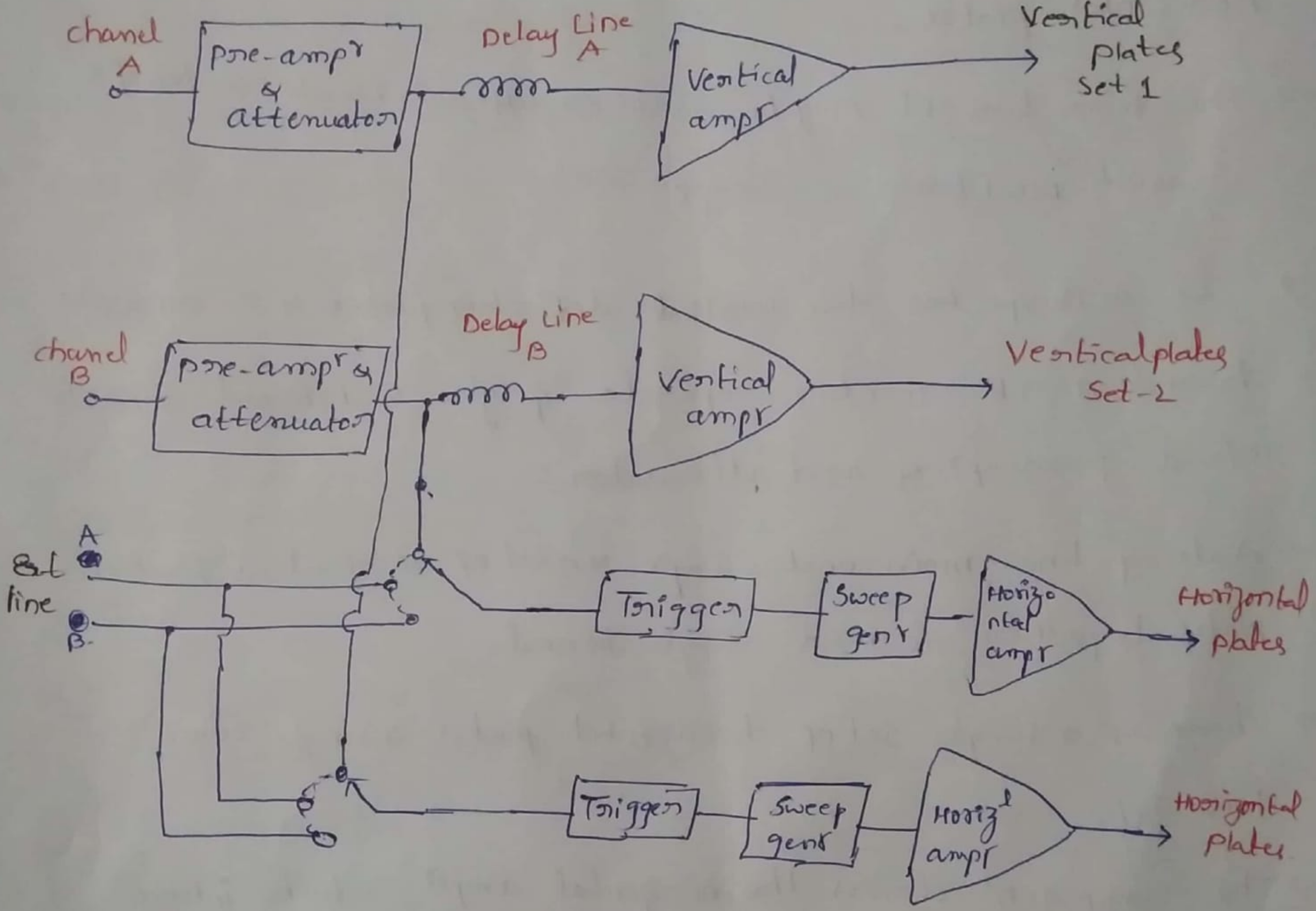
→ The sweep genr can be triggered internally by the channel A sgl or channel B. sgl.

→ lly it can also be triggered from an external sgl or line freq sgl. This is possible with the help of trigger selector

→ Switch , a front-panel control. Such oscilloscope may have seperate time base ckt for seperate channel.

→ This allows different sweep rates for two chanels but increase size & weight of of oscilloscope.

Fig: oscilloscope with seperate time base ckts.



multiple beam oscilloscope

→ It has a single tube but several beam producing s/ms inside. Each s/m has seperate vertical deflecting pair of plates & generally a common time base s/m.

→ The triggering can be done internally using either of the multiple i/ps or externally by an external sgl or line voltages.

# UNIT – IV

# Transducers

# TRANSDUCERS III - unit M. Ganesh. ①

## Introduction

- Transducer is a device that converts one form of energy to another form of energy.

- Instrumentation is a heart of industrial applications like measuring & controlling different variables, → (flow, temp) - automation.

- Basic Instrumentation S/m consist ~~of~~ a device i.e Transducer.

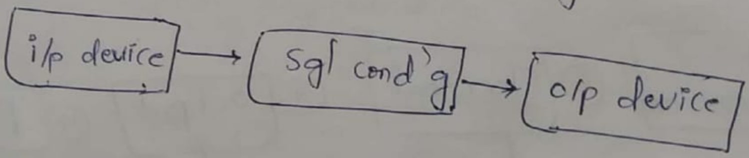
- Transducer is a device capable of converting phisical quantity in to a proportional electrical quantity, Such as Voltage or electric current.

→ o/p of Transducer is in electrical form.

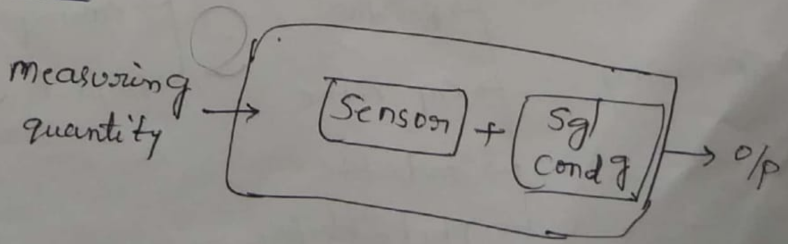
eg: Temp Transducer will convert temp to electrical potential.

→ In Instrumentation S/m generally consist of 3 major elements.

① i/p device ② Sgl conditioning device ③ o/p device.



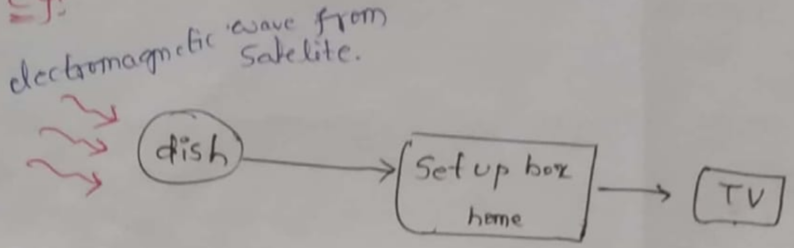
Basic Transducer:



→ The i/p device receives quantity & delivers a proportional electrical sgl to sgl cnd'g device, Here sgl is amplified, filtered or modified to a format, acceptable to the o/p device. o/p device is CRO or Recorder.

→ The i/p quantity in most of instrumentation s/m is non-electrical. These non-electrical quantity is converted into electrical by a device called "Transducer".

Eg:



↳ from dish the electromagnetic waves are converted in to electrical sgl & given to set up box.

↳ from this Transducer is a device, when actuated, which transforms a non-electrical physical quantity into an electrical sgl.

## Classification of Transducers

① physical phenomenon
  - primary
  - Secondary

② Electrical
  - Resistive
  - Capacitive
  - Inductive
  - Photo electric
  - photo voltaic

③ output
  - Analog
  - Digital

④ Power
  - Active
  - pasive

① physical phenomenon

↳consist Transducer, which will first converts ~~the~~ in to mechanical form & then in to electrical form.

↳mechanical part → primary Transducers

↳electrical part → seccondary Transducers.

Eg: mike → it has a diaphram inside the mike placed.

the sound waves will be converted by diaphram, so it will be converted in to displacement, hence it is called as primary Tranducer.

And the displacement of diaphram i.e movement of diaphram would be converted in to electrical sgl which is called secondary Transducer.

② Electrical ~~[illegible]~~

depends up on the o/p, either the sgl would be converted in to Resistive, (or) Capacitive, or Inductive (LVDT) (or) Light dependend.

**Sensor:** Sensor is a device which responds to the physical quantity (or) reacts to a physical, chemical (or) biological condition.

**Transducer:** is a device, which converts one form of energy to another form. it has two parts.

① Sensing element (Detector (or) sensor)

↳ sensing any physical quantity.

② Transdution element: is to convert non electrical quantity into electrical quantity.

* All the ~~sensors~~ ~~are~~ Transducers ~~but~~ , ~~not all~~ are sensors but all sensors are not Transducers. , b'coz they are not necesaryly converting any non electrical quantity in to electrical quantity.

* Transducer is more than sensor, it consist of a Sensor/Actuator along with sgl conditioning ckt.

① **Basic Transducers are two types.**

- → Sensor (i/p)
- → Actuator (o/p).

**Actuator:** It converts an electric sgl into a physical form of energy. eg: Speaker which Transforms Electronic sgl in to sound waves.

② Types of Transducers based on requirement of external power source.

↳ **Active Transducer:** (→ self generating) This Transducers does not require any power source for their ~~op~~ operation. They work on energy conversion principle. They produce an electrical sgl proportional to the i/p

↳ eg: Thermo couple Tr
photo voltaic "
piezo electric "

↳ **Passive Transducer:** which requires an external power source for their operation. They produce o/p sgl in the form of some variation in Resistance, capacitance.

↳ eg: Resistive Transducer (Strain gauge)
capacitive "
Inductive " (LVDT).

③ Types of Transducers based on quantity to be measured.

① ↳ (Thermo couple) Temp Transducer.
↳ Presure Transducer (Diaphram).
↳ Displacement Transducers. (LVDT)

**LVDT** → Linear Variable Differential Transducer → it is inductive transducer. → converts linear motion into electrical sgls. (it is a transformer).

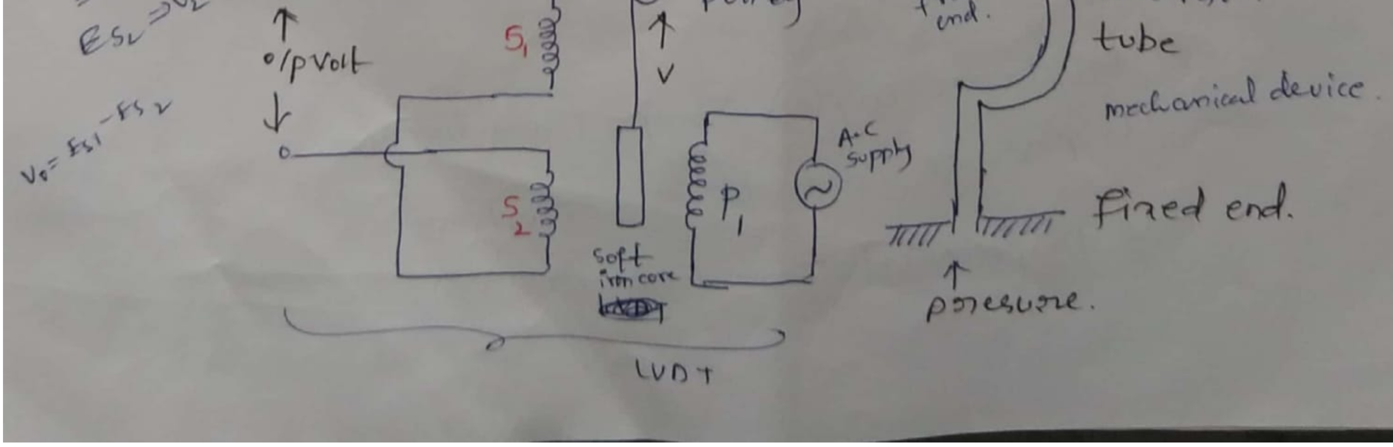
④ Types of Transducers based on principle of operation.

- → photo voltaic (solar cell)
- → piezo electric
- → chemical
- → mutual induction
- → Electro magnetic
- → photo conductors

* primary and Seccondary Transducers.

→ In ~~Sue~~ some Transducers consist of mechanical device along with electrical device. In such transducers, mechanical device acts as a primary transducer & it converts physical quantity into mechanical sgl. And Electrical device acts as a seccondary ~~device~~ transducer & it converts mechanical sgl produced by primary transducer in to an electrical sgl.

↳ for Eg: pressure measurement.



→ In this ~~an~~ air tube acts as a primary transducer, which converts pressure in to displacement (physical to mechanical)

→ LVDT is acts as a Secondary transducer, which converts displacement in to electrical sgl.
(non-electrical)
(mechanical)

## Selection Criteria :

↳ It considers to ~~Select~~ a select a transducer we consider 3 types of char'cs.

① I/p char'cs

↳ Type of i/p. → i/p quantity to be measured.

↳ Operating range → Range of max limit, capability of Transducer

↳ Loading effect → use of Transducer should not effect on i/p quantity which Tran^r to be used.

② Transfer char'cs :

→ Transfer function → Relationship b/w i/p & o/p quantity
$Q_0 = f(Q_i)$

→ Tran^r ~~sfer~~ response → Tran^r response to environmental condition

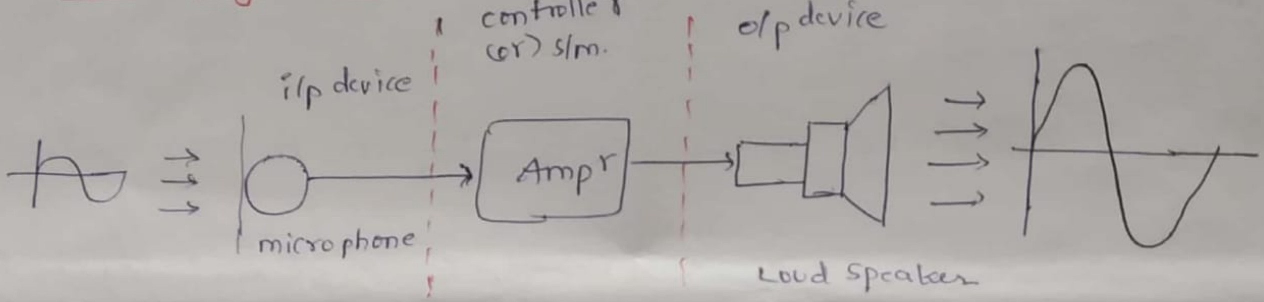
→ Error → The deviation from Relation of i/p & o/p quantity

→ $\varepsilon = Q_0' - Q_0$ ↱ desired o/p
↳ obtainted o/p.

⑤ o/p char'cs :

- → Type of electrical o/p ⇒ volt, current, Time funⁿ of amplitude.
  it should be matches the next s/m.
- → o/p impedance ⇒ o/p impedence should be as low as posible to minimize loading effect.
- → use full range ⇒ Based on i/p range.

→ one eg for sgl condⁿ



* Analog & Digital Transducers.

- → Analog → LVDT → voltage o/p.
- → Digital → o/p in digital → eg → optical encoder
  → Digital takometer.

* Based on principle of operation Types of Transducer

① Resistive → eg → strain gauge. ⇒ (S.G)

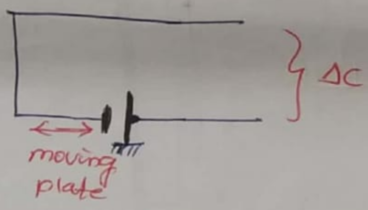
in S.G when external force is applied the resis of wire is changed, so change in resis, there will be change in voltage.

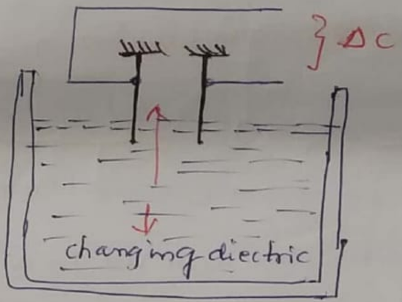
② capacitive: in which capacitance is changing by the distance b/w plates when external force is applied.

③ Inductive → eg: LVDT. → self inductance or mutual inductance of coil is changing when it is excited by A.C Supply.

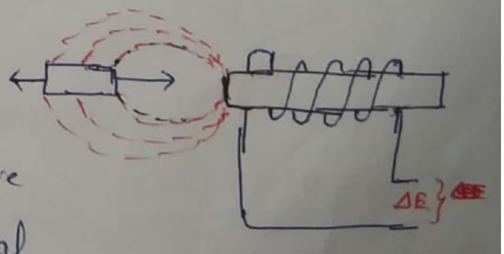
* According to Transduction principle.

capacitive Transduction: In this measurand is converted into change in capacitance, capacitor consist of two conductive plates Seperated by an insulator (dielectric). A change in the capacitor occuers either by changing the distance b/w two plates or by a change in the dielectric.



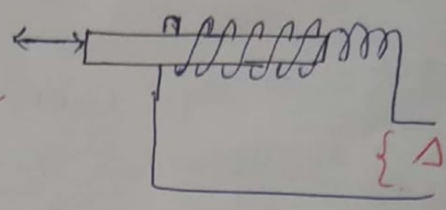


Electromagnetic Transduction: In this measurand is converted into an electromotive force (voltage) induced in a conductor by change in the magnetic flux, in the absenic of Excitation. Thus there type of transducers are Self generating active type transducers. The relative motion b/w a magnet or piece of magnetic material & an electromagnet brings out the change in the magnetic flux.



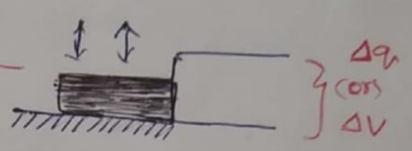
Inductive transduction: The measurand is converted into change in the self inductance of a single coil.

This is accomplished by displacing the coil's core, which is linked or attached to a mechanical sensing element.



## Piezo electric Transduction:

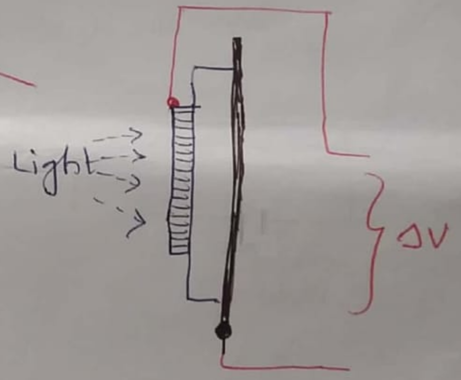
The measurand is converted into a change in electrostatic change, q or voltage V generated by crystals when mechanically stressed.



ⓐ compression.

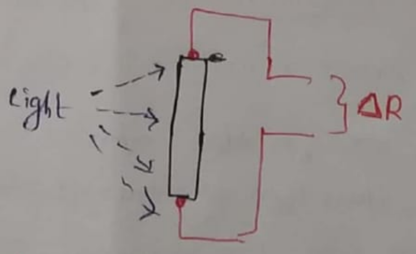
## Photo voltaic Transduction:

In this the measurand is converted in the voltage generated when a junction b/w dissimilar material is illuminated.



## Photoconductive Transduction:

The measurand is converted into a change in resis (conductance) of a semiconductor material by a change in the amount of illumination incident on the material.



## Transducer Selction factors:

→ considering the transducers char'cs, desired s/m performance & i/p requirements

① **Nature of measurement:** nature of quantity to be measured. for eg: temp measurement, temp sensors are used. ~~Or~~ For measuring stress or strain, strain gauges are used.

ⓐ ⑥

② **Loading Effect:-** Transducer has to select with min loading effect to keep min errors.

③ Environmental conditions.:

④ measuring S/m compatability

⑤ cost and availability.

## potentiometric Transducer (or) potentiometer.

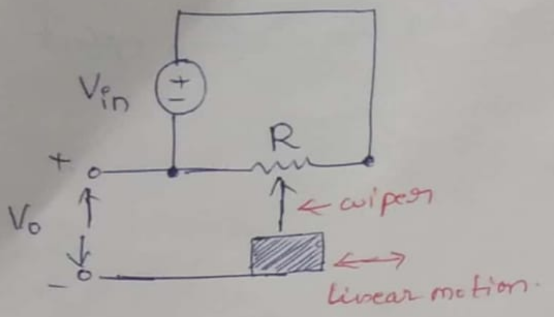
↳ It is used to measure linear or angular displacement.

↳ A Resistance potentiometer consist a wire wound resistive element along with a sliding contact which is called a wiper.

↳ A wire is made up of Nikel or platinum, with diameter of 0.01 mm., The resistive element is made up of cement, hot moulded carbon or carbon film. the wire is wound on an insulating former.

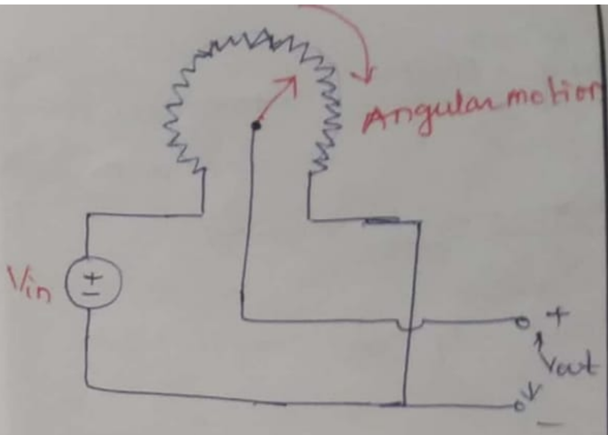
↳ using Resistance potentiometers mechanical displacement is converted in to an electrical o/p. Linear or angular displacement is applied to the sliding contact & then the corresponding change in in resis is converted in to voltage or current.

→ The motion of Sliding contact may be Rotational or Translatory.



ⓐ Linear type

(Translational)



ⓑ (Rotary) Angular type

(Rotational)

## potentiometer:

↳ is a 3 terminal resistor with a sliding or rotating contact that forms an adjustable voltage devider

→ If two terminals are used it acts as a Variable resistor (or "Rheostat".

→ It is a voltage devider to measure electric potential

→ To control ~~ele~~ electrical devices, as volume control on Audio devices.

## Strain Gauge Transducers

↳ The strain gauge is a passive Resistive transducer which is based on the principle of conversion of mechanical displacement into resistance change.

↳ The strength of material is essential in the design & construction of machines & structures.

↳ The strength of material is char'd ~~by~~ in terms of stress which is defined as force experienced per unit area and is expressed in pressure units.

↳ The stress can not be directly measured. It is normally deduced from the changes in mechanical dimensions & the applied load.

→ The mechanical deformation is measured with strain-gauge elements. the strain is defined as change 'Δl', in length 'l' per unit length & expressed as $\frac{\Delta l}{l}$ in microstrains.

→ The strain magnitude is of the order of a few m~~icrostrains~~ micrometers per meter, which is expressed as microstrains. Since the magnitude of strain is very small, it is practically difficult to measure it directly, Hence a gauage which can yield (produce) strain directly is used. Such gauge is called "Strain gauge"

→ The desirable char'cs of strain gauge are Gauge Sensitivity, Range of measurement, Accuracy, freq response & Environmental conditions.

→ Sensitivity is defined as the smallest value of Strain that can be measured.

→ "Strain Gauge" is also called variable resistance Transducer or the resistive Transducer.

## Principle of operation & construction of strain Gauge.

→ If a metal conductor is stretched or compressed, its resistance changes, b'coz → its length may change or diameter may change or resistivity may change.

→ The resistance of wire changes as function of strain increasing with stretch & reducing with compression. The change in the resistance is measured with wheatstone bridge.

$$R = \rho \frac{L}{A}$$

$\rho$ → resitivity
L → length
A → area

→ The materials used for fabrication of Electrical strain gauges must have basic qualities like high specific resistance, low temp coefficient of resis, constant gauge factor & constant strain sensitivity over a wide range of strain values, to achieve high accuracy, good sensitivity reproducibility of strain gauge.

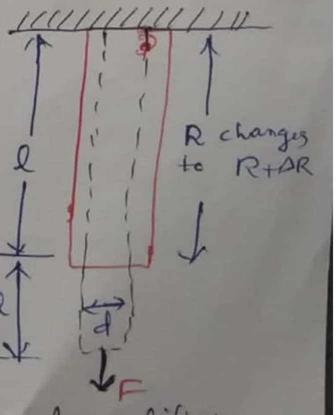
→ The bonding cement should have high insulation resis & excellent transmissibility of strain & must be immune to moisture effects.

→ The most common materials used for wire strain gauges are constant alloys. (45% Nickel & 55% of copper) as they exhibit high specific resis, constant gauge factor over a wide strain range, & good stability over a large temp range (0°c – 300°c).

## Gauge factor:

The proper functioning of S.G is dependent on the quality of bonding which holds the gauge to the surface of structure undergoing test

Gauge factor is a measure of sensitivity of material (or) its resistance change per unit applied strain



$$G.F = \frac{dR/R}{\varepsilon} \qquad S = \frac{\Delta R/R}{\Delta l/l}.$$

S → Gauge factor or sensitivity
R → Gauge wire resistance
ΔR → change in wire resistance
l → length of gauge wire in unstressed condition
Δl → change in length in stressed condition.

## Types of Strain gauges:

Depending on principle of operation and their Constructional features strain gauges are classified as

① mechanical ② optical ③ Electrical

① mechanical: → larger in size

→ for static strain measurements only

→ The change in length, Δl is magnified mechanically using gears.

② optical: used ~~[illegible]~~ mirror in this. → it rotates when stress applied through an angle. The measurement accuracy is high.

③ Electrical: It measures change that occure in resis, capacitance or inductance due to strain transfered from the specimen to the basic gauge ~~[illegible]~~ element.

* The most commonly used strain gauge is bonded resistance type of strain gauge.

### Basic forms of Resistance wire Strain gauges:

→ The resistance wire strain gauges of metalic type are available in two basic forms

① Bonded

② un Bonded.

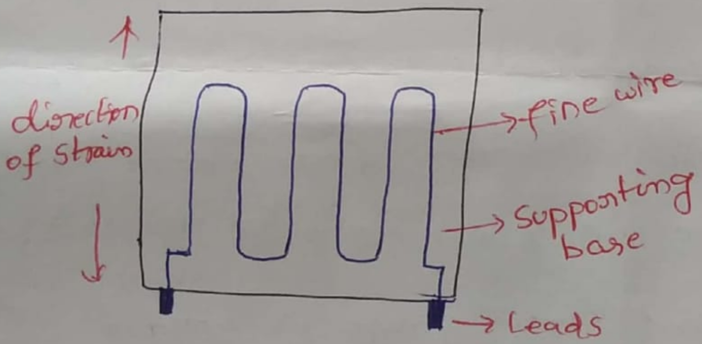
## Bonded Resistance wire strain gauges

X(~~It consist a wire stretched b/w 2 points in an insulating medium such as air~~) X

→ A fine wire element about 25 μm (0.625 in) or less in diameter is looped back ~~and~~ on a base or mounting plates

→ The grid of fine wire is cemented on a carrier which may be a thin sheet of paper (teflon)). the wire is covered on the top ~~of~~ with thin material. So it is not damaged mechanically

~~the spr~~



→ The spreading of wire permits uniform distribution of stress. the carrier is then bonded or cemented to the member being studied.

→ This permits a good transfer of stress from carrier to wire.

→ A tensile stress tends to extends the wire and increases its length & decrease its cross-sectional area, the combined effect is an increase in resistance.

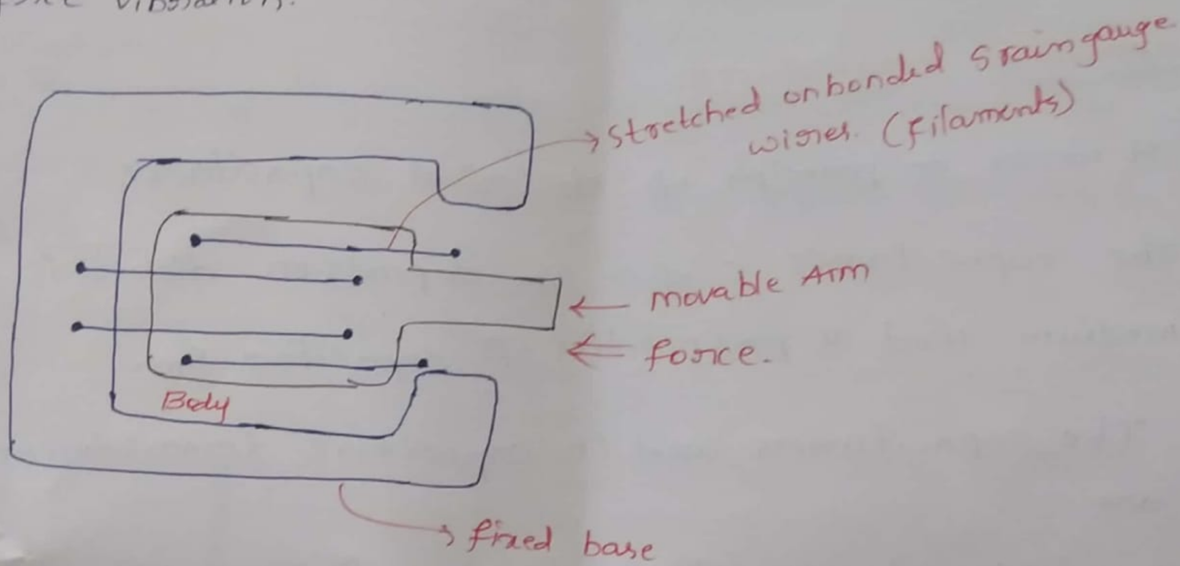
$$\boxed{R = \frac{\rho . l}{A}}$$

ρ → specific resis of material
l → length of conductor
A → area of conductor.

## unbonded wire strain gauges.

→ It consist a wire stretched b/w 2 points in an insulating medium such as air

→ The wire kept under tension (pressure), so there is no free vibration.



→ It is connected in bridge ckt, bridge is balanced with no load applied

→ when external load is applied, the resis of strain gauge is changes, causing an un balance of bridge ckt resulting in o/p voltage.

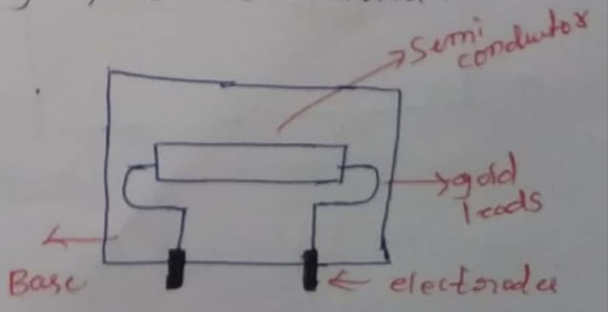
→ This Volt is proportional to applied strain.

## Semiconductor strain gauges:

→ It used for when high value of gauge factor is desired.

→ This gauge factor 50 times higher than wire gauges

→ principle used in this is "piezo-resistive effect."



change in resistance due to change in resistivity of Semiconductor b'coz of strain applied (ge, si).

→ S.C wafer used in this is 0.05 mm thickness.

→ it is very small in size.

## capacitive transducer:

→ It works on principle of electrical capacitance

→ The capacitance 'c' of a s/m depends on dielectric medium used & properties of capacitive s/m.

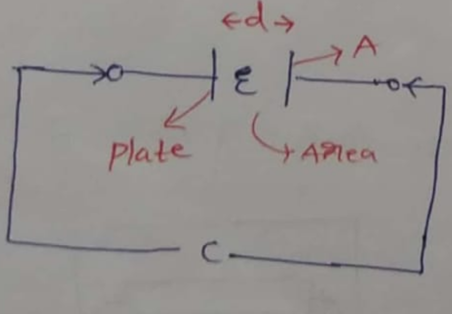
→ The capacitances used in capacitive transducers are

① parllel plate capacitor ② composite capacitor

③ cylindrical capacitor

→ In this the force requirement is very small, hence the power required to operate is small & very usefull in small systems.

### parllel plate capacitor:



↳ The capacitance of parllel plate capacitor is given by

$$C = \frac{\varepsilon A}{d}$$

$\varepsilon = \varepsilon_0 \varepsilon_r$ , $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

$\varepsilon_r$ → Relative permitivity of material.

A → Cross-sectional area of plates.

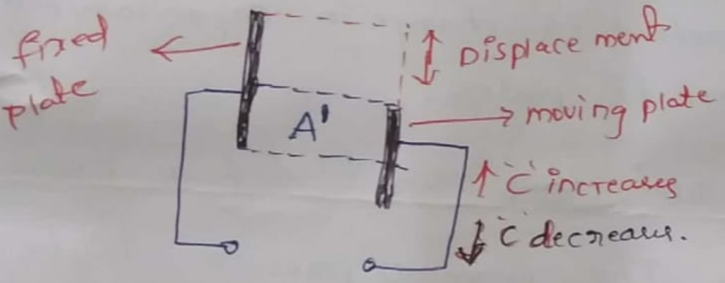
d → plate seperation.

→ By using simple methods, the capacitance of capacitor can be varied and change in its value can be used for transduction in transducer.

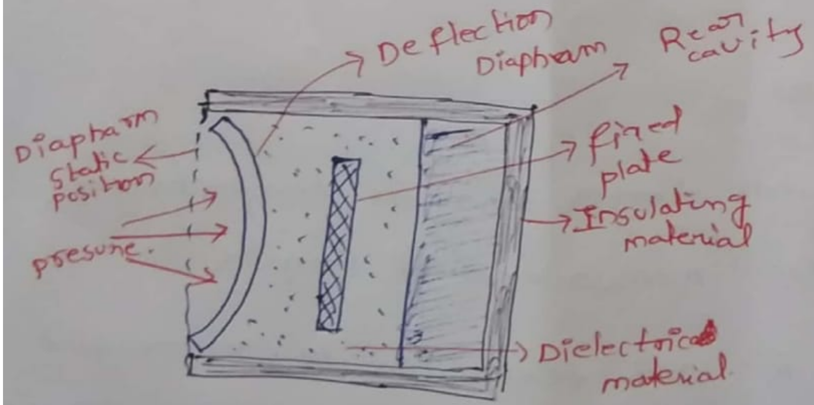
## Capacitive Transducer based on change in Area of plates.

→ By keeping the one plate moving and changing its position parllel to the other plate, common plate area can be varied.

→ By varying 'A', the capacitance can be varied.



## Capacitive pressure Transducer



→ The principle is, if the distance b/w two parllel plates changes, capacitance of parllel plate capacitor changes.

→ In this diapharm acts as a one ~~of~~ plates of two plates capacitor, other plate is fixed.

→ Both are seperated by dielectric medium.

→ when force is applied to diaphram it changes its position from inital static position, hence capacitance changes, the change in ~~the~~ capacitance is measured by A.C. Bridge.

## Applications of Capacitive Transducers:

- → Used for measurement of linear or angular displacement
- → Have high Sensitivity. can measure displacements as small as $0.1\times10^{-6}$ mm. & also measure large distance (up to 30 m) in aeroplanes.
- → For ~~the~~ very small & very large displacement measurements the most preferable method is change in capacitance due to change in distance b/w plates.

→ Along with displacement, they can used for measurement of force & pressure. The force & pressure to be measured are converted to displacement ~~with~~ which causes change in capacitance.

## Resistance Thermometer.

→ The Resistance of conductor changes when its temp changed. This property is utilized for measurement of temp.

→ The variation of resis 'R' with temp can be represented by the following relationship for metals.

$$R = R_0 (1 + \alpha_1 T + \alpha_2 T^2 + \cdots \alpha_n T^n)$$

$R_0$ → Resis at temp $T=0$

$\alpha_1, \alpha_2 \cdots \alpha_n$ are constants. (temp Co-efficient)

→ Resistance Thermometer is called "Resistance Temp - Detector" (RTD), are sensors used to measure temp.

→ The RTD elements Consist ~~of~~ a length of fine wire wrapped around a ceramic glass core. The RTD wire is a pure material of platinum, Nickel, Copper

→ materials used for temp measurement are

① conductors ② semiconductors.

→ if conductors are used to transduce the temp, they are called "Resistance Thermometers"

→ if semiconductors are used ~~to~~ to transduce the temp, then they are called "Thermister."

* conductive materials used in thermometers are

i) platinum ii) Nickel iii) copper iv) Tongstone.

→ platinum is used as primary element in all high accuracy resistance thermometer.

→ platinum is suitable for high temp & to maintain excellent Stability.

* T

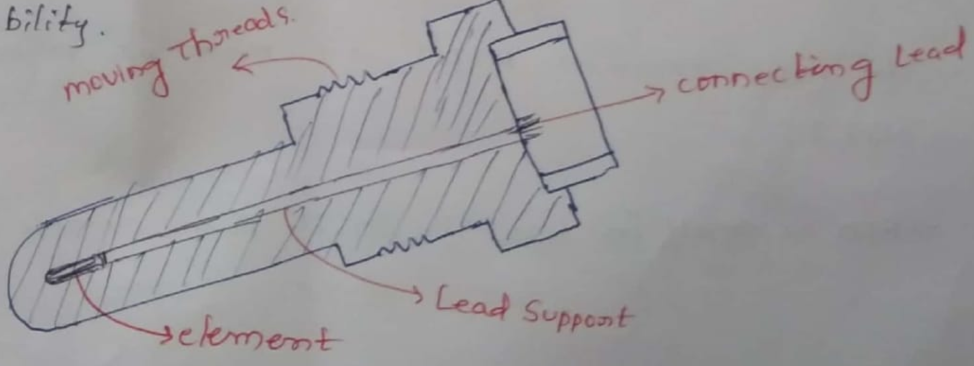


fig: Resist Thermometer (Industrial platinum)

$R_T = R_{ref} [1 + \alpha \Delta t]$

$R_t$ = Resis of conductor at temp t°c

$R_{ref}$ = Resis of " " ref temp (0°c)

$\alpha$ = temp co-efficient of resis

$\Delta t$ = Diff b/w the temp to be measured & ref temp.

→ all metalic conductors have a positive temp co-efficient. So that their resis increases with an increase in temp.

→ The metal with high value of Resistivity should be used for RTD's.

* The requirements of conductor material to be (for RTD) are

i) The change in resis of material per unit change in temp should be as large as posible.

ii) The material should have a high value of resistivity, so that the min value of material is used for the construction of RTD.

iii) The resis of ~~met~~ material should have a continous & stable relationship with temp.

→ Gold & silver are rarely used for construction of RTD's, they have low resistivity

→ Tongstone has high resistivity.

→ The most common RTD's are made of either platinum or Nickel.

→ RTD is small in size, Suitable for remote indication

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## Thermistors

→ called Thermal Resistors.

→ It is a type of resistor, whose resis is depends on temp.

→ used as a current limitors, temp sensors, self regulating heating sm.

→ used for measuring temp. (for low temp).

→ used for voltage reguation, ckt protection & volume control

→ used as a electrical components for temp compensation

* If Semiconductors are used to transduce the temp then it is called "Thermistor"

* most of thermistors have a -ve temp co-efficient of temp resis. i.e their resis decrease with increase of temp.

* This allows thermistor ckts ~~allows to~~ to detect very small changes in temp which could not be obscerved with RTD or a Thermocouple.

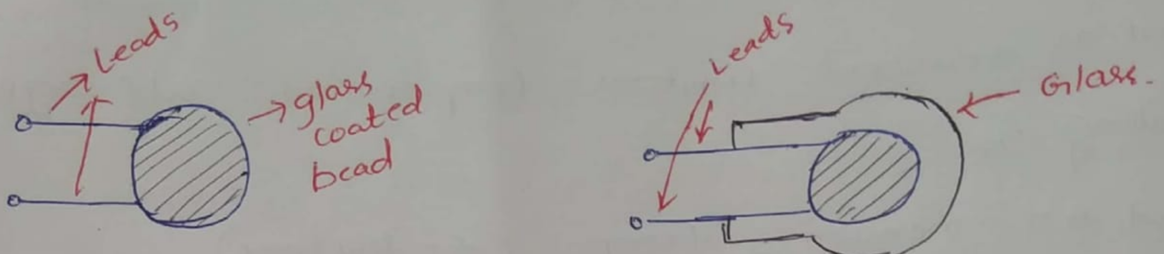
* The high sensitivity to temp changes makes thermistors extremely usefull for precision temp measurement control & compensation.

* It widely used in measurements range of -60°c to 15°c

* resis range from 0.5Ω to 0.75Ω.

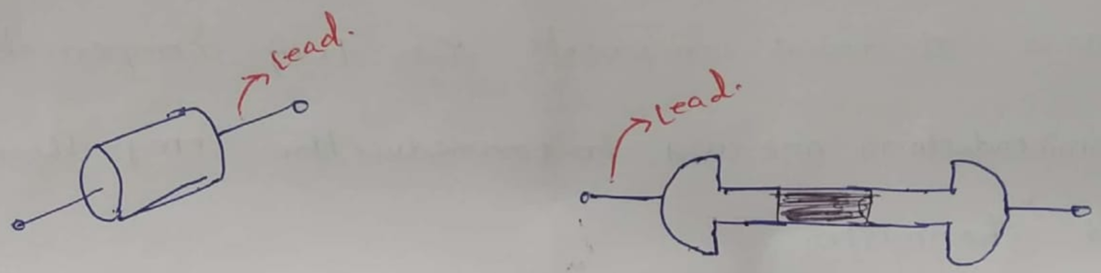
→ It is highly sensitive device , but it exibits highly non linear char'cs of resis Vs Temp.

fig : Diff forms of construction of Thermistors.



ⓐ Disk.

ⓑ probe



ⓒ Bead type.

ⓓ Rod.

→ If the temp of one end of a conductor is raised above than other end , excess electrons from the hot end will diffuse to cold end.

→ This results in an induced voltage , that makes hot end positive with respect to cold end.

→ when 2 dessimilar conductors are joined . ēs will diffuse across the Jn from the conduction with higher ē density

→ when this happens the conductor losing ēs acquires a +ve volt ~~ϕ~~ with respect to the other conductor , this volt is called E.m.f

## Thermocouple.

(For high temp measurements it is preferred).

→ when two metals having different work functions are placed together, a voltage is generated at the junction which is nearly proportional to temp.. This junction is called "Thermocouple".

→ This principle is used to convert heat energy to electrical energy at junction of two conductors.

→ Thermoelectric transducer is a temp transducer which converts thermal energy into an electrical energy.

* The most commonly used thermoelectric transducer is "Thermocouple".

Jn → Junction.

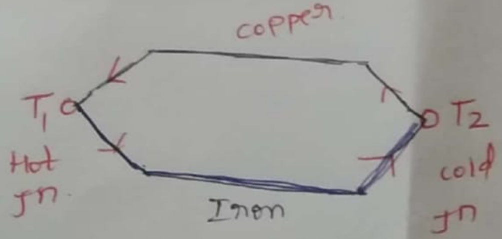


fig: Seeback effect.

→ if two wires of different metals are jointed together forming closed ckt & if 2 Jn's formed are at different temp, an electric ~~ckt~~ current flows around a closed ckt. This is called "See back" effect.

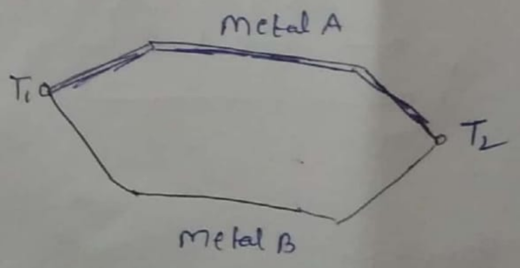


fig: Basic Thermocouple ckt.

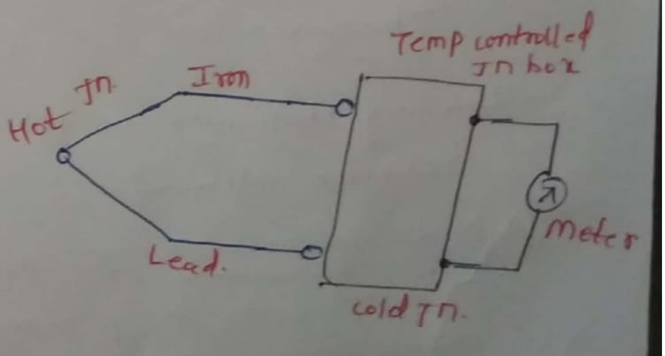


fig: practical Thermocouple

→ out of 2 Jn's $T_1$ & $T_2$ , $T_2$ is kept is constant ref temp. Hence it is reffered as cold Jn

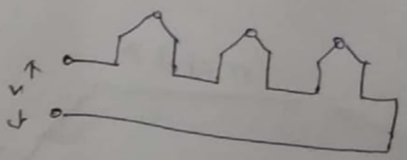
→ while temp changes to be measured are subjected to the Jn $T_1$ which is reffered as hot junction. ~~when~~

→ when hot Jn temp is greater than cold Jn, E.m.f is generated due to temp gradient. The magnitude of e.m.f generated depends on material used for the wires & temp diff b/w 2 Jn's.

| material used. | Temp range. |
|---|---|
| ① Copper – Constantan | → -250°c – 400°c |
| ② Iron – Constantan | → -200°c – 850°c |
| ③ chromel – Alumel | → -200°c – 110°c |
| ④ chromel – constantan | → -200°c to 850°c |
| ⑤ platinum – Rhodium | → 0°c to 1400°c |
| ⑥ Tungsten – molybdenum | → 0°c to 2700°c |
| ⑦ Tongsten – Rhenium | → 0°c to 2600°c |

* A series of thermo couple connected together is called "Thermopile"

↳ using this we can get more sensitive element



Adv of Thermocouple: ① rugged in construction ② covers wide temp range. (-270°c – 2700°). ③ cheep in cost ④ good reproducibility ⑤ Speed of response is high ⑥ Accuracy is good.

## Load cell:

↳ is a transducer that used to create an electrical sgl whose magnitude is directly proportional to the force being measured.

↳ It is an electro mechanical transducer to measure static & dynamic forces.

↳ The device can be designed to handle a wide range of operating forces ~~which~~ with high level of reliability. hence it is most papular transducer in industrial measurements.

↳ it o/p from deformation of an elastic member having high strength. (elastic member made with steel alloys).

# Inductive Transducers

↳ Inductive Transducer is a simple & most papular ~~of a~~ type of displacement transducer in which variation of inductance as a function of displacement is achieved by variation in self inductance or mutual inductance

↳ The Inductive transducers generally opeorate up on one of the following 3 principles

① Variation of self inductance of coil
② Variation of mutual inductance of coil
③ production of eddy currents.

## ① Transducer based on variation of Self inductance of coil

The value of self inductance of an inductor is

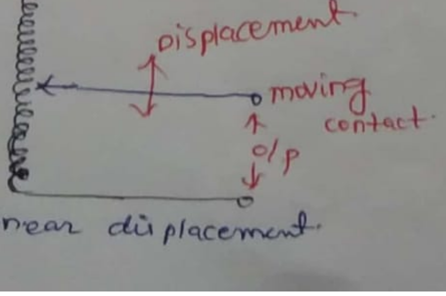
$L = \frac{N^2}{S}$ ; N → No. of turns of coil
S → Reluctance of coil (A/wb)

But ∵ $S = \frac{l}{\mu a}$
l → length of magnetic ckt (m)
a → Area of magnetic ckt
μ → permeability of core (H/m)

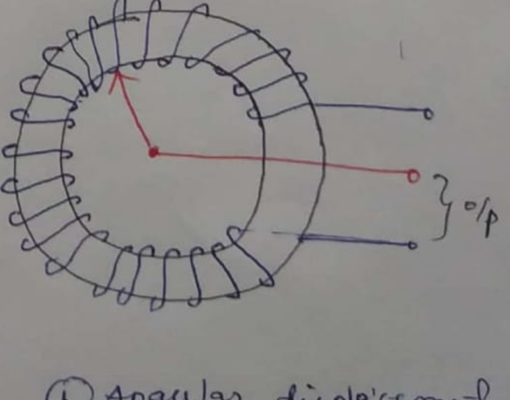
So ⇒ $L = \frac{N^2 \mu a}{l}$

↳ means the the variation ~~of~~ in self inductance may be due to

i) change in no. of turns
ii) change in reluctance
iii) change in permeability.



ⓐ Linear displacement



ⓑ Angular displacement

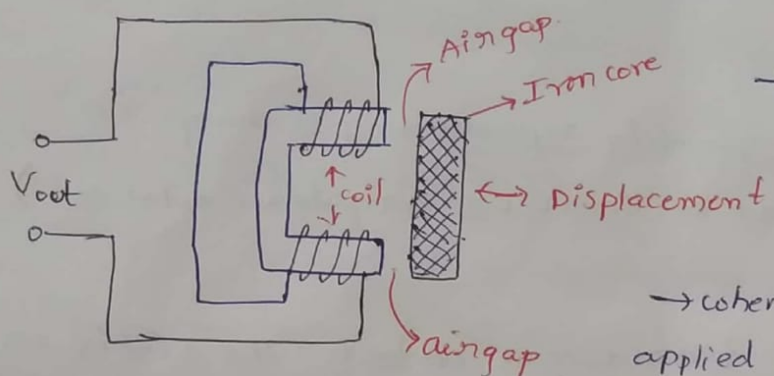
## ② Transducer based on Variation of Mutual Inductance

→ The mutual inductance b/w 2 coils is (M) given by

$$M = K\sqrt{L_1 \cdot L_2}$$

K → co-efficient of coils

→ The M can be varied ~~either~~ by varying either Self-inductance of coils (or 'K' value.



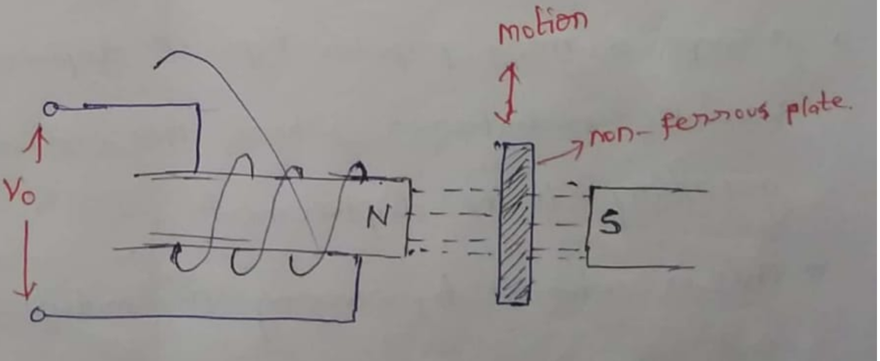
→ The total inductance Varies from $(L_1+L_2-2M)$ to $(L_1+L_2+2M)$

→ when linear displacement is applied to iron core, the core moves towards or away from ckt. This results in variation in air gap. thus magnetic flux linking with two coils changes, which results in variation of mutual inductance b/w two coils. This change is sensed by bridge ckt.

## ③ Transducer based on production of Eddy currents.

→ A non-ferrous plate moves in a direction perpendicular to the line of flux of a magnet. The eddy current generated in a plate which are proportional to the velocity of plate.

→ This currents set up a magnetic field in direction opposing the magnetic field producing these currents.



* **LVDT** (Linear Variable Differential Transformer (or))

(Linear Variable Displacement Transducer).

→ It is used in all applications where displacement ranging from fraction of few mm to few cm.

→ It acting as a secondary transducer

→ used as a device to measure force, stress, velocity, acceleration weight & preasure.

* Displacement is a vector quantity representing a change in position of body. It can be linear or angular (rotational) motion.

* majority of displacement transducers detect the static or dynamic displacement.

* The main electrical displacement transducers work on principle of

① Variable resistance → Transducer is strain gauge.

② Variable inductance → Transducer is LVDT.

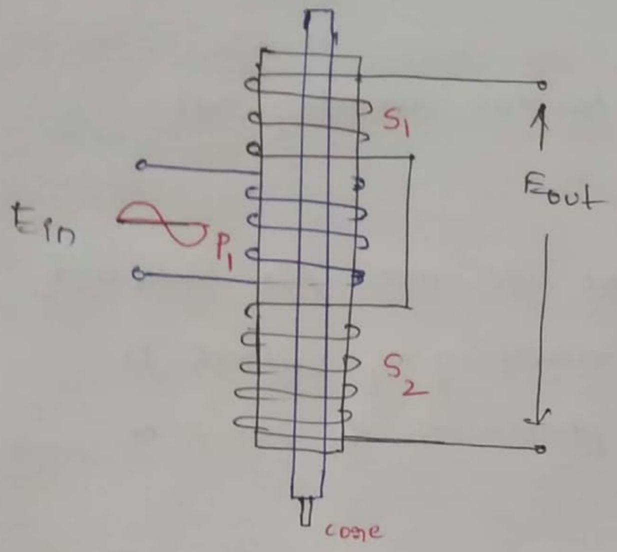
③ Variable capacitance → Transducer is parllel plate capacitor with variable gap.

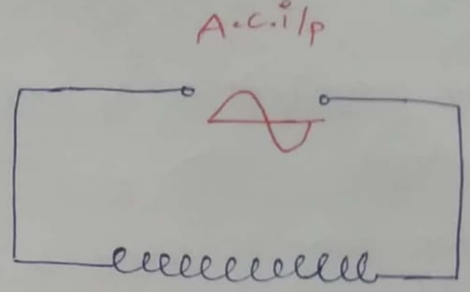
④ Synchros → To measure angular displacement.

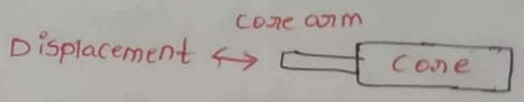
* A simple & more papular type of displacement transducer is variable inductance, where the inductance is varied according to the displacement.

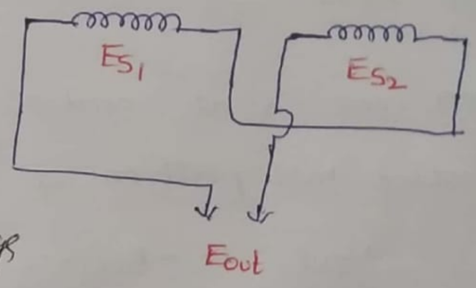
→ This is achieved by varying the mutual inductance b/w 2 coils (LVDT.)

# Construction & working of LVDT









→ It consist a single primary winding P1 & two secondary windings S1 & S2. wound on a cylindrical former.

→ The no. of turns of S1 & S2 are same but the emf induced in the coils oppose each other, b'coz they are connected in series opposition.

→ primary winding connected to A-C source, freq range 50H - 20K

→ A movable soft iron core slides inside the hollow former

→ The position of movable core determines the flux linkage b/w A-C excited primary winding & each of 2 secconday windings.

→ The core is made with Nikel-iron.

→ The displacement to be measured is applied to arm attached to the core.

→ when externally applied force moves the core to the left hand-side position, more flux links with left hand side coil S1 than S2.

→ The E.m.f induced in coil $S_1$ ($E_{S_1}$) is larger than, e.m.f induced in $S_2$ ($E_{S_2}$)

→ The magnitude of o/p Volt is diff b/w two Secondary coil Voltages.

→ when core is forced to move right side, more flux links with right hand coil $S_2$ than $S_1$. & resulting o/p voltage is diff b/w $E_{S_2}$ & $E_{S_1}$ & Now it is phase with the E.m.f of right hand coil

→ when core is at centre we get o/p volt is zero, which is called Null position of LVDT.

$$V_{out} = E_{S_1} \sim E_{S_2} = 0.$$

$E_{S_1}$ → o/p volt across $S_1$

$E_{S_2}$ → o/p volt across $S_2$

→ At Null position $E_{S_2} = E_{S_1}$, $V_{out} = 0$.

→ whe core is moved from null position, the induced volt in corresponding seccondary winding, ~~two~~ towards which the core is moved, increases while the induced volt in other winding decreases. The differential o/p Volt $V_0 = E_{S_1} - E_{S_2}$

**Advantages of LVDT**

→ Linearity

→ Infinite resolution

→ High o/p → High sensitivity → low power consumption.

## piezo electric Transducer:

→ It is used for measurement of non electrical quantities, such as acceleration, Vibration, Sound intensity & dynamic pressure.

→ It is widely used in Aerodynamics, supersonic wind tunnels, high speed explosions, bomb blasts.

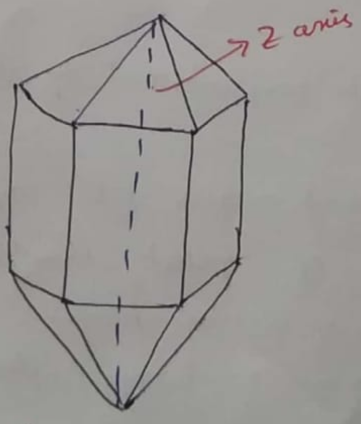
→ used in ultrasonic, non-destructive test equipments, ultrasonic flow meters.

→ used in Spark ignite engines.

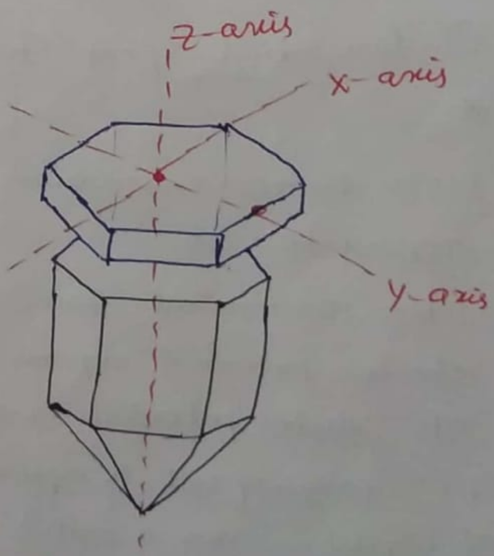
* when two opposite faces of thin Slice of crystals are subjected to a mechanical force, then opposite charges are developed on two faces of slice. The magnitude of electro potential b/w two faces is proportional to the deformation produced.

* The quartz crystal has unique property of generating electrical polarity when mechanical Stress applied on it.

* when we apply force or pressure on this material it converts in to electric Voltage. & this Volt is function of force or pressure applied on it



Diamond shaped crystal.



Axes of crystal.

→ The electric volt produced by piezo electric transducer can be measured by volt measuring instrument.

→ This phenomena is called piezo electric effect & materials exibiting this effect are called piezo electric materials.

→ The main substances (materials) exhibiting piezoelectric effect are "Quartz", "Rochelle salt", "Tourmaline."

① Rochelle salt shows great piezo-electric effect but mechanically they are week.

② Tourmaline is very strong but exhibits least piezo-electric activity.

③ Quartz is better than both ~~Rotle~~ Rochelle salt & Tourmaline
→ crystal having low temp sensitivity, high resistivity.

**Applications**

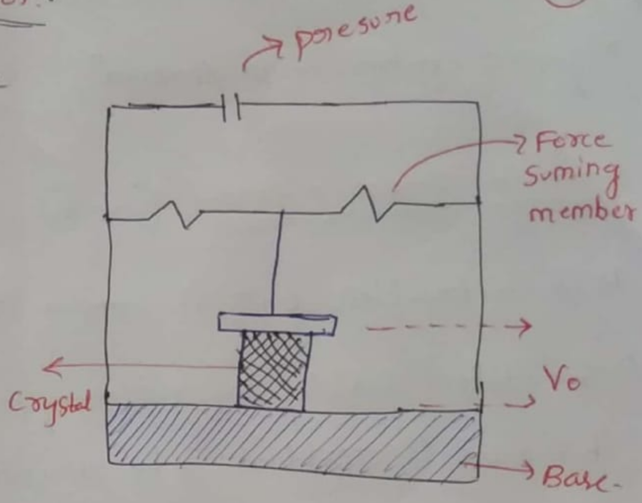
① microphones → the sound pressure is converted in to electric sgl.
② Auto mobile seat belts & lock
③ medical diagnosticks
④ In Electric lighters.
⑤ for High speed shock waves in inkjet printers.
⑥

* piezo electric Transducer can generate Volt proportional to stress applied to it.
* when mechanical force or pressure is applied across P.E. crystal, an electric potential appears across the surface of crystal. this generation of electric potential is due to displacement of electric charges.
* If a varying volt is applied across crystal, there is a change in dimensions of crystal. This is called P.E.E.

## Piezo-electric pressure Transducer:

→ A crystal is placed b/w solid base & force summing member.

→ metal electrodes plated on to faces of piezo-electric crystal are taken out to measure o/p.



→ The electrodes become plates of the parllel plate capacitor

→ so it can be considered as charge generator

The o/p Volt $V_o = Q/C$

→ The o/p is very high (1–30mv), no external power supply is required.

## * Synchros

→ It is widely used in control systems as detectors & encoders Bcoz of their rigidnees in construction.

→ It is basically a rotary device, an electro magnetic transducer which operates on same principle as transformer.

* It converts angular position of shaft in to eletric sgl.

* It is like an electric motor → The primary winding of transformer is fixed to rotor is excited by an A.C i/p, which by eletromagnetic induction, cause current flow in 3-Y-connected seccondary winding fixed at 120° to each other on the stator.

→ The relative magnitude of secondary currents are measured & used to find the angle of rotor relative to stator.

* In error detection we are using "Synchro Transmitter" & "Syncro control Transformer"

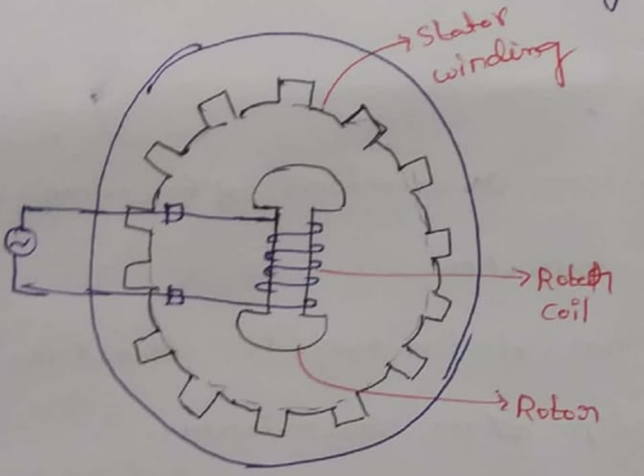
## Synchro Transmitter: (S.T)

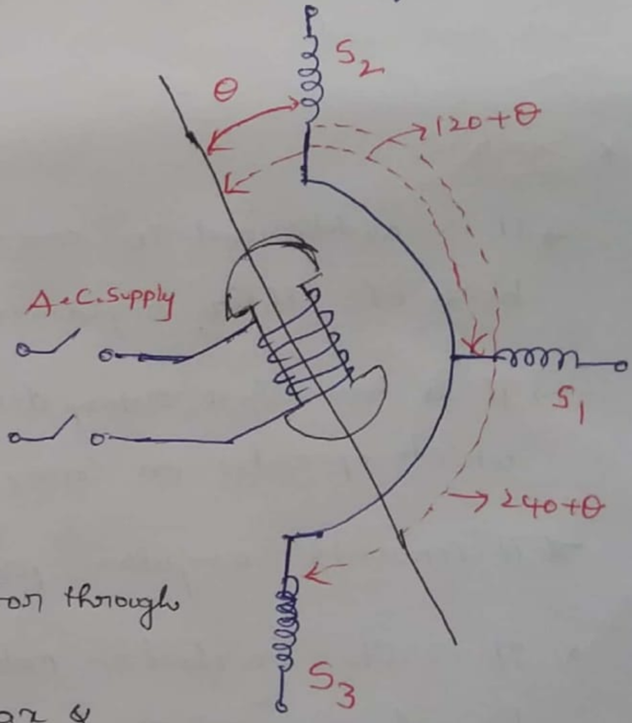
↳ It construction unit is similar to that 3-phase alternator

↳ The stator which is stationary part is made with laminated steel, this part is slatted to accomidate a balanced 3-phase winding

→ The stator windings are star connected which are usally of concentric coil type structure.

→ The rotar which is a sailent pole, dumb-bell shaped magnet with a single winding.





→ A single phase A.C volt is applied to rotor through slip rings. $e_r(t) = E_r \sin\omega_0 t$

→ when θ=0, volt induced in $S_2$ is max & position is called eletric zero.

## Synchro Control Transformer: (S.C.T)

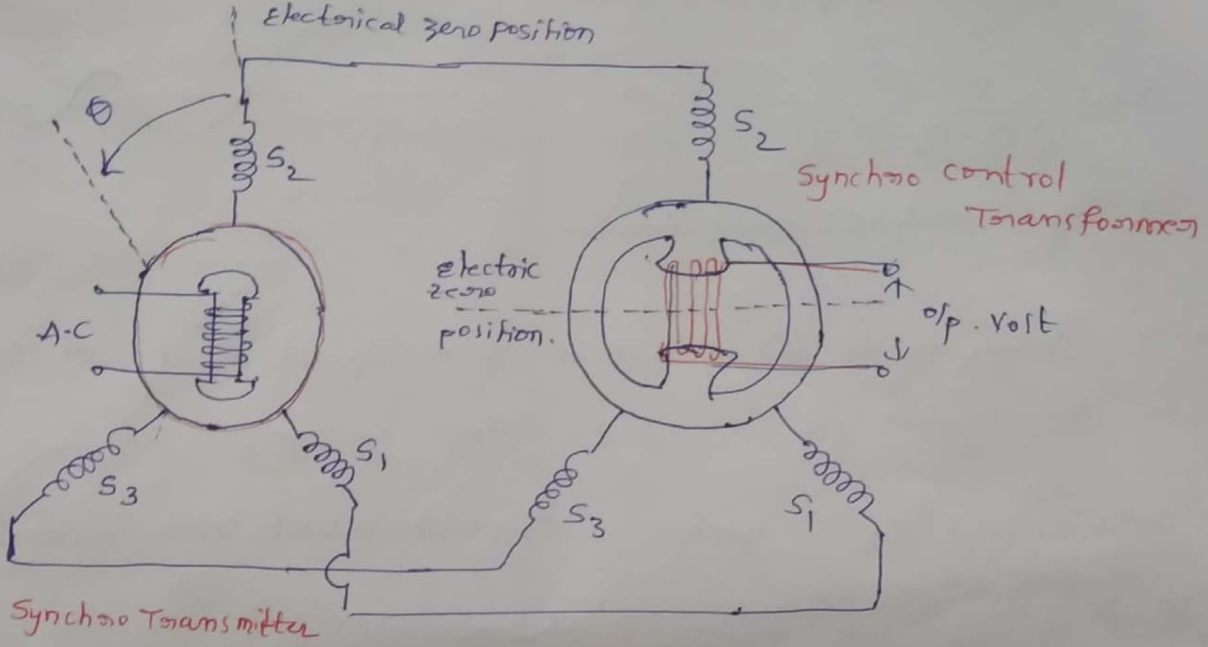
→ It is an electro mechanical device, which produces a single phase volt magnitude, is proportional to the sine of angle of rotation of its rotor w.r.t stator magnetic field

→ The principle of operation of S.C.T is same as syncro Transmitter

→ The function of error detector is to convert the diff of shaft positions in to an electrical sgl. So for this S.C.T & S.T are used

## ⑥ Error Detector using Synchros

→ The o/p of Synchro Transmitter is given to Synchro Control transformer.



→ When rotor position of two synchros are in perfect alignment the voltage generated across the terminals of the rotor of control transformer is zero. This position is called Electrical zero position of control transformer.

→ Let the transmitter rotates through an angle θ in the direction indicated & let control Transformer rotor rotates in the same direction through an angle α

→ So angular seperation of two rotors = $(90^\circ - \theta + \alpha)$

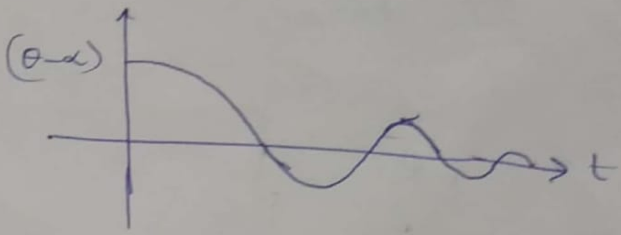
→ Voltage across rotor terminals of control Transformer is

$$e(t) = K' V_r \cos\phi \sin\omega_0 t$$

$$= K' V_r \sin(\theta - \alpha) \sin\omega_0 t$$

→ when two rotor shafts are not in alignment, the rotor Voltage of Control Transformer is a sine function of diff b/w two shaft angles.

$$e(t) = K' V_r (\theta - \alpha) \sin \omega_0 t$$



$$K_S = \frac{E}{\theta_r - \theta_L} = \frac{E}{\theta_e}.$$

$K_s$ → sensitivity of error detector.

* Here Error means 'the o/p voltage which depends upon the diff b/w the angular positions of two rotors of synchros pair

→ In a control s/m a synchro will provide a volt for conversion to torque through an ampr & a servometer.

① → Synchros are used for measuring the angle of a rotating machine such as an antena platform.

→ stator is the stationary part of a rotary s/m found in electric generators, electric motors

## ⑤ magneto Strictive Transducer:

→ magneto Strictive Transducer is a device that is used to convert mechanical energy into magnetic energy and vice versa. Such a device can be used as a sensor

→ The device also called as an electro magneto mechanical device as the electrical conversion to its appropriate mechanical energy is done by the device itself

→ The amount of strain is produced from null magnetization to full magnetization.

→ magnetostriction means is the corresponding change in length per unit length produced as result of magnetization.

→ The material should be magneto strictive in nature. this is called magnetostrictive effect

→ The same effect ~~is~~ can be reversed as, if an external force is applied on a magnetostrictive material there will be proportional change in magnetic state of material.

→ In the case of converting magnetic energy to mechanical energy it can be used for producing force in the case of actuators.

→ And it can be used for detecting magnetic field in case of sensors.

→ In the case of converting mechanical energy in to magnetic energy it can be used for detecting force or motion.

In early days.

→ It can be used in Torque motors, scaning devices, telephone receivers

→ Now a days it can be used in making high force linear motors, active Vibration or noise control s/ms, medical & industrial ultrasonic.

## Digital temp sensing s/m.

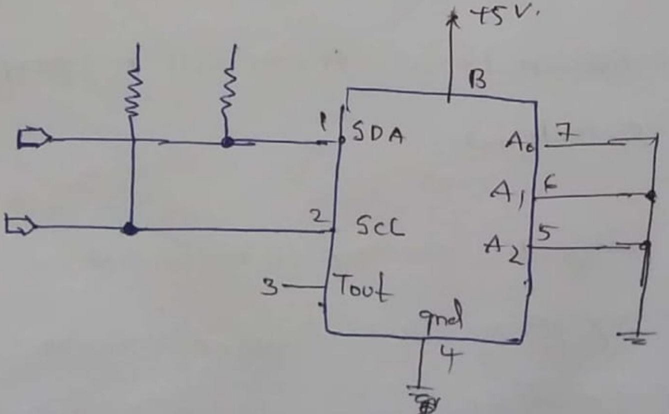
→ Digital temp sensors eliminate the necessity for extra components such as A/D converter with in applic$^n$. & there is no need to calibrate components or the s/m at sepecific reference temp as needed when utilizing terminators.

→ The sensor o/p is balanced digital reading

eg: sensor DS1621 → which provides 9-bit temp reading.

* Features of DS1621

① No external components required.
② Temp range -55°c to +125°c
③ wide power supply (2.7v - 5.5v)
④ converts temp to digital word in less than one sec.



SDA → serial data i/p
SCL → 2 wire serial link
Tout → Thermal o/p sgl
A0 → chip address i/p
A1 → " " "
A2 → " " "
VDD → power supply.

## Anemometer :

is a device used for measuring wind speed, and is a common weather station instrument.

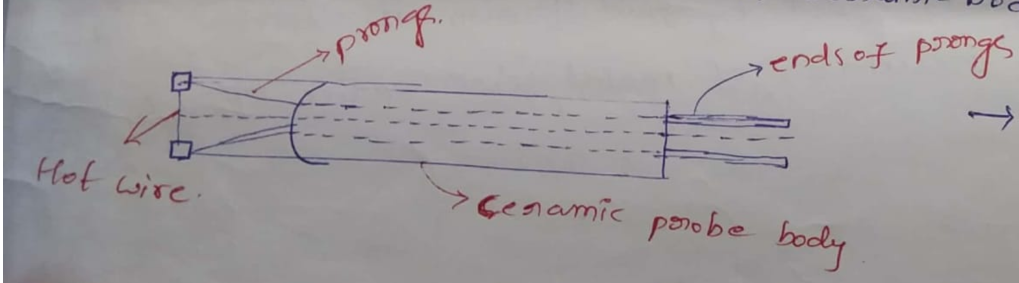
## Hot wire Anemometer :

→ It uses a fine wire electrically heated to some temp above ambient

→ To measuring mean & fluctuating velocities in fluid flows.

→ The flow sensing element is a short length of 5 um. platinum tongstone wire ~~stei~~ welded b/w two prongs of probe and heated electrically as a part of wheatstone ~~brig~~ bridge

→ conducting wires ~~on~~ are placed in ceramic body.



→ Leads are taken from conducting wires and they are connected to bridge ckt to enable measurement of chang in resis of wire.

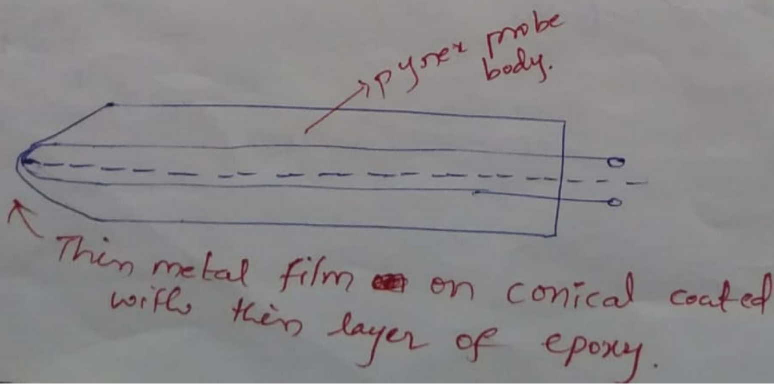
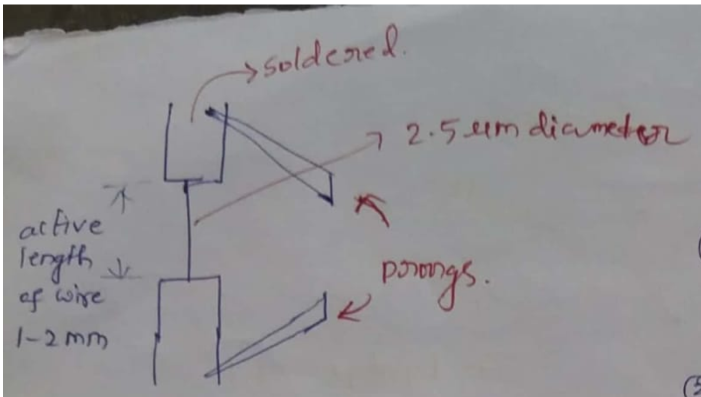


fig: Connecteg led for bridge ckt



→ The rate of cooling of wire depends on following.

① Shape size & physical properties of hot wire.

② velocity of fluid stream.

③ Physical properties of flowing fluid.

④ Diff in temp b/w heated hot wire & fluid Stream.

## * principle of working:

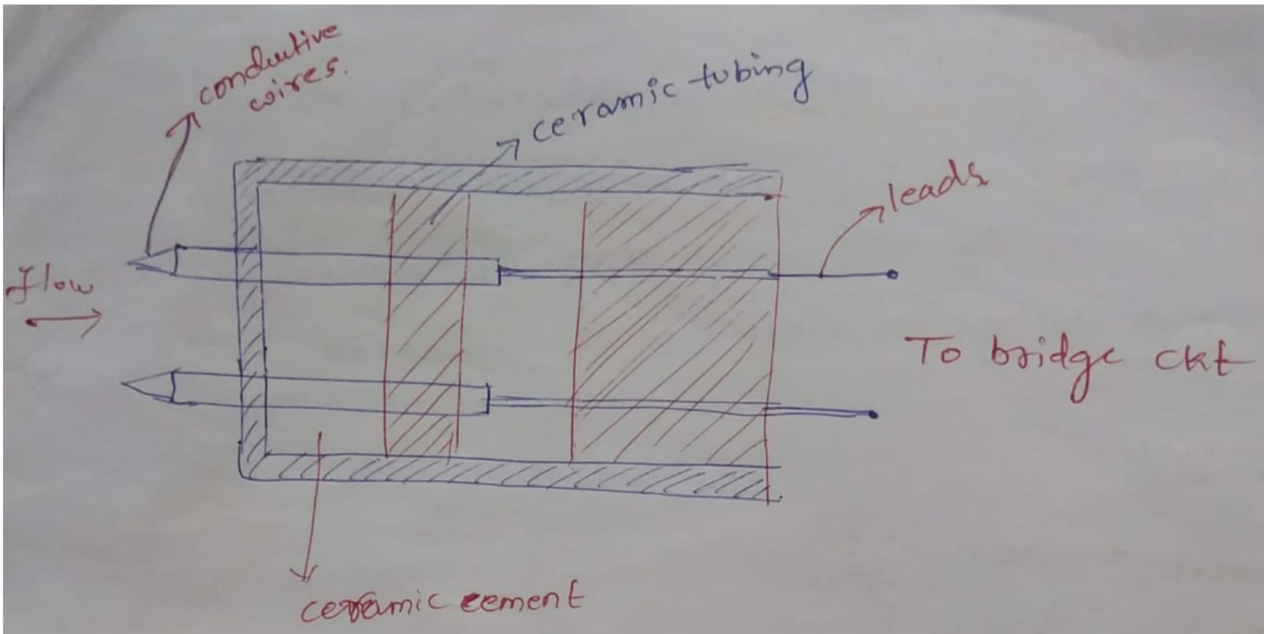
↳ The Hot wire Anemometer is used to measure fluid velocities by measuring heat loss by ~~Conven~~ convection from a very fine wire which is exposed to the fluid Stream. The wire is electrically heated by passing an electrical current through it.

→ when heated wire is cooled by fluid Stream its electrical resistance decreases, b'coz the resistance of metal wire varies linearly with its temp.

→ it has fast response.

→ Sensitivity is more at lower velocity.

convection → heat



→ when an electrically heated wire is placed in a flowing gas stream, heat is transfered from the wire to the gas and hence temp of wire reduces., due to this, the resis of wire also changes.

→ This change in resis of the wire becomes a measure of flow rate.

Hot wire Anemometer uses resistance wire as sensor. They are classified as two types.

① constant current type (C.C.T)

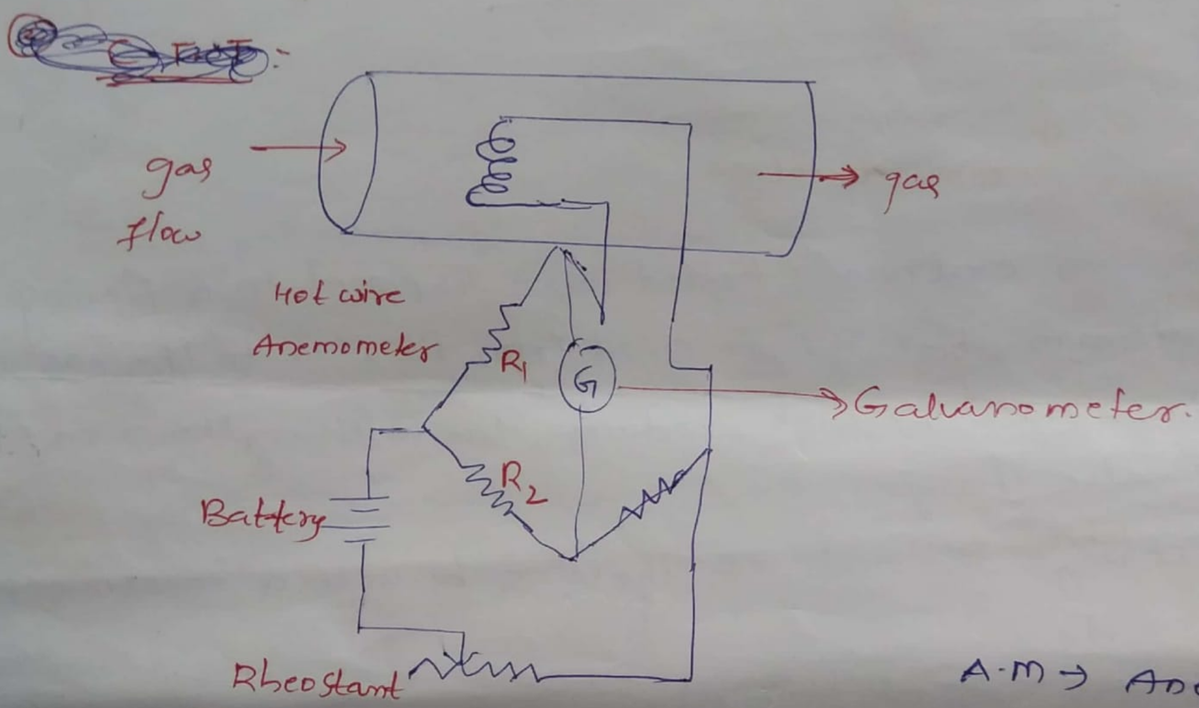
② Constant Temp type. (C.T.T)

C.C.T: The Anemometer is kept in the flowing gas stream to measure flow rate.

→ A constant current is passed through the sensing wire

→ i.e The volt across bridge ckt is kept constant.

→ Due to gas flow, heat transfer takes place from sensing wire to the flowing gas and hence temp of sensing wire reduces causing a change in resis of sensing wire.



A·M → Anemometer

② C-T-T

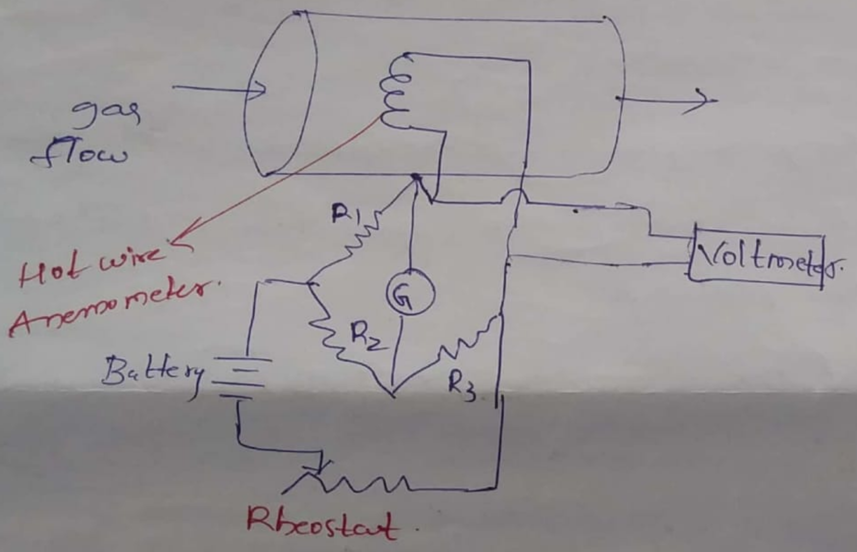
→ A current is initially passed through wire.

→ The A.m is kept in flowing gas stream to measure flow rate.

→ Due to gas flow, heat transfer takes place from sensing wire to the flowing gas and this tends to change in temp hence resis of wire.

→ principle in this is to maintain temp & resis of wire at constant level. So current through sensing wire is incre to bring the sensing wire to have its initial resis & temp.

The electrical current required in bringing back the resis and hence the temp of wire to its initial condition become a measure of flow rate of gas when cabrated.



Rheostat → to control current by varying R.

**Applications:** Studying varying flow of conditions.

III - unit 2ndpart ①

## Special purpose oscilloscope

→ In many applications it is necessary to investigate the waveforms having very high freq or sgls which are non repetitive and single event.

→ In some applications the data is required to be stored and to be used later. Such special functions can'not be achieved using conventional oscilloscopes.

→ The special oscilloscopes are necessary to perform such special functions

→ The various special oscilloscopes are ① delayed time base oscilloscopes
② Analog storage oscilloscope
③ Sampling oscilloscope
④ Digital storage oscilloscope.

## ① Digital storage oscilloscope.

→ The digital Storage oscilloscope eliminates the disadvantages of analog storage oscilloscope.

→ It replaces unrelaible storage method used in analog Storage scopes with the digital Storage with the help of of memory.

→ The memory can store data as long as required without degradenation.

→ it is also allows complex processing of sgl by the high speed digital sgl processing ckts.

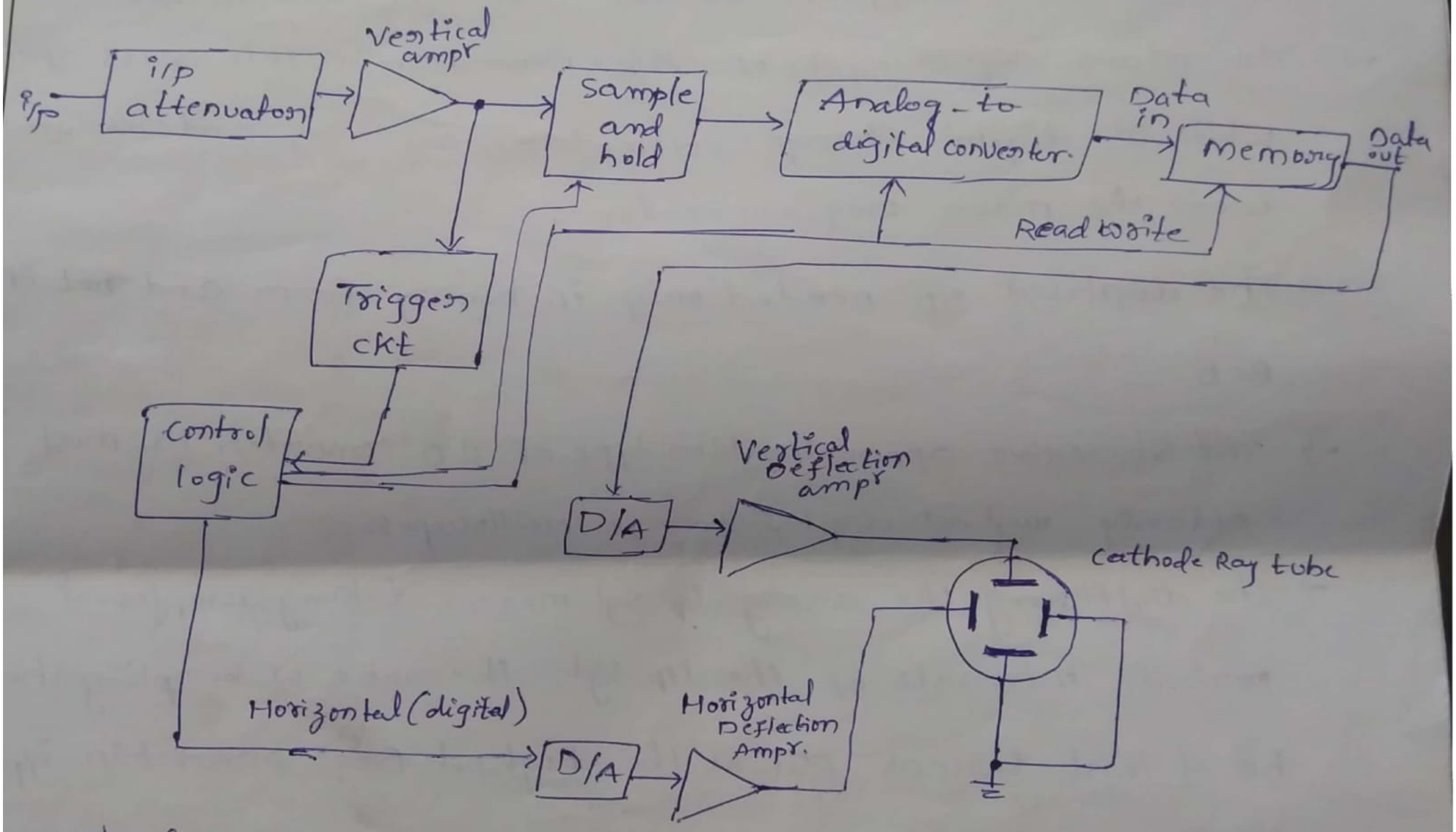
→ In this the waveform to be stored is digitised and then stored in digital memory.

→ The conventional cathode ray tube is used in this, b'coz cost is less.

→ The power to be applied to memory is small and can be supplied by small battery. due to this the stored image can be displayed indefinitely as long as power is supplied to memory.

→ once the wave form is ~~distin~~ digitised then it can be further loaded into the computer and can be analysed in detail.

block diagram:



→ The i/p sgl is applied to the ampr and attenuator section.

→ The oscilloscope uses same type of ampr and attenuator ckt as used in conventional oscilloscopes.

→ The attenuated sgl is then applied to the vertical ampr.

→ The vertical i/p, after passing through the vertical ampr, is digitised by an A/D converter to create a data set that is stored in memory.

→ The data set is processed by microprocessor and then sent to display.

→ To digitise the analog Sgl, A/D converter is used. the o/p of Vertical ampr is applied to the A/D converter section

→ The main requirement of A/D converter in this is its speed, while in digital ~~Storage~~ voltmeters accuracy and resolution were the main requirements.

→ The digitised o/p needed only in binary form and not in BCD.

→ The Successive approximation type of A/D converter is most oftenly used in digital storage oscilloscopes.

→ The digitising the analog i/p sgl means taking samples at periodic intervals of the i/p sgl. the rate of sampling should be at least twice as fast as the highest freq present in i/p sgl, according to sampling theorem. this ensures no loss of information.

* generally flash A/D converters are used, whose resolution decreases as the sampling rate increases

* The sampling rate and memory size are selected depending on the duration and waveform to be recorded

→ once i/p sgl is sampled, the A/D converter digites it. the sgl is then captured in memory.

→ The total digital memory storage capacity is 4096 for a single channel., 2048 for two channels.

## modes of operation:

The digital storage oscilloscope has 3 modes of operation.

① Roll mode: is used to display very fast varying sgls clearly on the screen.

② Store mode: → This is called refresh mode. in this i/p initiates a trigger ckt. the digital data is transfered to the memory.
→ when next trigger occures the memory is refreshed

③ Hold or Save mode: is called Automatic refresh mode. when new sweep sgl is generated by time base generator the old contents get over written by new one.

## ② Sampling oscilloscope

→ As freq of i/p sgl to vertical amp$^r$ increases, the writing speed of electron beam increases, this reduces image sensitivity. on screen.

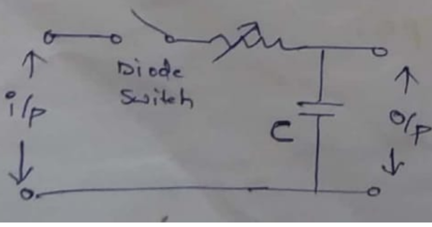
→ For high freq sgls the electron beam is required to accelerate more. Such increase in velocity is posible by increasing ~~velocity~~ voltage of accelerating anodes, but it requires higher deflection potential and puts higher demands on the vertical amp$^r$.

→ The solution to this problem is sampling technique., using this high freq sgl is converted to low freq sgl.

→ In this technique, instead of monitoring the i/p sgl continously it is sampled at the regular intervals. these samples are presented on the screen in the form of dots. Such samples are merged to reconstruct the i/p sgl.

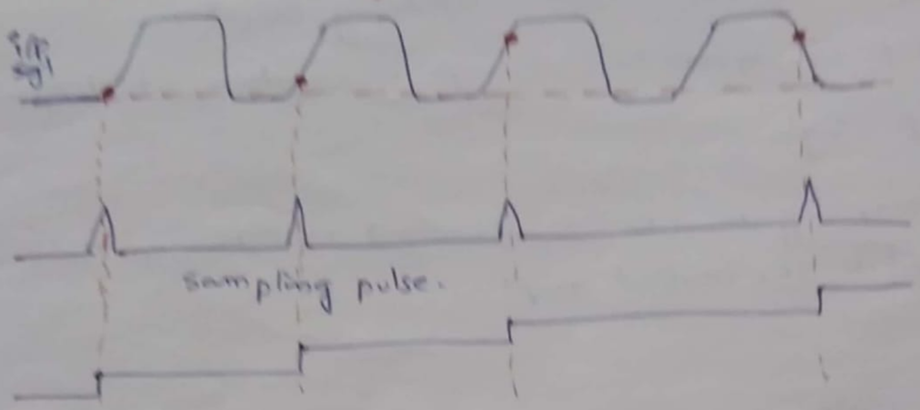
→ ~~Thus freq~~ Due to merging samples, observer receives a continous sgl on the screen.

→ Thus a very high freq more than 300MHz performance can be achieved using this technique.



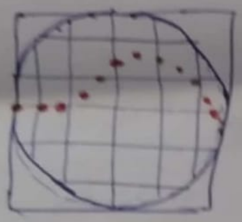
→ it is Basic sampling ckt, uses a diode switch, also called sampling gate.

Fig: Sampling principle.



Staire case time base waveforms.

Fig Display of dots on CRT (due to sampling operation).



→ The time base of sampling oscilloscope has two functions

i) To move the dots across screen

ii) To generate the sampling command pulses for sampling ckt.

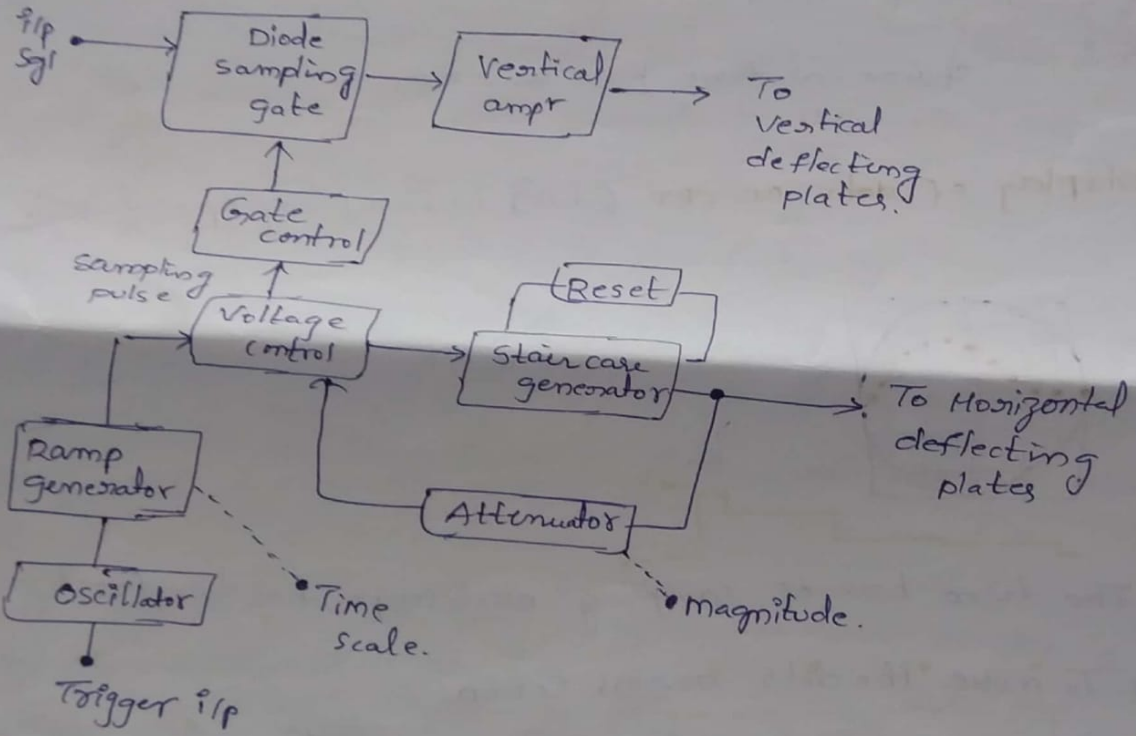
## Block diagram of Sampling oscilloscope:

→ The i/p sgl is applied to the diode sampling gate. At the start of each sampling cycle a triggered i/p pulse is

→ generated, which activates the blocking oscill^r.

→ The oscill^r o/p is given to ramp generator which generates linear ramp Sgl.

→ Since the sampling must be Synchronized with the i/p Sgl freq, the Sgl is delayed in the vertical amp^r.



→ The Staircase generator produces a Staircase waveform which is applied to an attenuator.

→ The attenuator controls the magnitude of Stair case Sgl and then it is applied to a voltage Comparator.

→ Another i/p to voltage comparator is o/p of ramp generator.

→ The volt comparator compares two sgls and produces the o/p pulse when two voltages are equal.

→ This pulse opens diode gate & sample is taken in. this sampled sgl is then applied to the vertical amp$^r$ and vertical deflecting plates.

→ The o/p of Staircase generator is also applied to horizontal deflecting plates. during each step of stair case the spot moves on screen. The comparator o/p advances the staircase o/p through one step.

→ After certain number of pulses (1000), the staircase generator resets.

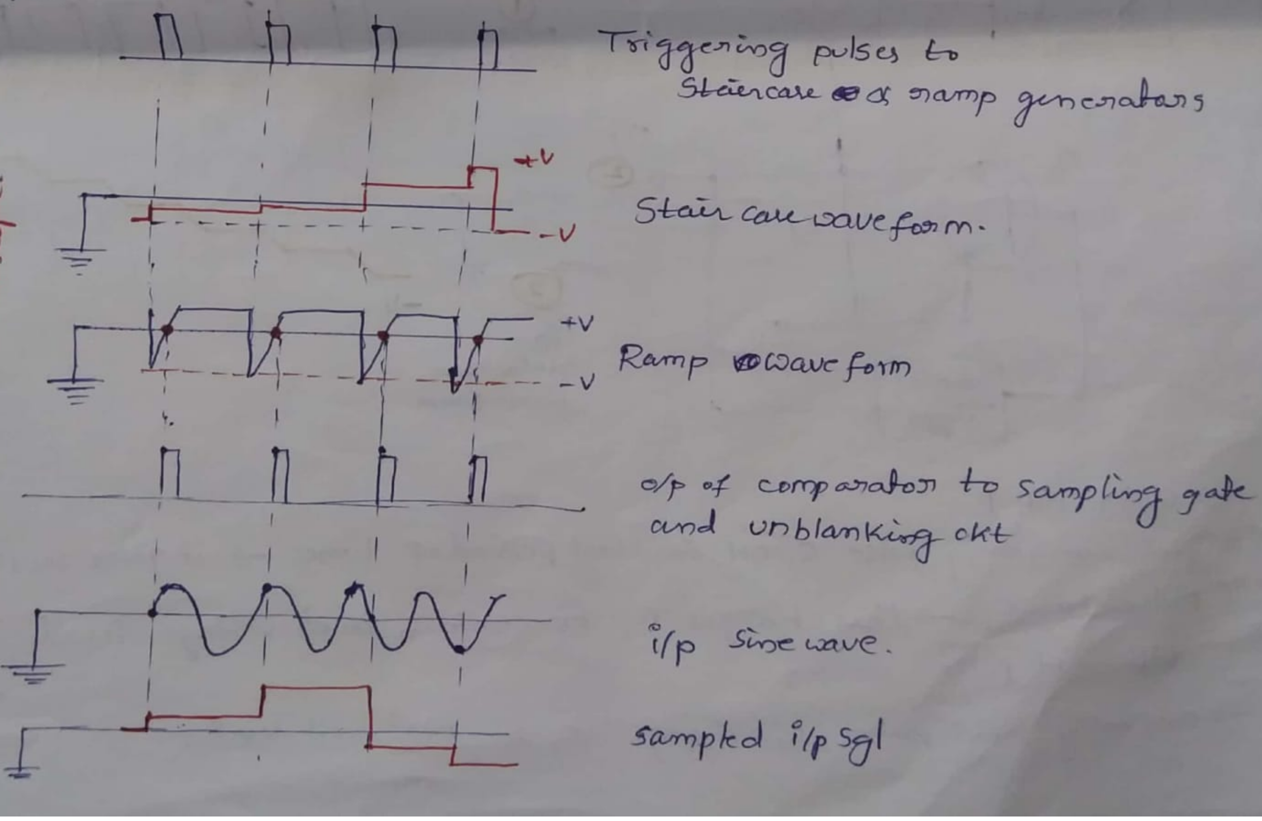


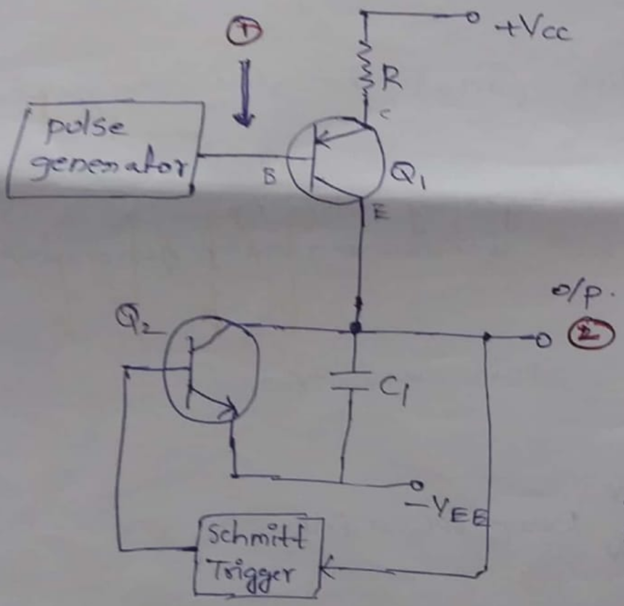
Fig wave forms of Sampling oscilloscope.

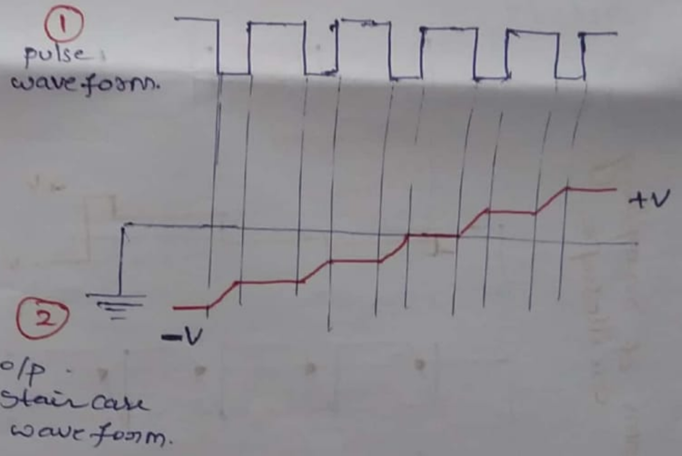
→ In sampling oscilloscope, a staircase generator is used as i/p to Horizontal Section instead of ramp.

→ The sampling of waveform is done at the beginning of each step of staircase waveform, the sampled o/p is used for Vertical Section.

→ when this sampled o/p is combined with unblanking pulses, a dot waveform is obtained on screen.

## Stair case Generator ckt:





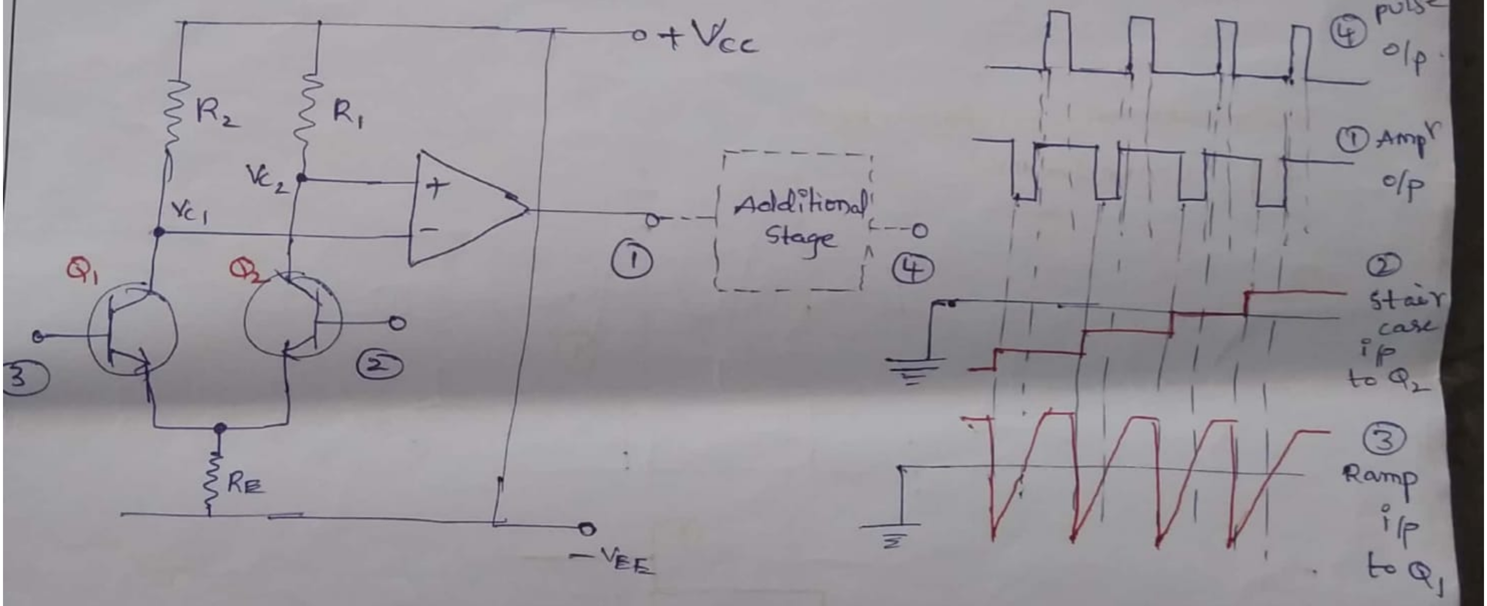
→ $Q_1$ is pnp

→ for -ve going pulse $Q_1$ → ON for short period of time → it gives current pulse to $C_1$ → This charges $C_1$ to certain ~~lead~~ voltage level, till next pulse occurs

→ During next pulse, $Q_1$ charges $C_1$ to next volt level.

→ This produces staircase waveform at o/p. , when volt level of $C_1$ exceeds required upper level, schmitt trigger ckt operates and $Q_2$ ON. The $C_1$ discharges through $Q_2$ to its starting level.

## Voltage comparator ckt:.



## Sampling gate ckt.

fig :ckt

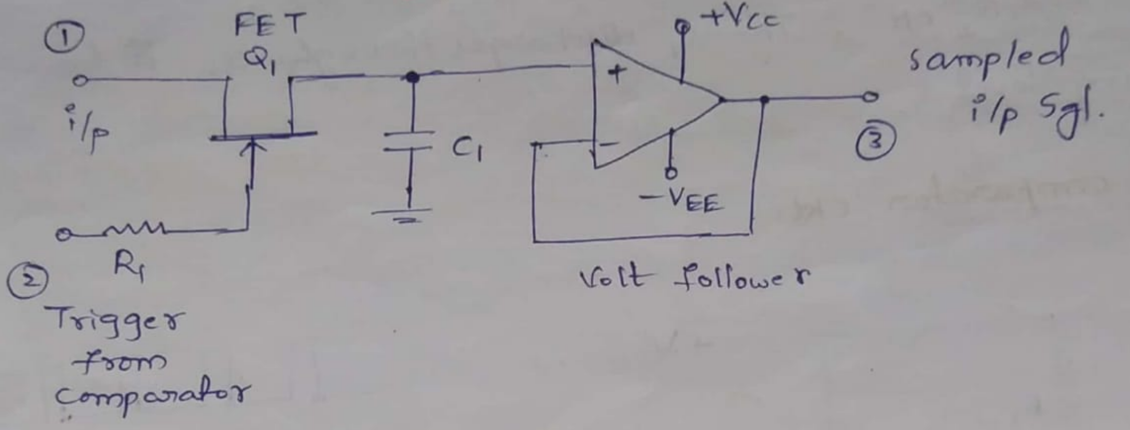
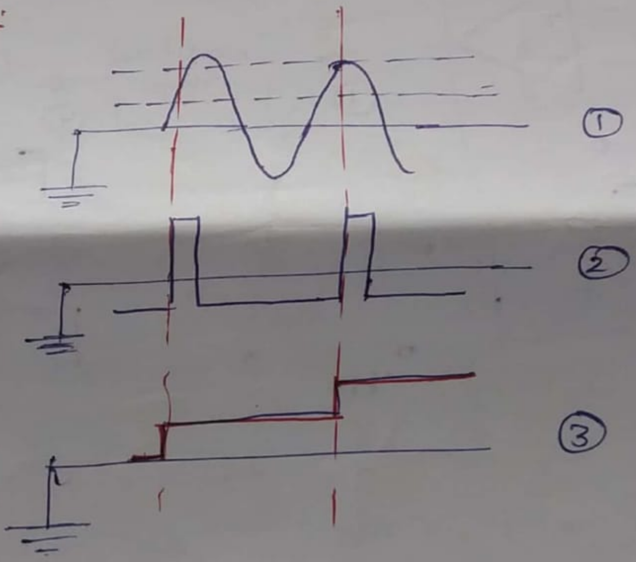


fig : wave forms:



# BRIDGES V-unit

→ Bridges are used for measurement of resistance capacitance & Inductance

→ A Bridge ckt consist of a N/w of 4 resistance arms forming a closed ckt.

→ A Source current is applied to 2 opposite Jn's, & the current detector (Galvanometer) is connected to other two junctions.

→ The bridge ckt operates on principle of null-indication

→ It compares the values of unknown component with known standard component

→ when no current flows through null-detector, then bridge is in balance condition

→ The relationship b/w the component values of 4 arms of bridge at the balancing is called Balancing eq$^n$ (or) balancing condition. This eq$^n$ gives value of unknown component.

## → Types of Bridges:

→ There are two types of bridges.

① D.C Bridges.

② A.C Bridges.

Balance
met

→ D.C Bridges are used to measure ~~impedence~~ resistance. & it uses D.C. Voltage as excitation voltage.

→ A.C Bridges are used to measure impedence (consist of capacitance & Inductance).

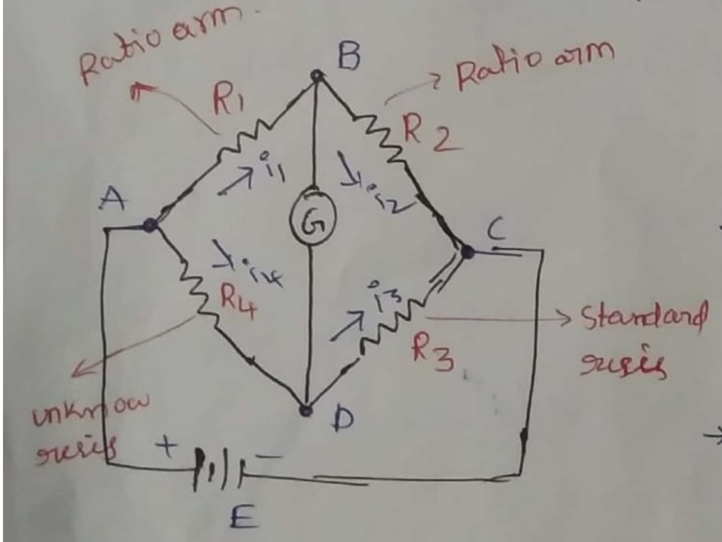
→ A.C Bridges uses A.C. volt as excitation voltage.

* There are two types of D.C. Bridges.

ⓐ Wheatstone Bridge ⓑ Kelvin bridge.

## ⓐ Wheatstone Bridge:

→ The bridge consist of 4 resistive arms together with a source of e.m.f. & a nulldetector. The galvanometer is used as a null detector.



→ The $R_1$ & $R_2$ are called Ratio arms

→ The arms consisting standard known resis $R_3$ is called standard arm.

→ $R_4$ is unknown resistance to be measured.

→ The batter is connected b/w A & C and Galvanometer is connected b/w B & D terminals.

~~B~~

Balance condition: when bridge is balanced, the galvanometer carries zero current & it does not shows any deflection. So bridge works on principle of null-deflection.

→ To have zero current through galvanometer, the points B & D must be at same potential. So potential across arm AB must be same as potential across arm AD.

① ← $I_1R_1 = I_4R_4$ (or) $I_2t_2 = I_3R_3$. as current across galvanometer is zero.

$I_1 = I_2$ & $I_3 = I_4$

$$I_1 = I_2 = \frac{E}{R_1+R_2}, \quad I_3 = I_4 = \frac{E}{R_3+R_4}$$

from eqⁿ ①

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

$$\Rightarrow \quad R_1(R_3+R_4) = R_4(R_1+R_2)$$

$$R_1R_3 + R_1\cancel{R_4} = R_1\cancel{R_4} + R_2R_4$$

$$R_1R_3 = R_2R_4$$

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

→ This is required balanced condition of wheatstone bridge.

## Sensitivity of wheatstone bridge:

when bridge is balanced, the current through galvanometer is zero, but bridge is not balanced current flows through galvanometer causing deflection. The amount of deflection depends on sensitivity of galvanometer, this sensitivity can be expressed as amount of deflection per unit current.

$$\text{Sensitivity}(S) = \frac{\text{deflection}(D)}{\text{Current } (I)}$$

## applications of wheatstone Bridge:

→ The W.B is basically a D.C. Bridge used to measure resis in the range, 1Ω to meghaohms.

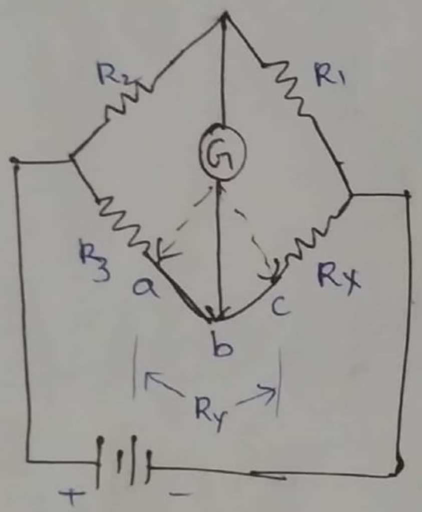
→ It is used to measure D.C resis of various types of wires for the purpose of quality control of wire

→ It is used to measure resis of motor winding, relay coils.

## Kelvin bridge:

→ In wheatstone bridge the bridge contact & lead resis causes significant error, while measuring low resistance.

→ So for measuring low resis below 1Ω, the modified form of wheatstone bridge is used, called "Kelvin bridge" also called Kelvin double bridge.



→ The Resis $R_y$ represents the resis of connecting leads from $R_3$ to $R_x$.

→ $R_x$ is unknown resis to be measured.

→ The galvanometer can be connected either terminals a & b c

→ when it is connected to 'a' the lead resis $R_y$ gets added to $R_x$, hence value measured by the bridge, indicates much higher value of $R_x$

→ If galvanometer connected to 'c' then, $R_y$ gets added to $R_3$, this results in the measurement of $R_x$ much lower than actual value

→ The point b is in b/w points a & c, in such a way that the ratio of the resis from c to b & that from a to b is equal to ratio of $R_1$ & $R_2$.

$$\boxed{\frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2}} \longrightarrow ①$$

Now the bridge balance eq$^n$ in its standard form is $R_1 R_3 = R_2 R_x$

$$\frac{R_1}{R_2} = \frac{R_x}{R_3} \longrightarrow ②$$

But $R_3$ & $R_x$ now are changed to $R_3 + R_{ab}$ & $R_x + R_{cb}$

$$\frac{R_1}{R_2} = \frac{R_x + R_{cb}}{R_3 + R_{ab}} \longrightarrow ③$$

$$(R_x + R_{cb}) = \frac{R_1}{R_2}(R_3 + R_{ab}) \longrightarrow ④$$

Now we have $\rightarrow$ $\frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2}$ (from eq$^n$ ①).

$$\frac{R_{cb}}{R_{ab}} + 1 = \frac{R_1}{R_2} + 1$$ (adding 1 both sides).

$$\frac{R_{cb} + R_{ab}}{R_{ab}} = \frac{R_1 + R_2}{R_2} \longrightarrow ⑤$$

($\because$ But we know from diagram

$R_{cb} + R_{ab} = R_y \rightarrow ⑥$.

Substitute eq$^n$ ⑥ in ⑤

$$\frac{R_y}{R_{ab}} = \frac{R_1 + R_2}{R_2} \Rightarrow \boxed{R_{ab} = \frac{R_2 R_y}{R_1 + R_2}} \longrightarrow ⑦$$

from ⑥ $R_{cb} + R_{ab} = R_y$

$$R_{cb} = R_y - R_{ab}. \longrightarrow ⑧$$

substitute ⑦ in ⑧

$$\Rightarrow R_{cb} = R_y - \frac{R_2R_y}{R_1+R_2} = R_y\left[1-\frac{R_2}{R_1+R_2}\right] = R_y\left[\frac{R_1+\cancel{R_2}-\cancel{R_2}}{R_1+R_2}\right]$$

$$\boxed{R_{cb} = \frac{R_1R_y}{R_1R_2}} \rightarrow ⑨$$

Substitute $R_{cb}$ & $R_{ab}$ in eq$^n$ ④

$$④ \Rightarrow R_x + R_{cb} = \frac{R_1}{R_2}(R_3 + R_{ab})$$

$$\Rightarrow R_x + \frac{R_1R_y}{R_1+R_2} = \frac{R_1}{R_2}\left(R_3 + \frac{R_2R_y}{R_1+R_2}\right)$$

$$R_x + \cancel{\frac{R_1R_y}{R_1+R_2}} = \frac{R_1R_3}{R_2} + \cancel{\frac{R_1\cancel{R_2}R_y}{\cancel{R_2}\cdot(R_1+R_2)}}$$

$$\boxed{R_x = \frac{R_1R_3}{R_2}} \rightarrow ⑩$$

→ The above eq$^n$ represents standard bridge balance eq$^n$ for wheatstone bridge. So the effect of connecting the lead reeis is completely eliminated by connecting galvanometer to an intermediate position 'b'

→ The principle forms the basis of the construction of Kelvin's double bridge which is called "kelvin bridge".

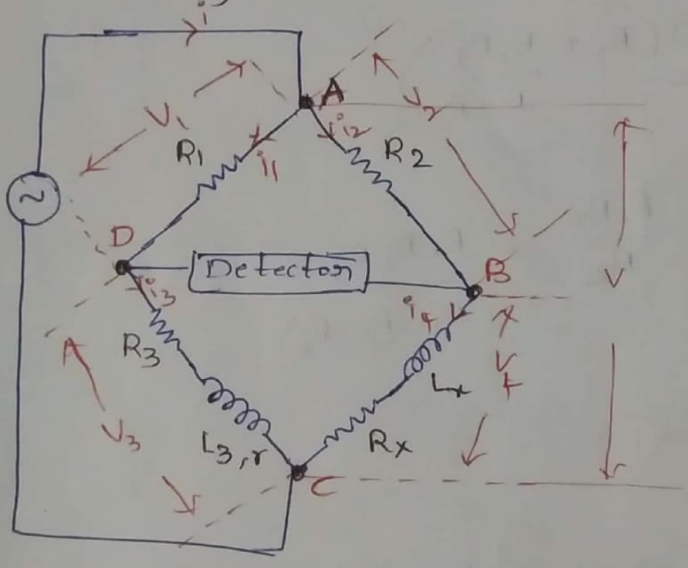
## A.C. Bridges:

① **Maxwell's Bridge:** It can be used to measure inductance by comparision either with a variable standard self inductance or with a standard variable capacitance.

→ These two measurements can be done by using the maxwell's bridge in two diff forms.

## ① Maxwell's Inductance bridge:

→ using this we can measure inductance by comparing it with a standard variable self inductance arranged in bridge ckt.



→ Two branches consist of non-inductive resis $R_1$ & $R_2$.

→ one of arms consist variable inductance with series resis 'r'.

→ The remaining arm consist unknown inductance $L_x$.

→ The bridge balance condition is.

$$\frac{R_1}{(R_3+r)+j\omega L_3} = \frac{R_2}{R_x + j\omega L_x}$$

$$R_1[R_x + j\omega L_x] = R_2[(R_3+r)+j\omega L_3] \rightarrow ①$$

$$R_1 R_x + j\omega R_1 L_x = R_2(R_3+r) + j\omega R_2 L_3$$

equating imaginary parts

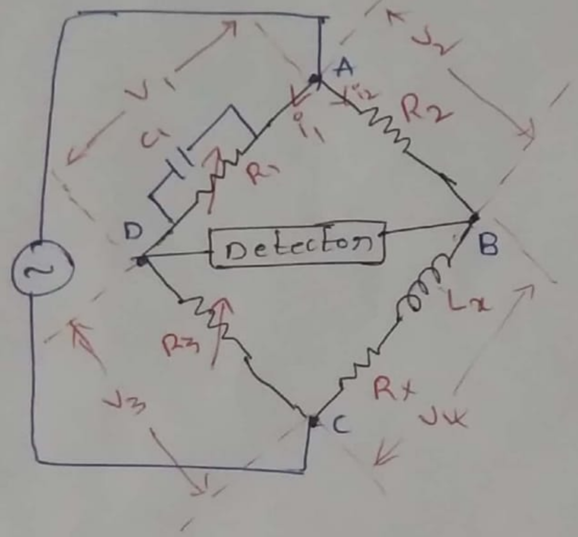
$$R_1 L_x = R_2 L_3 \Rightarrow \boxed{L_x = \frac{R_2 L_3}{R_1}} \rightarrow ②$$

from ① equating real parts.

$$R_1 R_x = R_2(R_3+r) \Rightarrow \boxed{R_x = \frac{R_2}{R_1}\cdot(R_3+r)} \longrightarrow ③$$

## maxwell's inductance capacitance bridge:

→ using this, we can measure inductance by comparing with a variable Standard capacitor.



→ one of the ratio arms consist of res̶is and capacitance in parllel. Hence it is simple to write bridge eqns in admittance form.

$$z_1 \cdot z_x = z_2 \cdot z_3$$

$$z_x = \frac{z_2 \cdot z_3}{z_1} = z_2 \cdot z_3 \cdot Y_1 \rightarrow ④ \quad (\because Y_1 = \frac{1}{z_1})$$

$$z_2 = R_2 \quad , \quad z_3 = R_3$$

$$z_x = R_x + j\omega L_x \quad (L_x \text{ is in Series with } R_x)$$

$$Y_1 = \frac{1}{R_1} + j\omega C_1 \quad (\because z_1 = R_1 \| \frac{1}{j\omega C_1}) \quad (\because \frac{1}{j} = -j)$$

from eqn ④ ⇒ $R_x + j\omega L_x = R_2 R_3 \left[\frac{1}{R_1} + j\omega C_1\right]$

$$R_x + j\omega L_x = \frac{R_2 R_3}{R_1} + jR_2 R_3 \omega C_1$$

equating real parts.

$$\boxed{R_x = \frac{R_2 R_3}{R_1}}$$

equating imaginary parts.

$$\omega L_x = R_2 R_3 \omega C_1$$

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

The quality factor of coil is

$$Q = \frac{\omega L_x}{R_x}$$

$$Q = \frac{\omega \cdot R_2 \cdot R_3 \cdot C_1}{\frac{R_2 \cdot R_3}{R_1}}$$

$$\boxed{Q = \omega \cdot R_1 C_1}$$