UNIT-I

→ Performance Characteristics of Instruments:

It Consists of 2 basic Characteristics
(1) Static Characteristics
(2) Dynamic Characteristics

(1) Static Characteristics:-

Accuracy: The degree of exactness (or) closeness of a Measurement Compared to the expected value.

Precision: A Measure of the repetability of Measurements. i.e. Successive reading do not differ.

Resolution: The Smallest Change in a measured Variable to which an instrument will respond.

Sensitivity: The ratio of the Change in output of the instrument to a Change of input.

Calibration: It is the Process of Configuring an instrument to provide a result for a Sample with an acceptable range.

Static Calibration: It refers to the i/p — o/p relations obtained when only one input of the instrument is varied at a time, all other inputs being Kept Constant.

Dynamic Calibration: It refers to the i/p — o/p relations obtained when all the inputs of the instrument are Varied.

Error: The deviation of the true value from the measured value.

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Errors in Measurement and their statistical Analysis:

→ Measurement is the Process of Comparing an unknown quantity with an accepted Standard quantity.

→ Error may be expressed either as absolute (or) as percentage of Error.

→ Absolute Error may be defined as the difference between the expected value of the variable and the measured value of the variable. (Expected value − Present value)

$$\therefore \quad e = Y_n - X_n$$

Here e = absolute Error

Y_n = Expected value

X_n = Measured value.

$$\therefore \quad \% \text{ Error} = \frac{\text{Absolute Value}}{\text{Expected Value}} \times 100$$

$$= \frac{e}{Y_n} \times 100$$

$$\therefore \quad \% \text{ Error} = \left(\frac{Y_n - X_n}{Y_n}\right) \times 100.$$

→ It is more frequently expressed as a accuracy rather than error.

$$\therefore \quad A = 1 - \left| \frac{Y_n - X_n}{Y_n} \right|$$

Here A = relative Accuracy.

Accuracy is Expressed as % accuracy.

$$a = A \times 100 \%$$

Here a = % accuracy.

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Static Error :-

→ The static Error of a Measuring instrument is the numerical difference between the true value of a quantity and its value as obtained by measurement.

→ static Errors are Categorized as gross Errors (or) Human Errors, Systematic Errors, and random Errors.

(1) Gross Errors:

- These Errors are mainly due to human mistakes in reading or in using instruments or Errors in recording observations. Errors may also occur due to incorrect adjustment of instruments and Computational mistakes. These Errors Cannot be treated mathematically.
- The complete elimination of gross Errors is not possible. but the Error Can be minimized by taking proper care in reading and recording the measurement parameter.

(2) Systematic Errors:

- These Errors occur due to short comings of the instrument, such as defective or worn parts or ageing or Effects of the Environment on the instrument.
- There are basically three types of systematic Errors (1) Instrumental (2) Environmental (3) Observational

(i) Instrumental Errors:

- Instrumental Errors are inherent in measuring instruments, because of their mechanical structure.
- Instrumental Errors Can be avoided by
  (a) Selecting a Suitable instrument for the particular measurement applications.
  (b) applying correction factors after determining the amount of instrumental Error.
  (c) Calibrating the instrument against a standard.

(ii) Environmental Error:

- Environmental Errors are due to Conditions external to the measuring device including Conditions in the area surrounding the instrument, Such as the effects of change in temperature, humidity, barometric pressure or of magnetic or electrostatic fields.
- These errors Can also be avoided by air Conditioning, hermetically Sealing Certain Components in the instruments, and by using magnetic shields.

(iii) Observational Errors:-

- These errors are introduced by the observer. The most Common error is the Parallax error introduced in reading a meter scale, and the error of estimation and obtaining a reading from a meter scale.

(3) Random Errors:

- These are errors that remain after gross and Systematic errors have been Substantially reduced or at least accounted for.
- Random errors are generally an accumulation of a large number of small effects and may be of real Concern only in measurements requiring a high degree of accuracy. Such errors can be analyzed statistically.
- These errors are due to unknown Causes, not determinable in the ordinary process of making measurements. Such errors are nominally Small and fallow the laws of Probability. Random errors can thus be treated Mathematically.

Sources of Errors:

(1) Insufficient Knowledge of Process Parameters and design Conditions

(2) poor design

(3) Poor Maintenance

(4) Certain design limitations.

(5) Errors Caused by person operating the instrument or equipment

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Dynamic Characteristics:-

Speed of Response: It is the rapidity with which an instrument responds to changes in the measured quantity.

Fidelity: It is the degree to which an instrument indicates the changes in the measured variable without dynamic Error.

Lag: It is the delay in the response of an instrument to changes in the measured variable.

Dynamic Error: It is the difference between the true value of a quantity changing with time and the value indicated by the instrument.
(True value changing with time − Measured value)

DC Ammeter :-

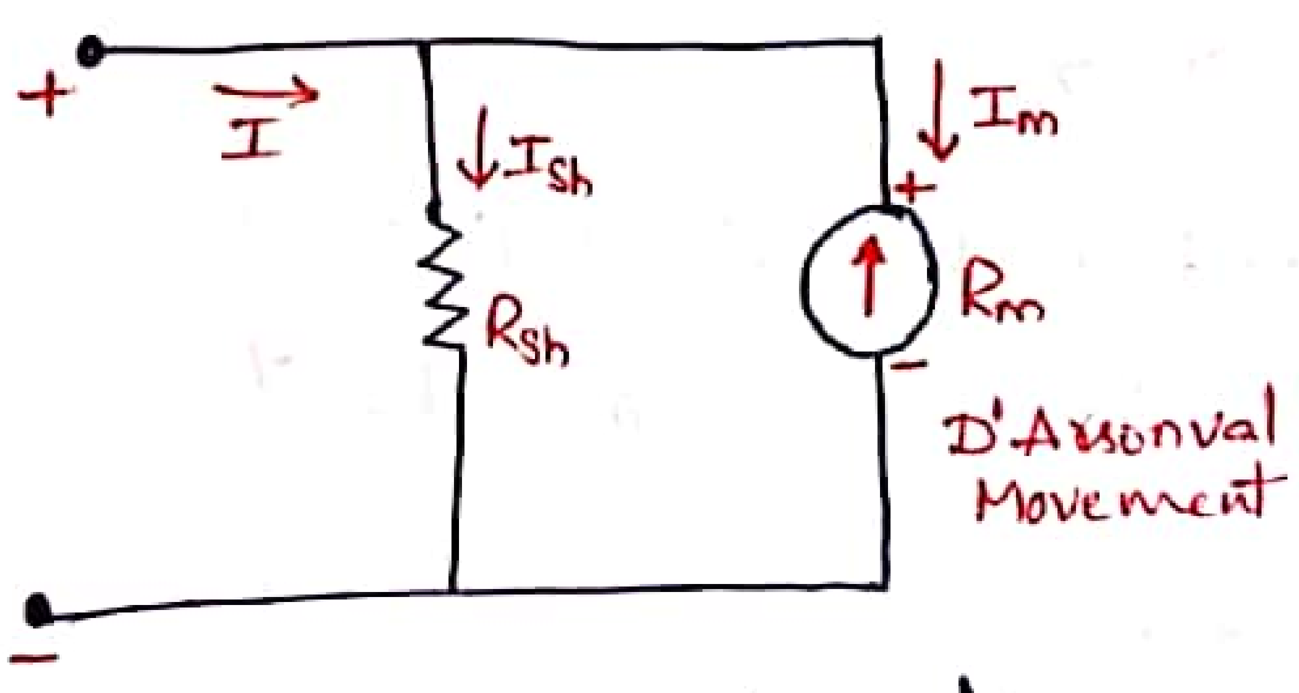

fig :- Basic DC Ammeter

→ The PMMC galvanometer constitutes the basic movement of a dc ammeter. Since the coil winding of a basic movement is small and light, it can carry only very small currents.

→ When large currents are to be measured, it is necessary to bypass a major part of the current through a resistance called a shunt. as shown in figure.

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

In fig R_m = Internal resistance of the movement.

I_{sh} = Shunt Current

I_m = full scale deflection Current of the movement.

I = full scale current of the ammeter + Shunt Current

$(I = I_m + I_{sh})$.

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

$$\therefore \quad V_{sh} = V_m$$

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

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

but we know $I = I_m + I_{sh}$

$$\therefore I_{sh} = I - I_m.$$

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

→ for each required value of full scale meter current, we can determine the value of shunt resistance.

Multirange Ammeters :-

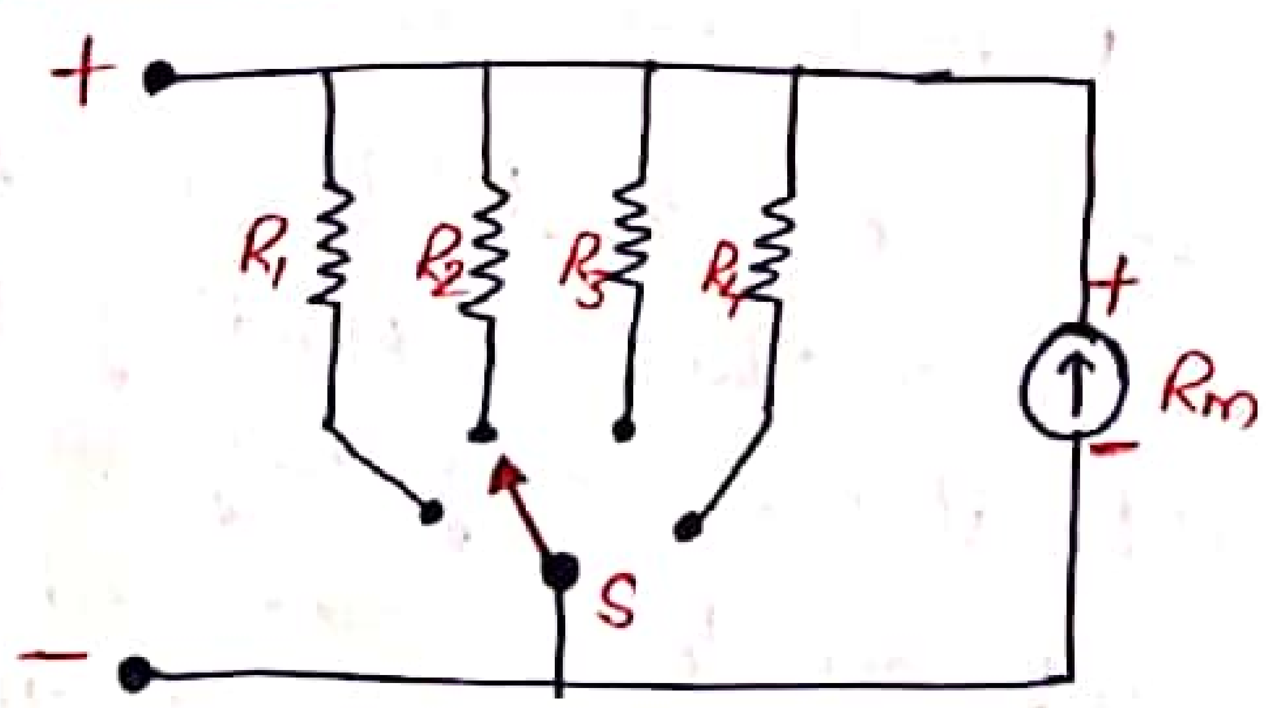

fig: Multirange ammeter.

→ The current range of the dc ammeter may be further extended by a number of shunts, selected by a range switch. Such a meter is called a multirange ammeter. Shown in figure.

→ The circuit has four shunts R_1, R_2, R_3 and R_4, which can be placed in parallel with the movement to give four different current ranges. Switch (S) is a multi positional switch.

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

→ Multi range ammeters are used for ranges up to 50A. When using a multirange ammeter, first use the highest current range then decrease the range until good upscale reading is obtained.

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Range Extension Ammeters :-

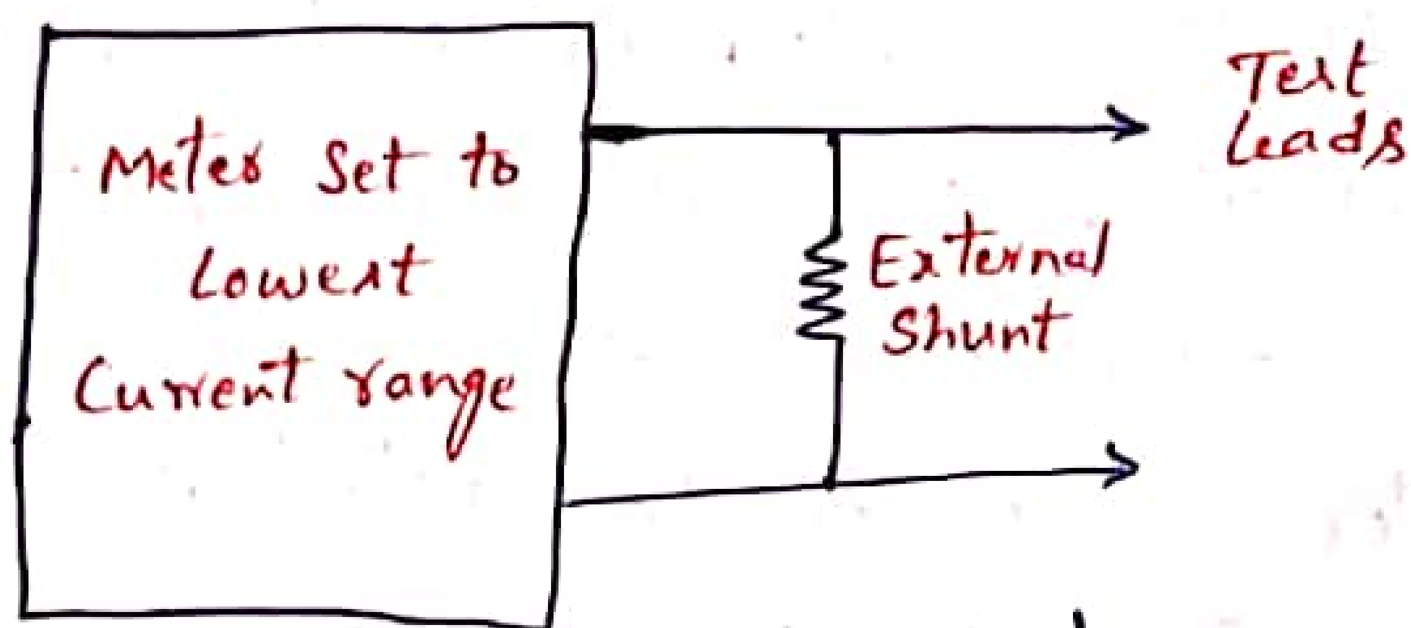

Fig: Range Extension Ammeter.

→ The range of an ammeter can be extended to measure high current values by using external shunts connected to the basic meter movement.

→ Note that the range of the basic meter movement cannot be lowered.

For example, if a 100μA movement with 100 scale division is used to measure 1μA, the meter will deflect by only one division. Hence ranges lower than the basic range are not practically possible.

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DC Voltmeter :-

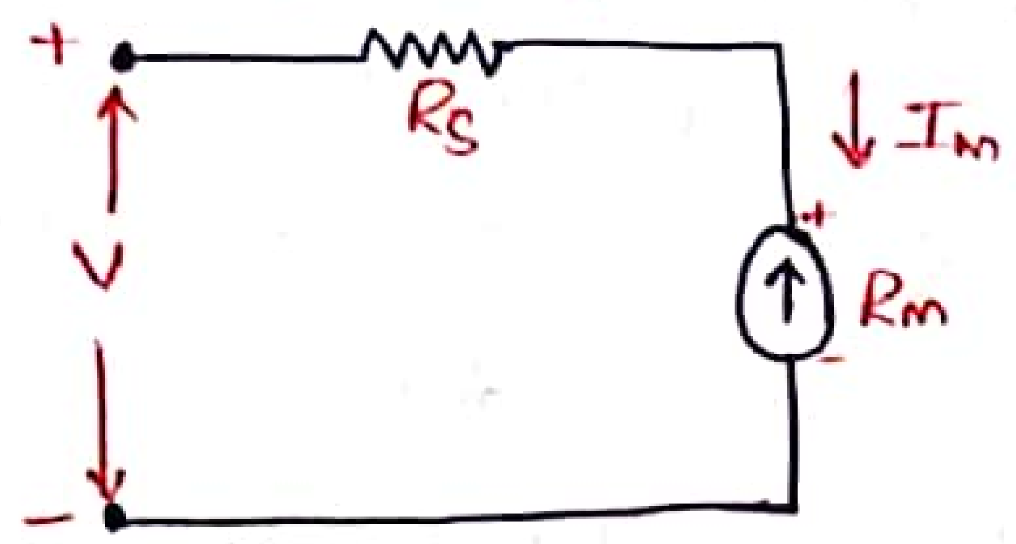

fig: Basic DC Voltmeter

→ A basic D'Arsonval movement can be converted into a dc voltmeter by adding a series resistor known as Multiplier, as shown in figure.

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

→ A dc voltmeter measures the potential difference between two points in a circuit component.

→ The value of the Multiplier (R_s) required is calculated as follows.

$$V = I R$$

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

$$V = I_m R_s + I_m R_m$$

$$I_m R_s = V - I_m R_m$$

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

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

Here R_m = Internal resistance of movement.

R_s = Multiplier resistance.

V = full range voltage of the instrument

I_m = full scale deflection current of the movement.

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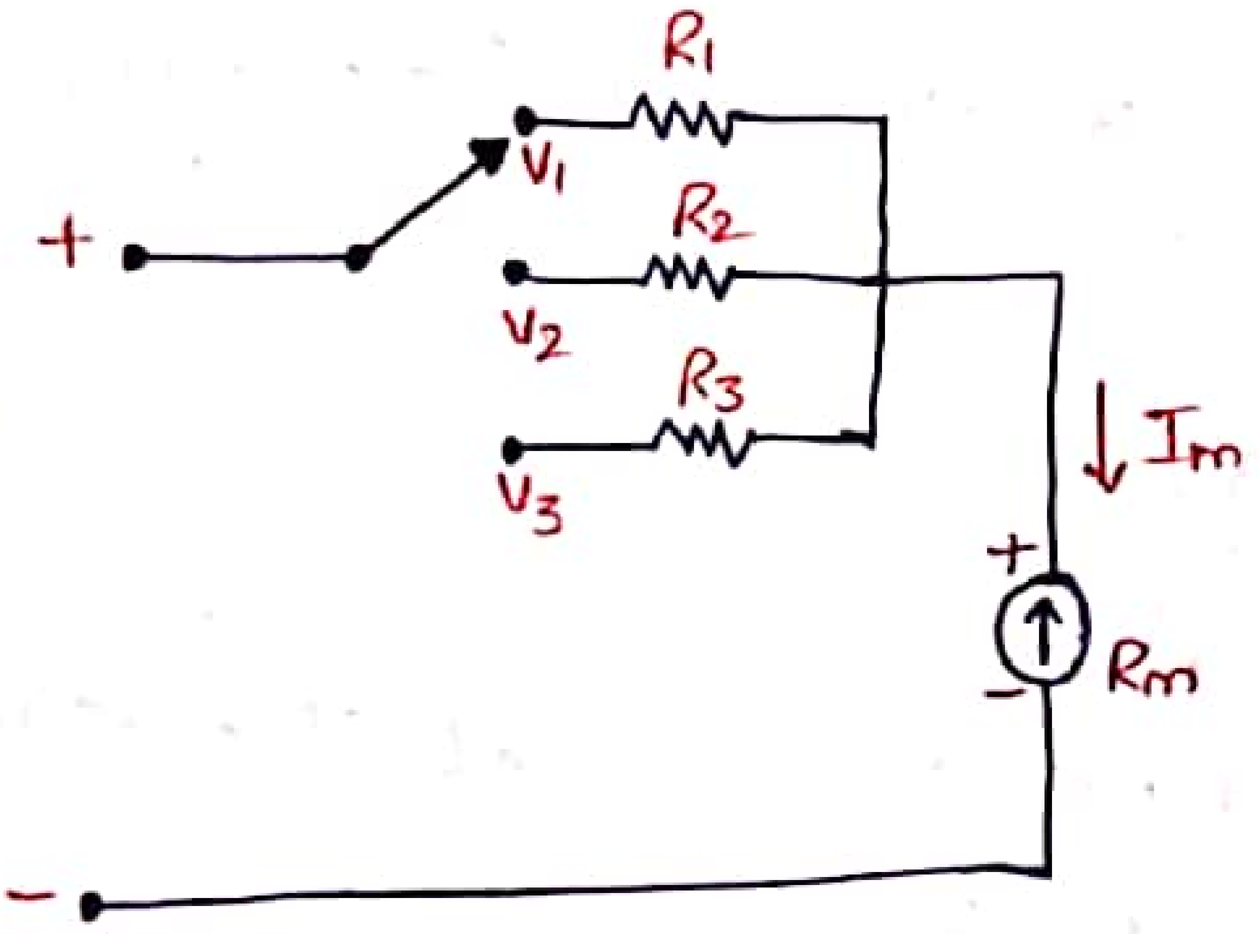
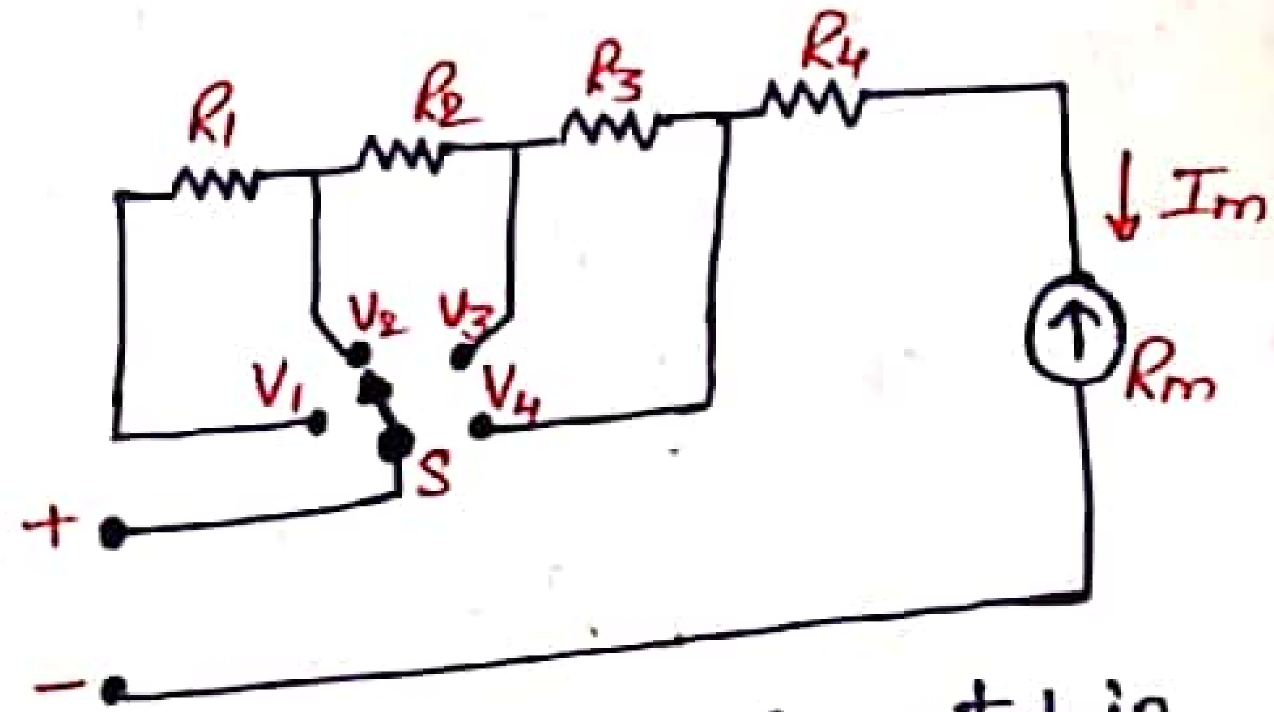
Multirange Voltmeter :-



fig(1): Multirange Voltmeter



fig(2): Multipliers Connected in Series String.

→ A dc voltmeter Can be Converted into a multirange voltmeter by Connecting a number of resistors (Multipliers) along with a range Switch to provide a greater no. of workable ranges.

→ fig (1) shows a Multirange voltmeter using a three position Switch and three Multipliers R_1, R_2 and R_3 for voltage values V_1, V_2 and V_3.

→ fig (2) which is a more practical arrangement of the Multiplier resistors of a Multirange voltmeter. In this arrangement the Multipliers are Connected in Series string and the range selector selects the appropriate amount of resistance required in Series with the movement.

Range Extension Voltmeter :-

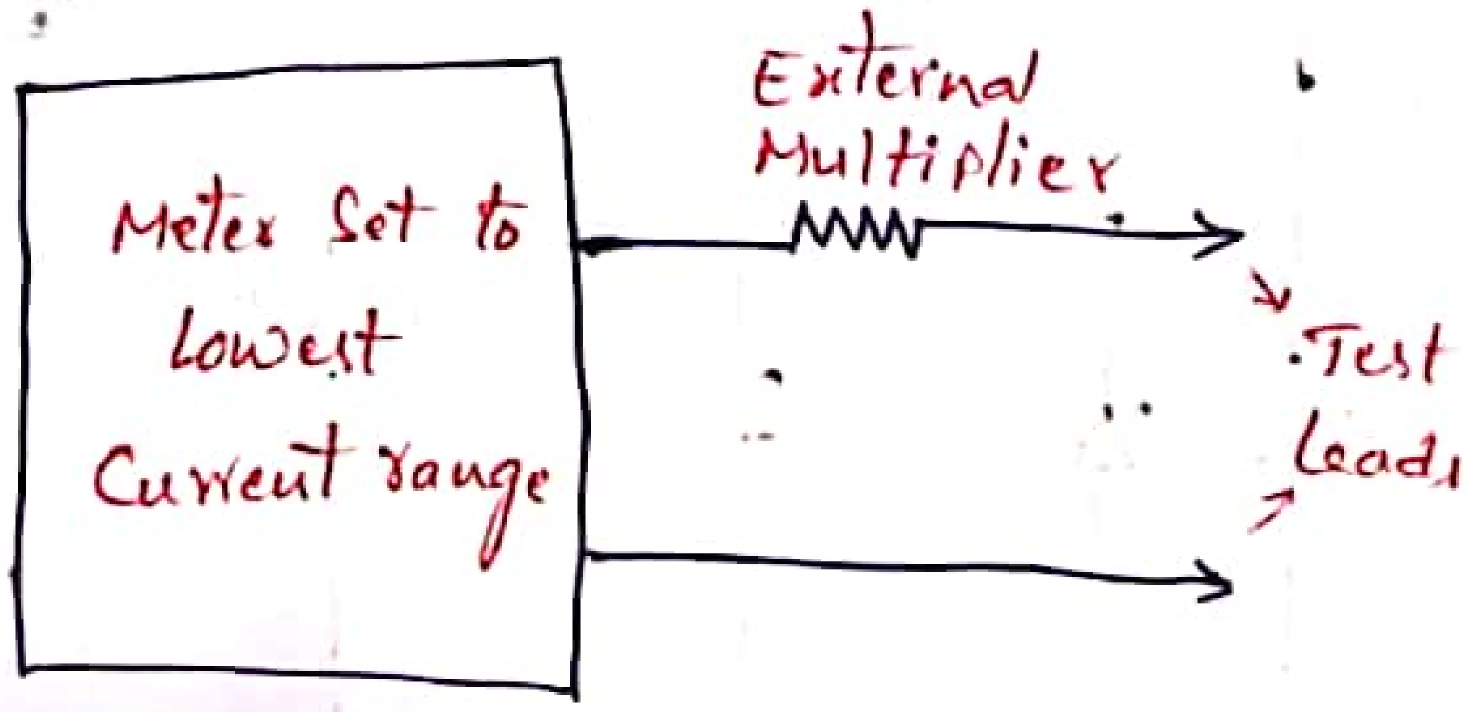


fig: Range Extension Voltmeter.

→ The range of voltmeter can be extended to measure high voltages, by using an external multiplier resistor.

→ The sensitivity is a reciprocal of the full scale deflection current of the basic movement.

$$S = \frac{1}{I_{fsd}} \; (\Omega/V)$$

→ By using this sensitivity (S) we can calculate the value of multiplier resistors in a dc voltmeter.

R_t = Total circuit resistance ($R_t = R_s + R_m$)

S = Sensitivity (Ω/V)

V = voltage range.

R_m = Internal resistance of the movement.

$$R_t = R_s + R_m$$

$$\therefore \; R_s = R_t - R_m \qquad \text{here } R_t = (S \times V)$$

$$R_s = (S \times V) - R_m$$

Solid State Voltmeters :-

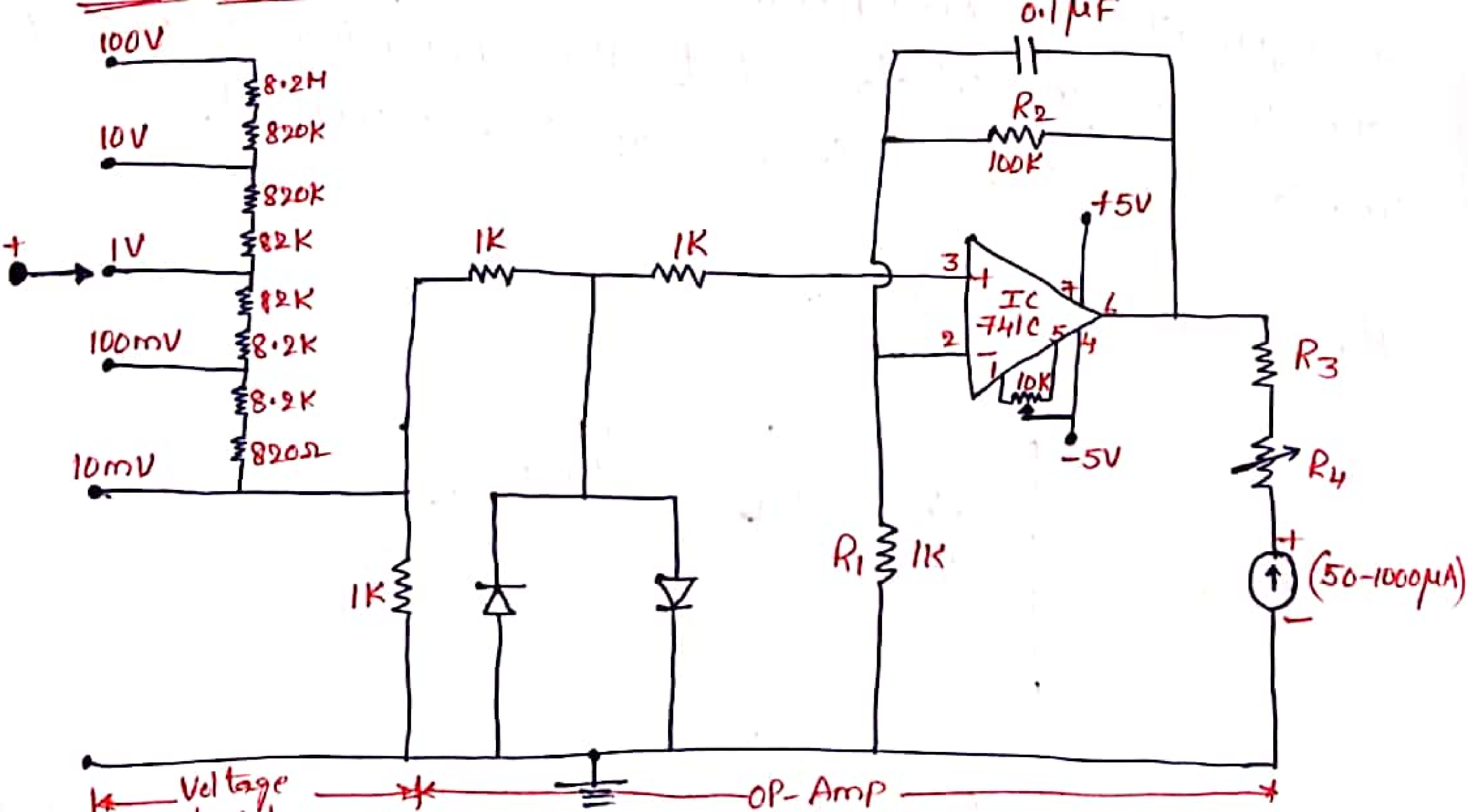


Fig: Solid state voltmeter using OP-Amp.

→ fig shows the CKt of an electronic voltmeter using an IC OP-Amp 741C

→ This is a directly Coupled very high gain Amplifier

→ The ratio R_2/R_1 determines the gain, Provided by the OP-Amp.

→ Terminals 1 and 5 are Called as offset Null terminals.

→ A 10KΩ Potentiometer is Connected b/w these two offset Null terminals with its Center tap Connected to a −5V Supply.

→ This Potentiometer is Called as zero set and is Used for adjusting zero output for zero input Conditions.

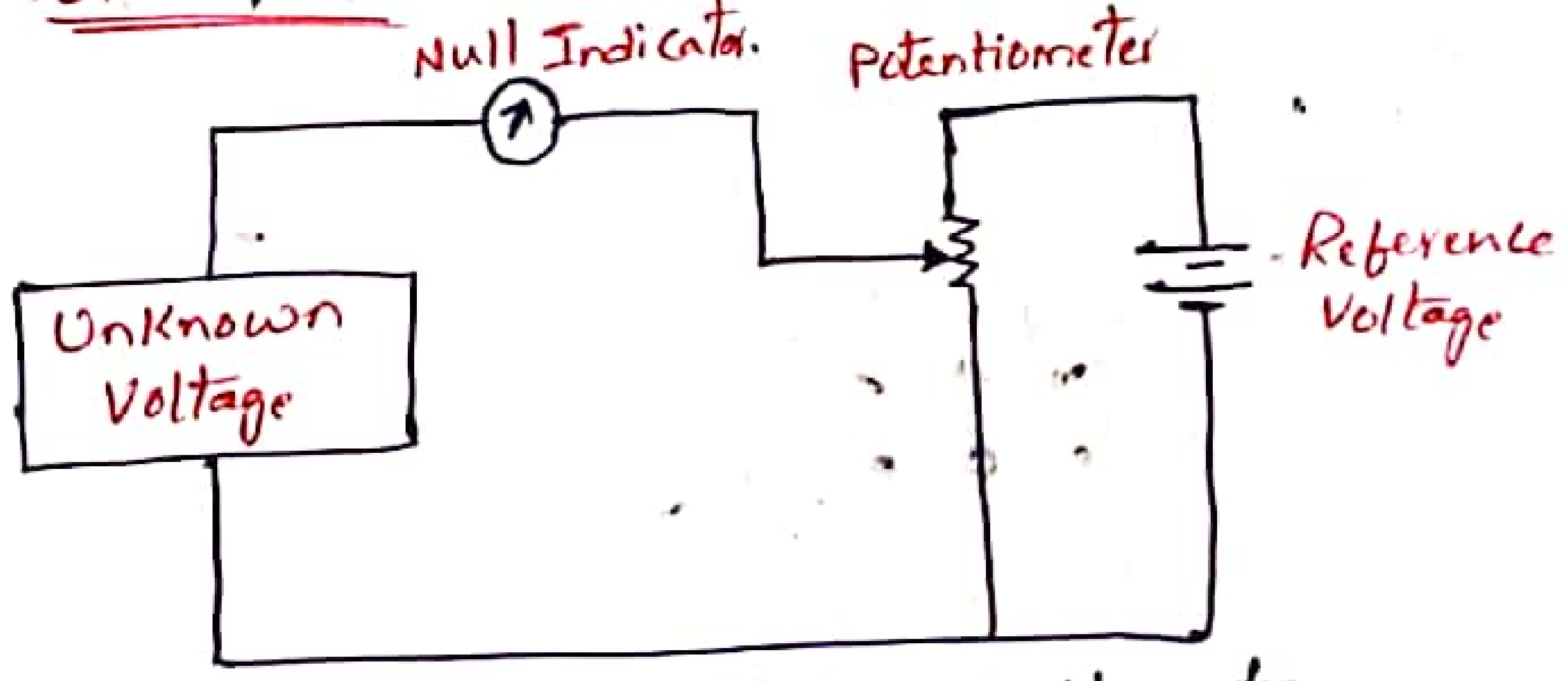
→ The two diodes are Used for IC Protection.

→ Under normal Conditions, they are non Conducting state, as the maximum Voltage across them is 10mV.

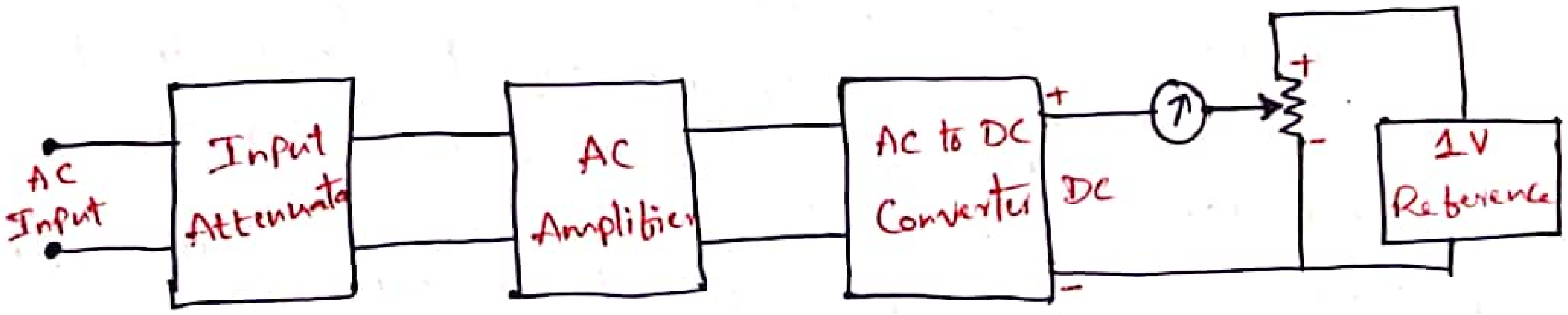
→ If an excessive voltage say more than 10mV appears across them, then One of the diodes Conducts and protects the IC.

→ A μA Scale of 50−1000 μA full scale deflection can be Used as an indicator. 'R_4' is adjusted to get Maximum full Scale deflection.

Differential Voltmeters:



fig(1): Basic differential Voltmeter.



fig(2): Block diagram of an AC differential Voltmeter.

→ In this technique, the voltmeter is used to indicate the difference between known and unknown voltages.

→ fig(1) shows a basic circuit of a differential voltmeter, based on the potentiometric method hence it is also called as "potentiometric voltmeter".

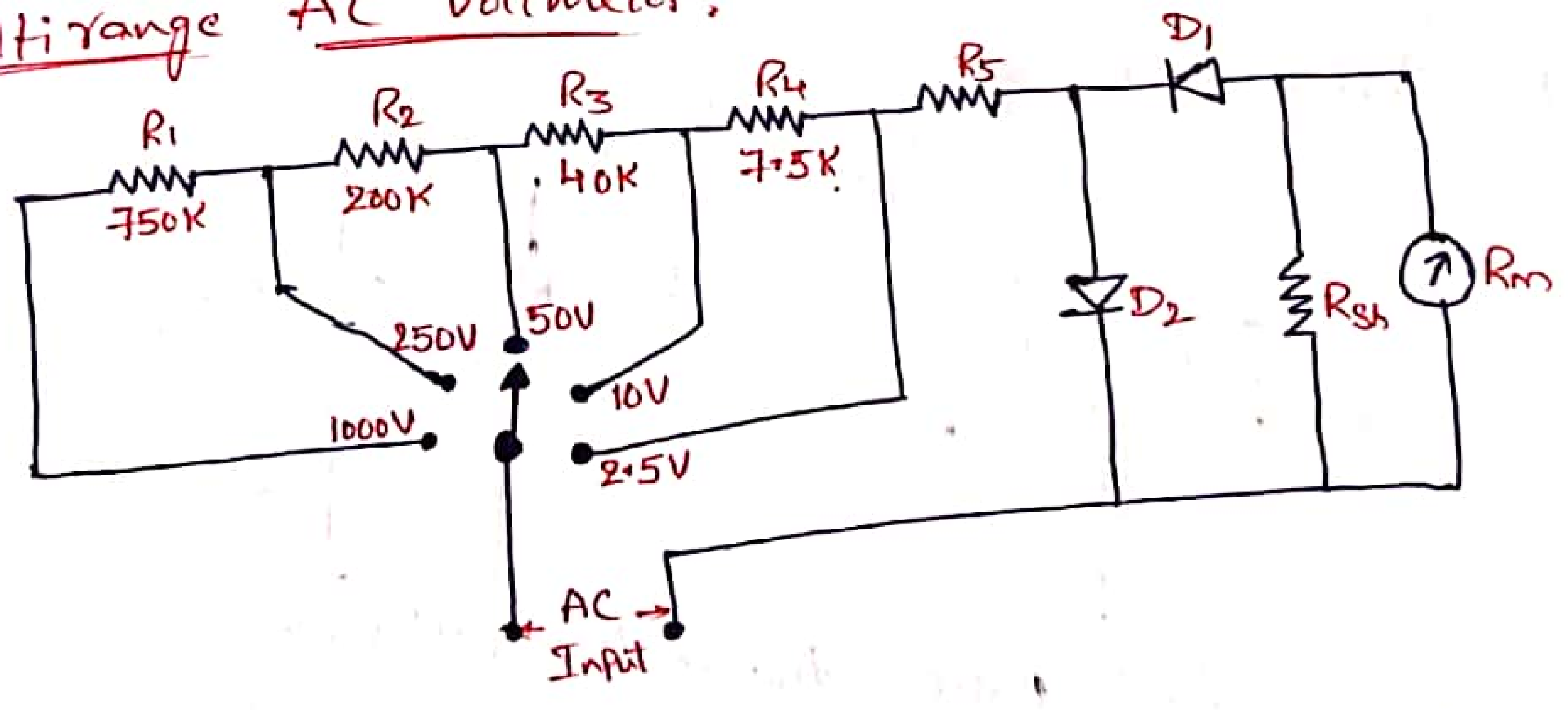
→ In this method, the potentiometer is varied until the voltage across it equals the unknown voltage, which is indicated by the null indicator reading 'zero'.

→ The reference source used is usually a '1V' dc standard source. A high voltage reference supply is used for measuring high voltages.

→ In order to measure ac voltages, the ac voltage must be converted into DC by incorporating a precision rectifier circuit shown in fig(2).

AC Voltmeters :-

Multirange AC voltmeter :



→ This is circuit for measuring AC voltages for different ranges. Resistances R_1, R_2, R_3 and R_4 form a chain of multipliers for voltage ranges of 1000V, 250V, 50V and 10V respectively.

→ Rsh is the meter shunt and acts to improve the rectifier operation.

Range Extension AC Voltmeter :-

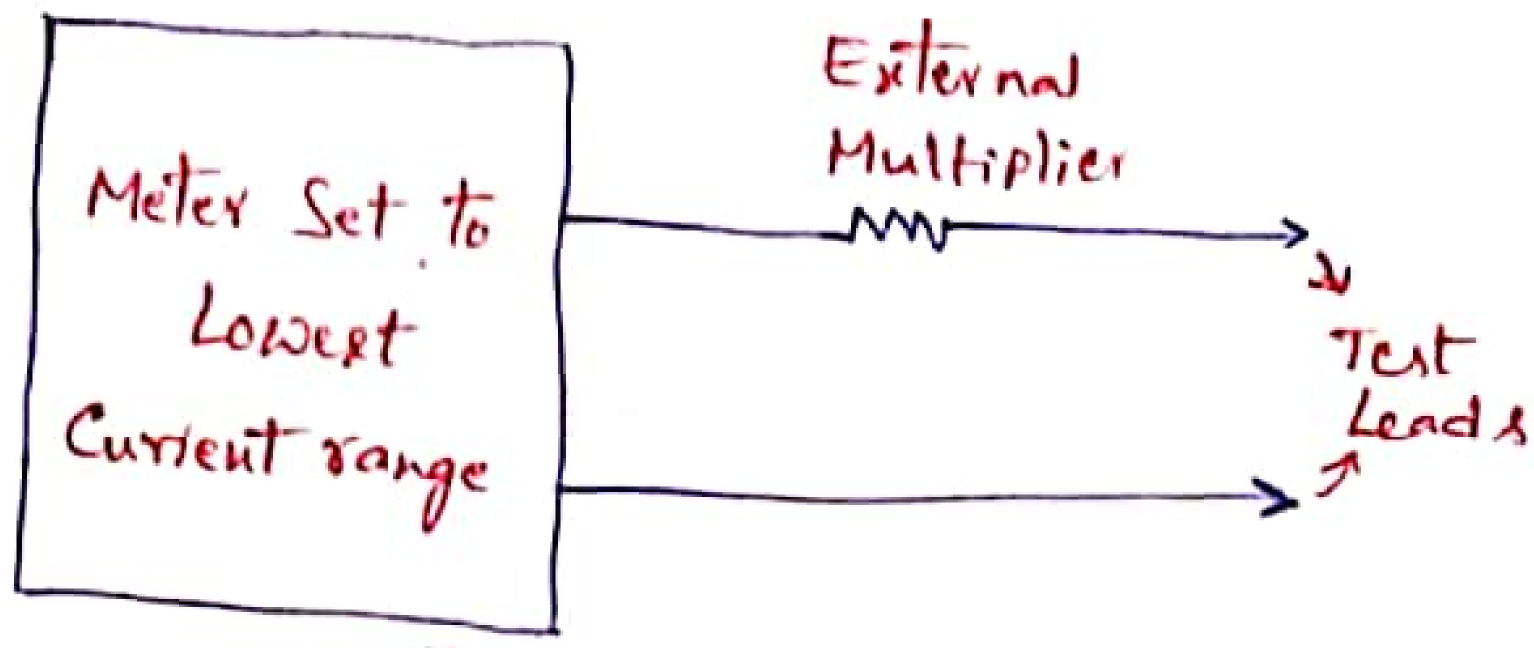


fig: Range Extension Voltmeter.

→ The range of Voltmeter Can be extended to measure high Voltages, by Using external Multiplier resistor.

→ The Sensitivity is a reciprocal of the full scale deflection Current of the basic Movement

$$S = \frac{1}{I_{fsd}} \ (\Omega/V)$$

→ By Using this Sensitivity (s) we Can calculate the Value of Multiplier resistors in a dc voltmeter.

R_t = Total circuit resistance ($R_t = R_s + R_m$)

S = Sensitivity (Ω/V)

V = Voltage range.

R_m = Internal resistance of the Movement.

$\therefore \ R_t = R_s + R_m$

$R_s = R_t - R_m$

$$R_s = (S \times V) - R_m$$

here $R_t = (S \times V)$

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Thermo Couple Type RF Ammeter :-

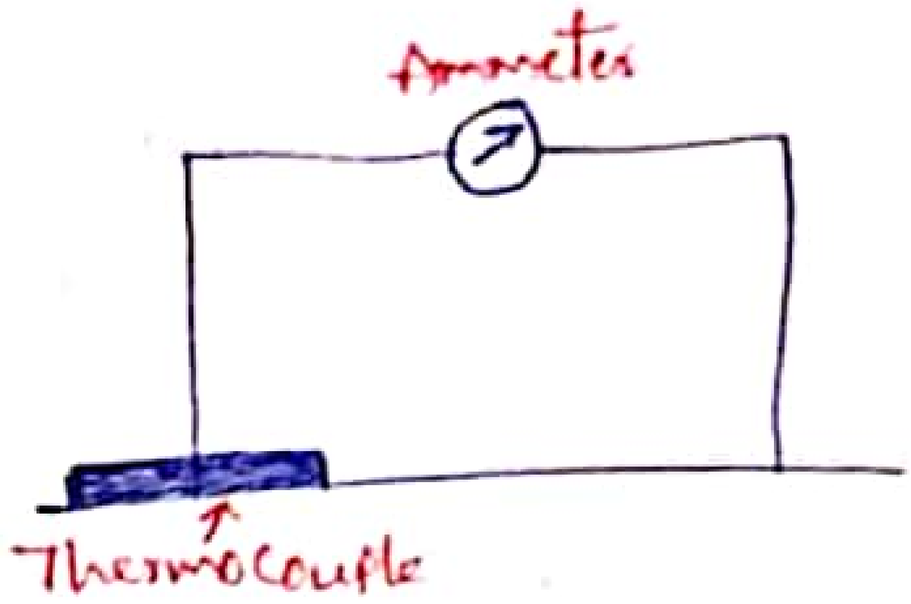
→ Thermocouples Consists of a Junction of two dissimilar wires so chosen that a voltage is generated by heating the Junction

→ The O/P of a thermocouple is delivered to a Sensitive dc micro ammeter.

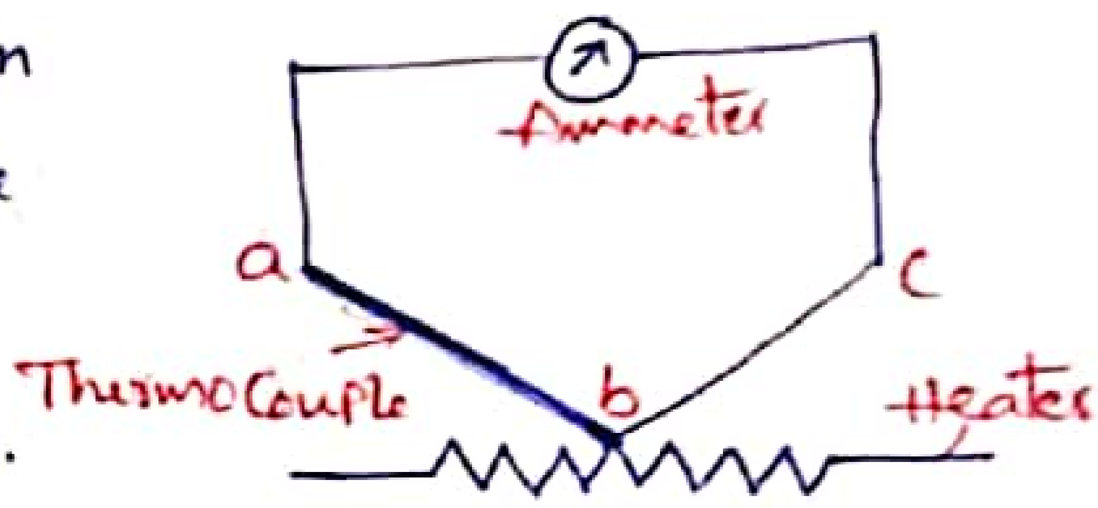
→ The generation of dc voltage by heating the junction is called "Thermo Electric Action" and the device is called a "Thermo Couple".

→ Various Types of Thermo Couples are as follows.

(1) **Manual Type:** In this type, the alternating Current passes through the thermocouple itself and not through a heater wire.



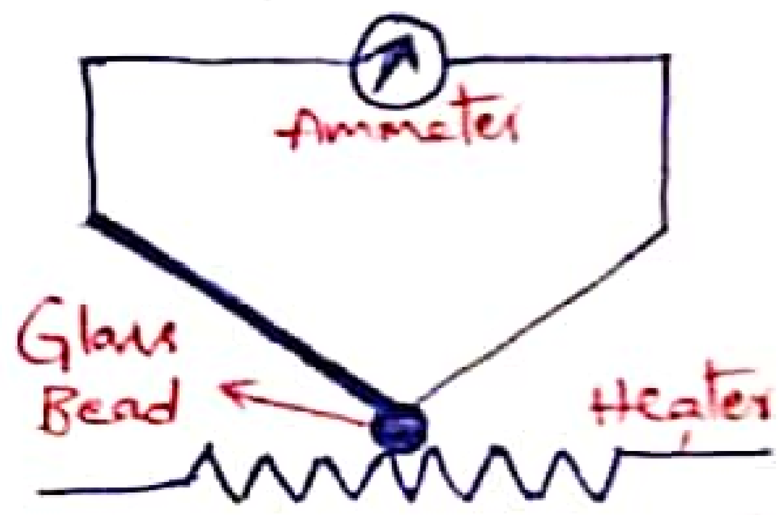
(2) **Contact Type:** This is less Sensitive than the mutual Type. In the Contact Type there are Seperate thermocouple leads which Conduct away the heat from the heater wire.



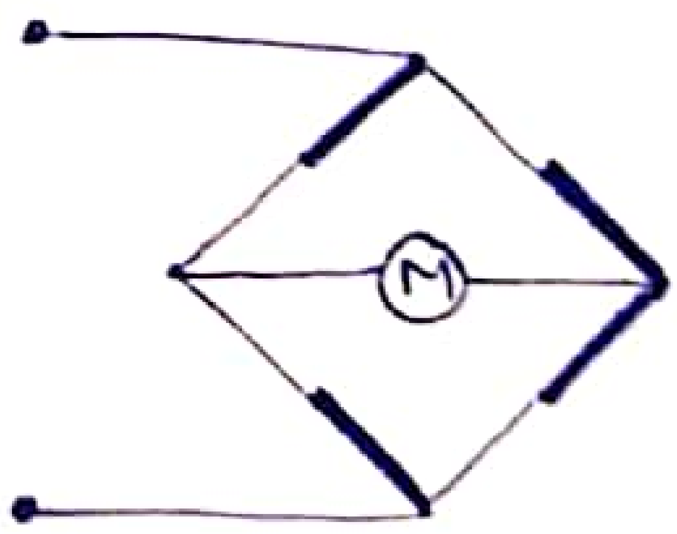
(3) **Seperate Heater Type:** In this Arrangement, the thermo Couple is held near the heater, but insulated from it by a glass bead.

→ This make the instrument sluggish and also less Sensitive because of temperature drop in the glass bead.

→ This type is Useful for Certain applications, like RF Current measurements.



(4) **Bridge Type:** This has the high Sensitivity of the mutual type and yet avoids the shunting effect of the Micro ammeter.



Ohmmeters:-

(1) Series type Ohmmeters:

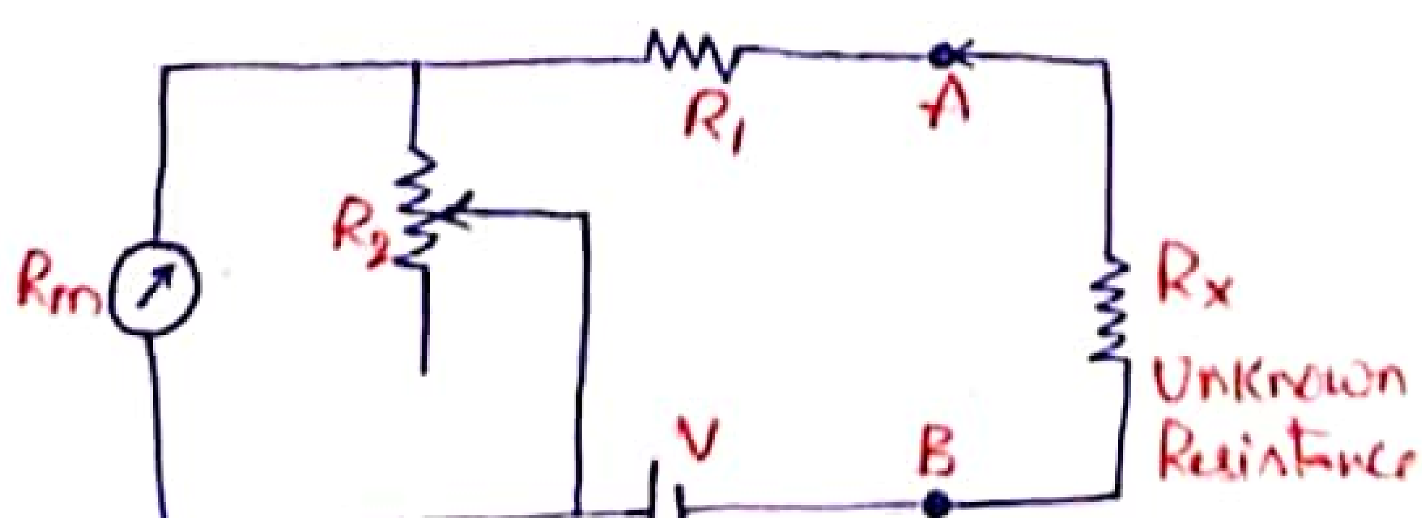
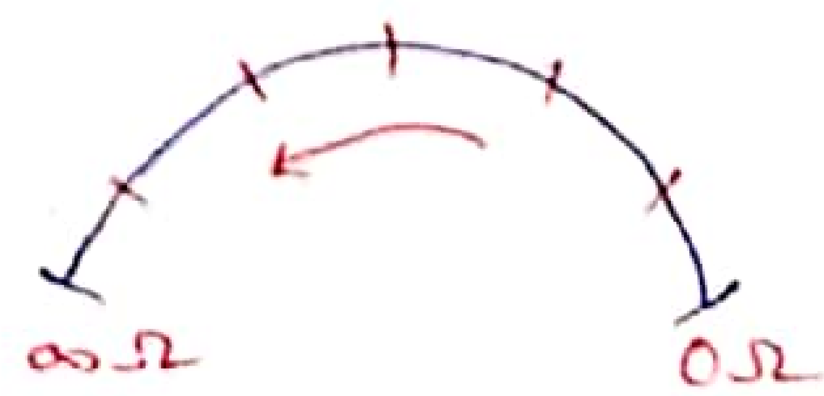


fig:(a): Series type Ohmmeter



fig(b): Dial of Series ohmmeter

→ A D'Arsonval movement is Connected in Series with a resistance R_1 and a battery which is Connected to a Pair of terminals A and B, across which the unknown resistance is Connected. This forms the basic type of Series Ohmmeter Shown in fig (a).

→ The Current flowing through the movement then depends On the magnitude of the unknown resistance. Therefore, the meter deflection is directly Proportional to the Value of the unknown resistance.

In fig (a): R_1 = Current limiting resistance.
R_2 = Zero adjust resistance.
V = Battery voltage.
R_m = meter resistance.
R_x = unknown resistance.

Calibration :-

→ To mark the '0' reading on the scale, the terminals 'A' and 'B' are shorted. i.e. the unknown resistance $R_x = 0$. then the maximum Current flows in the Circuit and the Shunt resistance R_2 is adjusted until the movement indicates full scale Current (I_{fsd}). The position of the Pointer on the scale is then marked '0' ohms.

→ Similarly to mark the infinity (∞) reading on the scale, terminals A and B are open, i.e. the unknown resistance $R_x = \infty$, no Current flow in the Circuit and there is no deflection of the pointer. The Position of the pointer on the scale, is then marked as '∞' ohms.

→ By Connecting different known values of the unknown resistance to terminals 'A' and 'B', intermediate markings Can be done on the Scale.

→ The Major drawback in the Series Ohmmeter is the decrease in voltage of the internal battery with time and age.

→ In a series Ohmmeter the scale marking on the dial. has '0' on the right side, corresponding to full scale deflection current and '∞' on the Left Side corresponding to no current flow. as shown in fig (b).

→ Value of 'R_1' and 'R_2' Can be determined from the value of 'R_x' which gives half the full scale deflection.

$$\therefore \quad R_h = R_1 + (R_2 \parallel R_m) = R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

Where R_h = half of full scale deflection resistance.

∴ The total resistance presented to the battery equals to '$2R_h$' and the Battery Current needed to Supply half scale deflection is

$$I_h = \frac{V}{2R_h}$$

To produce full Scale Current, the battery Current must be doubled.

∴ The total Current of the Circuit $I_t = 2I_h = 2\left(\frac{V}{2R_h}\right)$

$$I_t = \frac{V}{R_h}$$

→ The Shunt Current through 'R_2' is given by 'I_2'

We Know $I_t = I_2 + I_{fsd}$

$$\therefore I_2 = I_t - I_{fsd}$$

→ The Voltage across the Shunt (V_{sh}) is equals to the Voltage across the meter

$$\therefore \quad V_{sh} = V_m$$

$$I_2 R_2 = I_{fsd} \cdot R_m.$$

$$\rightarrow \quad R_2 = \frac{I_{fsd} \cdot R_m}{I_2}$$

$$R_2 = \frac{I_{fsd} \cdot R_m}{I_t - I_{fsd}}.$$

But $I_t = \frac{V}{R_h}$

$$\therefore \quad R_2 = \frac{I_{fsd} \cdot R_m}{\left(\frac{V}{R_h}\right) - I_{fsd}}$$

$$\therefore \quad \boxed{R_2 = \frac{I_{fsd} \cdot R_m \cdot R_h}{V - I_{fsd} \cdot R_h}}$$

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

$$\therefore \quad R_1 = R_h - \frac{R_2 R_m}{R_2 + R_m}$$

$$R_1 = R_h - \frac{\left(\frac{I_{fsd} \cdot R_m \cdot R_h}{V - I_{fsd} \cdot R_h}\right) R_m}{\left(\frac{I_{fsd} \cdot R_m \cdot R_h}{V - I_{fsd} \cdot R_h}\right) + R_m}$$

$$R_1 = R_h - \frac{\left(\frac{I_{fsd} \cdot R_m \cdot R_h}{V - I_{fsd} \cdot R_h}\right) R_m}{\frac{\left(I_{fsd} R_h + V - I_{fsd} \cdot R_h\right) R_m}{\left(V - I_{fsd} \cdot R_h\right)}}$$

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

Hence R_1 and R_2 can be determined.

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(2) Shunt Type Ohmmeter:

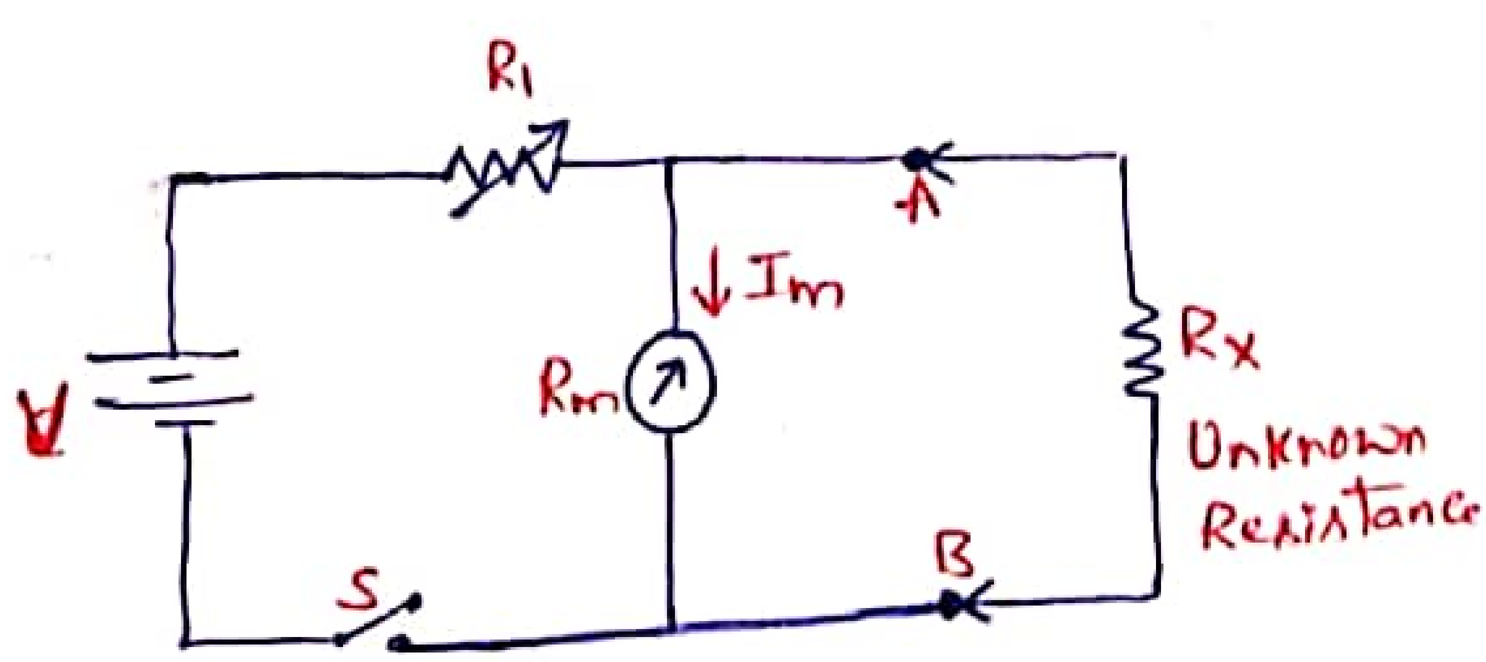

fig: Shunt Type Ohmmeter

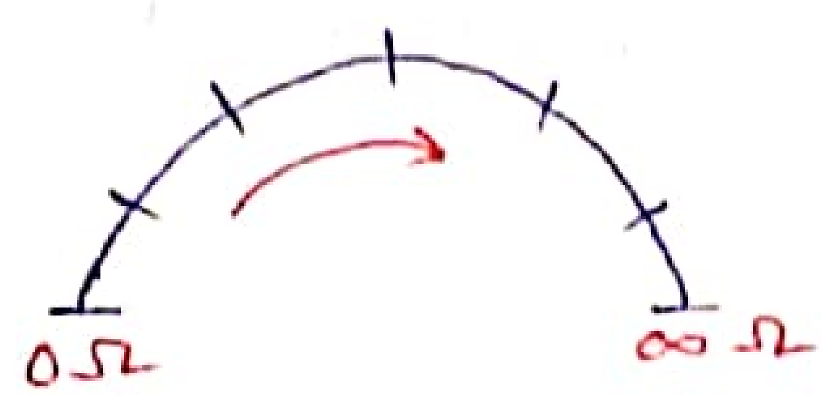

fig: Dial of Shunt Type Ohm meter

→ The Shunt type ohmmeter Consists of a battery in Series with an adjustable resistor R_1 and a D'Arsonval movement.

→ The unknown resistance (R_x) is Connected in Parallel with the meter, across the terminals A and B, hence the name Shunt type ohmmeter.

→ In this Circuit it is necessary to have an ON/OFF Switch to disconnect the battery from the Circuit when the instrument is not Used.

Calibration:

→ If $R_x = 0\,\Omega$ the meter Current is Zero.

→ If $R_x = \infty\,\Omega$ the meter Choose the full scale Current (I_{fsd})

→ This ohmmeter generally Used for Low Value resistors.

→ When $R_x = \infty$ the full scale meter Current will be

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

V = internal Battery Voltage.

R_1 - Current Limiting resistor

R_m = internal resistance of the meter.

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

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

→ This ohmmeter therefore has a Zero Mark at the left side of the Scale and an '∞' mark at the right side of the scale, Corresponding to full scale deflection Current shown in fig (b).

→ Shunt type ohmmeter is Used as a Test instrument in the laboratory for special low resistance applications.

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Multirange Ohmmeter:-

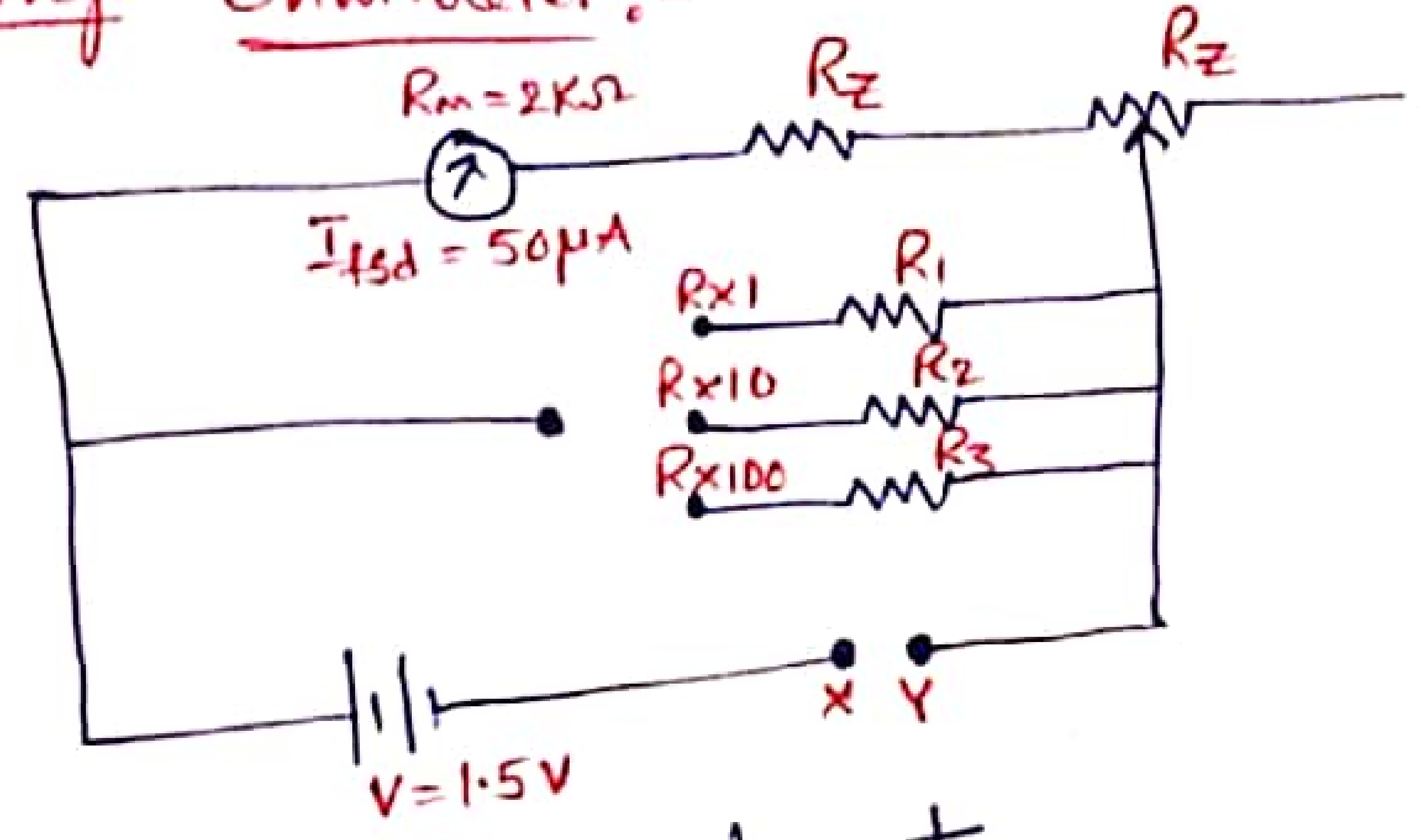

fig: Multirange ohmmeter

→ To measure resistance over a wide range of values, we need to extend the ohmmeter ranges. This type of ohmmeter is called a Multirange ohmmeter.

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Multimeter: (for voltage, current and resistance Measurements)

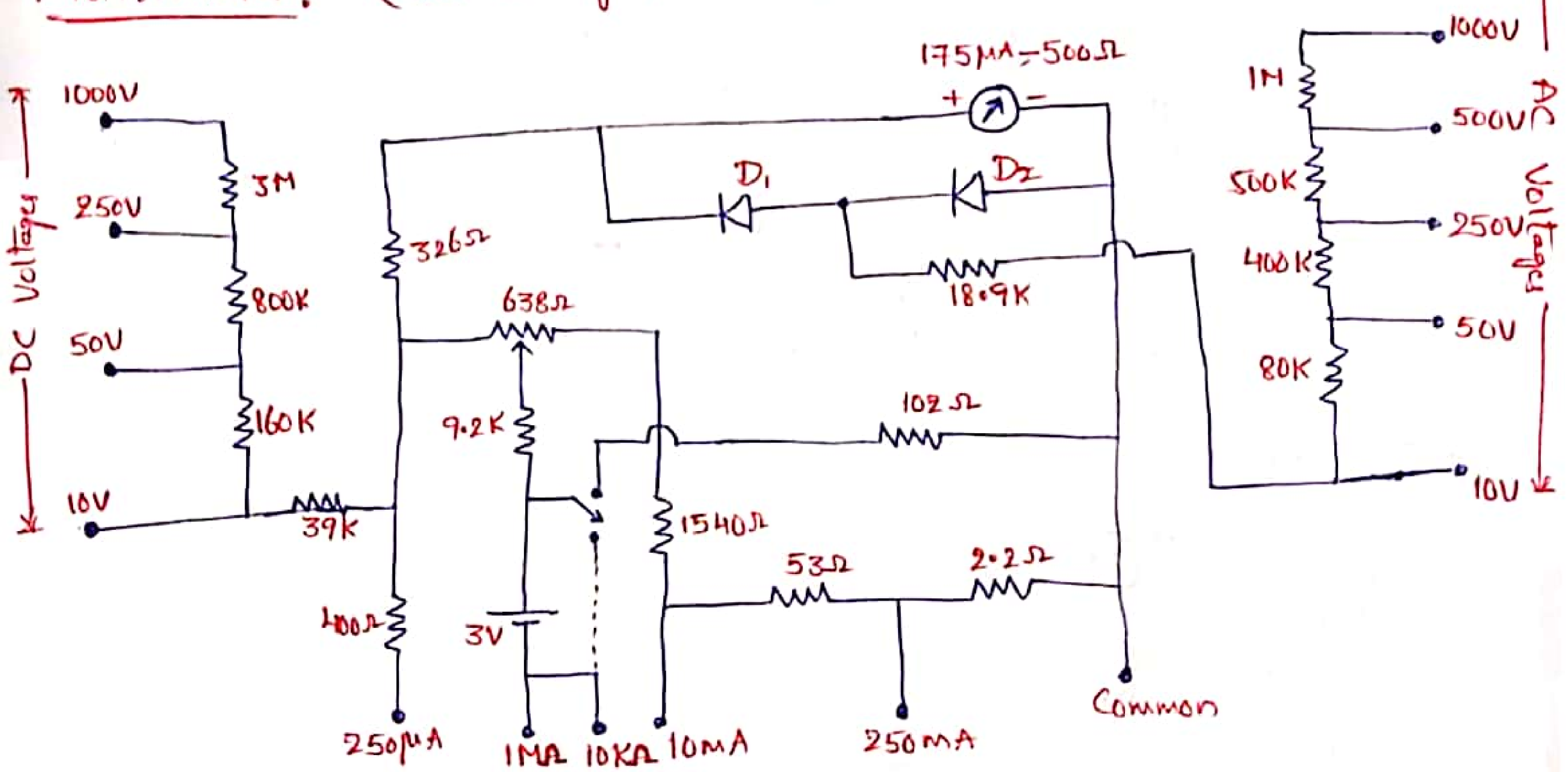


fig: Diagram of a Multimeter

→ A Multimeter is basically a PMMC meter

→ To Measure dc Current the meter acts as an ammeter with low Series resistance.

→ A Multimeter Consists of an ammeter, Voltmeter and ohmmeter Combined with a function Switch to Connect the appropriate Circuit to the D'Arsonval Movement.

Multimeter as DC Voltmeter:

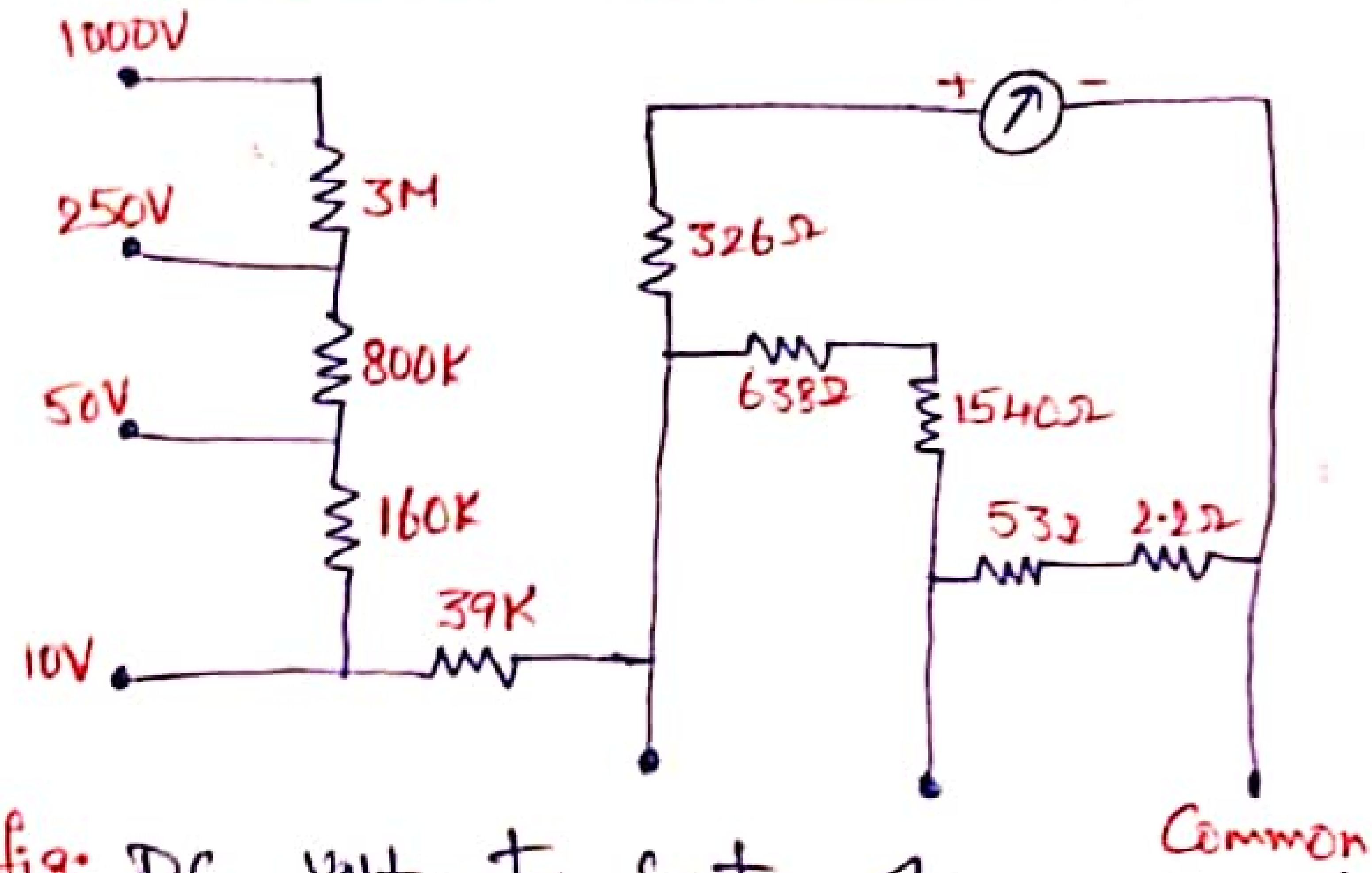


fig: DC Voltmeter Section of a Multimeter

Multimeter as AC Voltmeter:

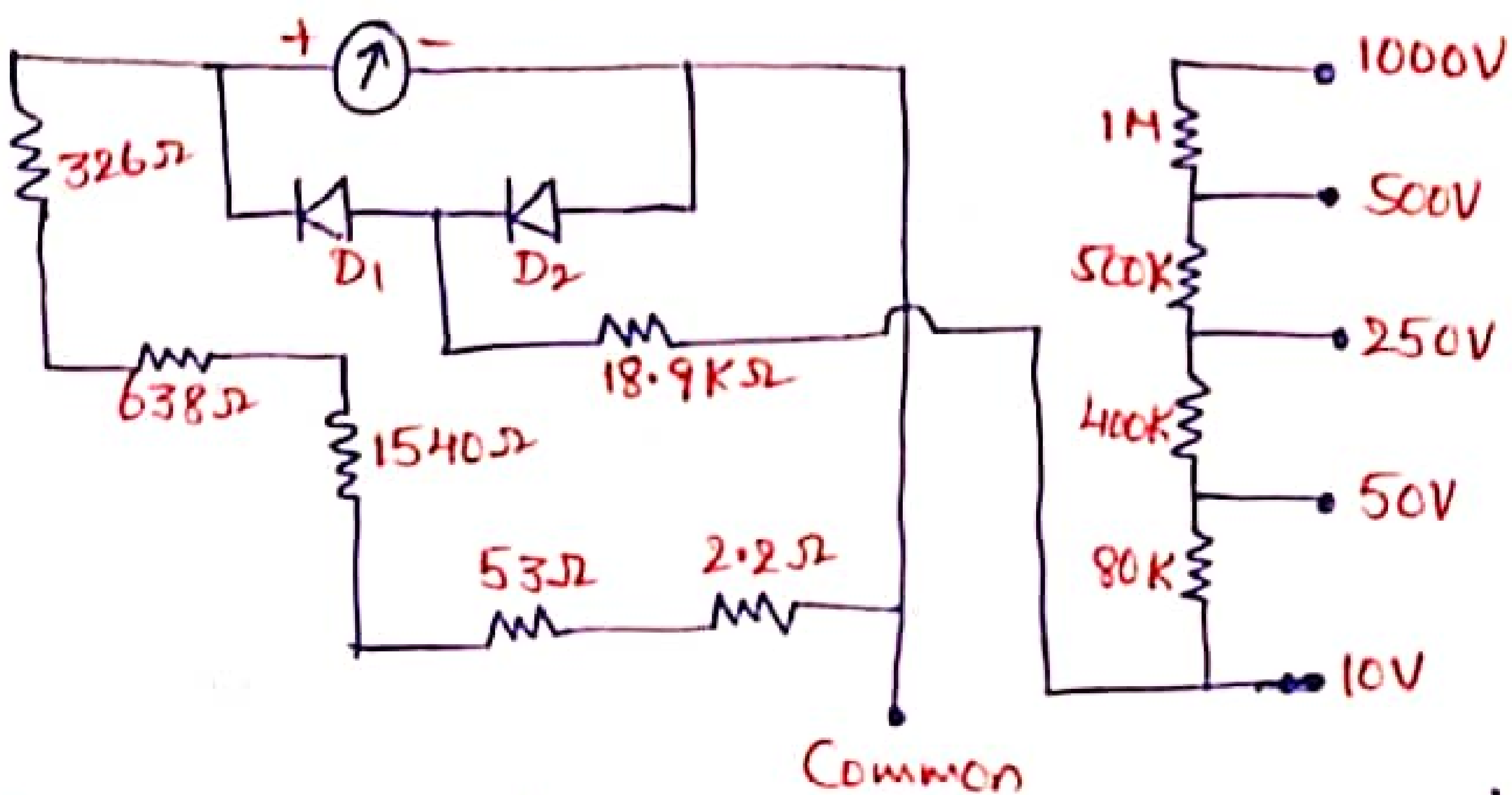


fig: AC Voltmeter Section of a Multimeter

Multimeter as DC Ammeter:

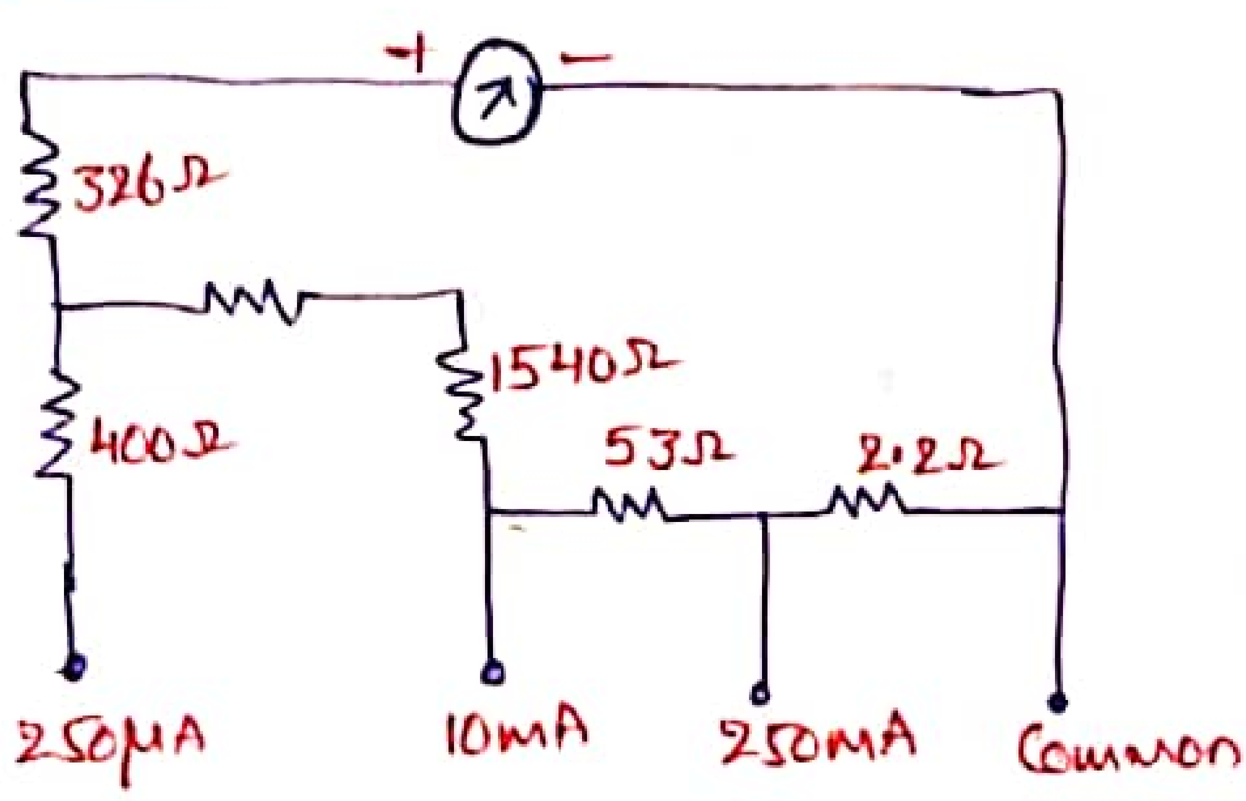


fig: DC Ammeter Section of a Multimeter

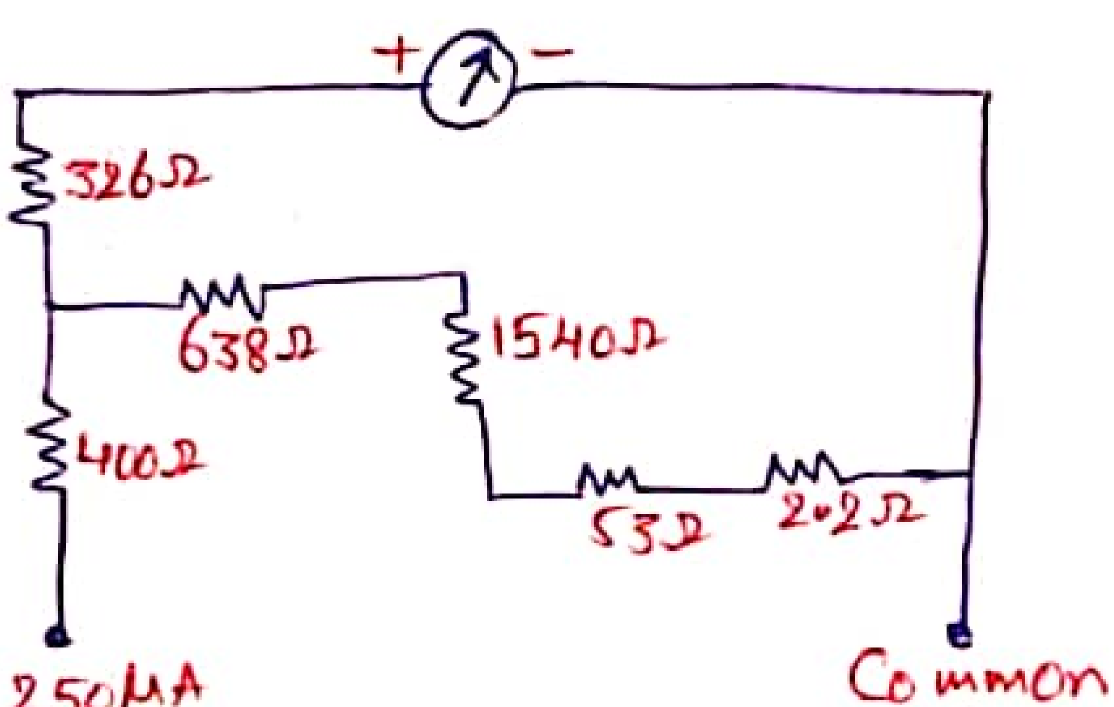


fig: Micro Ammeter Section of a Multimeter

Multimeter as Ohmmeter:

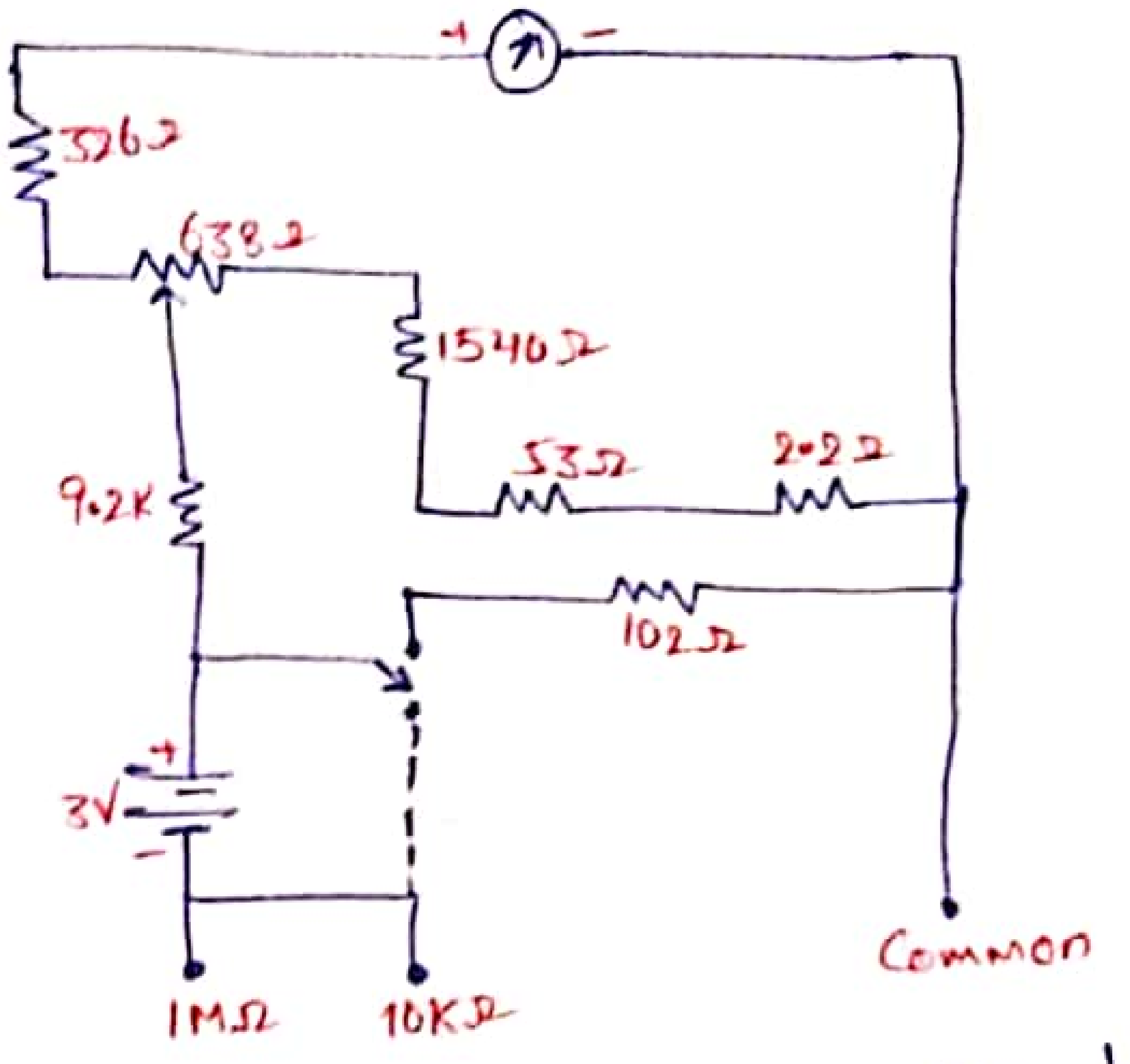


fig: Ohmmeter Section of a Multimeter.

Multimeter operating Instructions:-

→ The Combination volt-ohm-Ammeter is a basic tool in any electronic laboratory. The proper use of this instrument increases its accuracy and life. The following Precautions should be observed.

1) To prevent meter overloading and possible damage when checking voltage or current. Start with the highest range of the instrument and move down the range successively.

2) Take extra precautions when checking high voltages and checking current in high voltage circuits.

3) Verify the circuit polarity before making a test, particularly when measuring dc current or voltages.

4) Renew ohmmeter batteries frequently to insure accuracy of the resistance scale.

5) Recalibrate the instrument at frequent intervals

6) Protect the instrument from dust, moisture, fumes and heat.

———— x ————

- **Dead Zone:** The Maximum Value of the input to which the instrument does not respond due to hysteresis of the instrument is called as "Dead Zone".

- **Threshold:** It is the Minimum Value to which the instrument responds when the input is gradually increased from Zero Value.

- **Limiting Error (or) Guarantee Error:** The limit of deviation from the specified Value is known as limiting Error (or) Guarantee Error

Drift:

1) **Zero Drift:** If the whole Calibration shifts by the Same amount, because initially zero adjustment is not made, it is called "Zero drift".

2) **Span drift:** It is the drift is not Constant but increases gradually with the deflection of the pointer, it is called "Span drift".

3) **Zone drift:** If the drift occurs only in a particular Zone of the instrument. it is called "Zone drift".

- **Repeatability:** This is defined as the Variation of Scale reading when the input is randomly applied. (with out gaps)

- **Reproducibility:** This is the Scale reading over a given period of time when the input is Constantly applied.

UNIT-II

Oscilloscopes

Standard Specifications of CRO:-

Vertical Amplifier:-

Sensitivity : 5mV/div to 20 V/div

Accuracy : ±3%

Bandwidth : 0.5 Hz to 20MHz

Rise time : 18nSec.

Input Impedance : 1MΩ / 40PF.

Time base:

Sweep Ranges : 0.1 μs/div to 0.5 s/div

Accuracy : ±5%

Triggering:

Source : Internal – External – Line

Polarity : Positive (or) Negative

Maximum Trigger i/p : 250V

Input Impedance : 1MΩ/30PF.

Internal Trigger level : 3 Div from 2Hz to 20MHz
(1 Div, 30Hz to 20MHz in AUTO Mode)

External Trigger Level : 3V Peak to Peak, 2Hz to 20MHz
(1V, 30Hz to 20MHz in AUTO Mode)

Horizontal Amplifier:

Band Width : 2MHz

Sensitivity : 100mV and 0.5 V/div

Input Impedance : 1MΩ / 50PF

Maximum i/p Voltage : 250V

Calibration : 200mV (P-P) Square wave at 1KHz

Accelerating potential : 4.5 KV

Graticule : 8 × 10 DIV of 8mm each

Power requirements : 230 V ac, 50 Hz, 50 W

Dimensions : 220 × 275 × 430 mm

Weight : 10 Kg Approximately

CRT Features:-

(1) **Size:** Size refers to the screen diameter. CRT's for oscilloscopes are available in sizes of 1, 2, 3, 5 and 7 inches. 3 inches is most common for portable instruments.

for example a CRT having a number 5GP1. The first number 5 indicates that it is a 5 inch tube.

(2) **Phosphor:** The screen is coated with a fluorescent material called as phosphor.

→ The trace colours in electronic CRT's for oscilloscopes are blue, green and bluegreen.

→ White colour is used in TV's

→ Blue-white, orange and yellow are used for radar.

→ The phosphor of the oscilloscope is designated as follows

P_1 = Green Medium

P_2 = Blue Green Medium

P_5 = Blue Very short

P_{11} = Blue Short.

(3) **Operating Voltages:-**

→ The CRT requires a heater voltage of 6.3 volts ac (or) dc at 600mA.

→ The voltages vary with the type of tube used.

(1) Negative grid voltage (−14V to −200V)

(2) +Ve Anode NO:1 (focusing Anode) : −100V to −1100V

(3) +Ve Anode NO:2 (Accelerating Anode): 600V to 6000V

(4) +Ve Anode NO:3 (Accelerating Anode): 200V to 20000V

(4) Deflection Voltages:-

→ Either ac (or) dc Voltage will deflect the beam.

→ The distance through which the spot moves on the Screen is proportional to the dc (or) Peak ac amplitude.

→ The deflection Sensitivity of the tube is usually stated as the dc voltage required for each cm of deflection of the Spot on the screen.

(5) Viewing Screen:-

→ The Viewing screen is the glass face plate, the inside wall of which is Coated with Phosphor.

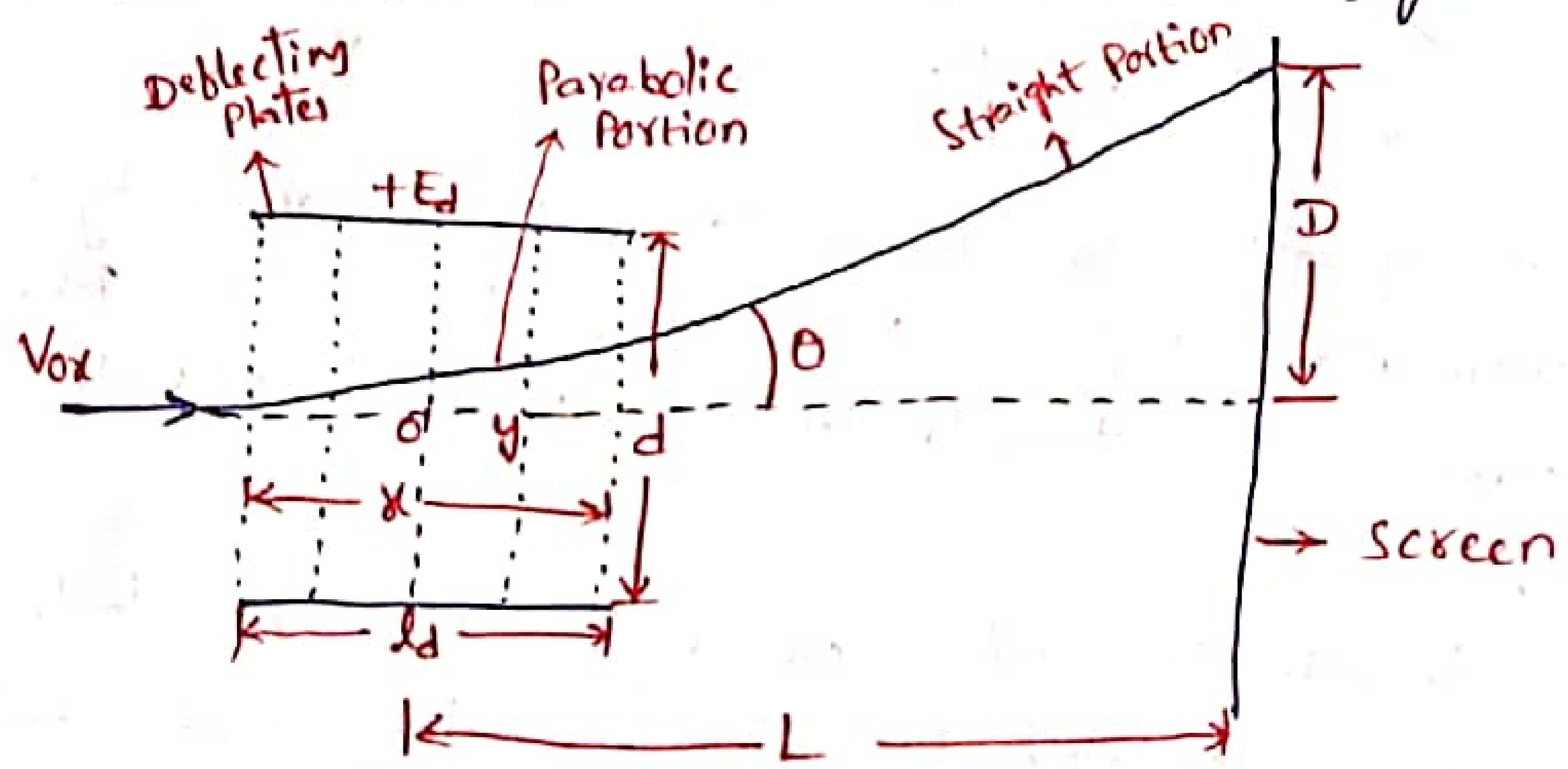
→ The Viewing Screen is a rectangular screen having graticules marked on it.

→ The standard Size used now a days is 8cm × 10cm. (8cm on the vertical and 10cm on the Horizontal)

Derivation of Deflection Sensitivity of CRT:-

→ Deflection Sensitivity is defined as deflection produced per volt of deflection Voltage and has units of (m/v)

→ Electrostatic deflection sensitivity of CRT is associated with the deflection System as in the figure below.



→ A beam of Electrons produced, focused and accelerated by the electron gun and its Components enters the two deflecting plates with velocity 'V_{ox}'. A voltage of 'E_d' is applied across the plates so that electric field produced is along +y axis as shown.

→ If 'V_a' is the Voltage of the anode with respect to Cathod, the Kinetic energy gained by the electron of charge is 'eV_a'. Which is also equals to '$\frac{1}{2}mV_{ox}^2$'.

$$\therefore \frac{1}{2}mV_{ox}^2 = eV_a \longrightarrow ①$$

→ Let 'd' be distance between the Plates. Electric field b/w the plates is given by $\bar{E} = \frac{E_d}{d}.\hat{y}$

∴ Electric force on a electron of Charge 'e' is $\vec{F_y} = e\frac{E_d}{d}\hat{y}$.

→ If 'm' is the mass of charge then acceleration $a_y = \frac{F_y}{m}$

$$\therefore a_y = e\frac{E_d}{d \cdot m}.\hat{y}$$

→ Writing Kinetic equation for 'y' deflection Produced in time 't' and Using the equation $s = ut + \frac{1}{2}at^2$ and inserting above values and noting that initial deflection is zero, we get

$$y = \frac{1}{2}\left(e\frac{E_d}{d \cdot m}\right)t^2 \longrightarrow ②$$

→ As the velocity along the x-direction is Constant therefore we can write for displacement 'x'.

$$\therefore x = V_{ox}t \longrightarrow ③$$

Inserting Value of 't' from eq③ in eq② we get,

$$y = \frac{1}{2}\left(e\frac{E_d}{d \cdot m V_{ox}^2}\right)x^2 \longrightarrow ④$$

→ This is an equation of Parabolic Path followed by Electron in the deflection plate region. Just after leaving the deflection plates the electron beam travels in a straight line path hits the screen at $y = L$

→ If 'l_d' is length of deflection Plates slope of electron at the exit Can be Calculated by differentiating eq④ and evaluating slope at the $x = l_d$, which is

$$\frac{dy}{dx} = \frac{1}{2}\left(e\frac{E_d}{d \cdot m \cdot V_{ox}^2}\right)(2x)$$

here $x = l_d$, so $\frac{dy}{dx} = \left(e\frac{E_d}{d \cdot m \cdot V_{ox}^2}\right)l_d$. $\longrightarrow ⑤$

from Eq ① $m V_{0x}^2 = 2 e V_a$. Sub. in Eq

$$\therefore \frac{dy}{dx} = \left(e \cdot \frac{E_d}{d \cdot (2 e V_a)} \right) l_d$$

$$\frac{dy}{dx} = \frac{E_d \cdot l_d}{2 d V_a} \longrightarrow ⑥$$

→ for a small deflection in the deflecting plate region, ∠θ can be approximated as shown in fig.

$$\frac{dy}{dx} = \tan\theta = \frac{D}{L} \longrightarrow ⑦$$

where 'L' is as shown in fig. It is straight portion of the electron beam at the exit point extended backwards which meets the x-axis at the mid point of length 'l_d'.

Using Eq ⑥ & Eq ⑦, we get

$$\frac{D}{L} = \frac{E_d \cdot l_d}{2 \cdot d \cdot V_a}$$

$$\therefore \boxed{\frac{D}{E_d} = \frac{L \cdot l_d}{2 \cdot d \cdot V_a}} \quad (m/v)$$

(from defination).

Here $\frac{D}{E_d}$ = Deflection Sensitivity

---x---

Vertical Amplifier and Vertical deflection System :-

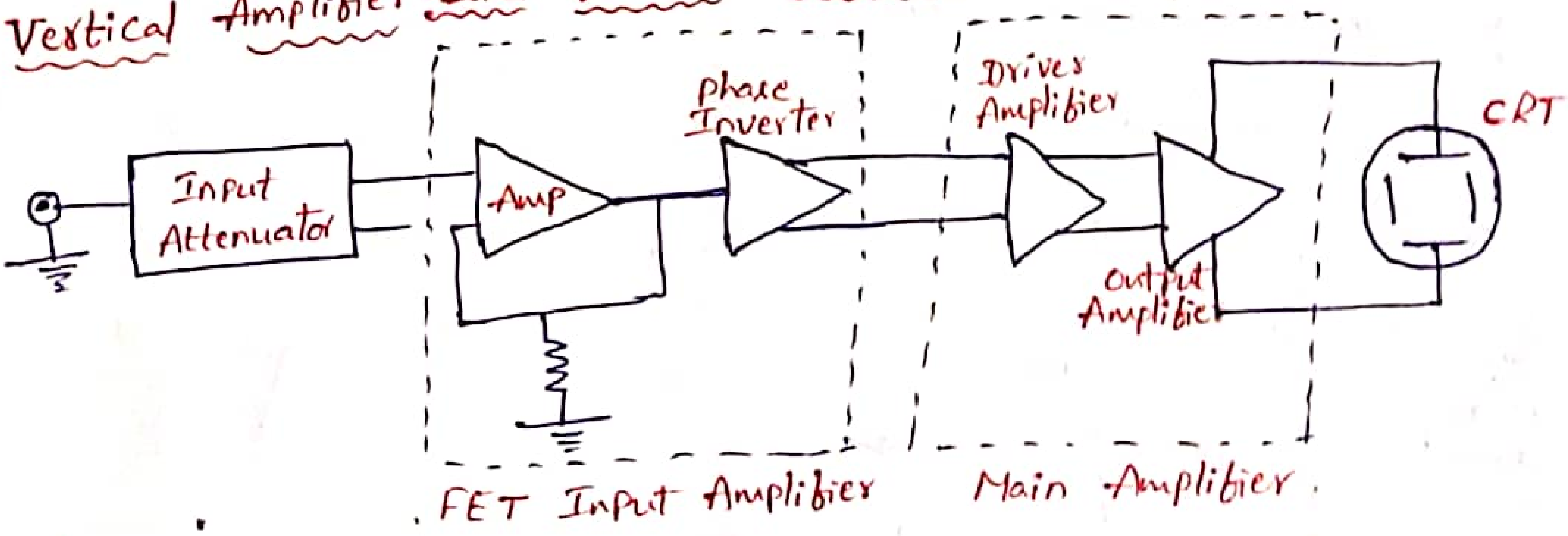


fig: Vertical Amplifier.

→ The Sensitivity (Gain) and frequency, Bandwidth (B.W) response characteristics of the oscilloscope are mainly determined by the vertical Amplifier.

→ Since the gain-B.W product is constant, to obtain a greater sensitivity the B.W is narrowed or vice-versa.

→ Some oscilloscopes have two alternatives, switching to a wide bandwidth position and switching to a high sensitivity position.

→ The first element of the pre-amplifier is the i/p stage, often consisting of a FET source follower whose high i/p impedance isolates the amplifier from the attenuator.

→ This FET i/p stage is followed by a BJT emitter follower to match the medium impedance of FET o/p with the low impedance input of the phase inverter.

→ This phase inverter provides two antiphase o/p signals which are required to operate the push-pull o/p amplifier. The push-pull o/p stage delivers equal signal voltages of opposite polarity to the vertical plates of the CRT.

Horizontal Amplifier and Horizontal deflection System :-

→ The horizontal deflecting system consist of a "Time base generator" and an "Output Amplifier."

Sweep Generator (or) Time base generator :-

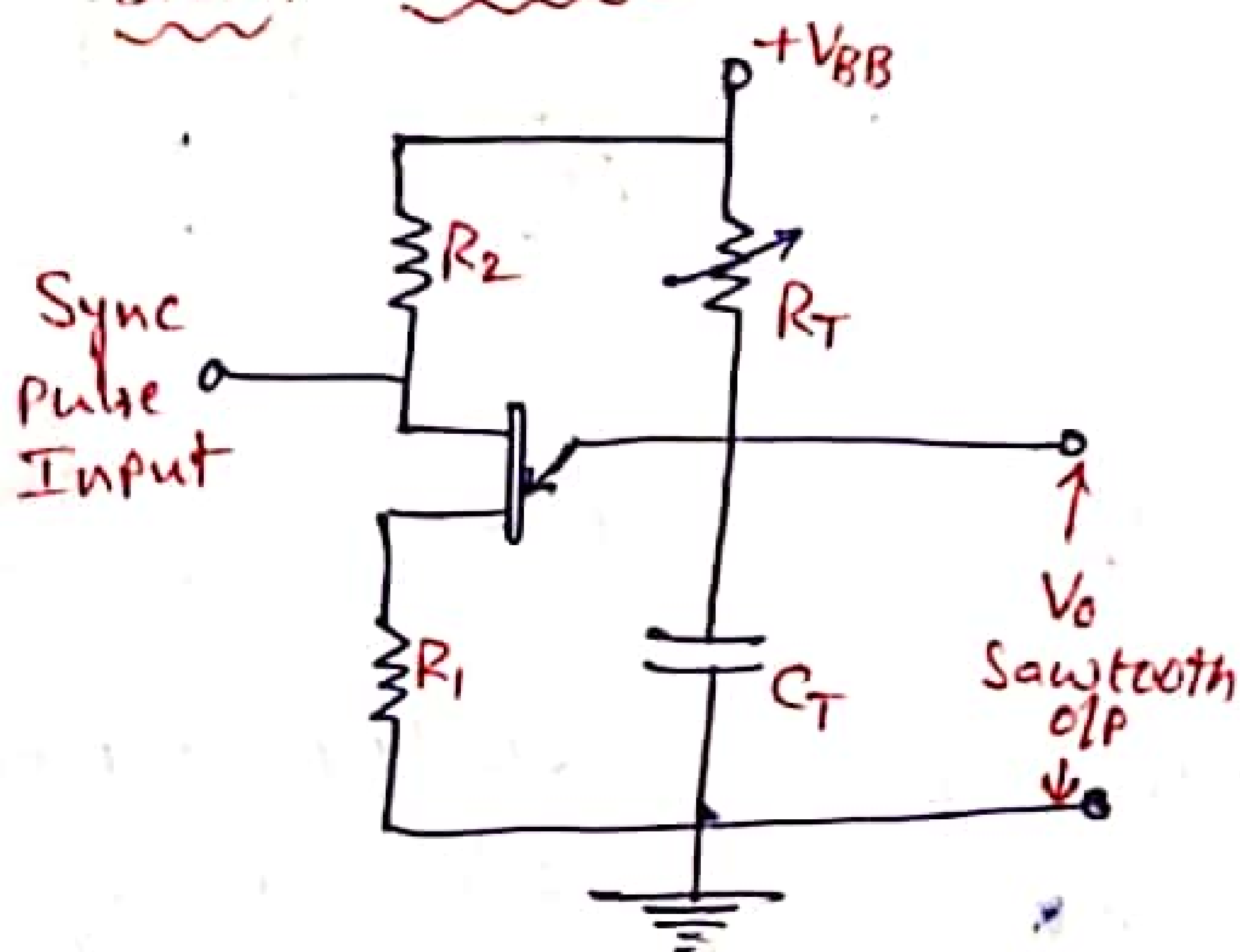
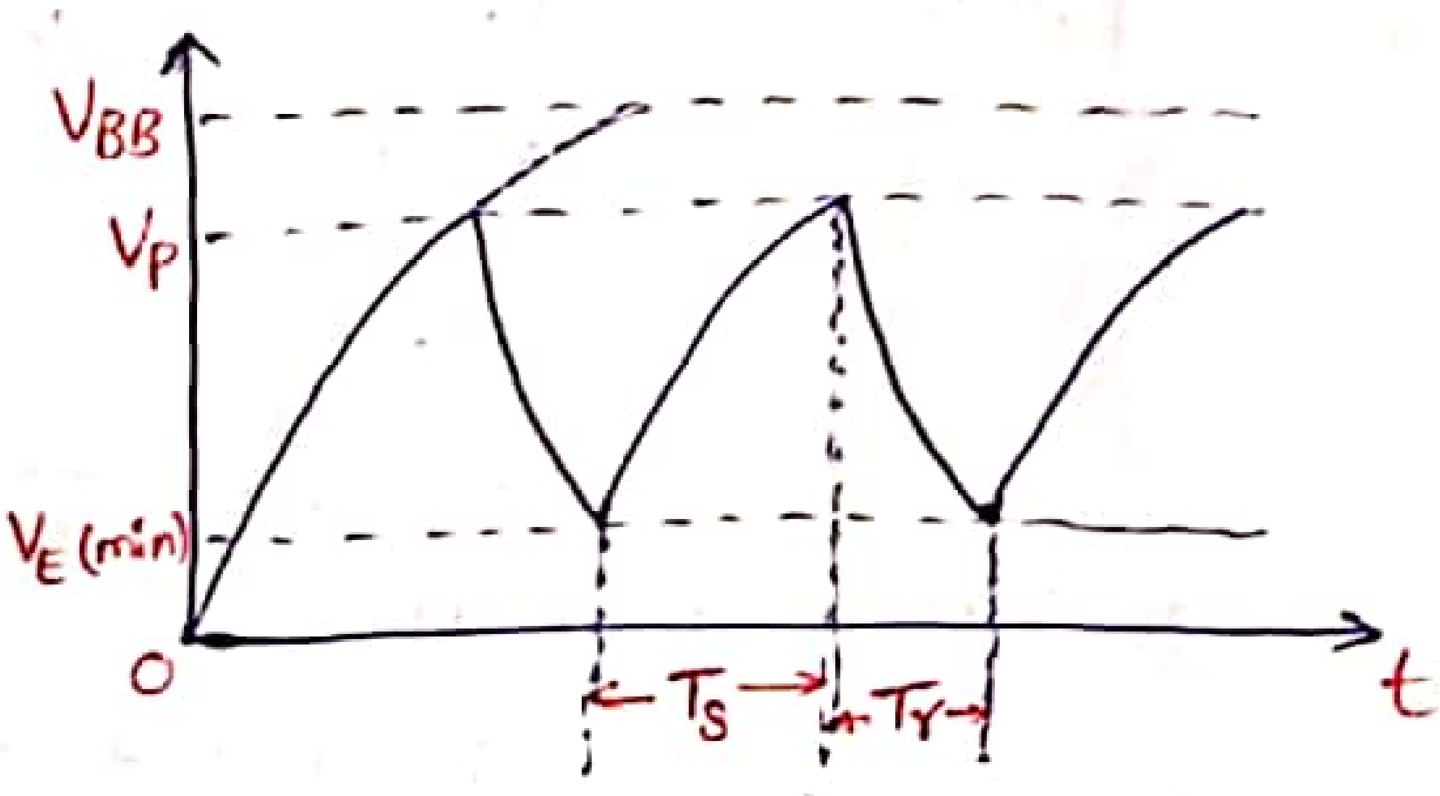


fig: Sweep Generator



Tr = Retrace Period
Ts = Sweep Period

fig: Sawtooth output waveform.

→ A Continous Sweep CRO Using a UJT as a time base generator is shown in figure.
→ The UJT is Used to Produce the Sweep.
→ When the Power is applied, the UJT is off and the 'C_T' changes exponentially through 'R_T'.
→ The UJT Emitter Voltage 'V_E' rises towards 'V_{BB}' and when 'V_E' reaches the Peak Voltage 'V_P' as shown in figure.
→ The Emitter to Base diode becomes forward biased and the UJT triggers ON.
→ This provides a low resistance discharge path and the Capacitor discharges rapidly.
→ The Emitter Voltage V_E reaches the minimum Value. The Capacitor recharges rapidly and the UJT goes OFF. and the cycle repeats.
→ To improve Sweep Linearity, two Seperate Voltage Supplies are Used, a low Voltage supply for UJT and a high Voltage Supply for the R_T C_T Circuit.

Trigger Pulse Circuit :-

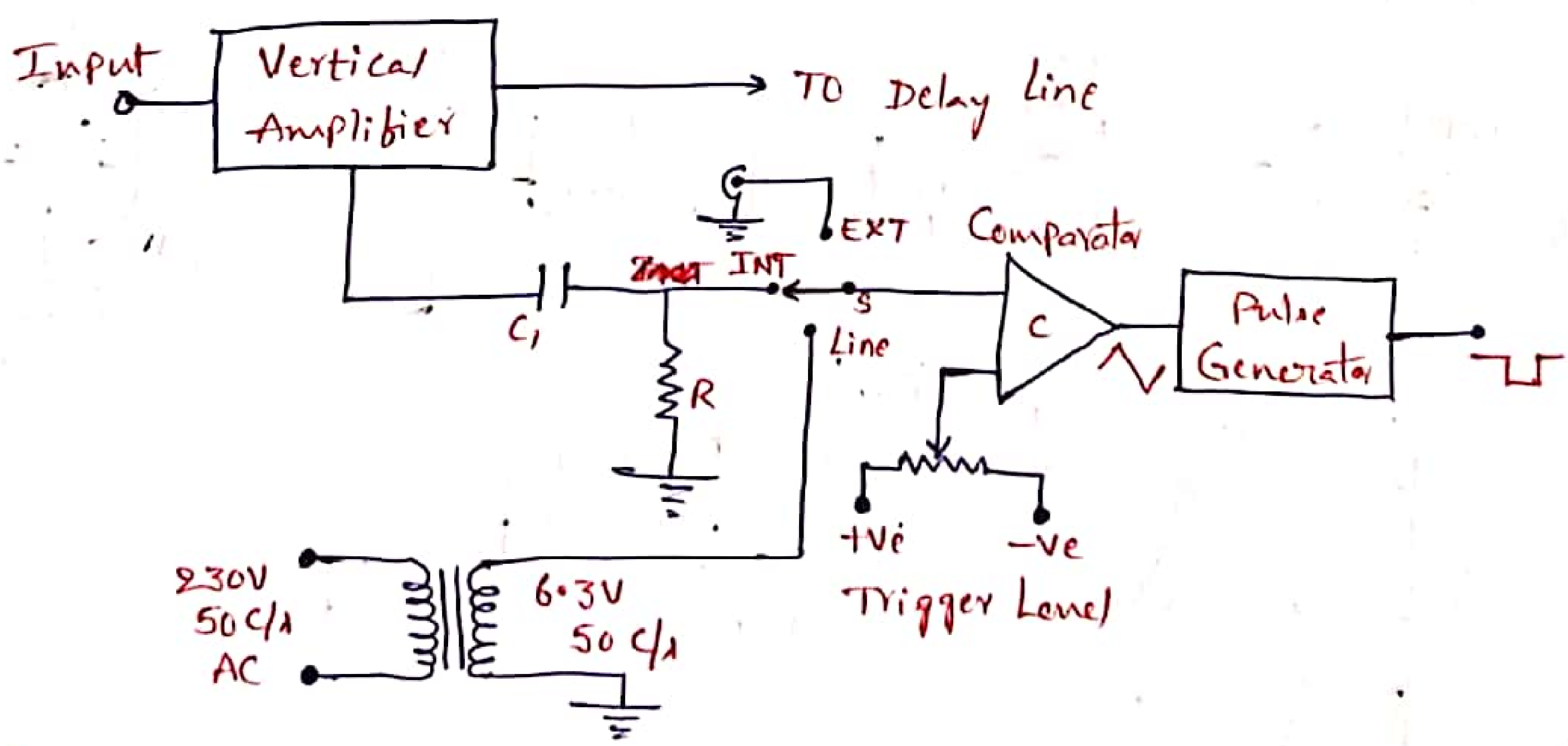


fig: Trigger Pulse Circuit.

→ The Trigger Circuit is activated by signals of a variety of shapes and amplitudes, which are converted to trigger pulses of uniform amplitude for the precision sweep operation.

→ If the trigger level is set too low, the trigger generator will operate, on the other hand, if the level is too high, the UJT conduct for too long and part of the i/p signal may be lost.

→ The trigger selection is a 3-position switch
(1) Internal (2) External (3) Line.

→ The trigger i/p signal is applied to a voltage comparator, whose reference level is set by the trigger level control on the CRO front panel.

→ The comparator circuit 'c' produces a change in the output whenever the trigger input exceeds the percent trigger level.

→ The pulse generator that follows the comparator produces -ve trigger pulses each time the comparator o/p crosses its quiescent level. which in turn triggers the sweep generator to start the next sweep.

→ The trigger sweep generator contains the stability control, which prevents the display from running on the screen.

Delay Line Circuit :-

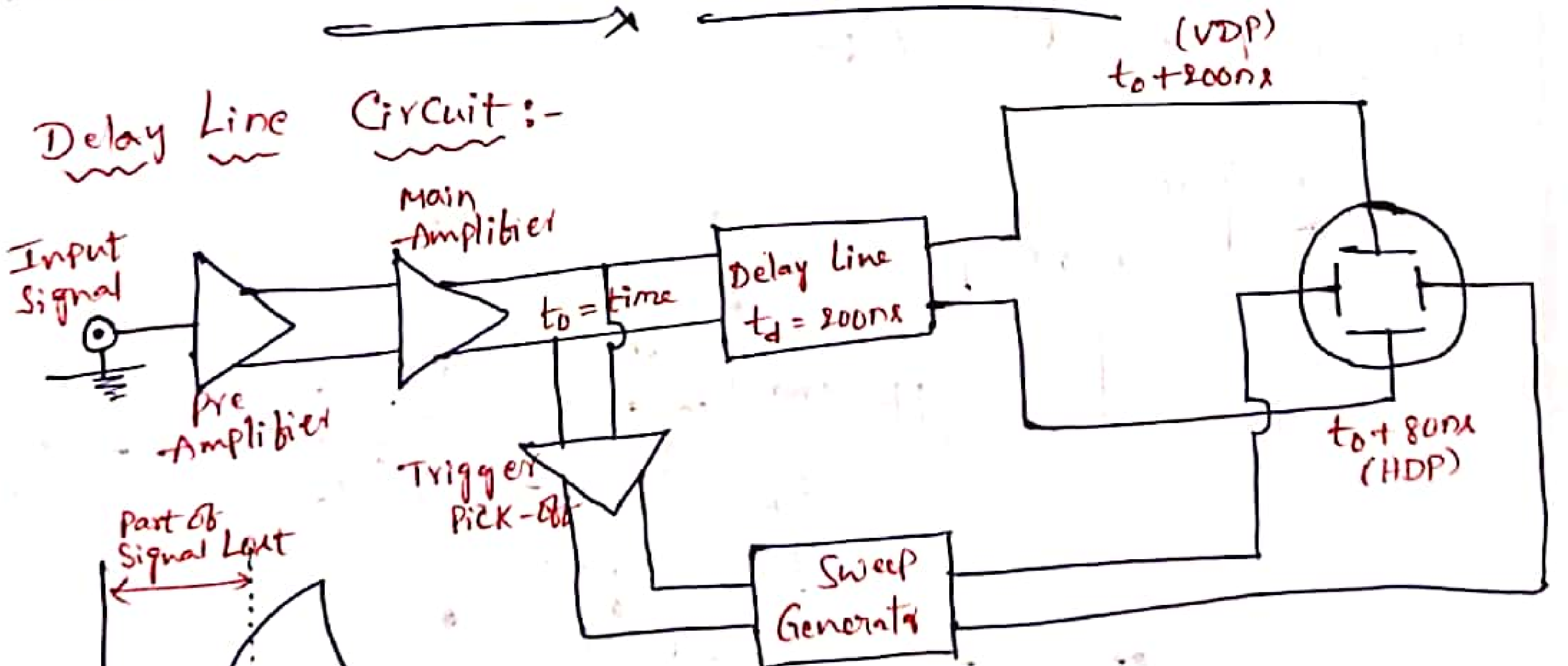
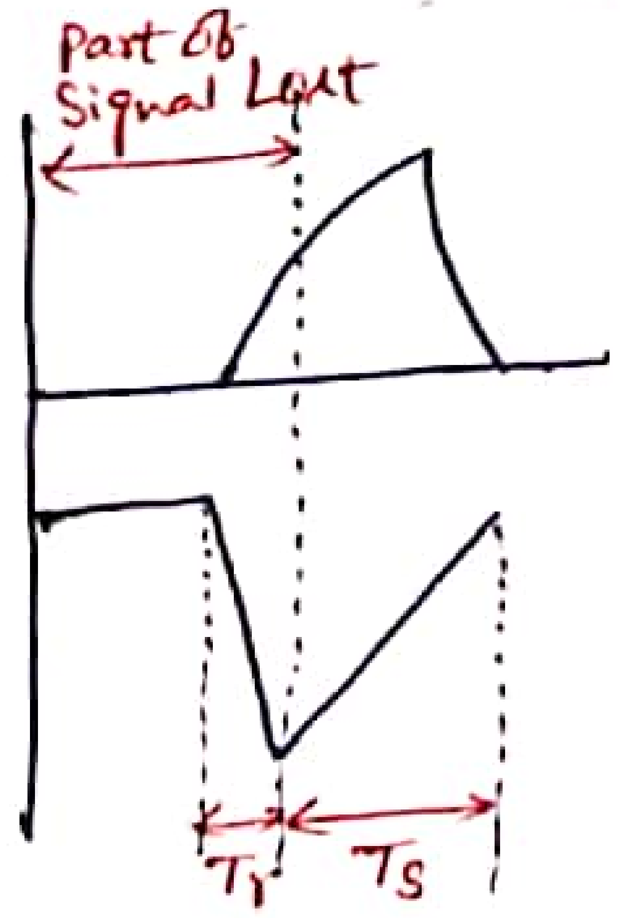


fig:(1) Delay Line Circuit



fig(2): Delay Line waveform

→ fig (2) indicates the amplitude of the Signal with respect to time and the relative Position of the Sweep generator output Signal.

→ fig (1) shows that when the delay line is not used, the initial part of the Signal lost and only part of the Signal is displayed.

→ To over come this disadvantage the signal is not applied directly to the Vertical Plates, but it is Passed through a delay Line circuit.

→ The trigger Pulse is Picked off at a time 'to' after the Signal has Passed through the main Amplifier.

→ The Sweep Generator delivers the Sweep to the horizontal plates and the Sweep starts at the Horizontal deflection plates at time to + 80ns.

→ Hence Sweep starts well in time, since the Signal arrives at the vertical deflection plates at time to + 200ns

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Sync Selector Circuit :-

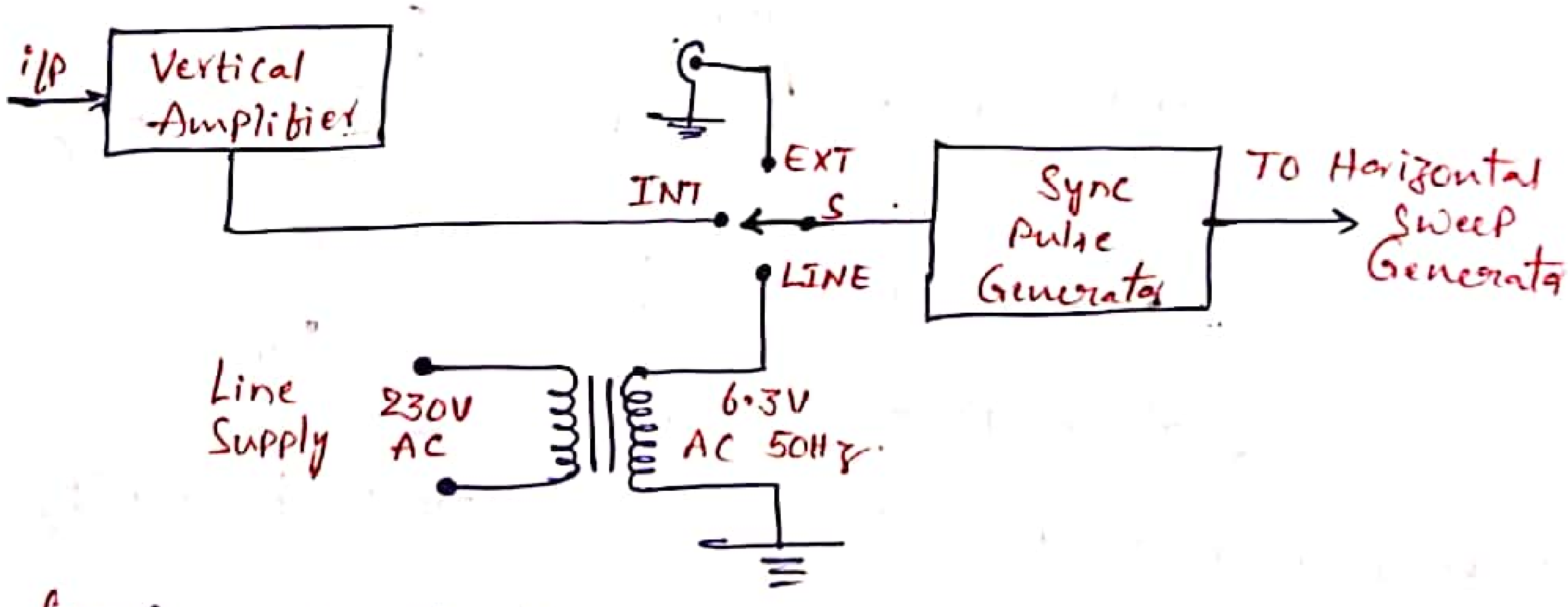

fig: Sync Selector Circuit.

→ The Sync selector circuit having 3-position Switch INT, EXT and LINE.

→ Therefore Horizontal Sweep Can be Synchronized with the Signals Comming from any of the three Sources.

→ These Sync Selector is Used for Continuous Sweep CRO.

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Probes for CRO :-

① Active Probes :-

→ Active Probes are designed to provide an efficient method of coupling high frequency, fast rise time signals to the CRO input.

→ Usually Active Probes have very high i/p impedance, with less attenuation than passive probes. Active devices may be diodes, FET's, BJT's ..... etc.

→ Active Probes are more expensive and bulky than passive probes, but they are useful for small signal measurements, because their attenuation is less.

Active Probes Using FET's :-

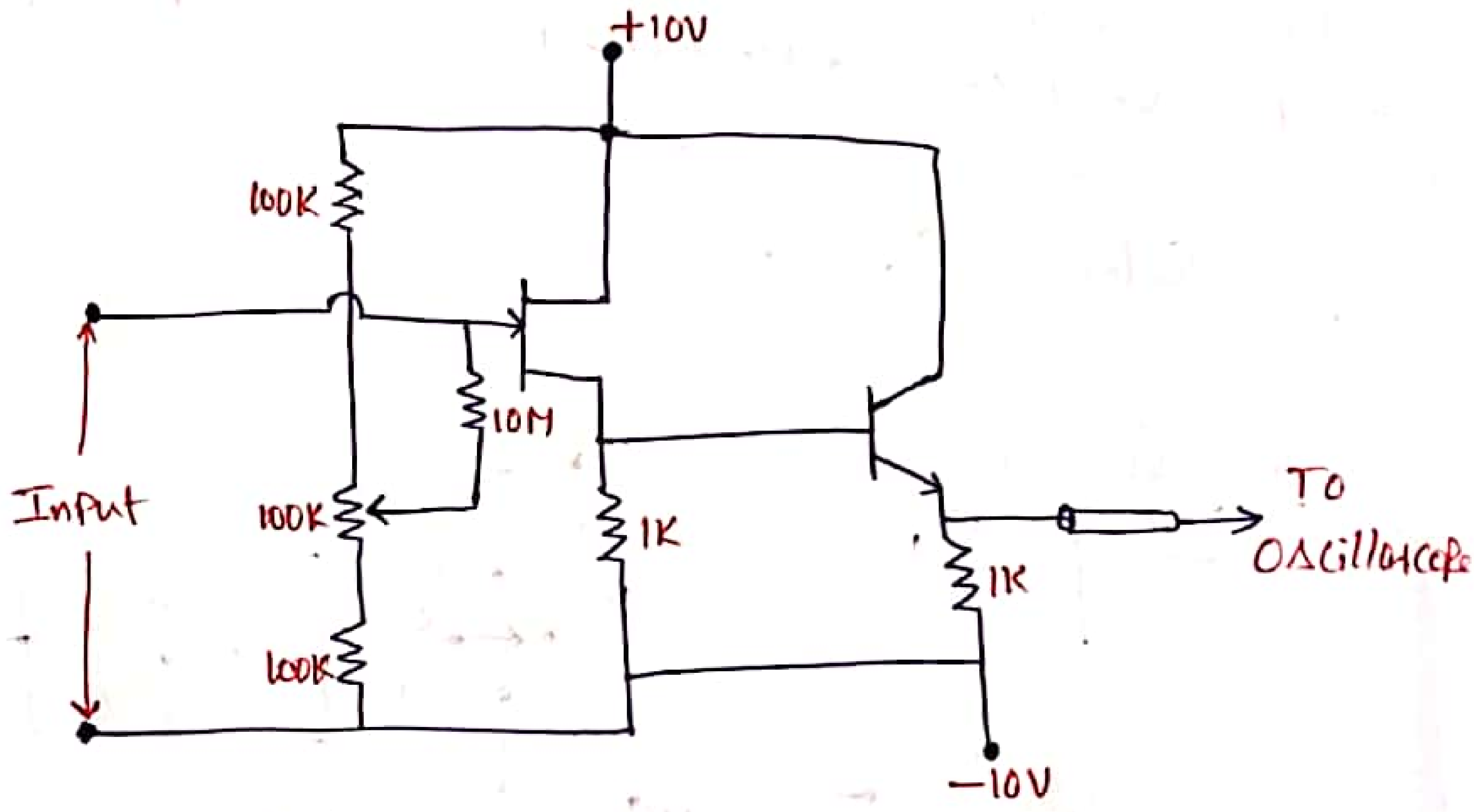

fig: Active Probe Using FET.

→ The FET is used as the active element to amplify the i/p signal.

→ Although the voltage gain of the FET follower circuit provides a power gain so that the i/p impedance can be increased.

→ To be effective the FET must be mounted directly in the voltage probe tip, so that the capacitance of the inter connecting cable can be eliminated.

→ This requires that the power for the FET be supplied from the oscilloscope to the FET in the probe tip.

→ The FET voltage follower drives a coaxial cable, but instead of the cable connecting directly to the high input impedance of the oscilloscope, it is terminated in its characteristic impedance.

→ There is no signal attenuation between the FET amplifier and the probe tip.

→ The range of the signals that can be handled by the FET probe is limited to the dynamic range of the FET amplifier and is typically less than a few volts.

→ To handle, a larger dynamic range, external attenuators are added at the probe tip.

→ Active probes have limited use because the FET probe effectively becomes an FET attenuator. Therefore, oscilloscopes are typically used with a 10 to 1 attenuator type.

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② **Passive Probes :-**

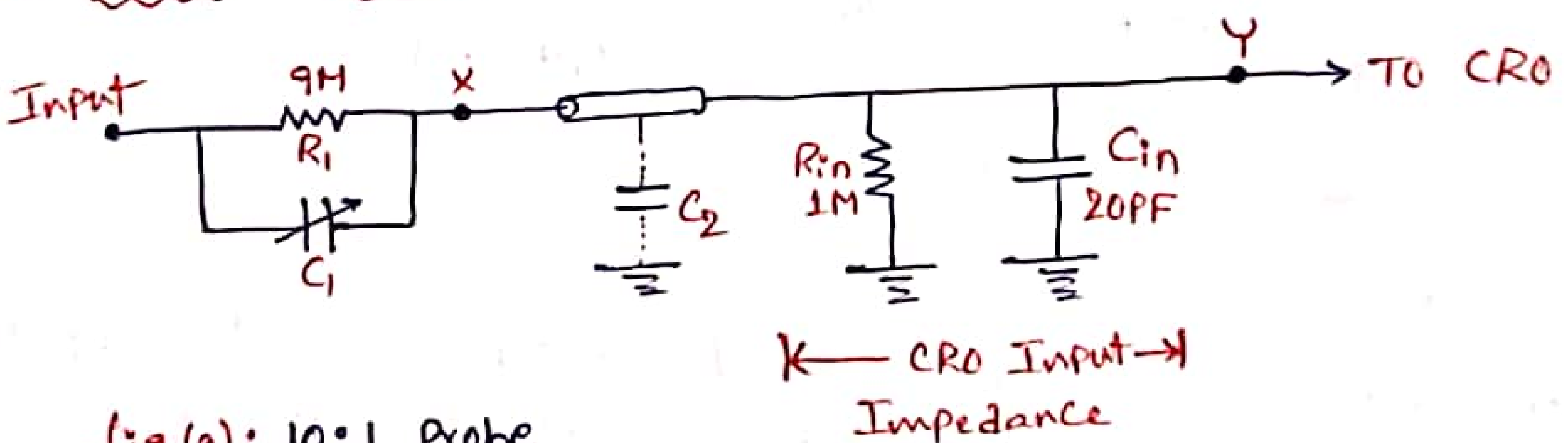

fig (a): 10:1 Probe

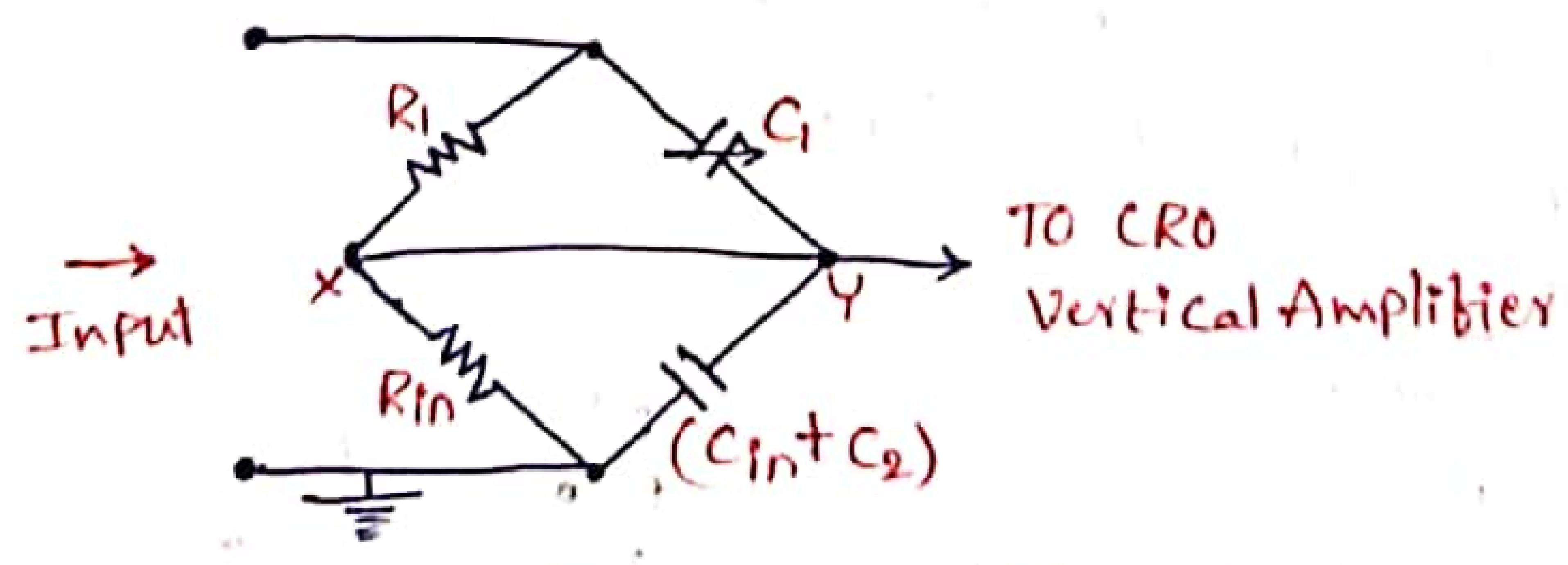

fig (b): Equivalent Circuit of 10:1 probe.

→ The capacitor (C_1) is adjusted, so that the elements of the bridge are balanced; under conditions of balance we have

$$R_1 \cdot X_{(C_{in}+C_2)} = R_{in} X_{(C_1)}$$

$$\therefore \frac{R_1}{\omega(C_{in}+C_2)} = \frac{R_{in}}{\omega C_1}$$

$$R_1 C_1 = R_{in}(C_2 + C_{in})$$

→ Therefore 'x' and 'y' are equipotential and the effect of the Probe is equivalent to placing a potential divider consisting of R_1 and R_{in} across the input circuit.

→ The attenuation of the signal is 10:1

i.e. $\frac{(R_1+R_{in})}{R_{in}} = 10:1$ over a wide range frequency.

∴ It is called a Compensated 10×1 probe.

→ The 'C_1' adjustment is done by connecting the probe tip to a square wave of 1KHz and observing the CRT display.

→ When the CRT display has optimum response, the 'C_1' value is deemed to be appropriate

$$\therefore V_{out} = (0.1)V_{in} = \frac{V_{in} \times R_{in}}{(R_1 + R_{in})}$$

Attenuators :-

→ Attenuators are designed to change the magnitude of the i/p signal seen at the input stage, while presenting a constant impedance on all ranges at the attenuator input.

① Un Compensated Attenuators :-

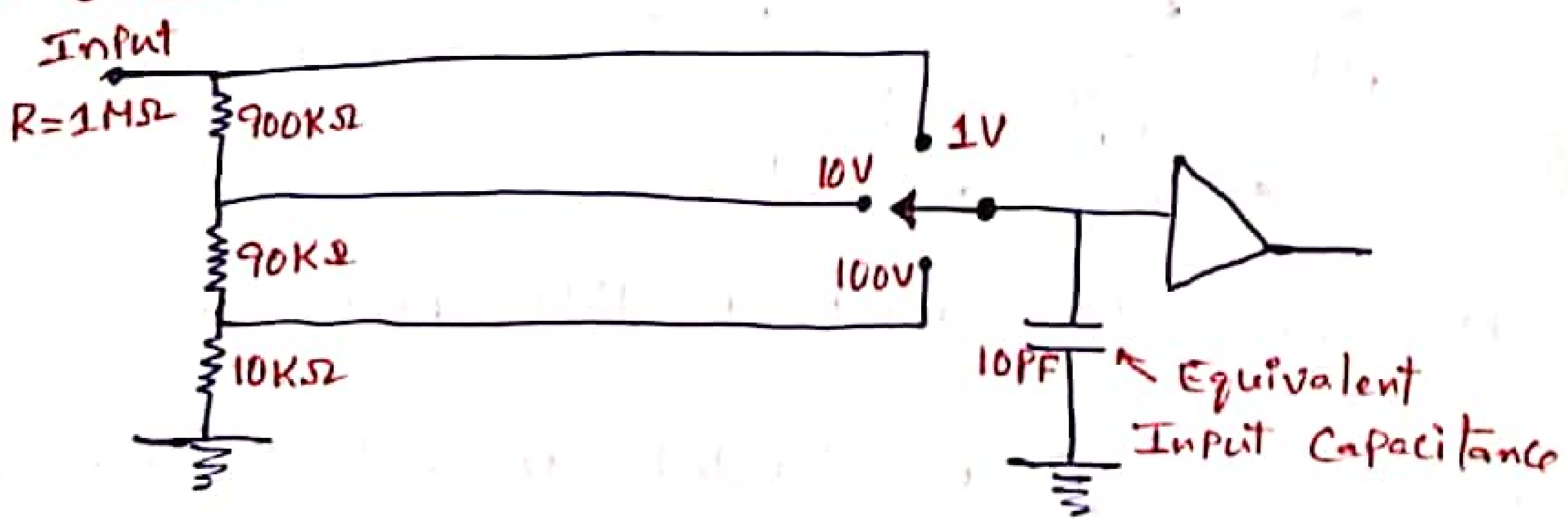

fig: Un Compensated Attenuators.

→ The figure gives a resistance divider Attenuator Connected to an amplifier with a 10PF input Capacitance.

→ If the i/p impedance of the amplifier is high, the input impedance of the attenuator is relatively Constant, immaterial of the Switch setting of the attenuator.

→ The i/p impedance, as seen by the amplifier, changes greatly depending on the setting of the attenuator.

→ Because of this, the RC time Constant and frequency response of the amplifier are dependent on the setting of the attenuator, which is an undesirable feature.

② Simple Compensated Attenuator:-

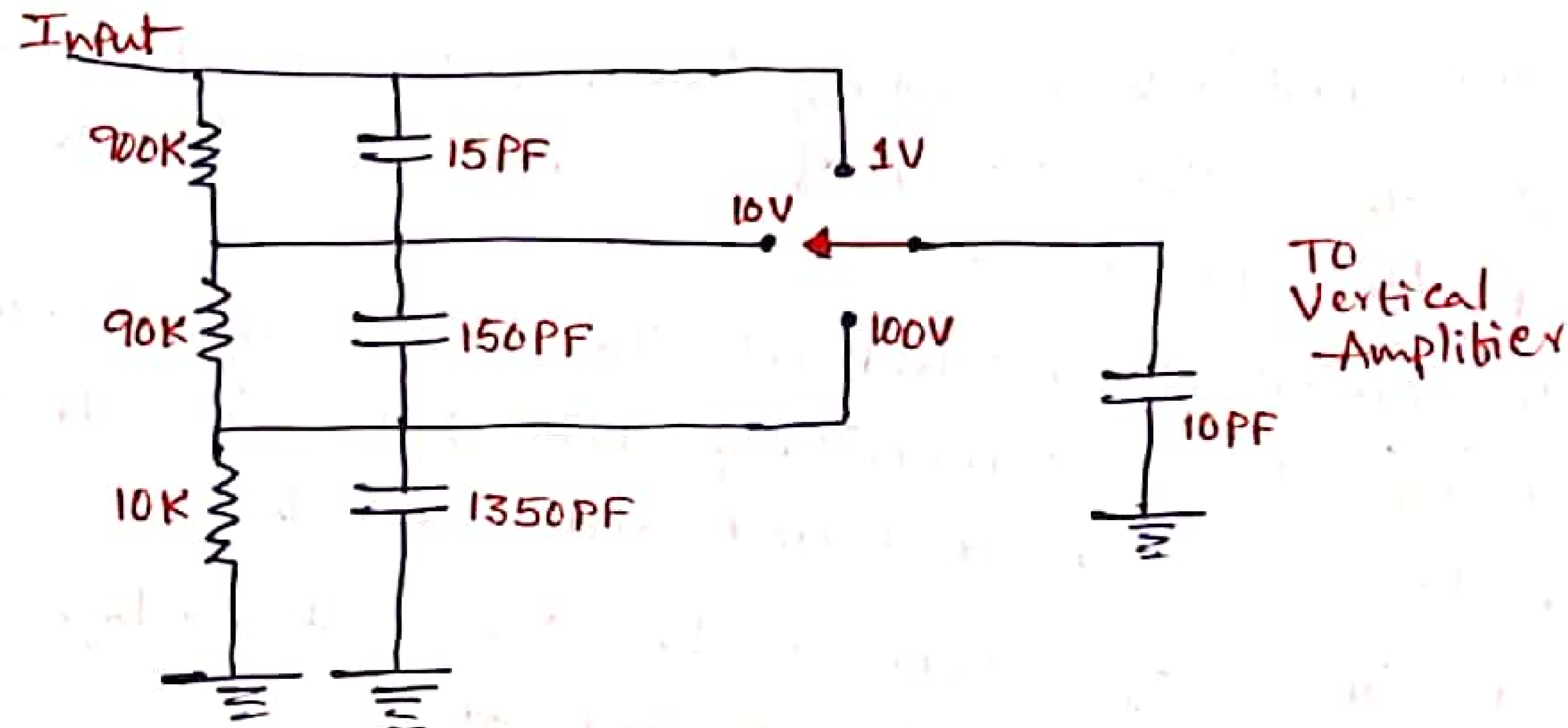

fig: Simple Compensated Attenuator.

→ fig shows an attenuator with both resistive and Capacitive voltage dividers.

→ The Capacitive Voltage dividers improve the HF response of the attenuator.

→ This Combination of Capacitive and resistive voltage dividers is known as "Compensated attenuator".

→ For oscilloscopes where the frequency range extends to 100MHz and beyond, More Complex dividers are used.

Triggered Sweep CRO :-

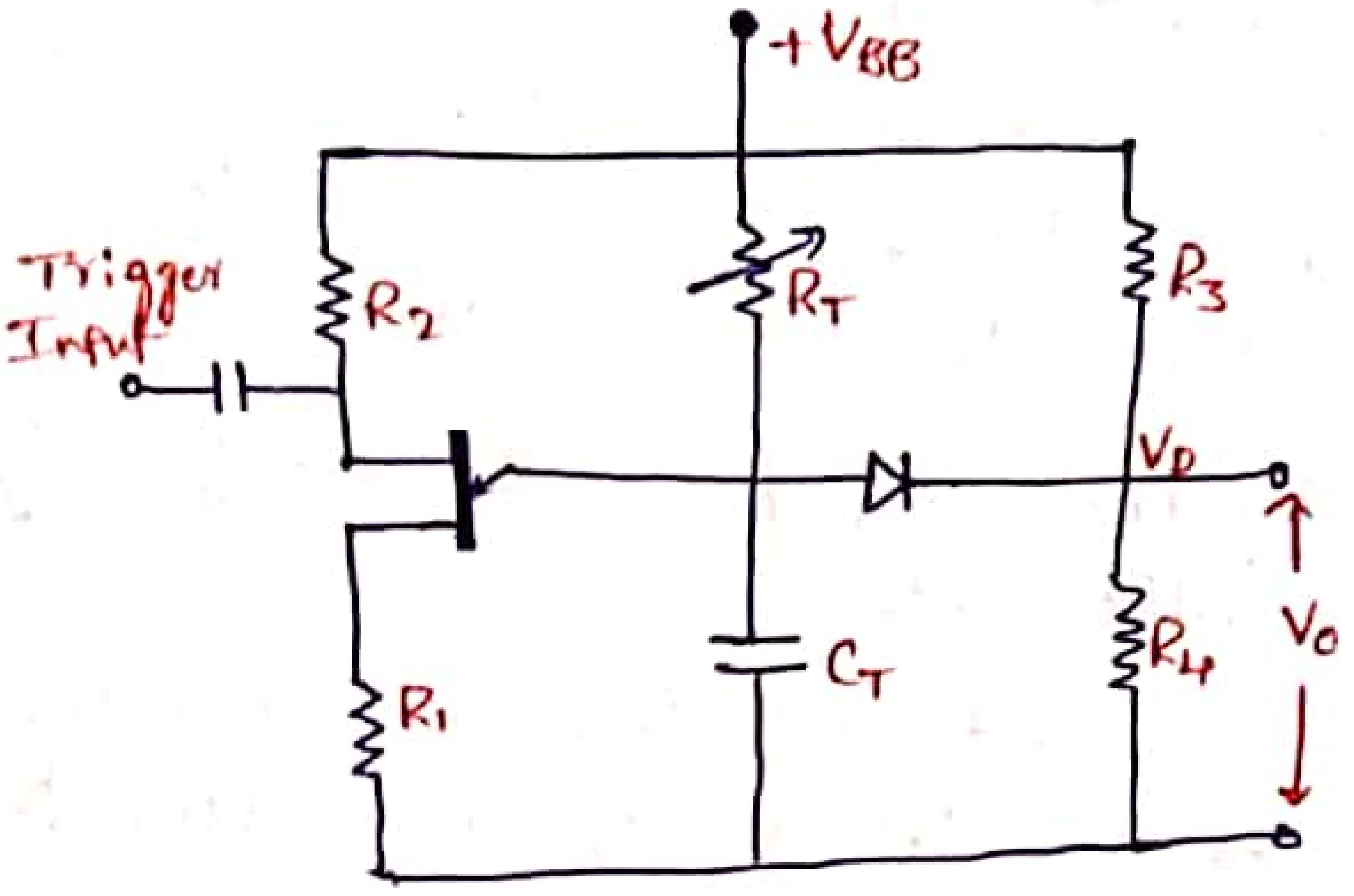

fig: Triggered Sweep

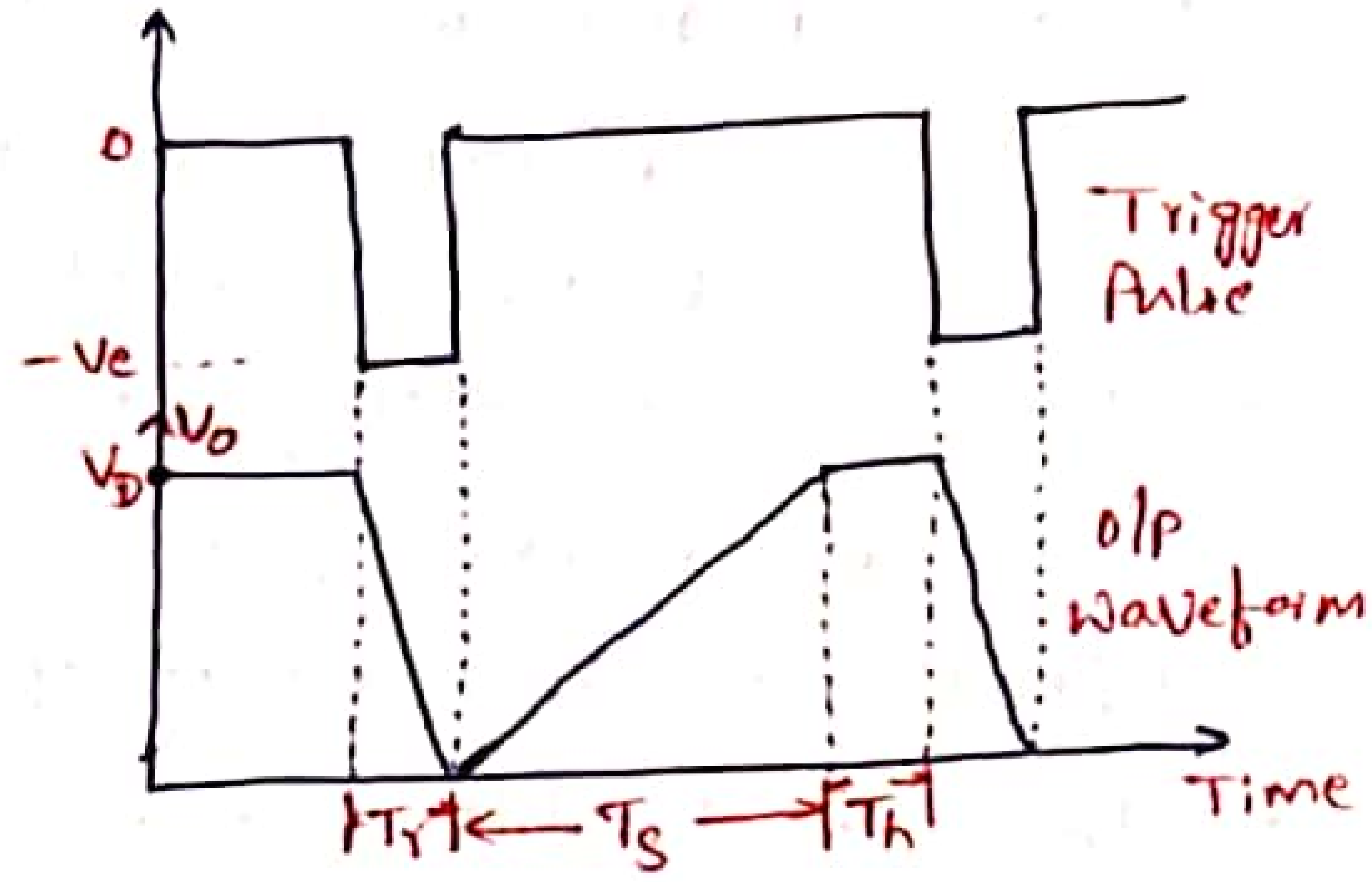

fig: output waveform.

T_S = Sweep period
T_r = retrace period
T_h = Hold off period

→ In figure, Resistance R_3 and R_4 form a voltage divider such that the voltage 'V_D' at the cathod of the diode is below the peak voltage 'V_P' for UJT Conduction.

→ When the circuit is switched ON, the UJT is in the non conducting stage and 'C_T' charges exponentially through 'R_T' towards V_{BB} until the diode becomes forward biased and conducts.

→ The capacitor voltage never reaches the peak voltage required for UJT conduction but is clamped at 'V_D'.

→ If a -ve pulse of sufficiant amplitude is applied to the base and the peak voltage 'V_P' is momentarily lowered, the UJT fires.

→ As a result, the 'C_T' discharges rapidly through the UJT until the maintaining voltage of the UJT is reached, at this point the UJT switches off and the C_T charges towards V_{BB} until it is clamped again at 'V_D'.

Delayed Sweep :-

→ Many Oscilloscopes of laboratory quality include a delayed Sweep feature.

→ This instrument is Used to Magnify a Selected Portion of an undelayed Sweep, measure waveform Jitter (or) rise time, check Pulse time modulation, as well as many applications.

→ Delayed Sweep is a technique that adds a precise amount of time b/w the trigger point and the begining of the scope Sweep.

→ When the scope is being used in the Sweep mode, the Start of the horizontal Sweep Can be delayed, typically from a few μsec to perhaps '10 seconds' (or) More

→ Delayed Sweep Operation allows the User to view a Small Segment of the waveform.

→ The Most Common approaches Used by Oscilloscope Manifacturer for the delayed Sweep Operations are as follows...

(1) Normal triggering Sweep after the desired time delay. which is set from the Panel Controls.

(2) The 'Delay' plus 'Trigger Mode' where a Visual indication such as light, indicates that the delay time has elapsed and the Sweep is ready to be triggered.

(3) Intensified Sweep, where the delayed Sweep acts as a Positional Magnifier

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Dual Beam CRO :-

→ The Dual beam CRO Uses two Completly Seperate electron beams, two Sets of vertical deflection plates (VDP) and a Single Set of Horizontal deflection plates (HDP).

→ Only one beam Can be Synchronized at One Time, Since the Sweep is the Same for both Signals i.e. A Common time base is Used for both beams.

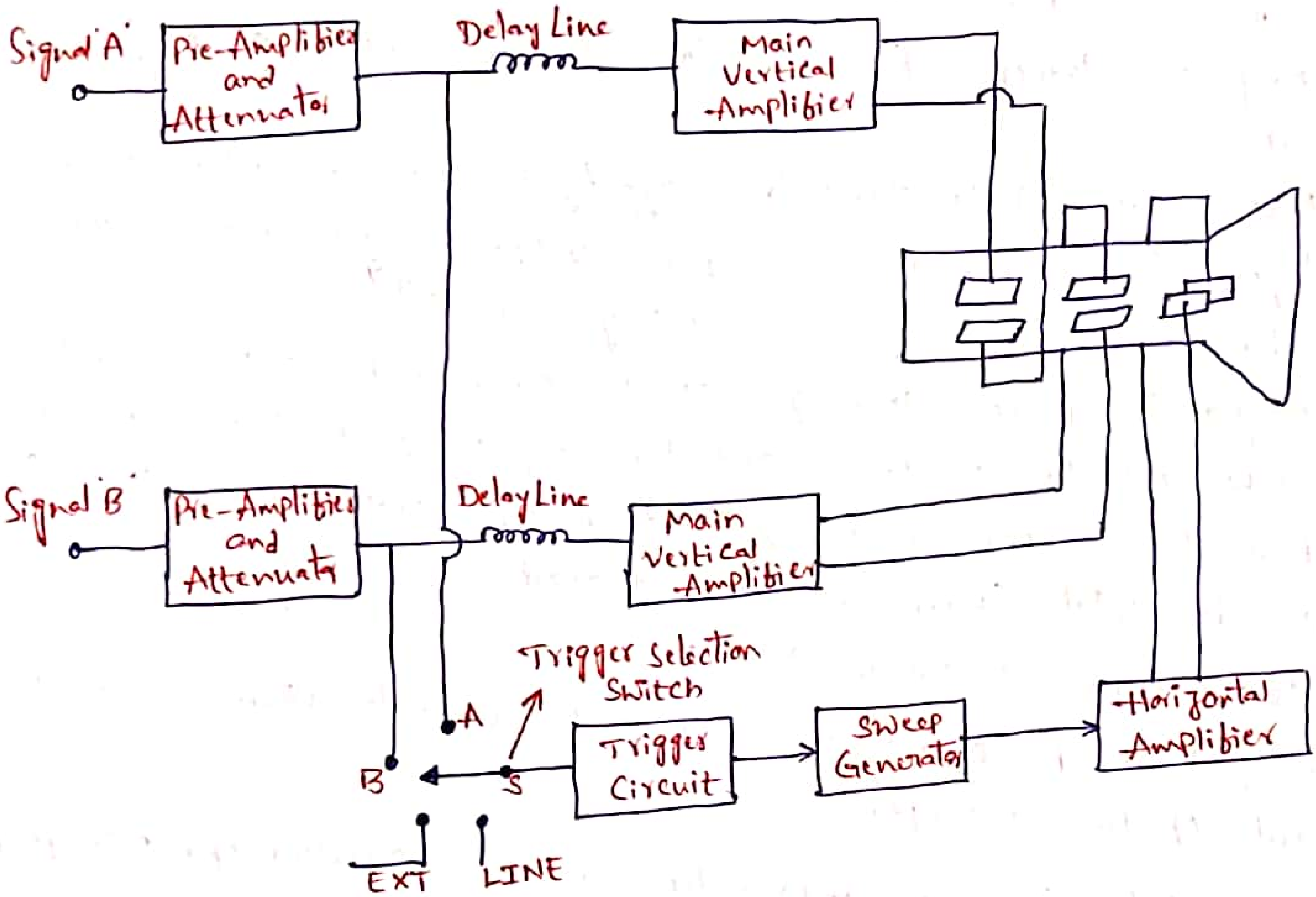


fig: Dual Beam CRO

→ Therefore, the signals must have the same frequency (or) must be related harmonically, in order to obtain both beams locked on the CRT screen. for Example the input signal of an amplifier can be used as signal 'A' and its output signal as signal 'B'.

Dual Trace Oscilloscope :-

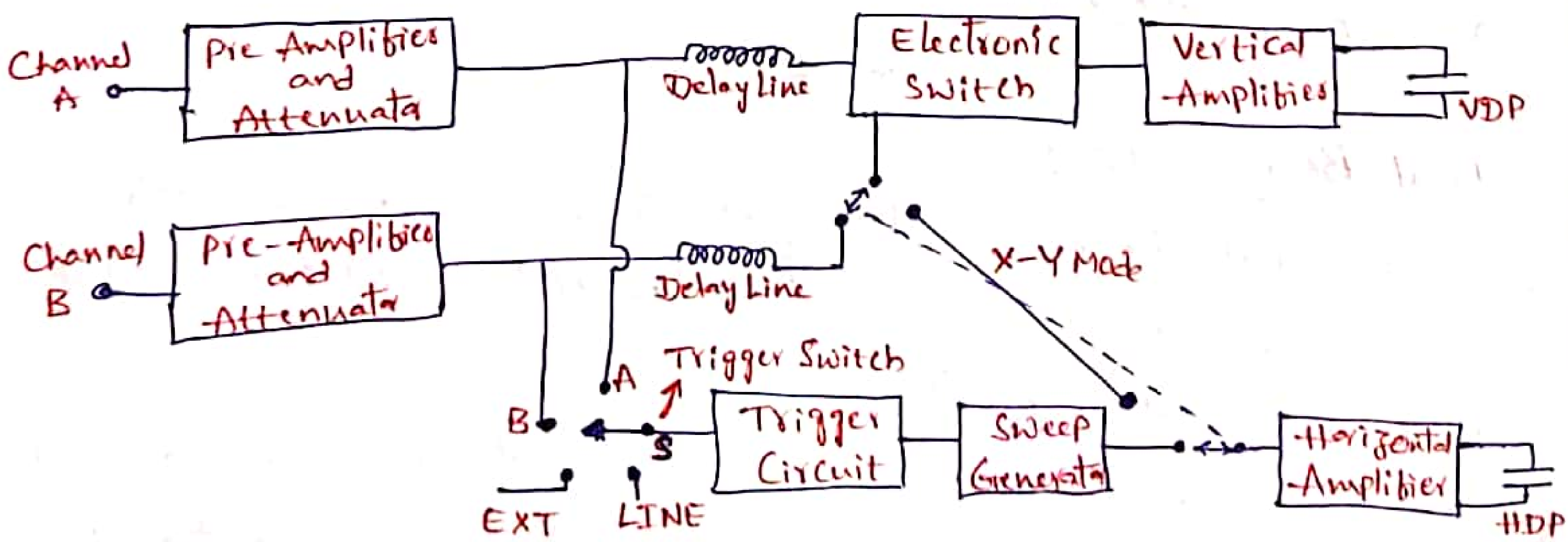


fig :- Dual Trace CRO

→ This CRO has a single electron gun whose electron beam is split into two by an electronic switch.
→ There is one control for focus and another for intensity. two signals are displayed simultaneously.
→ each signal has its own calibrated input attenuator, so that the amplitude of each signal can be adjusted independently.
→ A mode control switch enables the electronic switch to operate in two modes.
→ When the switch is in "alternate position" the electronic switch feeds each signal alternately to the vertical amplifier.
→ The electronic switch alternately connects the main vertical amplifier to channel 'A' and 'B' and adds a different dc component to each signal. this dc components directs the beam alternately to the upper (or) lower half of the screen.
→ The switching rate of the electronic switch is synchronized to the sweep rate, so that the CRT spot traces the channel 'A' signal on one sweep and the channel 'B' signal on the succeeding sweep.
→ In the X-Y mode of operation the sweep generator is disconnected and channel 'B' is connected to the horizontal amplifier.
→ Since both pre-amplifiers are identical and have the same delay time. accurate X-Y measurements can be made.

Lissajous Method: (Measurement of Amplitude, frequency & Phase)

Jules Antonie Lissajous (1822 - 1880)

→ Lissajous patterns are formed when two sine waves are applied simultaneously to the vertical & horizontal deflecting plates of the CRO.
→ The shape of the Lissajous pattern depends on the frequency and phase relationship of the two sine waves.
→ Two sine waves of the same frequency and amplitude may produced a line, an ellipse (or) a circle depending on their phase difference.

→ In general the shape of Lissajous figure depends on
(1) amplitude.
(2) Phase difference.
(3) Ratio of frequency of the two waves.

Measurement of Phase angle :-

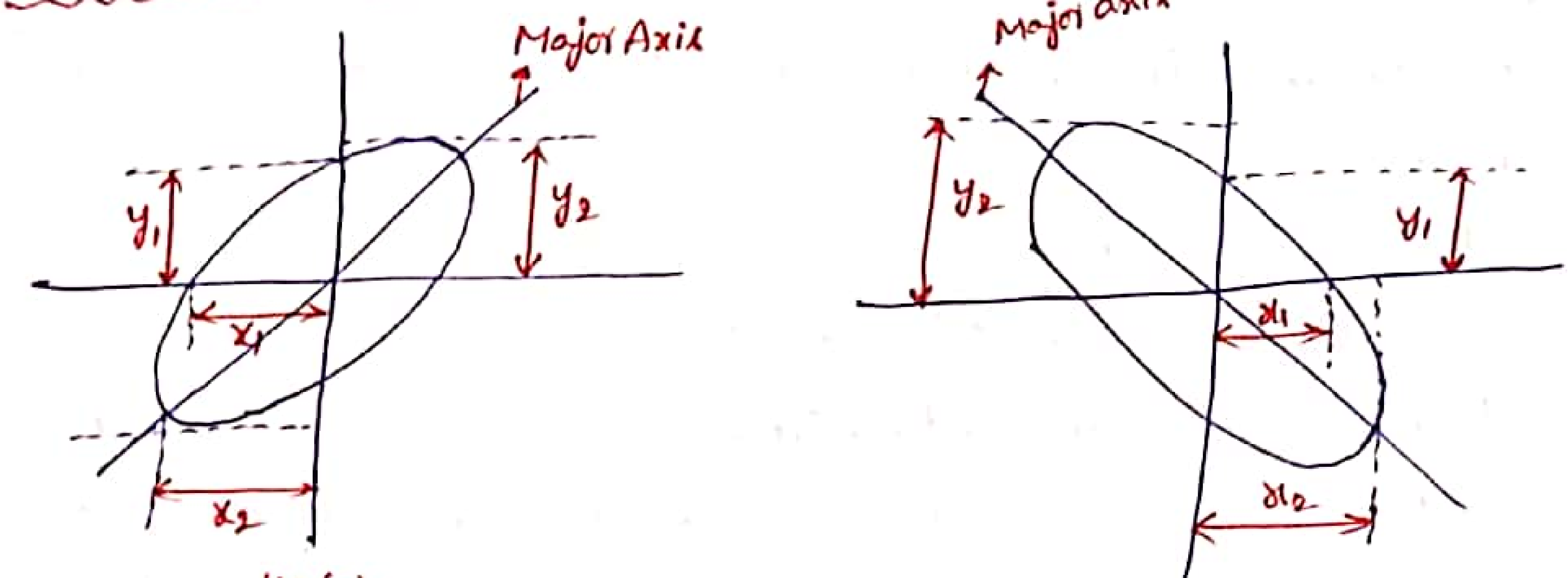


fig (a): fig (b):

fig: Measurement of Phase angles by Using CRO.

→ An oscilloscope can be used to find the phase angle between the two sinusoidal quantities of the same frequency.

→ Consider the Lissajous figure obtained on CRO with an unknown phase difference 'ϕ' as shown in figure (a). The frequency and amplitude of the two waves are same.

→ The Parameters y_1, y_2 (or) x_1, x_2 can be measured.

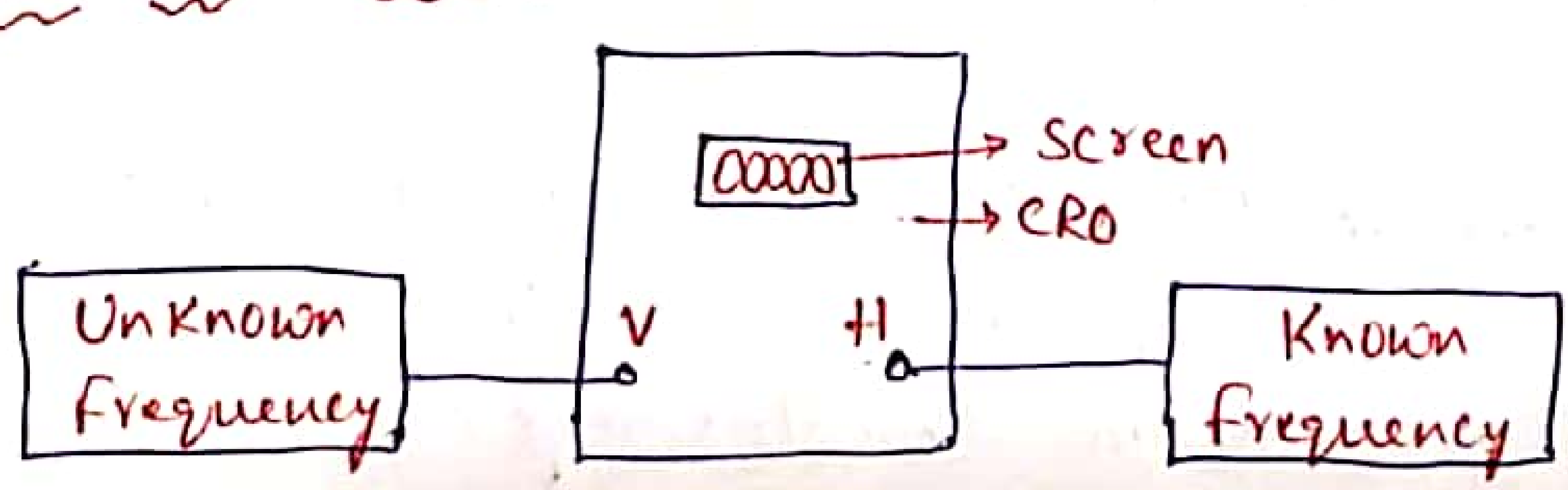
→ Then the phase angle can be obtained as

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

→ If the pattern is as shown in fig (b) then the phase angle is given by

$$\phi = 180^\circ - \sin^{-1}\left(\frac{y_1}{y_2}\right) \text{ (or) } 180^\circ - \sin^{-1}\left(\frac{x_1}{x_2}\right)$$

Measurement of Frequency:-



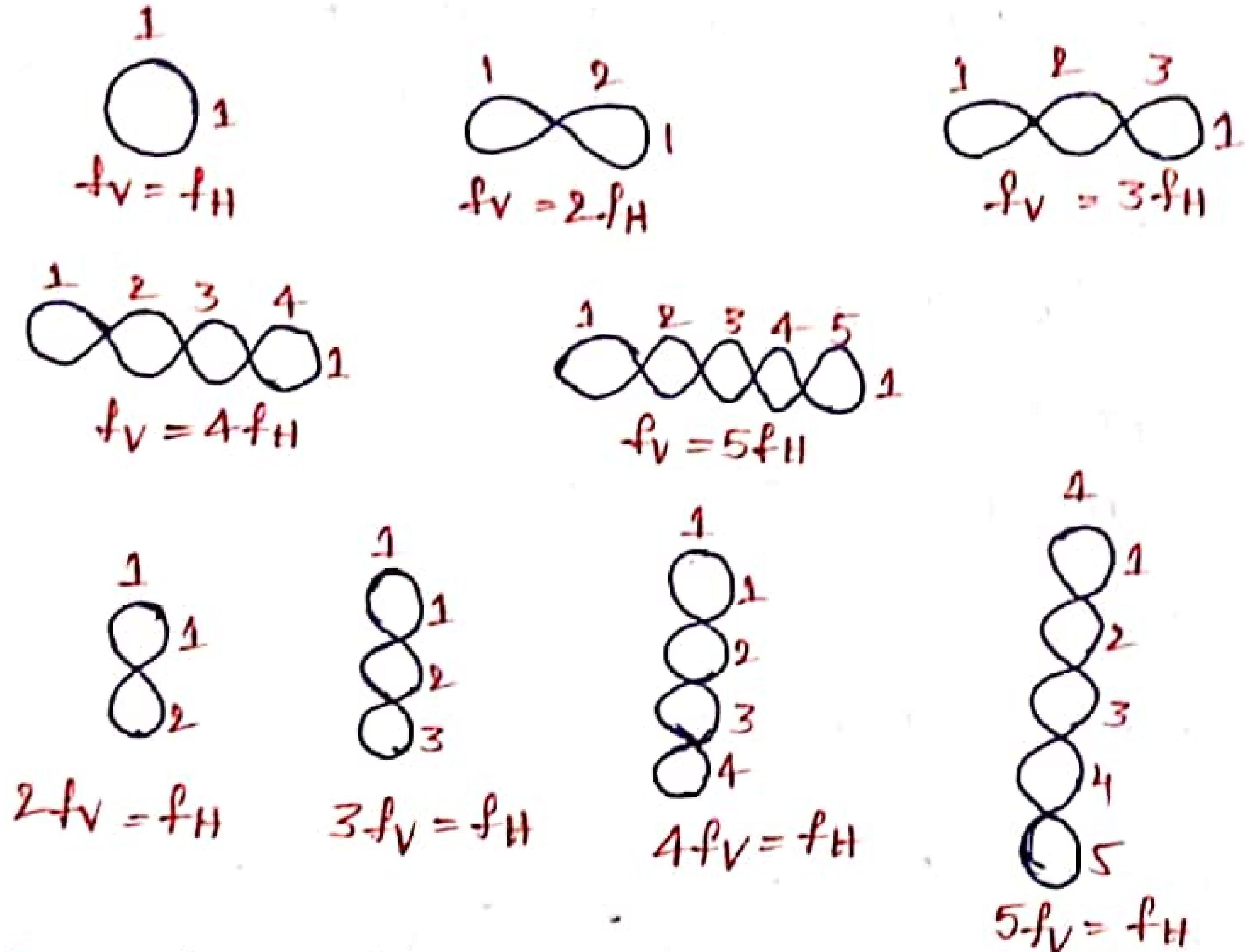
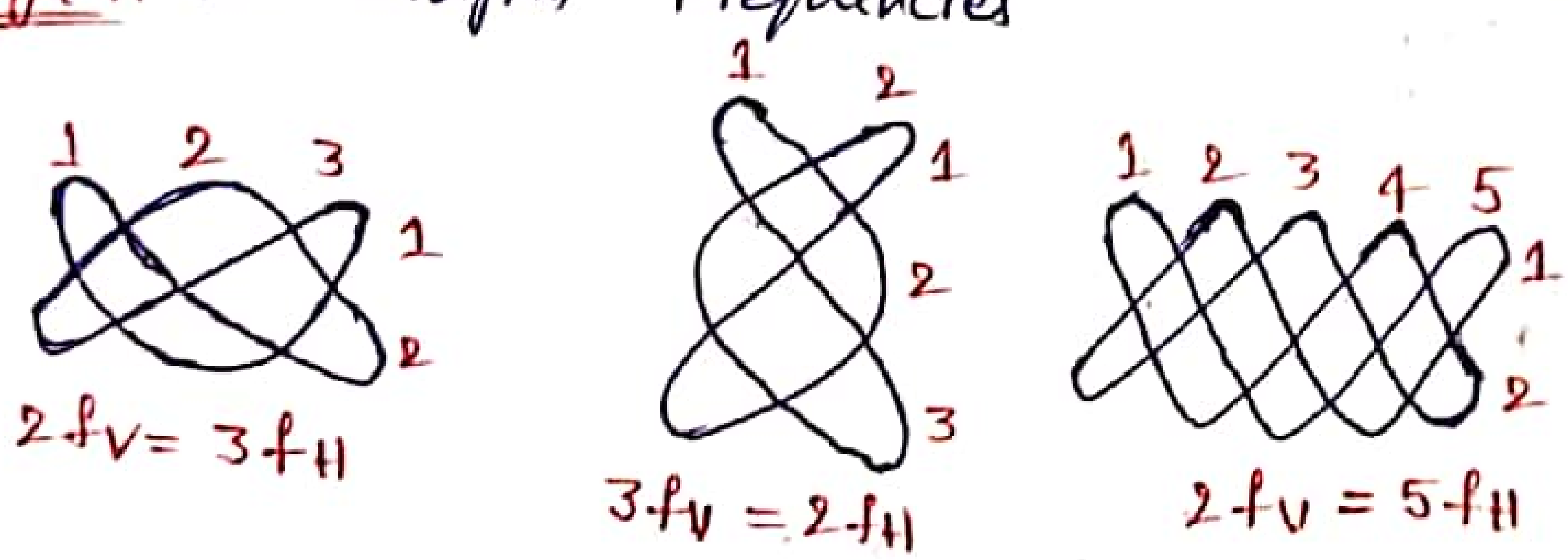


fig (a): For Integral Frequencies



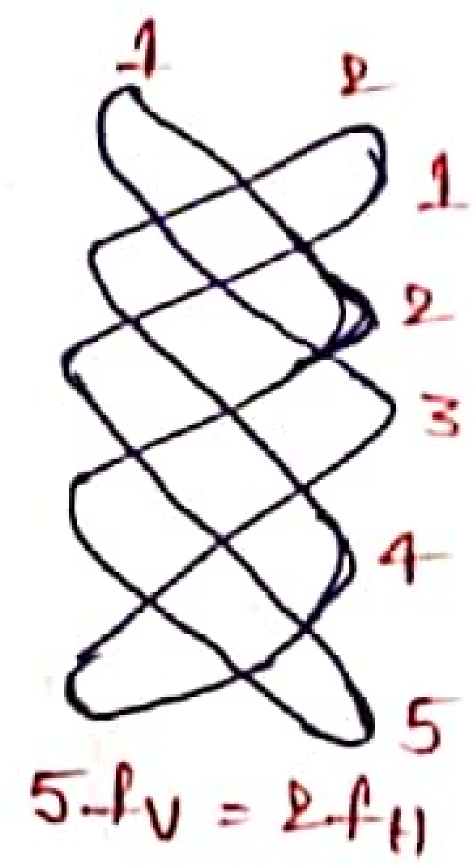


fig (b): For Non-Integral frequencies

fig: Lissajous Patterns

Procedure:

→ Set up the oscilloscope and switch off the internal sweep (change to External)

→ Switch off Sync. Control

→ Connect the signal source as shown in figure.

→ Set the Horizontal and Vertical gain control for the desired width & Height of the pattern.

→ Keep frequency 'f_V' constant and vary frequency f_H nothing that the pattern spins in alternate directions and changes shape.

→ When $f_V = f_H$ pattern stands still and is a single circle (or) ellipse

→ When $f_V = 2f_H$ a two loop horizontal pattern is obtained.

→ The Fractional relationship between the two Frequencies is determined by Counting the no. of cycles in the Vertical and Horizontal.

$$f_V = (\text{fraction}) \times f_H$$

$$\frac{f_V}{f_H} = \frac{\text{No. of Horizontal Tangencies}}{\text{No. of Vertical tangencies}}$$

Sampling Oscilloscopes: (For VHF Signals)

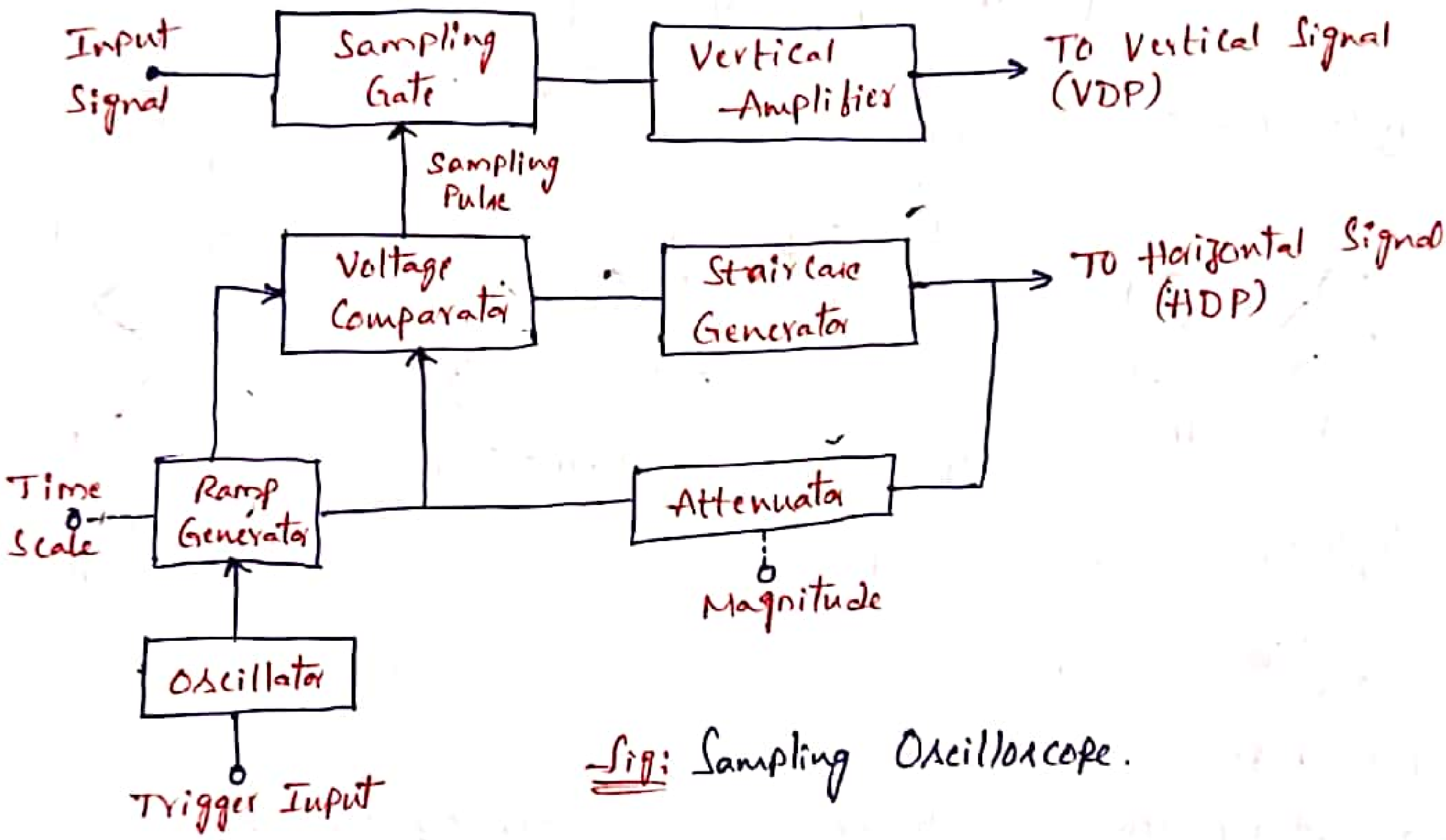


fig: Sampling Oscilloscope.

→

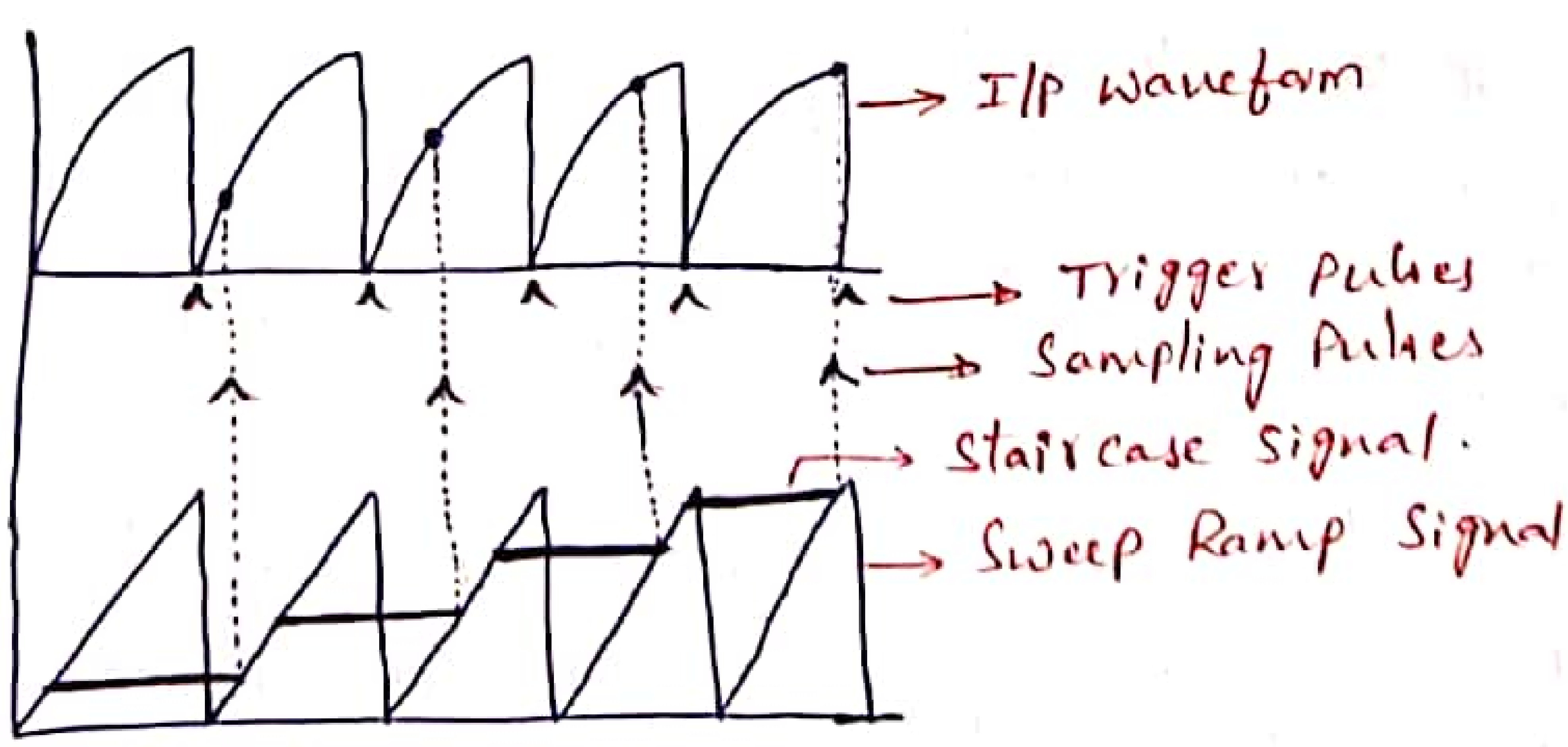


fig: Various waveforms at each block of a Sampling Oscilloscope.

→ An ordinary Oscilloscope has a B.W. of 10MHz.

→ The HF performance Can be improved by means of Sampling the input waveform and reconstructing its shape from the Sample.

→ The shape of the waveform is reconstructed by joining the sample levels together.
→ The sampling frequency may be as low as $\frac{1}{10}$th of the input signal frequency.
→ The i/p waveform is applied to the sampling gate.
→ The i/p waveform is sampled whenever a sampling pulse opens the sampling gate.
→ The sampling must be synchronized with the i/p signal frequency.
→ The signal is delayed in the vertical amplifier, allowing the horizontal sweep to be initiated by the input signal.
→ At the begining of each sampling cycle, the trigger pulse activates an oscillator and a linear ramp voltage is generated.
→ This ramp voltage is applied to a voltage comparator which compares the ramp voltage to a staircase generator.
→ When the two voltages are equal in amplitude, the staircase advances one step and a sampling pulse is generated, which opens the sampling gate for a next sample of i/p voltage.
→ The resolution of the final image depends upon the size of the steps of the staircase generator. The smaller the size of the steps the larger the number of samples and higher the resolution of the image.

Storage Oscilloscope: (For VLF Signals)

→ Two storage techniques are used in oscilloscope CRTs
(i) Mesh storage
(ii) phosphor storage

(i) Mesh storage:-

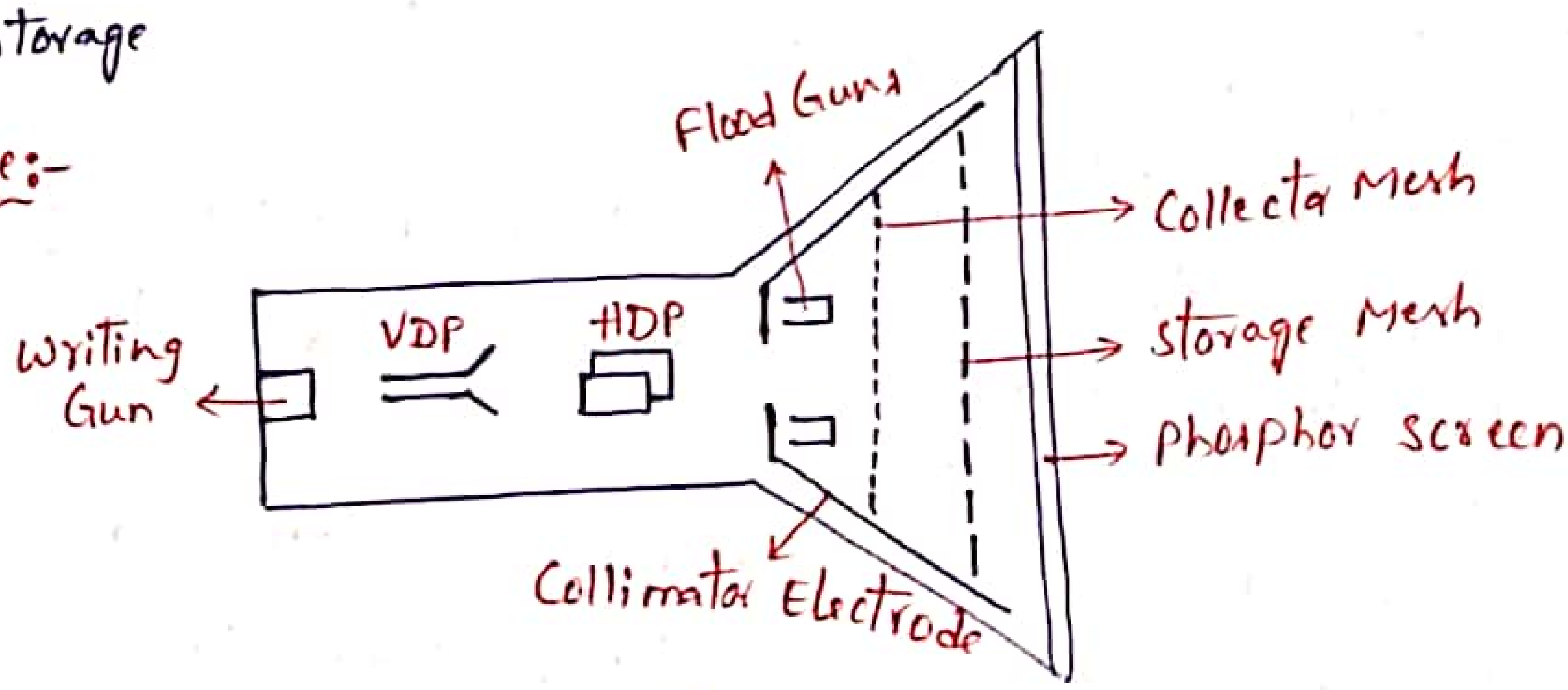


Fig: Basic elements of Storage Mesh CRT

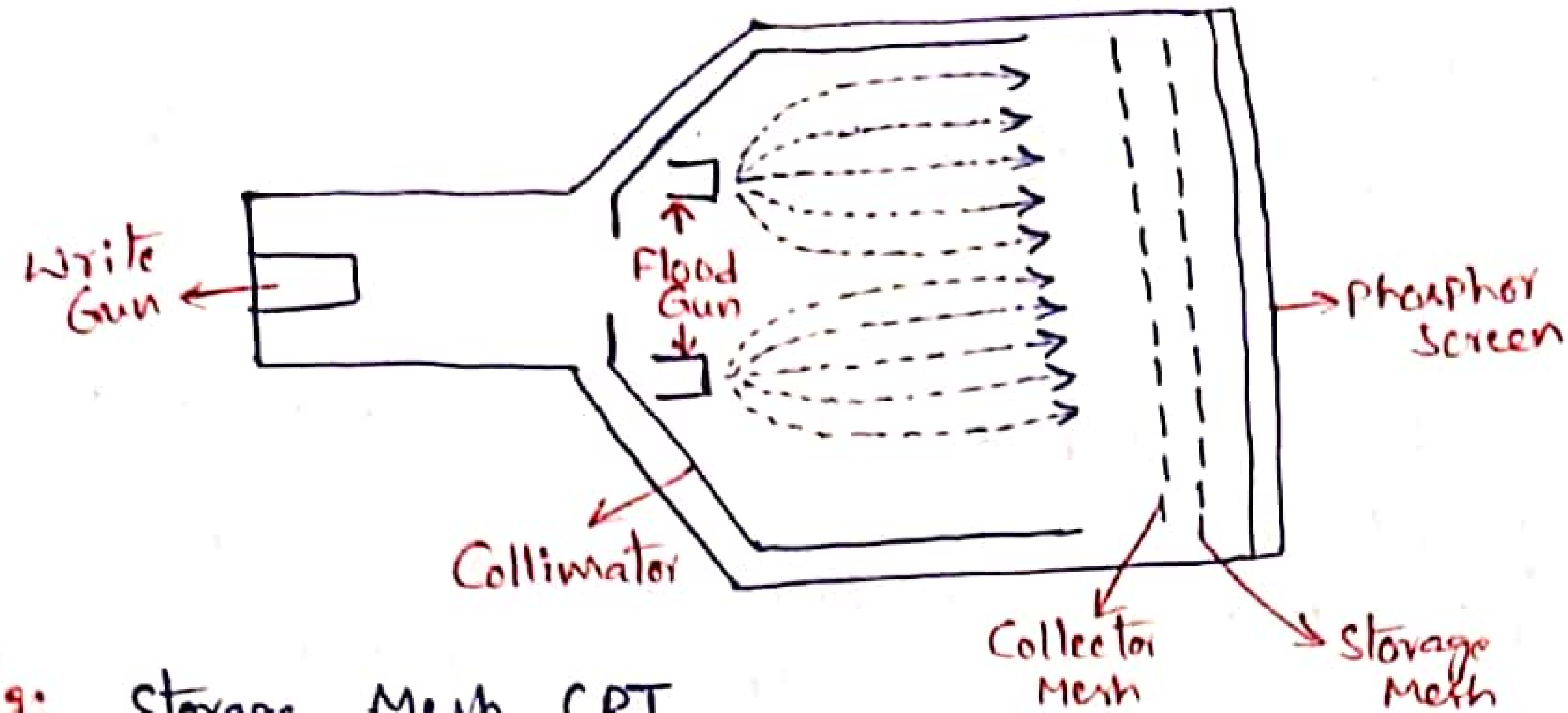


fig: Storage Mesh CRT

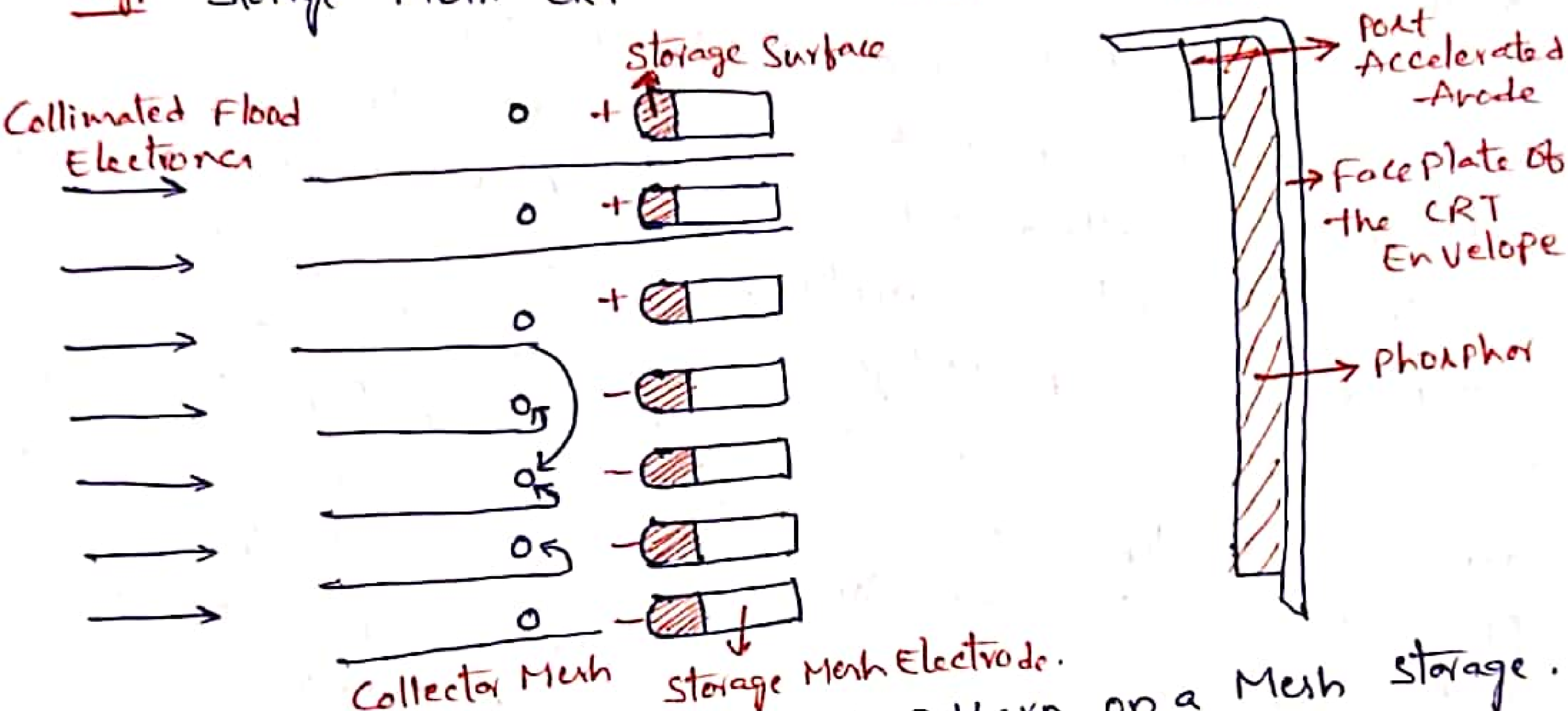


fig: Display of stored charged pattern on a Mesh storage.

→ A Mesh storage CRT, Contains a dielectric material deposited on a storage Mesh, a Collector Mesh, flood guns and a collimator, in addition to all the Elements of a standard CRT.

→ In order to Make a pattern Visible, a Special Electron gun Called the "Flood Gun" is Switched ON.

→ The electron paths are adjusted by the Collimator electrode.

→ Most of the electrons are stopped and Collected by the Collector Mesh.

→ Only Electron near the stored positive Charge are Pulled to the Storage target with Sufficient force to hit the Phosphor screen.

→ The CRT will now display the Signal and it will remain Visible as long as the flood guns operate.

→ To erase the pattern of the storage mesh, a negative voltage is applied to neutralise the stored positive charge.

② Phosphor storage: The phosphor storage CRT uses a thin layer of phosphor to serve both as the storage and the display element.

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Digital Storage Oscilloscope :— (DSO)

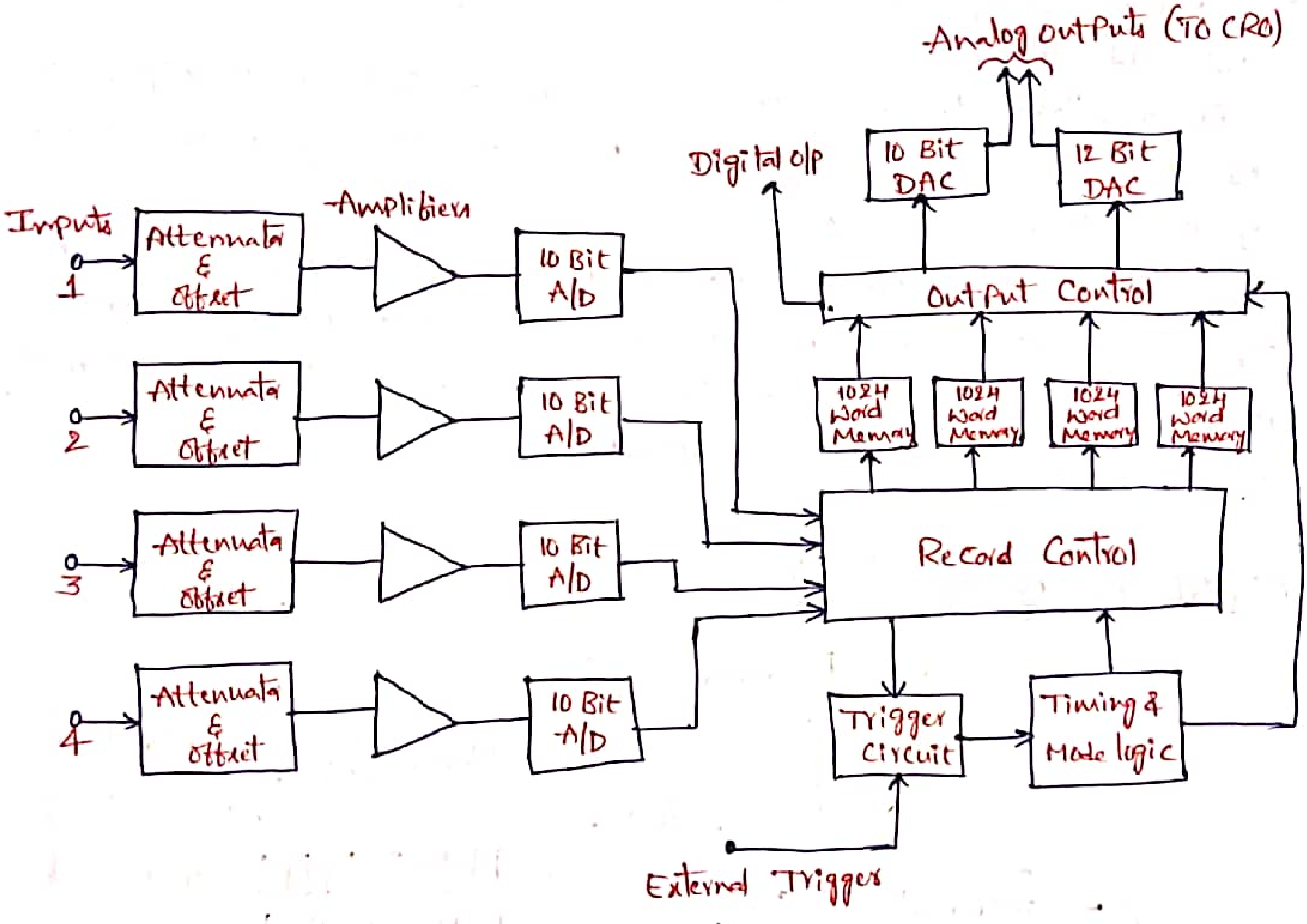

fig: Digital Storage CRO

→ Consider a single channel of figure.

→ The Analog voltage input signal is digitised in a 10 Bit A/D converter with a resolution of 0.1% and frequency response of 25 KHz.

→ The total digital memory storage capacity is 4096 words and 2048 for two channels.

→ Having 1024 word memory for four channels each.

→ so A Maximum of 4096 Points are Storable in this Particular instrument.

→ Once the Sampled record of the event is Captured in Memory, many Useful Manipulations are Possible, Since memory can be read out without being erased.

→ The digital Memory also May be read directly.

→ As in Digital storage oscilloscope Can be set to record Continuously, Until the trigger Signal is received. then the recording is stopped. thus freezing data received Prior to the trigger Signal in the Memory.

→ Suppose memory is full, New data Comming in to the Memory Pushes out old data

→ An adjustable trigger delay allows Operator Control of the stop Point, so that the trigger may occur near the begining, middle (or) end of the stored information.

→ The display of stored data is Possible in both amplitude (vs) time and XY-Modes. In addition to the fast memory readout used for CRT display, a slow read out is possible for producing hard copy with external plotters.

Digital Frequency Counter :-

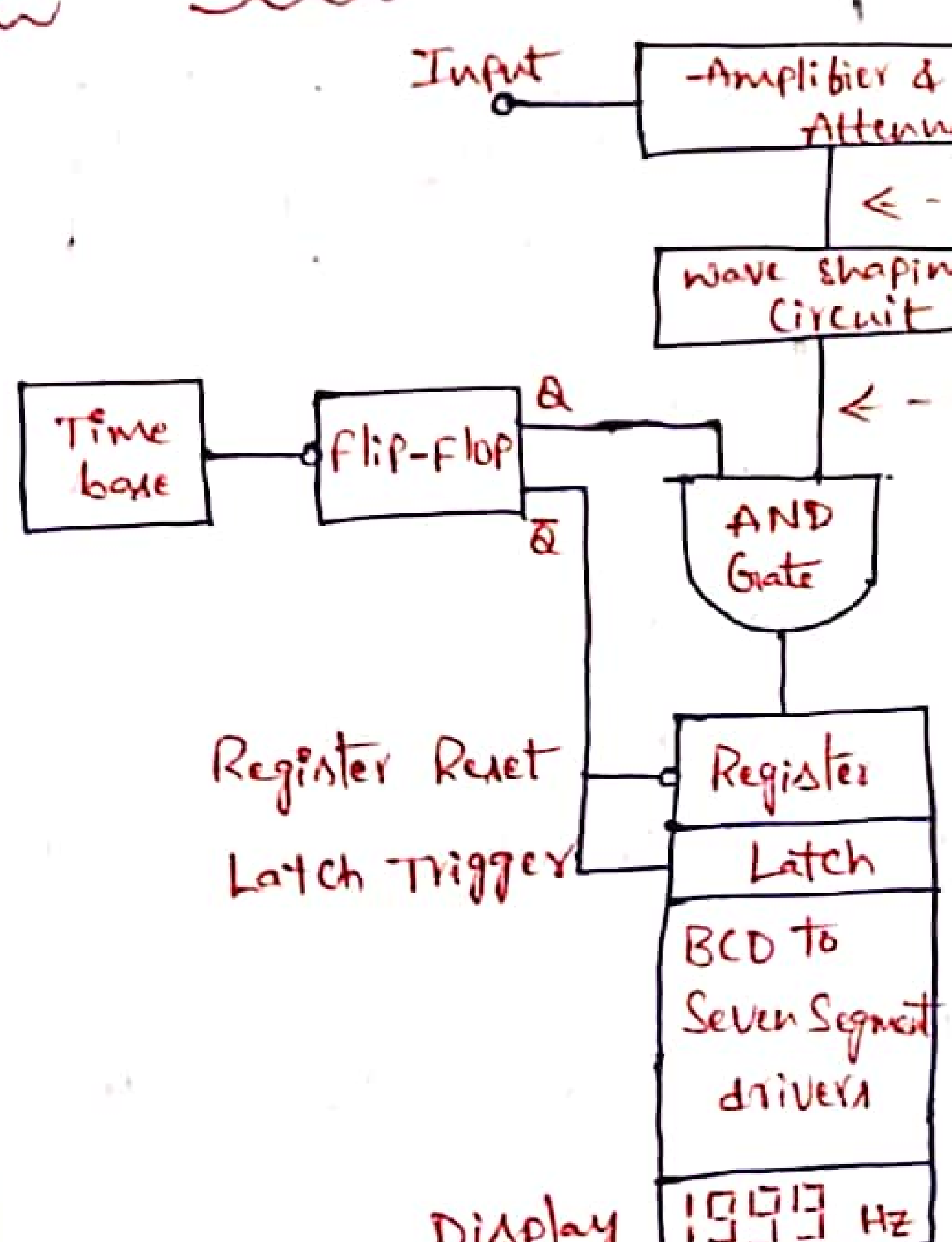

fig: Digital Frequency Counter

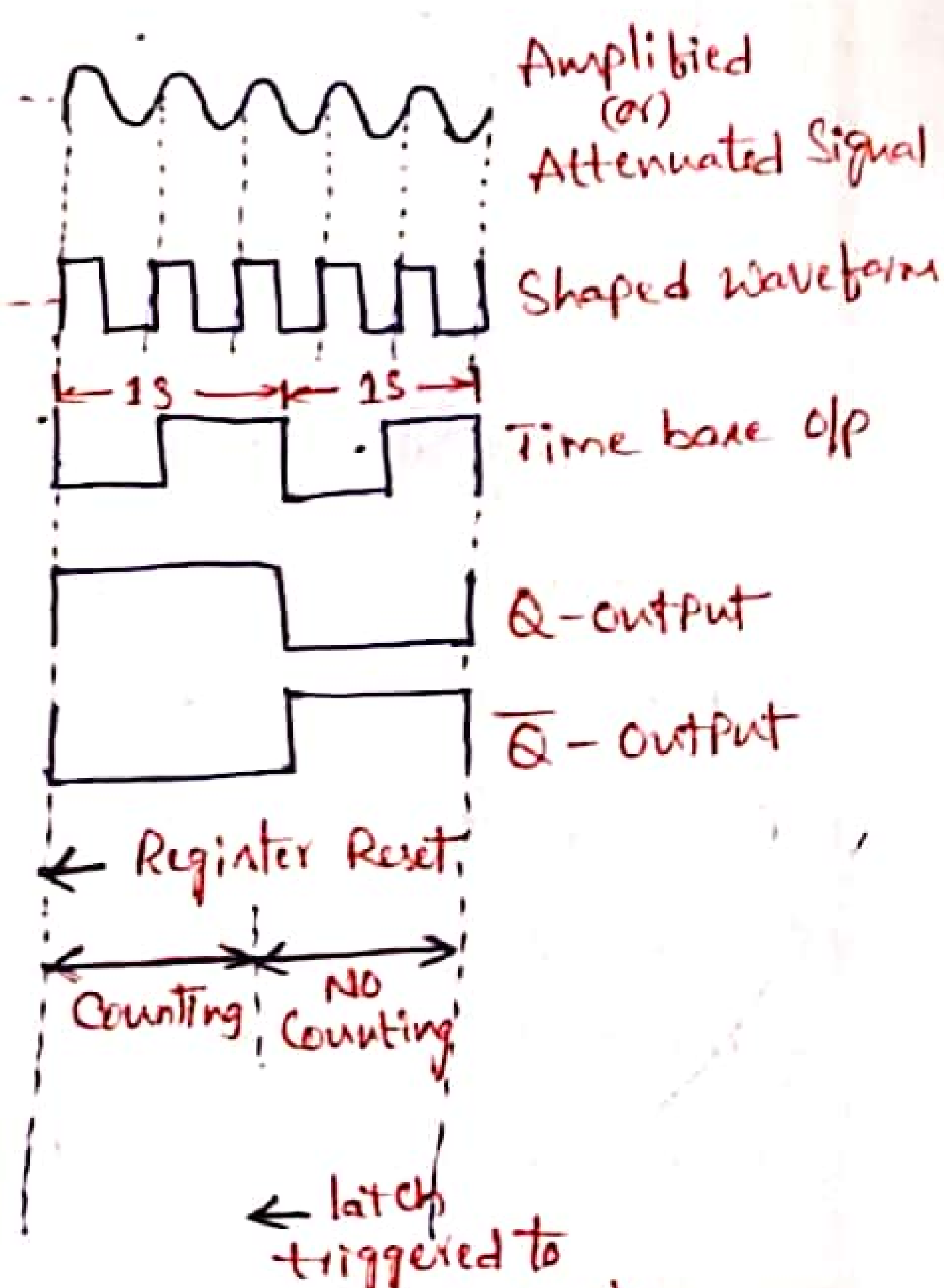

fig: System Waveforms.

→ The Input is first amplified (or) Attenuated as necessary and then fed to the wave shapping circuit, which converts it into a square (or) pulse waveform with the same frequency as the I/P.

→ The shaped waveform is fed to one input terminal of a two-input AND Gate, and the other AND gate input is controlled by the 'Q' output from a flip-flop. Consequently, the pulses to be counted pass through the AND Gate only when the flip-flop 'Q' terminal is 'High'.

→ The flip-flop is controlled by the timing circuit, changing state each instant that the timer output waveform goes in a negative direction.

→ When the timing circuit O/P frequency is 1 Hz, the flip-flop 'Q' O/P terminal is alternately 'High' for a period of '1 sec'.

→ In this case, the counting circuits are toggled (by the pulses from the wave-shaping circuit) for a period (termed the gate time) of 1 sec, and the total count indicates the frequency directly in "Hertz".

→ The counting circuits are reset to the zero-count condition by the negative-going edge of the $\bar{Q}$ output from the flip-flop so that the count always starts from zero.

Time Period Measurement :-

→ The time period of a signal is determined by measuring the time for one cycle in Horizontal divisions and multiplying by the setting of the TIME/DIV control.

$$T = \left(\frac{\text{No. of Horizontal divisions}}{\text{cycle}}\right) \times \left(\frac{\text{Time}}{\text{DIV}}\right)$$

→ Then, the frequency is calculated as the inverse of the time period.

$$f = \frac{1}{T}$$

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Signal Generators

Fixed AF Oscillator:-

→ In many cases, a self contained oscillator circuit is an internal part of the instrument circuitry and is used to generate a signal at some specified audio frequency.

→ Such a fixed frequency might be a 400Hz signal used for audio testing (or) a 1000 Hz signal for exciting a bridge circuit.

→ Oscillations at specified audio frequencies are easily generated by the use of an iron core transformer to obtain positive feed back through inductive coupling between the primary and secondary windings.

Variable AF Oscillator:-

→ A variable AF oscillator for general purpose use in a laboratory should cover atleast the full range of audibility (20 Hz to 20KHz) and should have a fairly constant pure sinusoidal wave output over the entire frequency range.

→ Hence, variable frequency AF generators for laboratory use of the RC feed back oscillator type. (or) beat frequency oscillator (BFO) type.

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Function Generator:-

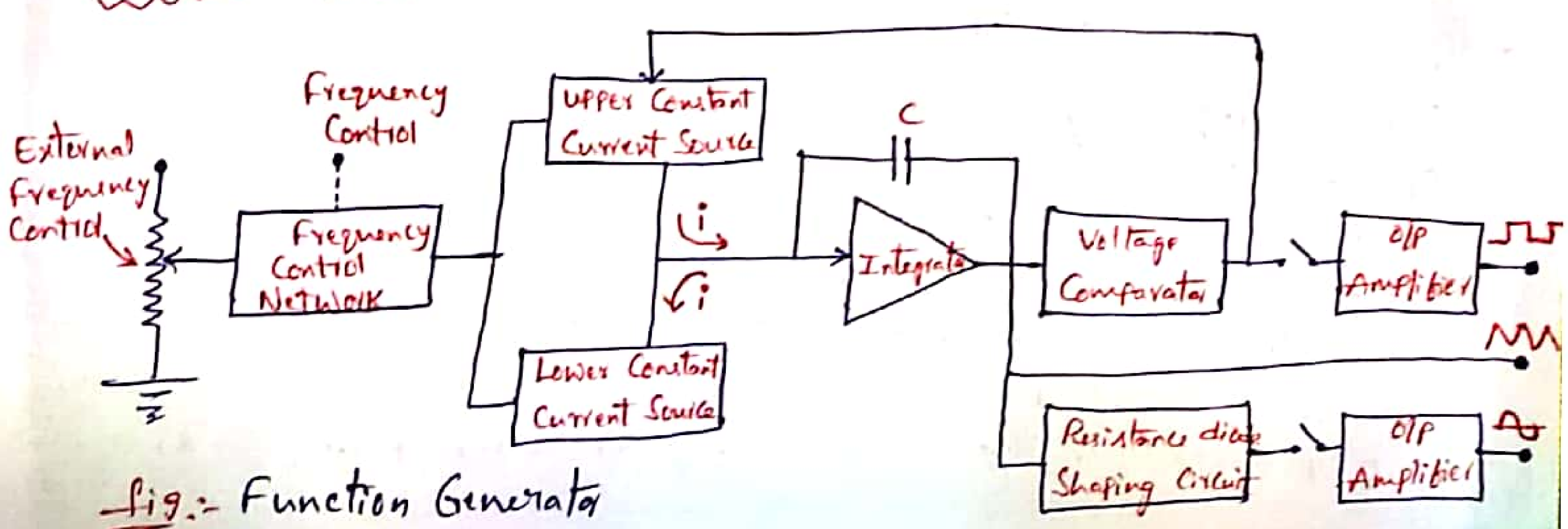

fig:- Function Generator

→ A function Generator produces different waveforms of adjustable frequency. The Common O/P waveforms are the Sine, Square, triangular, and Sawtooth waves. The frequency may be adjusted from a fraction of a Hertz to Several Hundred KHz.

→ Usually, the frequency is Controlled by Varying the Capacitor in the LC or RC Circuit. In this instrument frequency is Controlled by Varying the Magnitude of Current which drives the integrator.

→ The instrument Produces Sine, triangular and Square wave with different frequency ranges.

→ The frequency Controlled Voltage regulates two Current Sources.

→ The Upper Current Source Supplies Constant Current to the integrator whose o/p voltage increases linearly with time, according to the eq of the O/P signal voltage.

$$e_{out} = \frac{-1}{c} \int_{0}^{t} i \, dt$$

→ The lower Current Source Supplies a reverse Current to the integrator, So that its output decreases Linearly with time, When the o/p reaches a Predetermined minimum level, the Voltage Comparator again changes state and Switches on the upper Current Source.

→ The O/P of the integrator is a triangular waveform. Whose frequency is determined by the Magnitude of the Current Supplied by the Constant Current Sources.

→ The Comparator O/P delivers a Square wave Voltage of the Same frequency.

Specifications :-

1) Frequency Range : 0.001 Hz to 20MHz
2) Frequency stability: 0.05 %
3) Distortion : −55 dB below 50 KHz, −40 dB above 50 KHz.
4) O/P Amplitude & Impedance : 10 Vp-p , 50Ω.
5) O/P Waveforms: Sine, Square, triangular, ramp, pulse, AM & FM Modulated, Arbitrary.

Pulse Generator (or) Square wave Generator :-

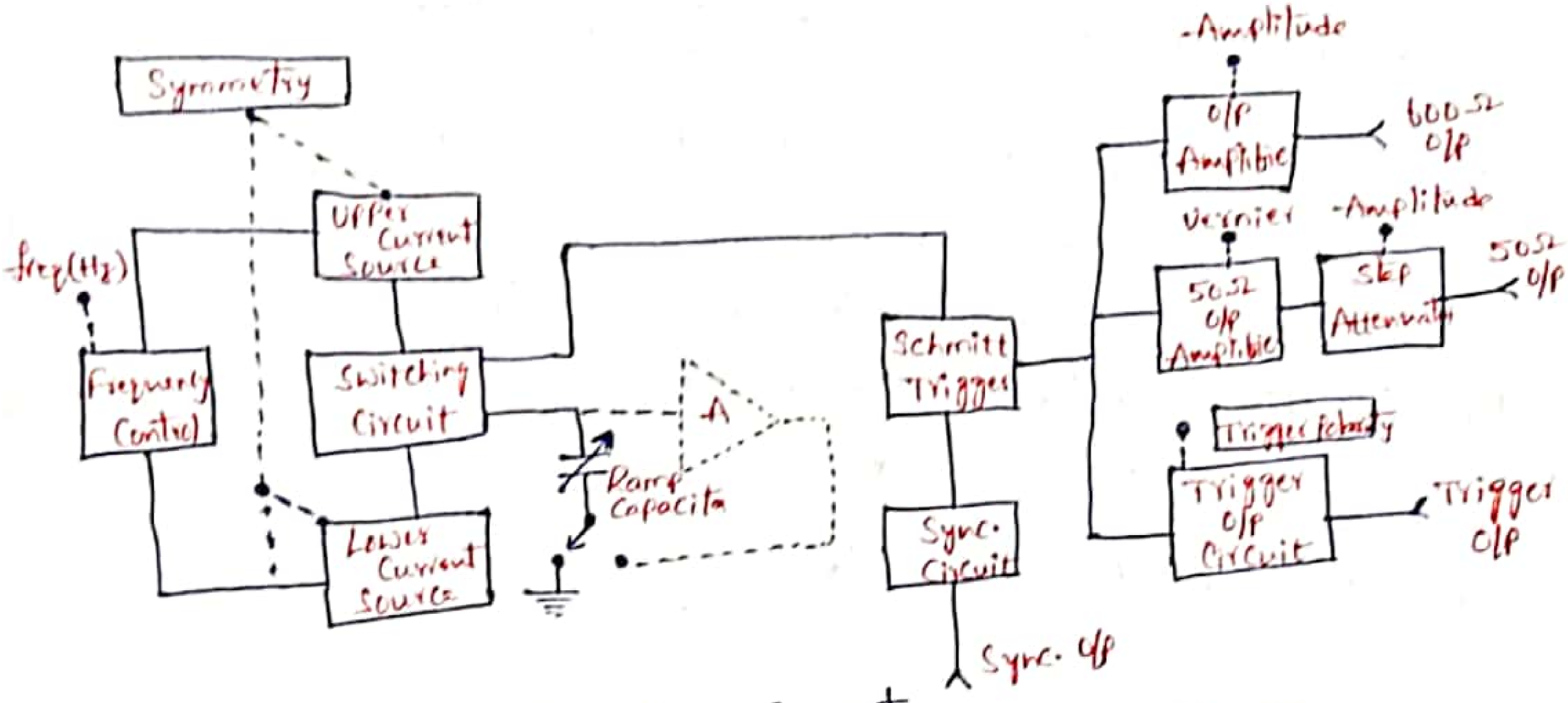

fig: Block diagram of a Pulse Generator

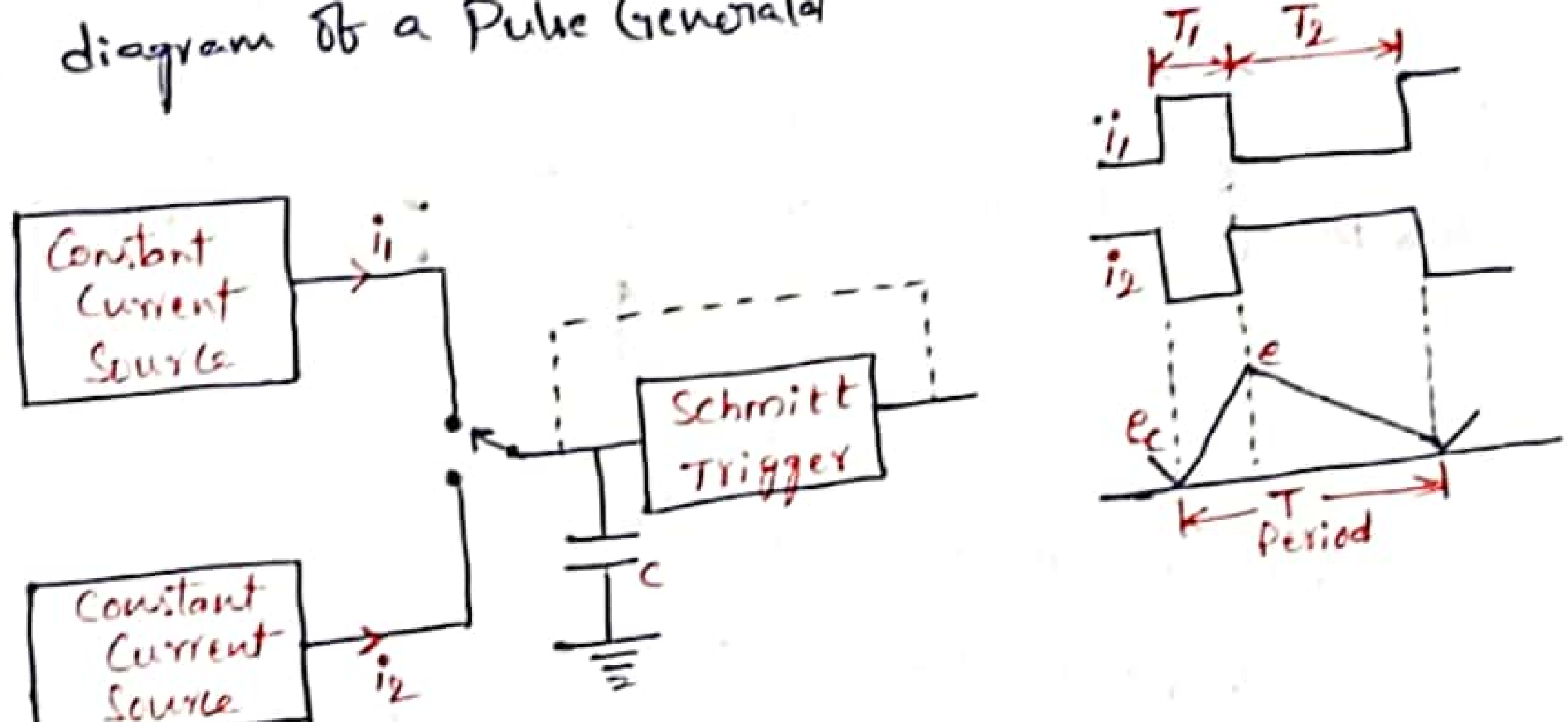

fig: Basic Generating loop.

→ The Fundamental difference between 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 Duty cycle Can be Varied from 25 - 75%. Two independent outputs are available, a 50Ω Source that Supplies pulses with a rise and fall time of 5nsec at 5V Peak amplitude and a 600Ω Source which Supplies a ~~nsec at~~ a Pulses with a rise and fall time of 70nsec at 30V Peak amplitude

→ The upper Current Source supplies a Constant Current to the Capacitor and the capacitor voltage increases linearly.

→ The Capacitor discharges Linearly. Controlled by the lower Current Source.

→ The ratio i_1/i_2 determines the duty cycle. and is Controlled by Symmetry Control.

→ The Sum of i_1 and i_2 determines the 'frequency. The Size of the Capacitor. Selected by the Multiplier Switch.

Random Noise Generator:-

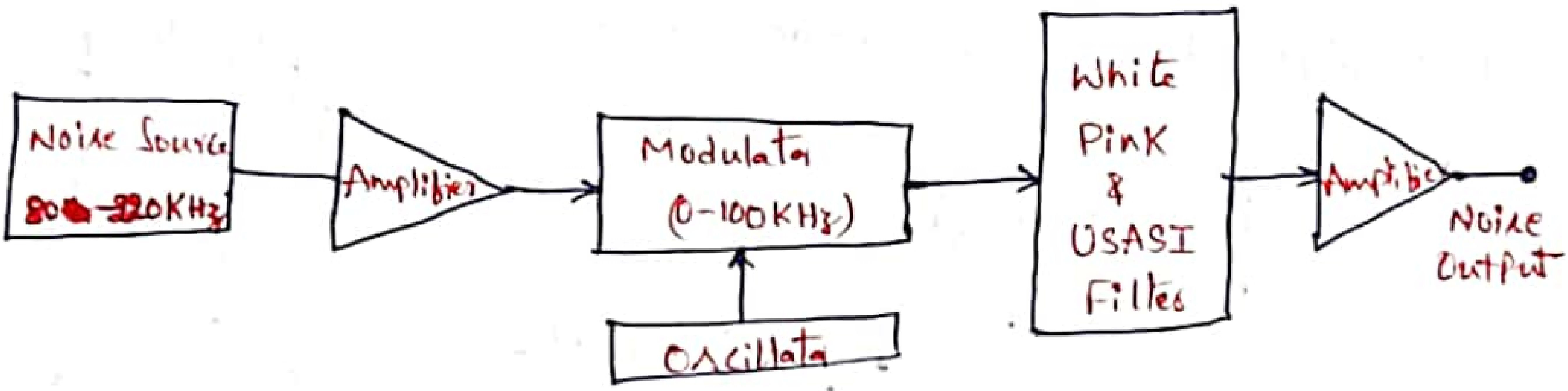

fig: Random Noise Generator.

→ The instrument offers the possibility of using a single measurement to indicate Performance over a wide frequency band, instead of many measurements at one frequency at a time.

→ The Method of generating Noise is usually to use a Semi-Conductor noise diode, which delivers freq's in a band roughly extending from 80-220KHz.

→ The o/p from the Noise diode is amplified and heterodyned down to the audio frequency band by means of a balanced Symmetrical Modulator.

→ White Noise is flat from 20Hz to 20KHz and has an upper Cut off frequency of 50KHz with a cut off slope of -12dbs.

→ Pink Noise has a Voltage spectrum which is inversely proportional to the Square root of frequency and is used in bandwidth Analysis.

→ USASI Noise ranging simulates the energy distribution of Speech and music frequencies and is used for testing audio amplifiers and loud speakers.

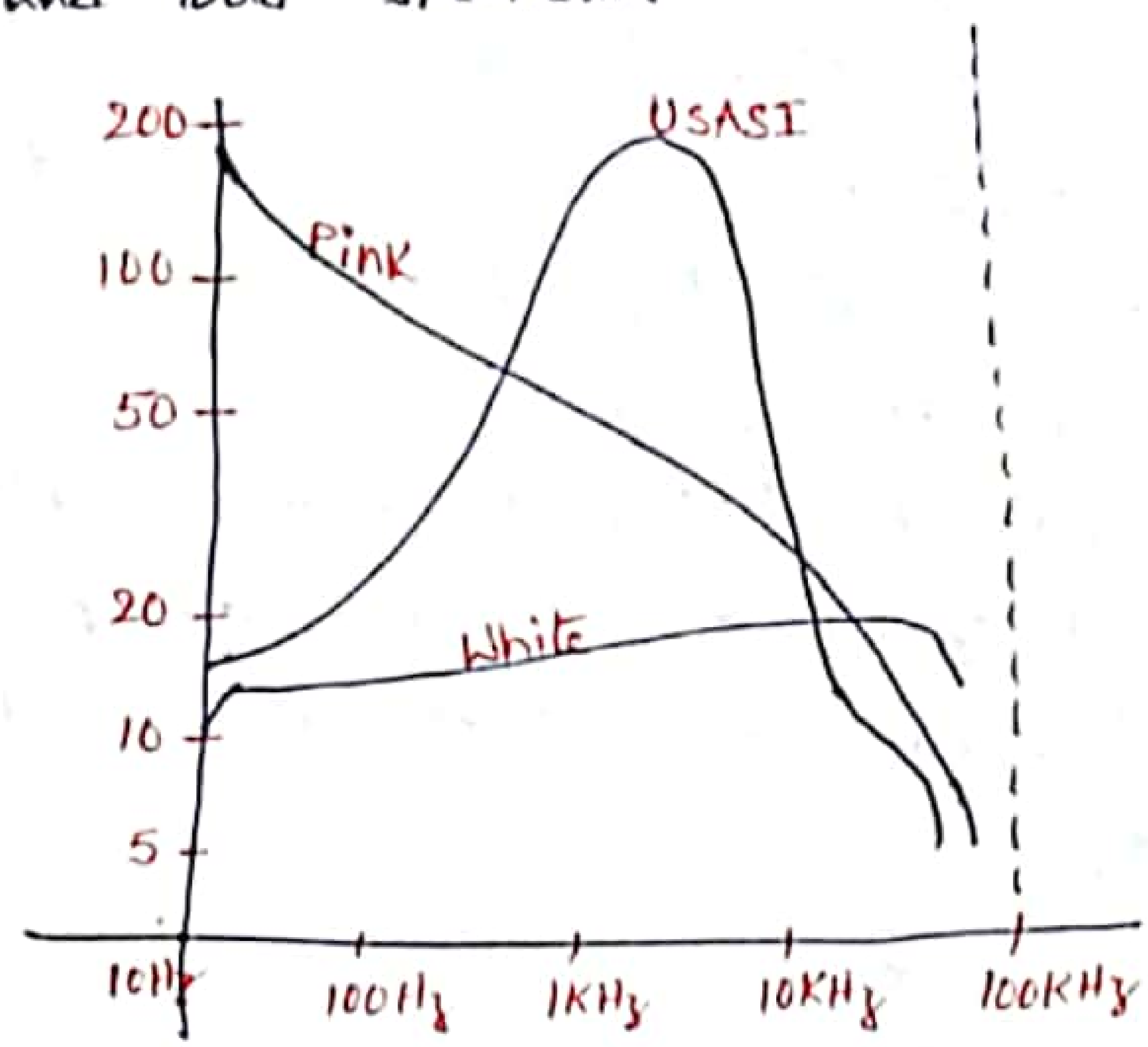

fig: Frequency Response.

Sweep Generator :-

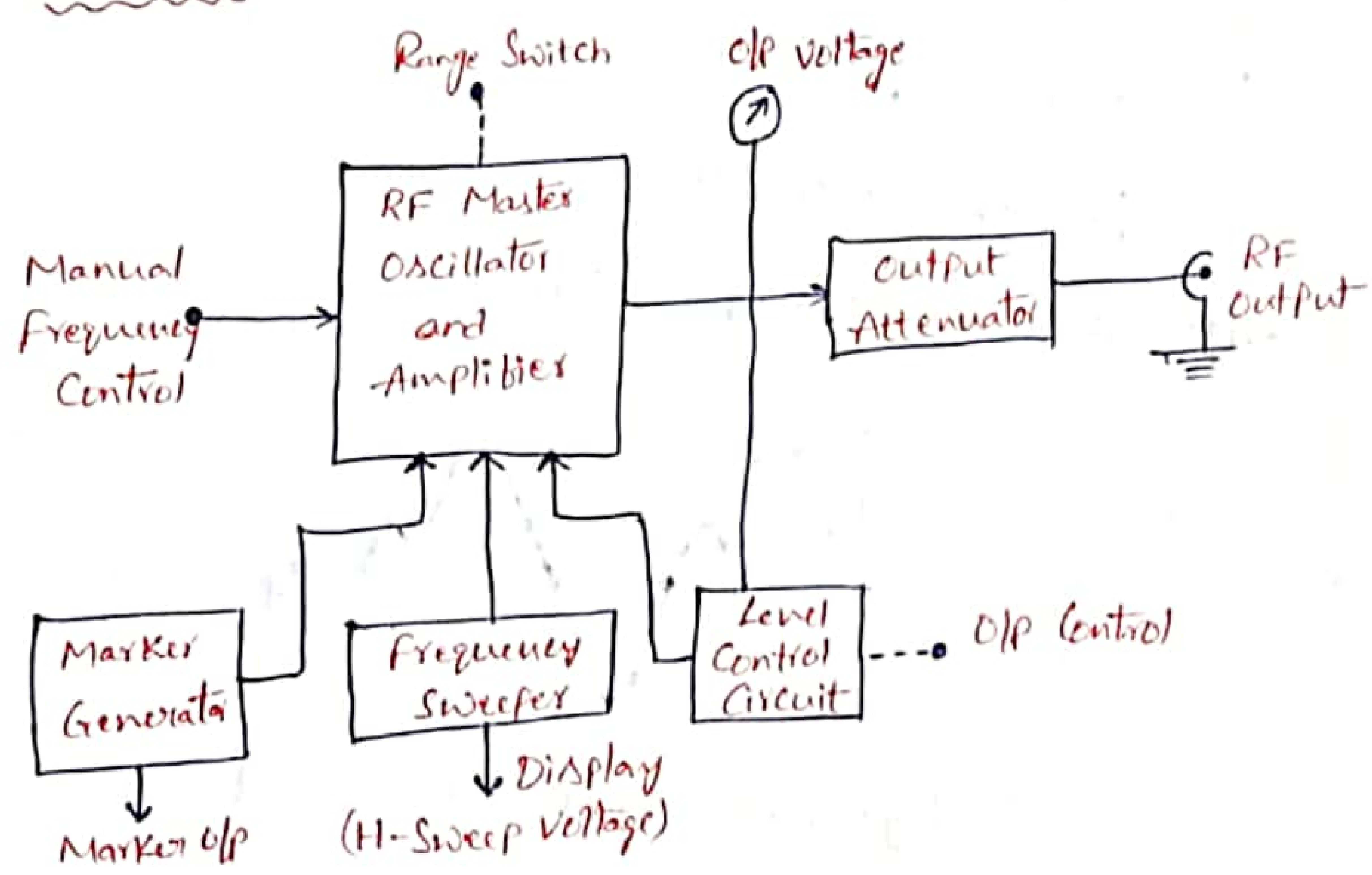

fig:- Sweep Generator

→ It provides a sinusoidal O/P voltage whose frequency varies smoothly and continuously over an entire frequency band usually at an audio rate.

→ The process of freq. Modulation may be accomplished electronically, (or) Mechanically.

→ It is done electronically by using the Modulating voltage to vary the reactance of the oscillator tank circuit component.

→ It is done Mechanically by means of a Motor driven Capacitor, as provided for a Modern laboratory type Signal generator.

→ The Frequency Sweeper provides a varying sweep voltage for synchronization to drive the horizontal deflection plates of the CRO.

→ The Automatic level Control circuit is a closed loop feed back system which monitors the RF level at some point in the Measurement System.

Arbitrary Wave-form Generator:-

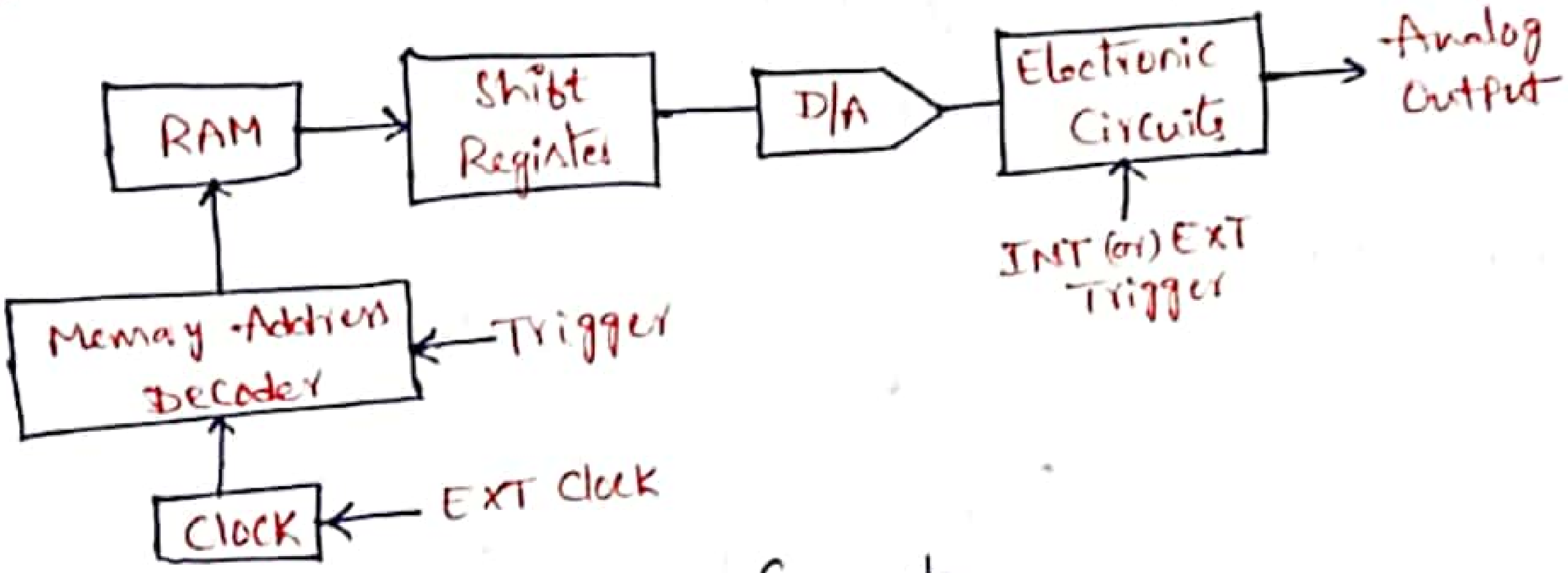

fig:- Arbitrary Waveform Generator.

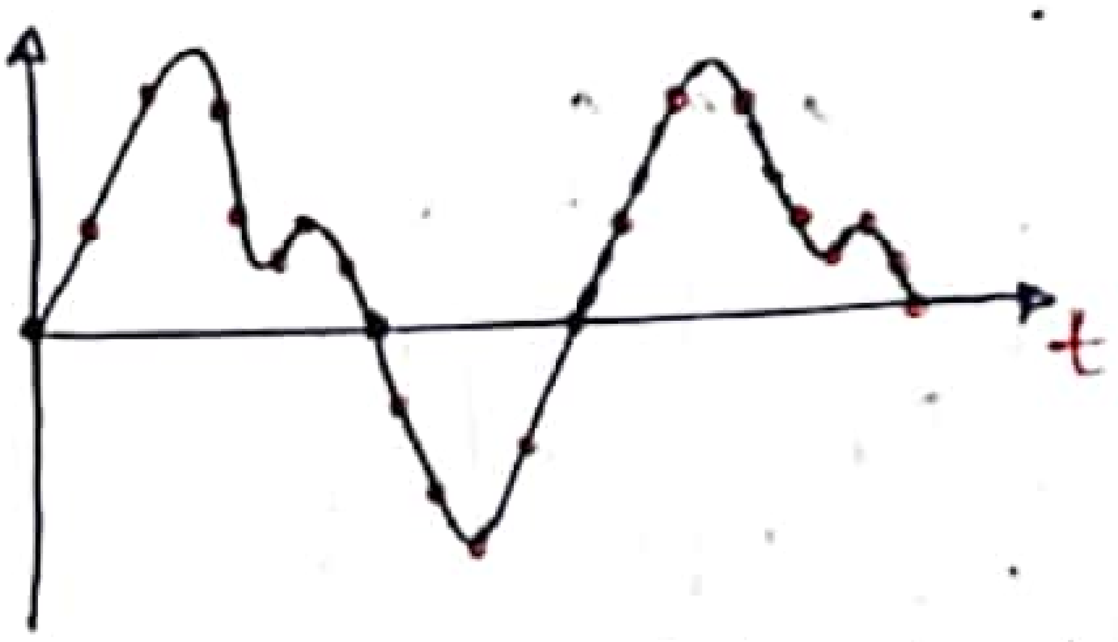

fig:- Arbitrary periodic waveform.

→ The word "Arbitrary" is used for the waveforms other than sine, square, triangular, sawtooth....etc. but for the waveforms that user defines.

→ The Basic idea of the arbitrary waveform generator is to generate a periodic waveform which the user defines.

→ Thus User Can define Various Samples with a graphical editing Capability such as a display screen and a Mouse (or) even a set of Sample values Can be downloaded from a Computer Connected to the arbitrary waveform generator.

→ The More Complex waveform Can be generated Using it Provided that More Sample Points are supplied.

→ It Can also Control the frequency and the amplitude once a set of Sample Points is loaded in the Memory of generator, an electronic Circuitary generates a waveform passing Smoothly and repetatively through the set.

→ Thus basically it is a Playback System which generates waveform based on the digital data stored in the fast RAM of the instrument.

→ The Sampling of the stored data Can be done either by Using graphical, Mathematical techniques or by measuring a waveform actually with instruments such as oscilloscopes.

→ For regenerating the waveform, the Memory locations are read and the data is fed to the digital to Analog Converters.

Parameters of Arbitrary waveform Generator:-

① Vertical Resolution (Amplitude):-

→ The Resolution of an AWG is expressed as the resolution of D/A Converter expressed in bits. so if the no. of bits are More, the resolution of D/A Converter is higher.

→ Even though More bits give higher resolution, the higher frequency AWG offers only 8-bits resolution, while the general purpose AWG offers 12 (or) 14 bits better than previous.

② Memory Depth:-

→ The flexibility of the AWG is decided by the Memory depth. More Memory provides either of the two benifits explained below

(1) with the help of More Memory, More cycles of the desired waveform Can be stored. The last Memory location occupied for the waveform stored is called the "End Point". After the END Point the AWG takes a transition and returns back to the starting Point

of the waveform in order to produce it. During such transitions unavoidable errors are introduced. In order to over come this the no. of end points are reduced in Number.

(2) The other benefit of More Memory is that More details related to the waveform to be generated can be stored.

(3) Frequency and Memory depth Relationship :-

→ The output frequency is given by

$$f_{out} = \left[\frac{\text{Clock Frequency}}{\text{Memory depth}}\right] \quad \text{(Cycles in Memory)}.$$

Wave Analyzers :-

① Frequency Selective Wave Analyzer :-

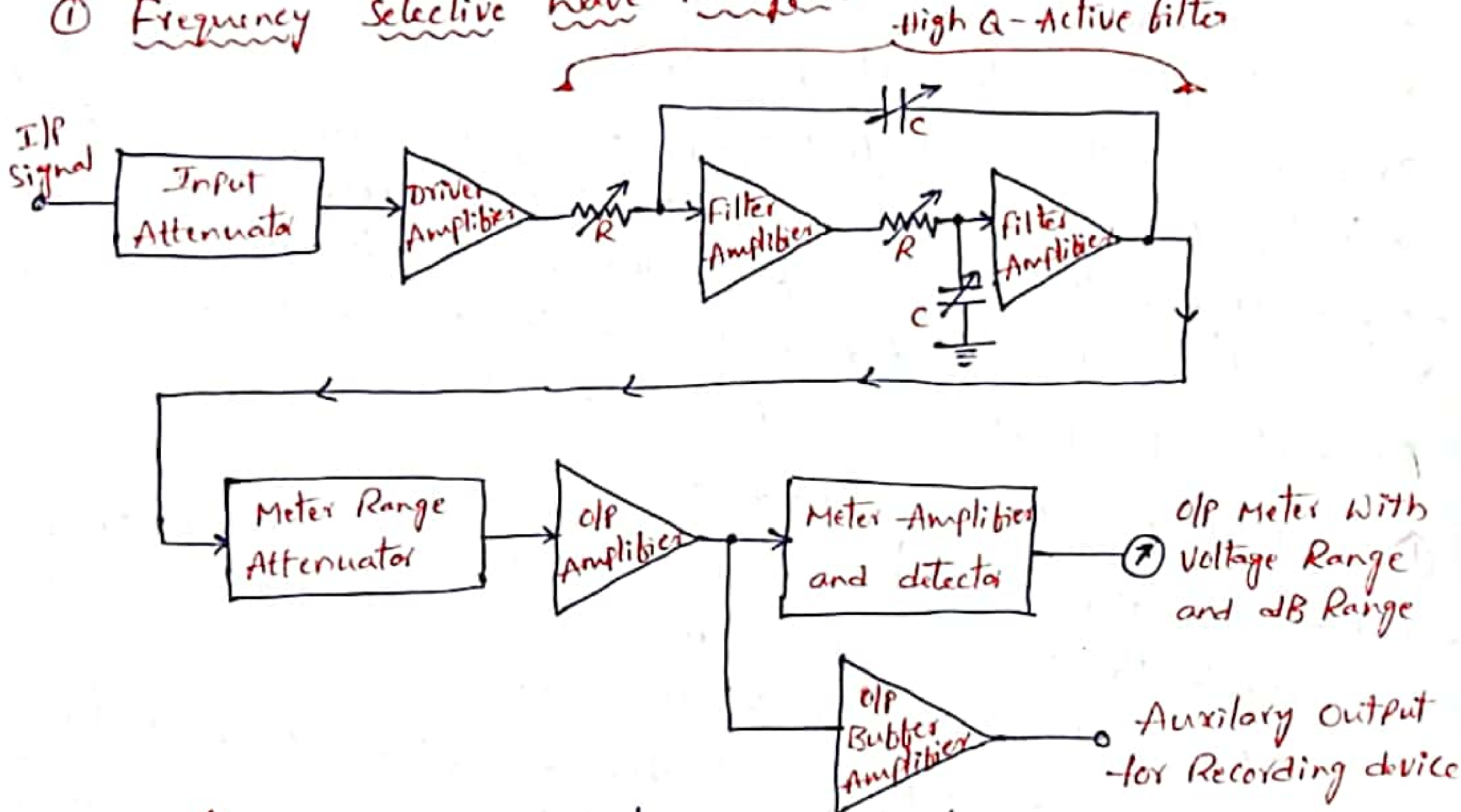

fig: Frequency Selective Wave Analyzer.

→ A wave Analyzer is an instrument designed to measure the relative amplitudes of single - frequency components in a distorted waveform.

→ For Measurements in the Audio frequency range (20Hz to 20KHz) the Analyzer has a filter section with a very narrow passband that can be tuned to the frequency components.

→ The i/p signal given to the attenuator. A driver amplifier feeds the attenuated waveform to a "High Q - Active filter".

→ This filter Consists of a Cascaded arrangement of RC resonant Sections and filter amplifiers.

→ A final amplifier stage Supplies the Selected Signal to the meter ckt and to an Untuned buffer amplifier

→ The buffer amplifier Can be Used to drive a recorder (or) an electronic Counter.

→ The Meter is driven by an average type detector and usually has a several voltage ranges as well as a decibel scale.

→ The bandwidth of the instrument is Very Narrow, typically about 1 percent of the selected frequency.

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② Heterodyne Wave Analyzer:-

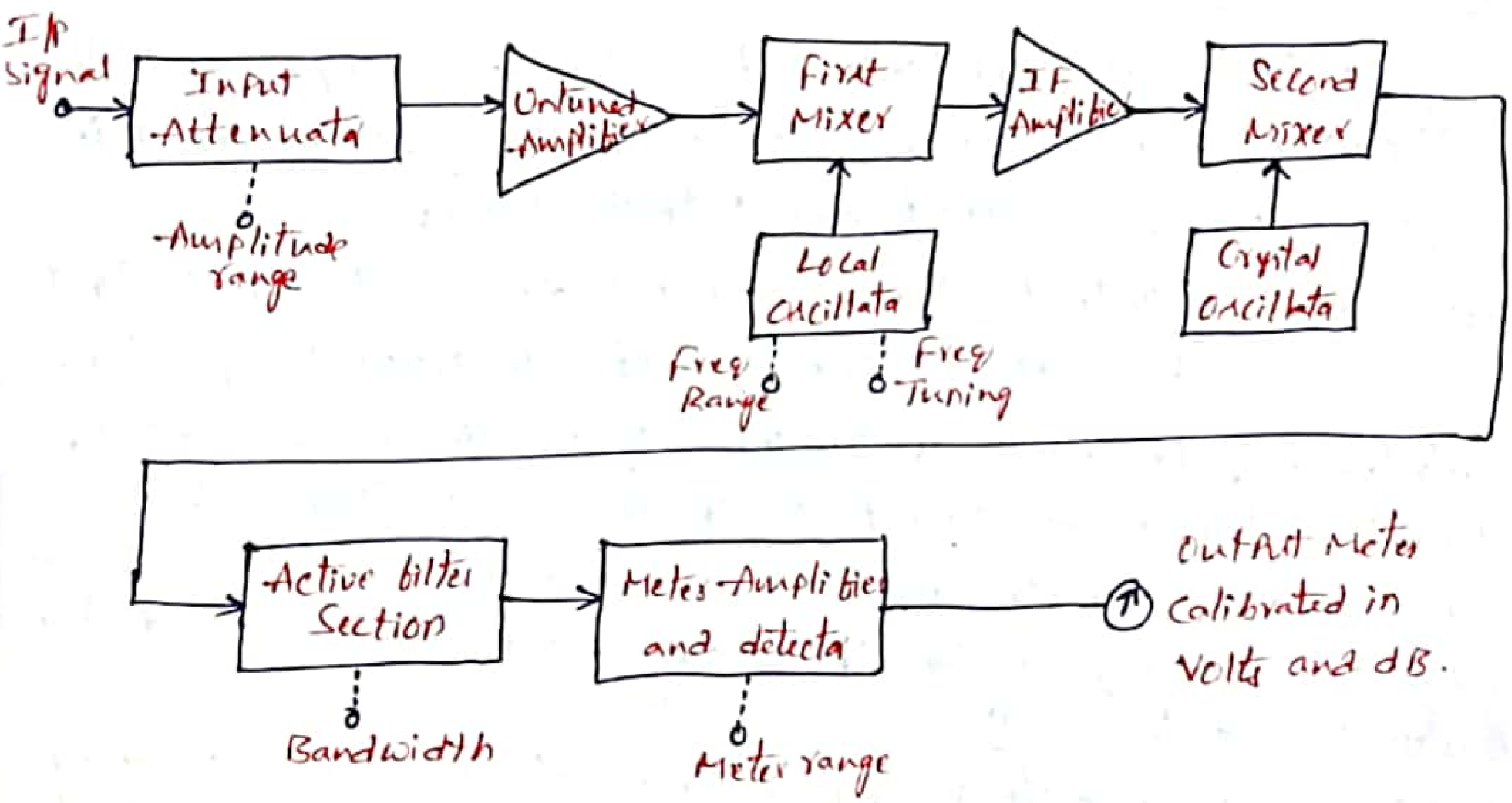

fig: Heterodyne Wave Analyzer.

→ This Instrument is Particularly Suited for higher frequencies.

→ The i/p Signal to be analyzed is heterodyned to a higher Intermediate frequency (IF) by an Internal Local Oscillator.

→ Tuning the local Oscillator Shifts the Various Signal frequency Components into the Passband of the IF amplifier.

→ The o/p of the IF amplifier is rectified and applied to the metering Circuit.

→ An Instrument that uses the Heterodyning principle is often called a "Heterodyning Tuned Voltmeter".

→ The operating frequency range of this instrument is from 10 KHz to 18 MHz.

→ The band width is controlled by an active filter and can be selected at 200, 1000 and 3000 Hz.

Applications:

1) In the field of electrical Measurements

2) Sound and Vibration Analysis.

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Harmonic Distortion Analyzers :-

Harmonic Distortion:-

→ In the ideal case, application of a Sinusoidal i/p Signal to an Electronic device, Such as an Amplifier should result in the generation of a sinusoidal output waveform.

→ However, the output waveform is not an exact replica of the i/p waveform because various types of distortion may arise.

→ Distortion may be result of the inherent non-Linear characteristics of the transistors in the circuit (or) of the circuit components.

→ Non Linear behaviour of circuit Elements introduces harmonics of the fundamental frequency in the o/p waveform. and the resultant distortion is often reffered to as "Harmonic Distortion".

→ A Measure of the distortion represented by a particular Harmonics is simply the ratio of the amplitude of the harmonic to that of the fundamental frequency Expressed as a percentage.

→ Harmonic Distortion is defined as

$$D_1 = \frac{B_1}{B_0}, \quad D_2 = \frac{B_2}{B_0}, \quad \ldots \ldots \quad D_n = \frac{B_n}{B_0}$$

where

D_n $(n = 1,2,3,4 \ldots)$ represents the distortion of the n^{th} Harmonic

B_n $(n = 1,2,3,4 \ldots)$ represents the Amplitude of the n^{th} Harmonic

B_0 = Amplitude of the fundamental Harmonic

→ The Total Harmonic distortion (or) Distortion factor is defined as

$$D = \sqrt{D_1^2 + D_2^2 + D_3^2 + \cdots}$$

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① Tuned Circuit Harmonic Analyzer:-

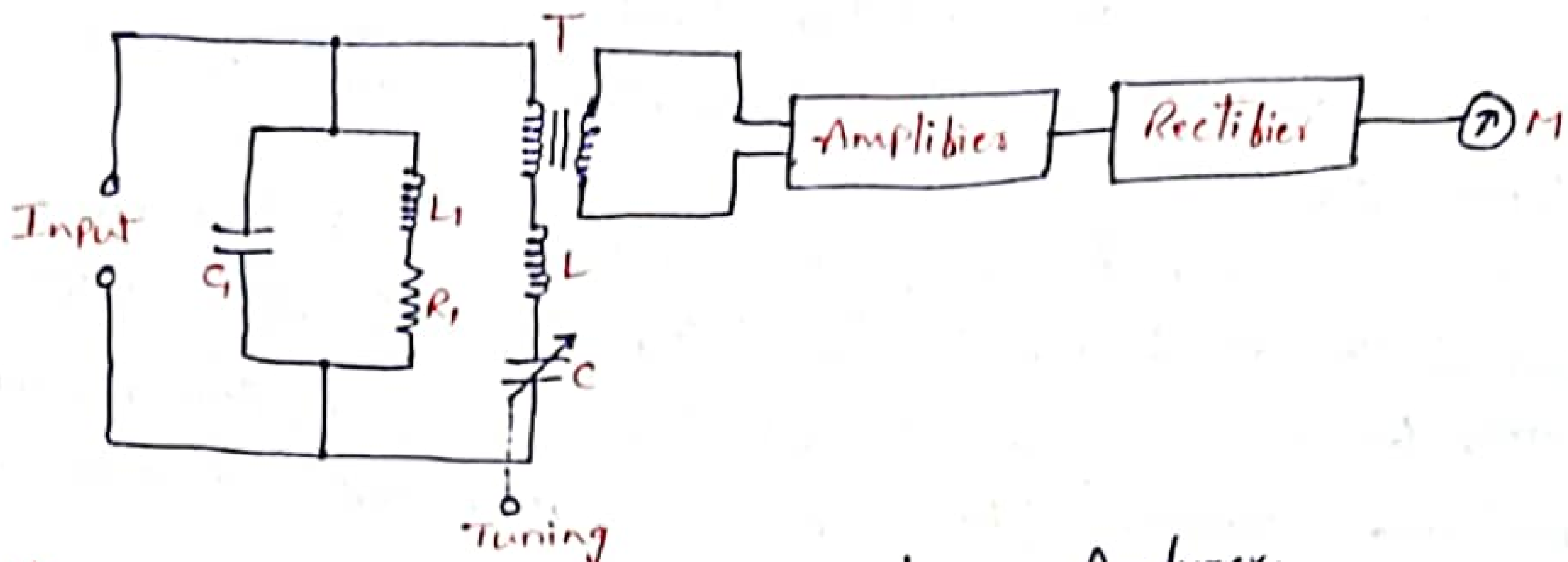


fig:- Tuned Circuit Harmonic Distortion Analyzer.

→ This is one of the oldest method of determining the harmonic content of a waveform uses a tuned circuit.

→ A series resonant circuit, consisting of inductor 'L' and capacitor 'C' is tuned to a specific harmonic frequency.

→ This harmonic component is transformer coupled to the input of an amplifier.

The output of the amplifier is rectified and applied to a meter circuit.

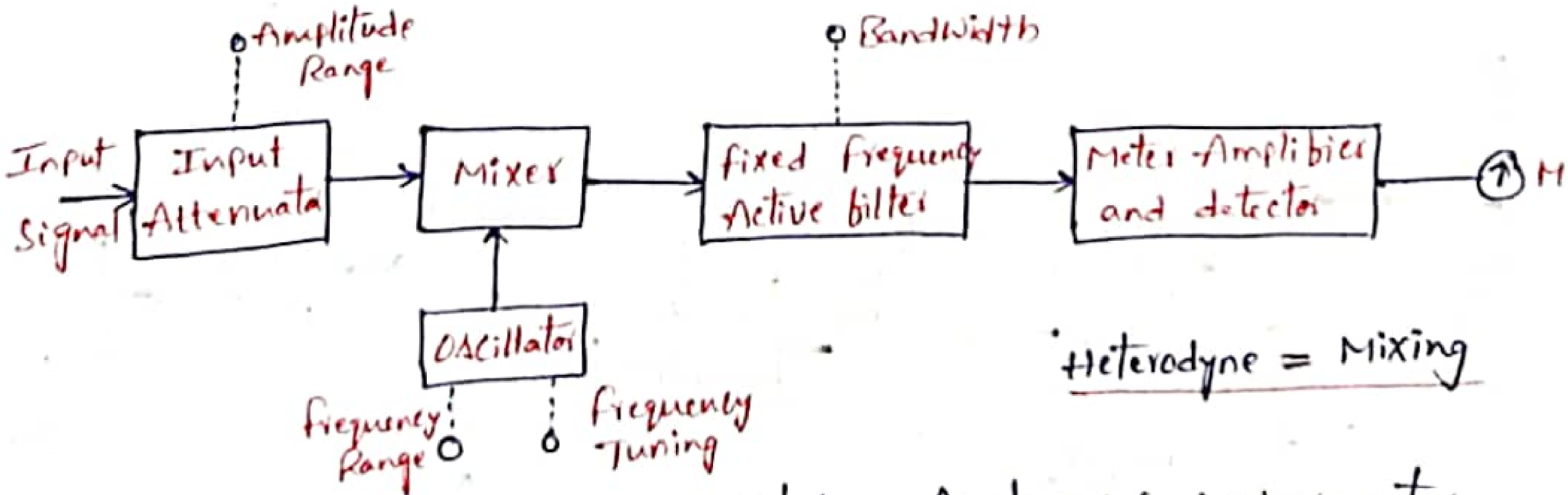
→ After a reading is obtained on the meter, the resonant circuit is returned to another harmonic frequency and the next reading is taken, and so on.....

→ The parallel resonant circuit consisting of L_1, R_1 and C_1 provides compensation for the variation in the ac resistance of the series resonant circuit and also for the variations in the amplifier gain over the frequency range of the instrument.

Application :-

→ To measure each harmonic component individually rather than to take a reading for the total harmonic distortion.

② Heterodyne Harmonic Distortion Analyzer (or) Wavemeter :-



Heterodyne = Mixing

fig:- Heterodyne Harmonic Distortion Analyzer (or) Wavemeter.

→ The difficulties of the tuned CKT are overcome in the Heterodyne analyzer by using a highly selective, fixed frequency active filter.

→ The O/P of a Variable frequency Oscillator is mixed with each harmonics of the input Signal.

→ Now, each harmonic frequency is Converted to a Constant frequency, it is possible to Use highly Selective filters of the Quartz - Crystal type.

→ With this technique, only the Constant frequency Signal Corresponding to the perticular Harmonic being Measured is passed and delivered to a Measuring Circuit.

→ The Mixer Usually Consists of a Balanced Modulator, Since it Eliminating the original frequency of the Harmonic

→ The low Harmonic distortion generated by the balanced Modulator is another advantage over different types of Mixers.

→ Excellent Selectivity is obtained by Using quartz-crystal filters (or) Inverse feed back filters.

→ On some heterodyne analyzers the meter reading is calibrated directly in terms of voltage.

→ These Instruments are Known as "frequency - Selective voltmeters".

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③ Fundamental - Suppression Harmonic Distortion Analyzer :-

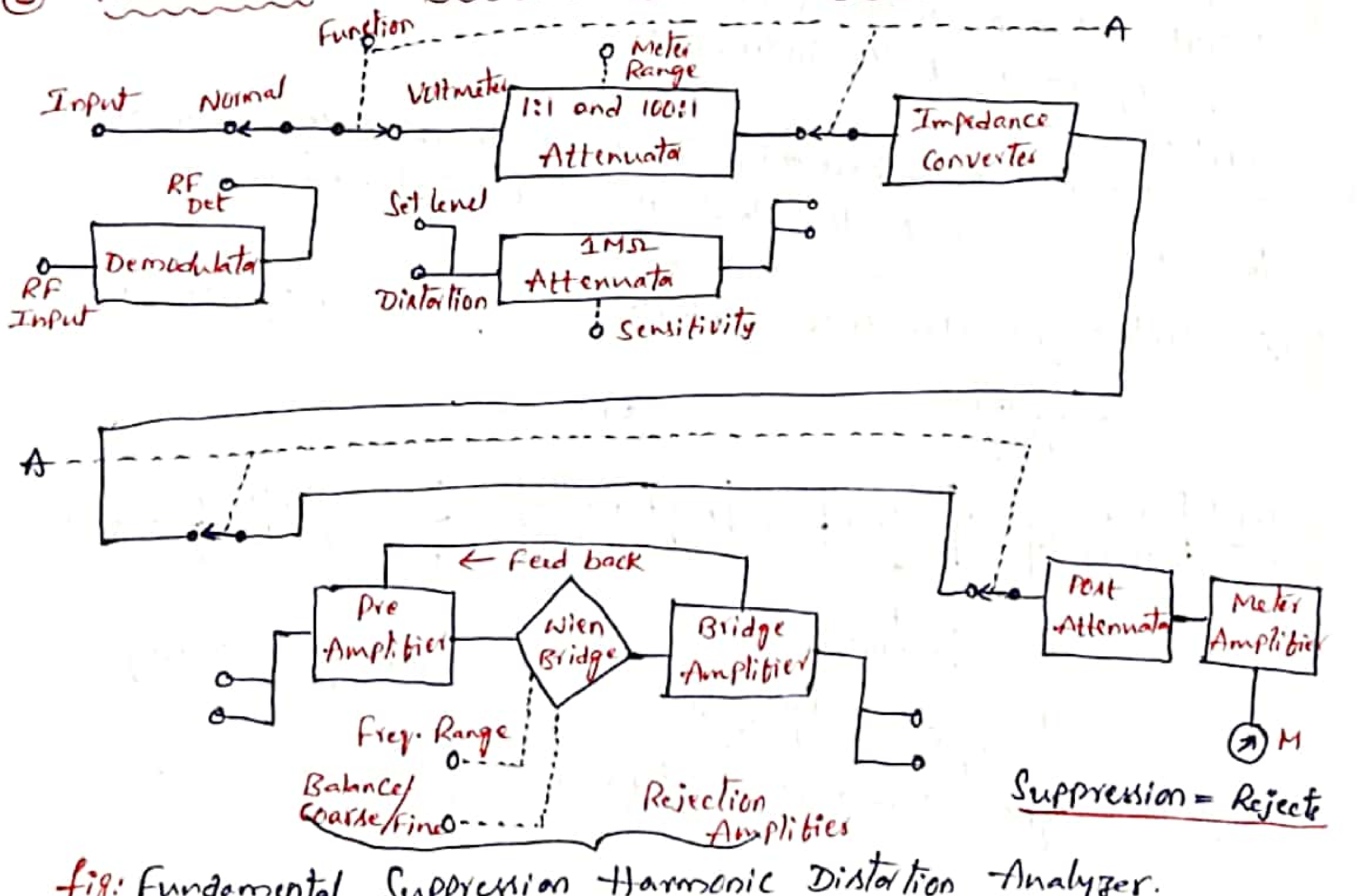

fig: Fundamental Suppression Harmonic Distortion Analyzer.

→ It is Used when it is important to Measure total Harmonic distortion (THD) rather than the distortion Caused by each Component.

→ In this Method the i/p waveform is applied to a network that Suppresses (or) Rejects the fundamental frequency, but Passes all the Harmonic frequency components.

→ In this instrument four Major Sections are there.

(1) The i/p Circuit with impedance Converter

(2) The Rejection Amplifier

(3) The Metering Circuit

(4) The Power Supply.

→ The Impedance Circuit provides a low-noise and high impedance

→ The Rejection Amplifier rejects the fundamental frequency of the i/p Signal and passes the remaining frequency Components on to the metering circuit.

→ The Metering Circuit Provides a Visual indication of total Harmonic distortion interms of a percentage of total i/p voltage.

→ Here two Modes of Operations are Possible.

① When the function Switch is in the Voltmeter Position, the instrument operates as a Conventional ac Voltmeter.

→ In this mode, the i/p Signal is applied to the impedance Converter circuit through the 1/1 and 100/1 attenuator, which selects the appropriate Meter range.

→ The o/p of the impedance Converter then by pass the rejection amplifier and the signal is applied directly to the Metering circuit.

→ This voltmeter Section Can be Used separatly for general Purpose voltage and gain.

② When the function Switch is in the distortion Position, the rejection amplifier becomes part of the Circuit and distortion measurements are Made.

→ In this mode the i/p Signal is applied to a 1MΩ i/p attenuator that Provides 50 dB attenuation.

→ When the desired attenuation is selected, the signal is fed to the impedance converter, which is a low-distortion, high input impedance amplifier circuit.

→ The rejection amplifier consists of a pre amplifier, a wien bridge, and a bridge amplifier.

(1) The pre amplifier receives the signal from the impedance converter and provides additional amplification at extremely low distortion levels.

(2) The wien bridge circuit is used as a rejection filter for the fundamental frequency of the i/p signal.

(3) The Bridge amplifier is tuned to the fundamental frequency of the i/p signal by setting the freq range selector and is balanced for zero o/p by the coarse and fine balance controls.

Advantages:

(1) The Harmonic distortion generated with in the instrument itself is very small and can be neglected.

(2) The selectivity requirements are not severe because only the fundamental frequency component must be suppressed.

Spectrum Analyzers:-

① Swept TRF Spectrum Analyzer:-

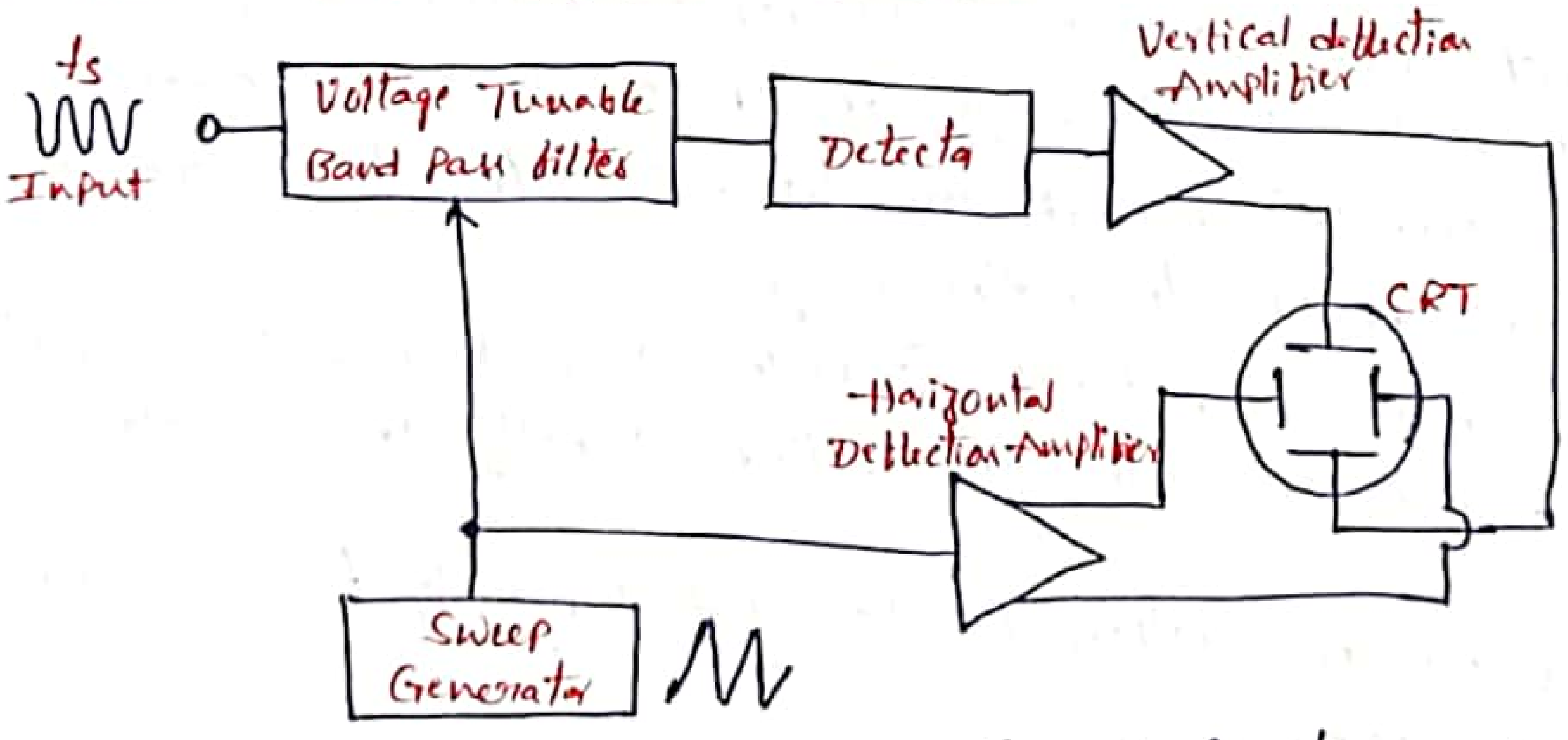

fig: Swept Tuned Radio frequency (TRF) Spectrum Analyzer.

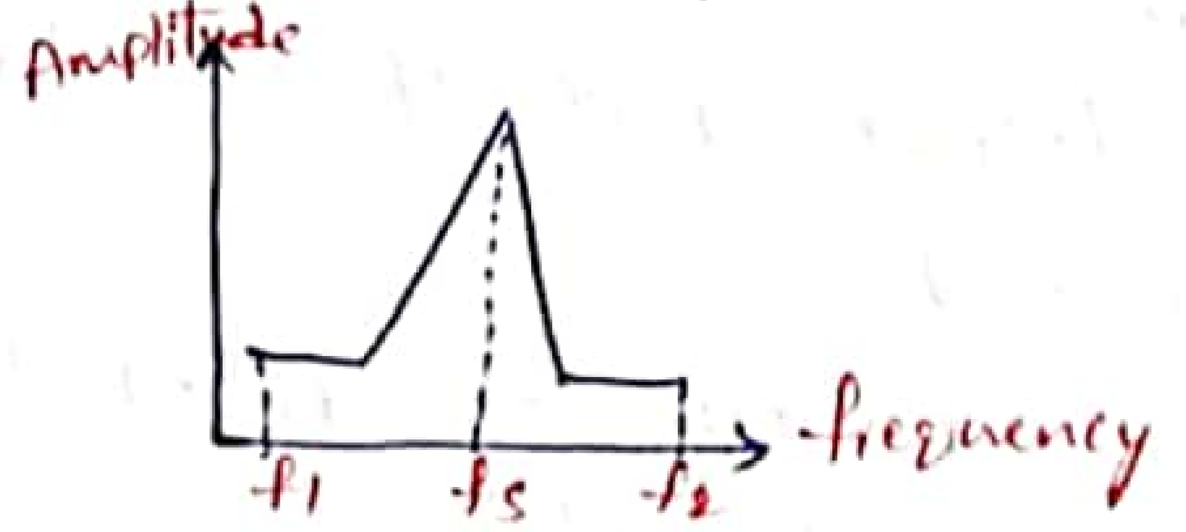

fig: Display Produced by a Single Input frequency.

→ A Spectrum Analyzer separates an ac signal into its various frequency components and displays each component as a vertical line on a CRT screen.

→ The amplitude of each vertical line in the display represents the amplitude of each frequency component and the horizontal position of each line defines the frequency.

→ A Sweep Generator produces a linear ramp, which provides horizontal deflection voltage for the CRT.

→ The Ramp is applied to a "Voltage Tunable band pass filter". This is a filter with a very narrow passband.

→ The Center frequency of the passband is swept from a Minimum frequency (f_1) to a Maximum frequency (f_2).

→ An i/p signal with a frequency 'f_s' would pass through the band pass filter only during the "Brief Time" that the filter pass band is tuned to 'f_s'.

→ Then the signal is converted to a dc voltage level by the detector and applied as an i/p to the vertical deflection amplifier of the CRT.

→ The Horizontal position of the vertical line is determined by the amplitude of the sweep generator ramp voltage at the instant 'f_s' is passing through the filter.

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② Swept Superheterodyne Spectrum Analyzer:-

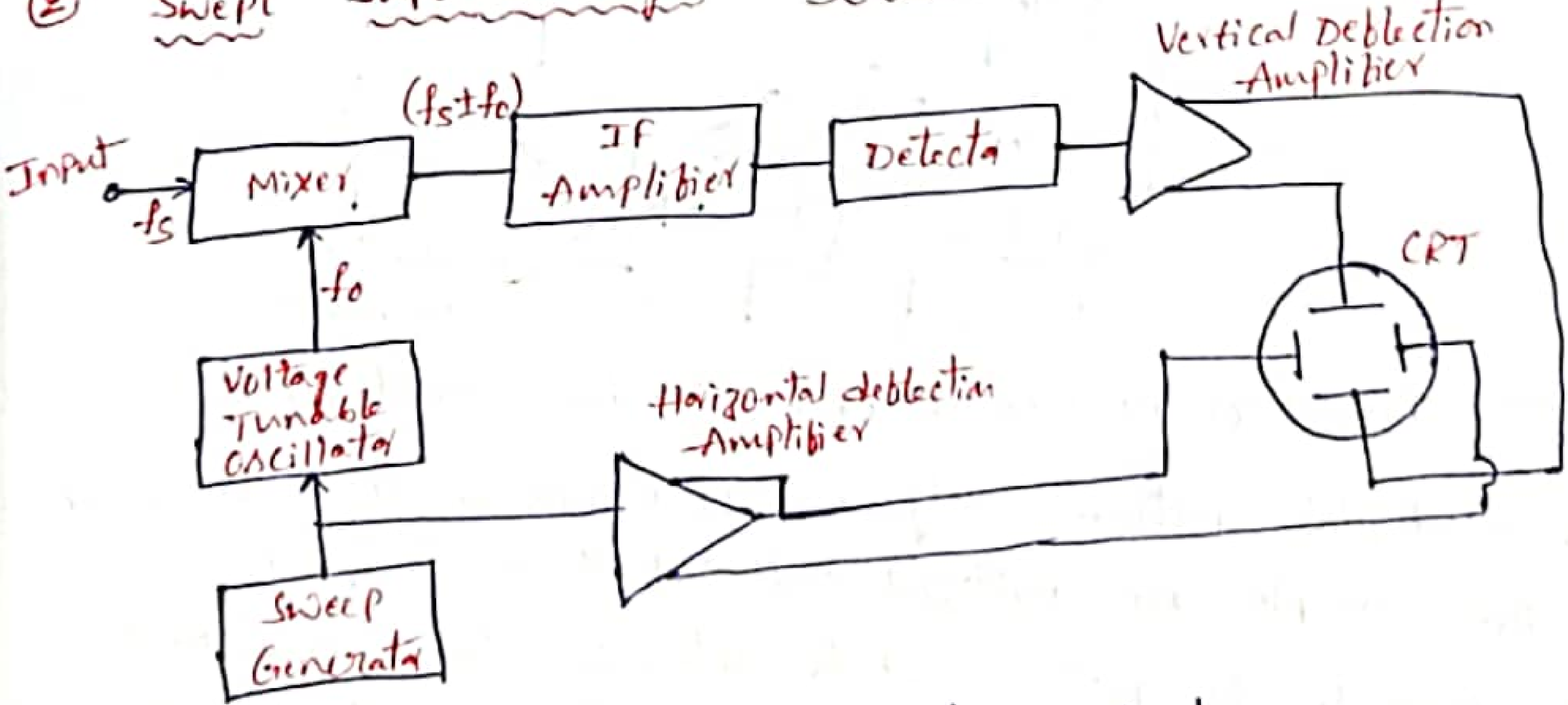

fig: Swept Superheterodyne Spectrum Analyzer.

→ The difference between Swept TRF & Swept Superheterodyne Spectrum analyzers are the voltage tunable band pass filter is replaced with a voltage tunable Oscillator (VTO), a freq. Mixer and an IF amplifier.

→ The ramp is applied to the VTO to produce a VTO o/p frequency that sweeps from a minimum (f_1) to a maximum (f_2).

→ The VTO o/p is applied to one i/p of the mixer, and the other i/p terminal receives the signal to be analyzed.

→ If the signal frequency is 'f_s', the VTO frequency is 'f_o', then the mixer o/p is the sum and difference of the two frequencies

$$\therefore \; f_m = (f_o \pm f_s)$$

→ These are applied to the IF amplifier, which passes and amplifies only one intermediate frequency.

Advantages:

1) The IF amplifier improves the instrument sensitivity.
2) The detector can give the better performance, since it has to operate at only one (IF) frequency.

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③ Digital Spectrum Analyzer:-

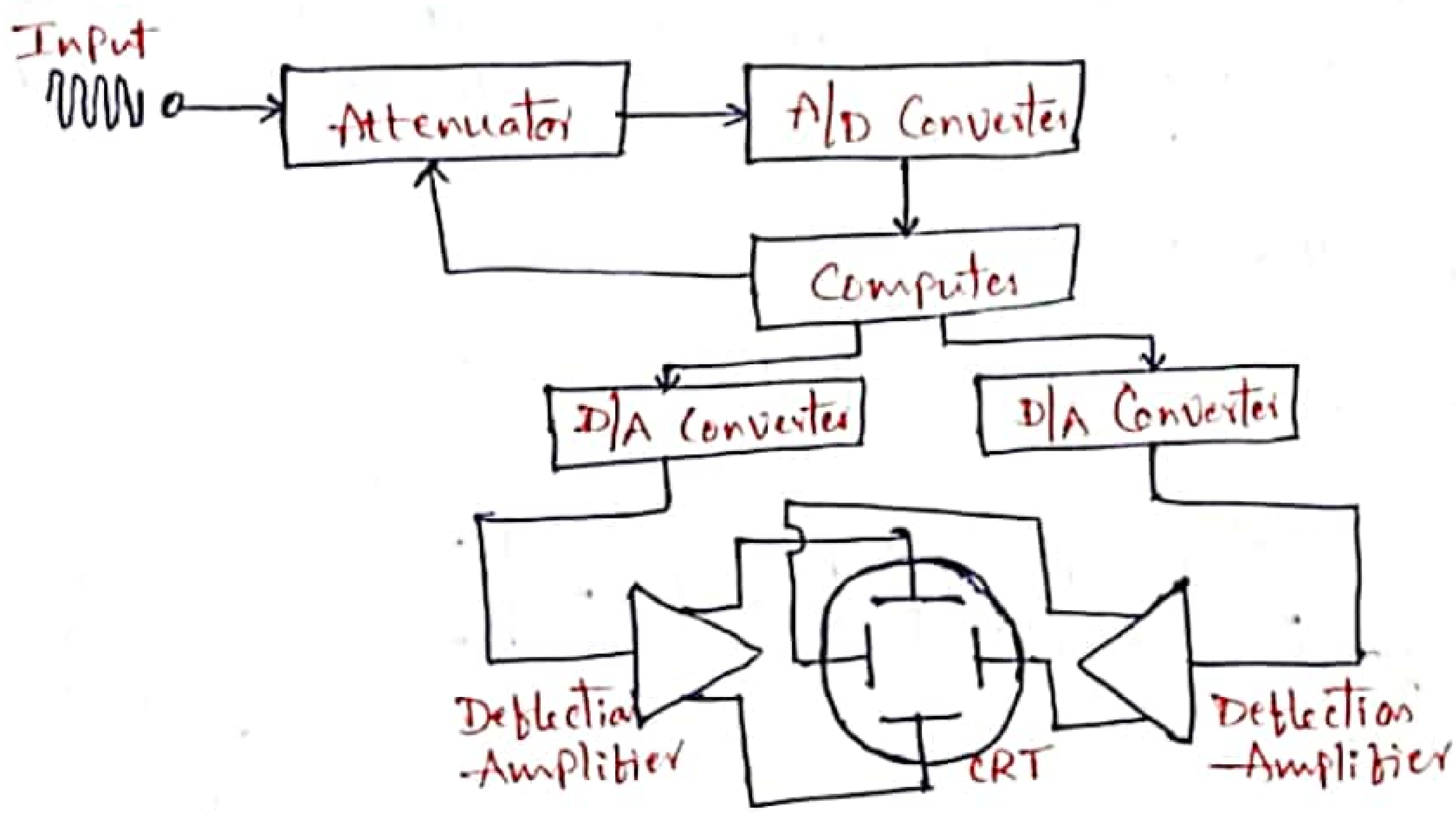

fig: Digital (or) Fourier (or) FFT Spectrum analyzer.

→ In a digital spectrum analyzer, the waveform to be sampled, and the samples are digitized and fed to a computer.

→ The computer is programmed to determine the waveform eq to calculate the component from the samples, and to analyze the eq to calculate the component waves.

→ The component waveforms are stored in the computer memory.

→ The computer can also access the peak values, rms values and phase of the waves.

→ The Sampling and Conversion techniques are Used in this digital spectrum analyzer.

→ The Algorithm Used by the computer in a digital spectrum analyzer is known as "Fast Fourier Transform" (FFT).

∴ This type of instrument is also known as "FFT Analyzers" (or) "Fourier Analyzers".

→ Digital spectrum analyzers measure all frequencies Simultaniously so they are able to investigate changing (or) dynamic waveforms. so they are also called as "Dynamic Signal Analyzers".

Applications:

1) These instruments can be employed for investigating the characteristics of audio amplifiers, filters and loud speakers.

2) Machinery Vibration analysis is a Major application of Fourier Analyzer.

Logic Analyzer:-

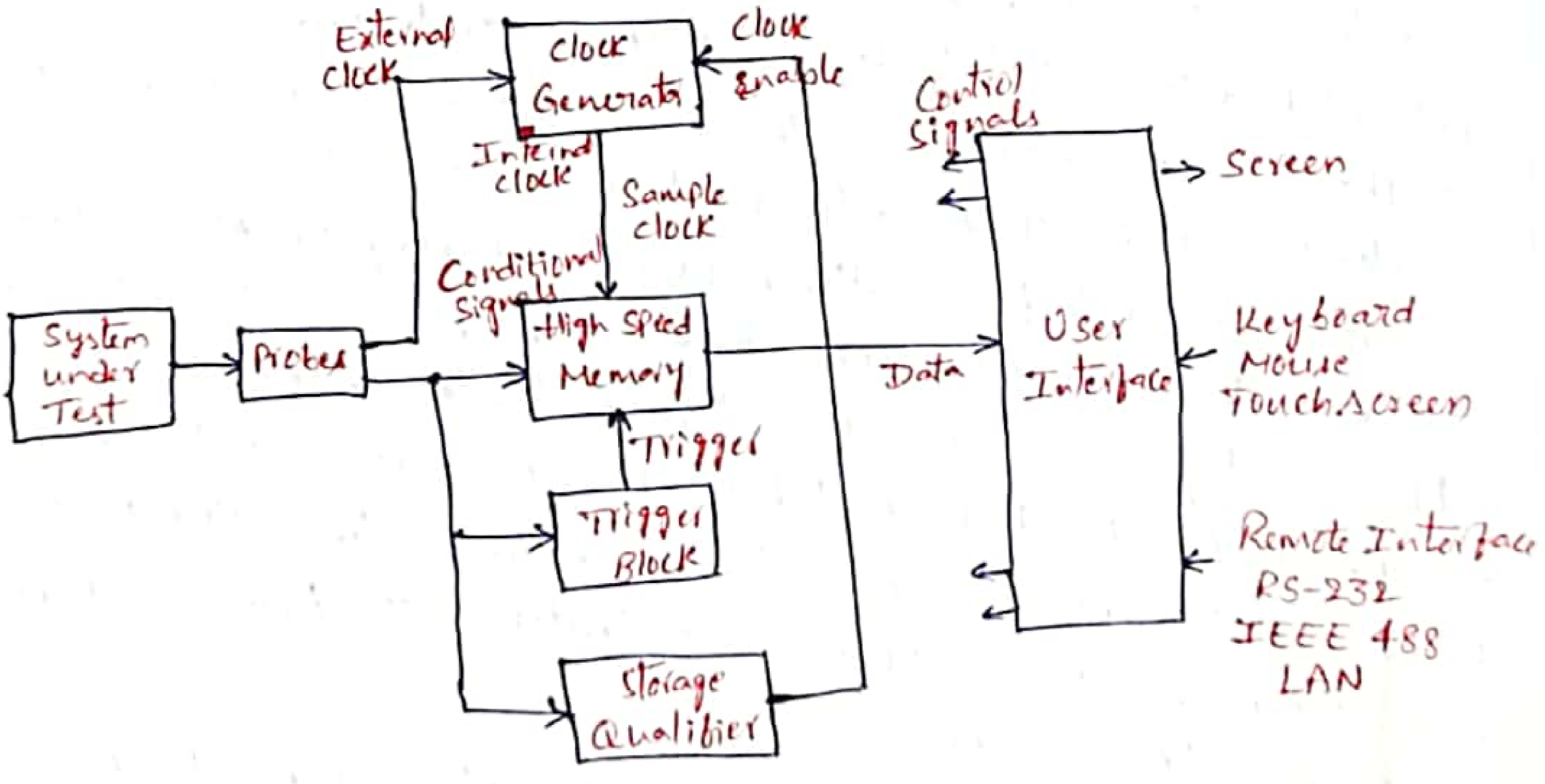

fig:- Logic Analyzer.

→ The logic Analyzer has basic Six functional blocks

1) Probes
2) High Speed Memory
3) clock generator
4) Trigger Block
5) storage qualifier
6) User Interface.

→ The probes. Connects physically the instruments to the system under test. The probes as voltage dividers, the lowest slew rate can be selected by dividing the input signal.

→ This helps in capturing high speed signals. The voltage comparators in probe, transform the input signals into logic values.

→ The logic Analyzers uses a high speed recording memory sub system which stores the sampled values. The memory address for a given sample is internally supplied.

→ The clock signal may be external clock (or) an internal asynchronous clock input depending up on the clock signals the input data is sampled and stored in memory.

→ The memory sub system continuously writes the data until the trigger signal is received from trigger block.

→ The Trigger block generates a trigger signal. The user can set the trigger word switches to set the required binary word.
i.e. pattern of logical ones & zeros.

→ The storage qualifier function is to determine which data samples are to be clocked into memory. The storage qualifier looks at the sampled data and tests it against a criterion.

→ The storage qualifier criterion is also a binary word. If the criterion is matched, data is stored in memory.

→ The User Interface allows user to display the measurements. It may be an oscilloscope which displays the data on the screen. the display device may be Liquid Crystal display.

→ The key board which is dedicated and screen are the part which users are to operate the instrument. apart from keyboard, mouse and screen users can operate the instrument from a computer or work station also.

→ The remote interface can be user's web browser it an instrument is web enabled.

Specifications:-

1) No. of channels : 68
2) Max. state clock speed : 200 MHz
3) Max. Timing clock speed : 400 MHz

4) Memory depth for logic state Analyzer : 256K state.

5) Memory depth for logic family Analyzer : 512 states.

6) Trigger Sequence levels : 16.

7) Input Voltage : $\pm$ 40V

8) Voltage Swing : 500 mV_{p-p}

9) Range of Voltage Threshold : −6V to +6V

Uses :-

1) Many digital designs, including those of IC's are Simulated to detect defects before the Unit is Contructed.

2) Often Complex discrete logic is Verified by Simulating inputs and Testing outputs using boundary scan.

3) Field Programmable gate array (FPGA) have become a Common measurement Point for logic Analyzers.

4) The logic Analyzers are Usually Provided With a series of personality Modules to reconfigure the equipment for a wide range of Microprocessors.

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BRIDGES

Wheatstone Bridge :-

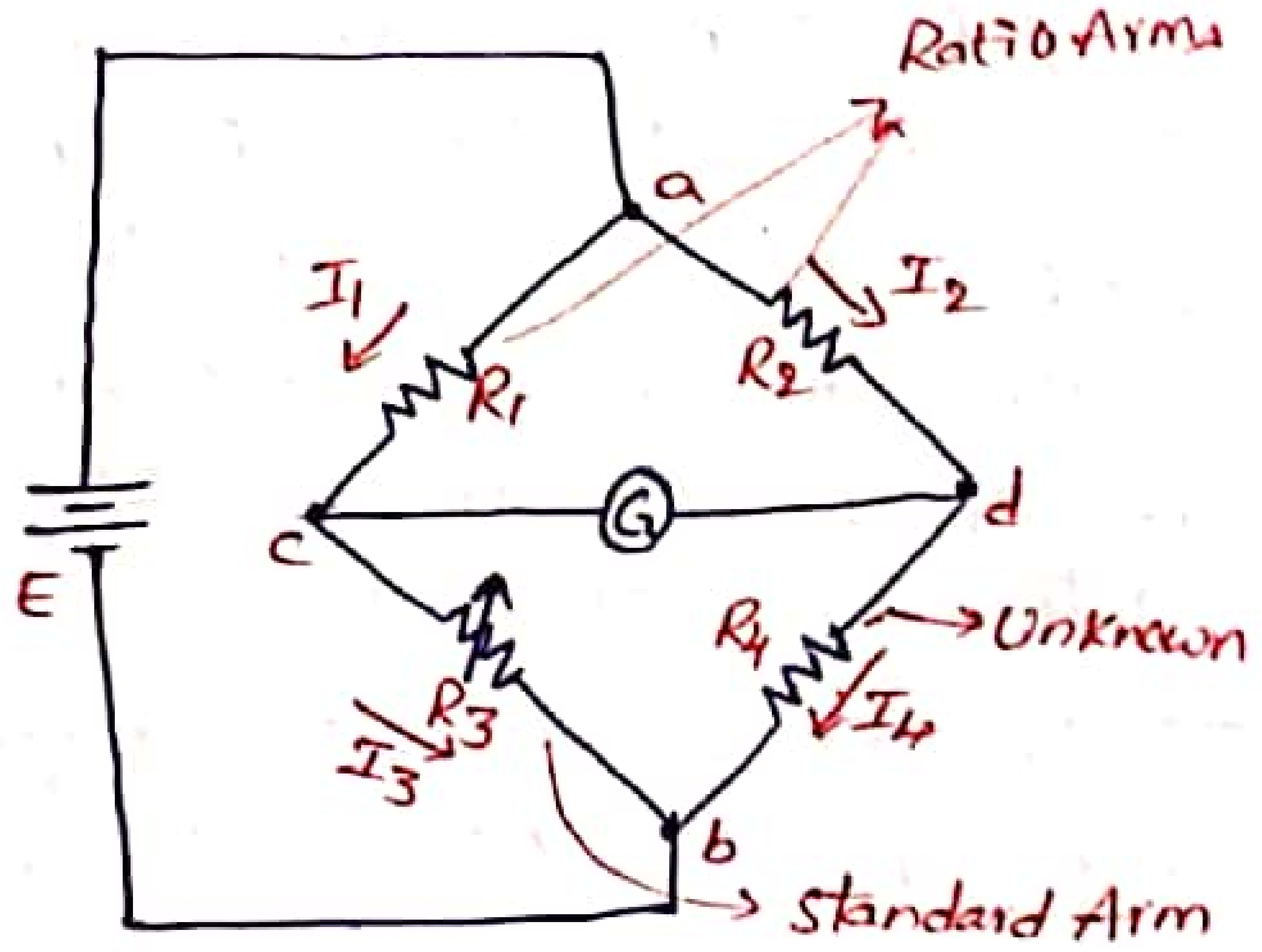

fig: Wheatstone Bridge

→ The Current through the galvanometer depends on the potential difference between points c & d.

→ The bridge is said to be balanced when the potential difference across the galvanometer is '0V', so that there is no Current through the galvanometer.

→ This Condition occurs when the Voltage from point 'c' to point 'a' equals the Voltage from point 'd' to point 'a' (or) by reffering to the other battery terminal, when the Voltage from point 'c' to point 'b' equals the Voltage from point 'd' to point 'b'.

∴ Hence the bridge is balanced when

$$I_1 R_1 = I_2 R_2 \longrightarrow (1)$$

→ If the galvanometer Current is zero, the fallowing Conditions Exist

$$I_1 = I_3 = \frac{E}{R_1 + R_3} \longrightarrow (2)$$

and $$I_2 = I_4 = \frac{E}{R_2 + R_4} \longrightarrow (3)$$

Sub. Eq (2) & Eq (3) in Eq (1)

$$\left(\frac{R_1}{R_1+R_3}\right)\cancel{E} = \left(\frac{R_2}{R_2+R_4}\right)\cancel{E}$$

$$R_1 \cancel{R_2} + R_1 R_4 = \cancel{R_1 R_2} + R_2 R_3$$

$$\boxed{R_1 R_4 = R_2 R_3} \longrightarrow (4)$$

→ If 'R_4' is the unknown resistor its resistance 'R_x' Can be expressed interms of the remaining resistors as fallows.

$$\boxed{R_x = \frac{R_2 R_3}{R_1}}$$

→ Here 'R_3' is called as Standard Arm of the bridge. R_1 & R_2 are called as Ratio Arms of the bridge.

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Wien Bridge :- (Measurement of frequency)

→ The wien bridge is presented here not only for its use as an 'ac' bridge to measure 'frequency' but also for its application in various other useful circuits.

→ The wien bridge also finds application in audio and HF oscillators as the freq determining element.

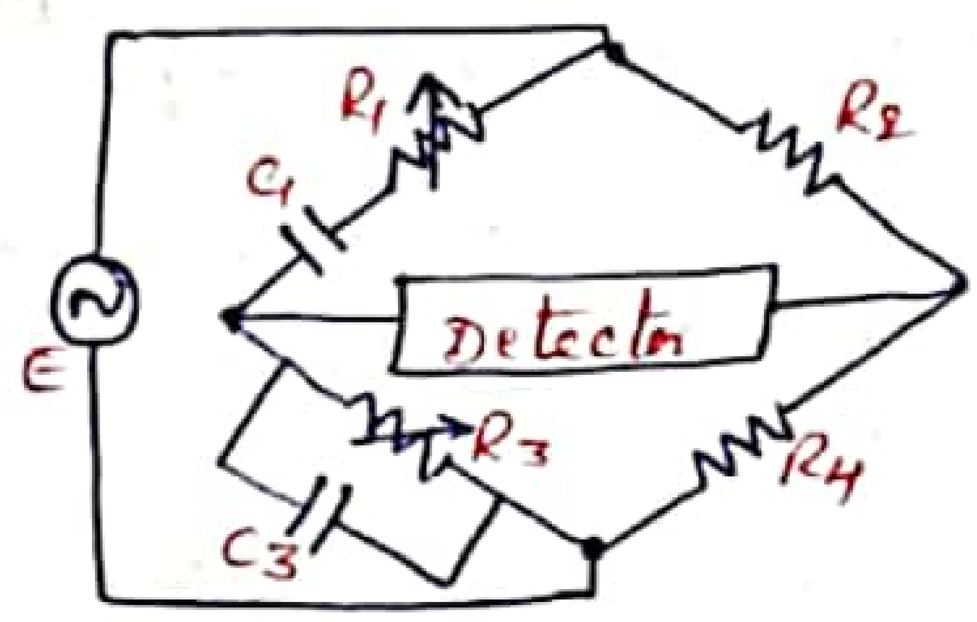


fig: Wien Bridge

→ In this figure wien bridge has a series RC combination in one arm, and a parallel RC combinations in the adjoining arm.

→ The Impedance of arm 1 is $Z_1 = R_1 - \frac{j}{\omega C_1}$ → ①

→ The Admittance of Arm 3 is $Y_3 = \frac{1}{R_3} + j\omega C_3$ → ②

→ The Impedance of arm 2 is $Z_2 = R_2$ → ③

→ The Impedance of Arm 4 is $Z_4 = R_4$ → ④

→ Using the basic eq for bridge balance and substituting appropriate values to obtain

$$Z_1 Z_4 = Z_2 Z_3$$

$$Z_2 = \frac{Z_1 Z_4}{Z_3} = Z_1 Z_4 \cdot Y_3$$

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

$$R_2 = \frac{R_1 R_4}{R_3} + j\omega C_3 R_1 R_4 - \frac{jR_4}{\omega C_1 R_3} + \frac{R_4 C_3}{C_1} \rightarrow ⑤$$

By equating real terms in eq ⑤

$$R_2 = \frac{R_1 R_4}{R_3} + \frac{R_4 C_3}{C_1}$$

$$\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1} \rightarrow ⑥$$

By equating imaginary terms in eq ⑤

$$\omega C_3 R_1 R_4 - \frac{R_4}{\omega C_1 R_3} = 0 \rightarrow ⑦$$

$$\omega C_3 R_1 \cancel{R_4} = \frac{\cancel{R_4}}{\omega C_1 R_3}$$

Here $\omega = 2\pi f$

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

$$(2\pi f)^2 = \frac{1}{C_1 C_3 R_1 R_3}$$

$$\therefore \boxed{f = \frac{1}{2\pi\sqrt{C_1 C_3 R_1 R_3}}} \rightarrow (8)$$

→ In most wien bridge circuits, the components are chosen such that $R_1 = R_3$ and $C_1 = C_3$

Then Eq (6) is $\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1} = 1+1 = 2$

Eq (8) is $\boxed{f = \frac{1}{2\pi RC}} \rightarrow (9)$

→ This is the general Eq for the frequency of the wien bridge.

---x---

Errors and Precautions in using bridges:-

Sources of Errors:

→ The Idealized arrangement work failures if (1) frequency is low
(2) Component Impedance is not high
(3) Accuracy desired is not high

→ Stray couplings cause to fauke bridge balance.

Factors Causing Errors:

→ Stray Conductive Effects due to imperfect insulation.

→ Mutual inductance Effects due to magnetic coupling between various components of the bridge.

→ Stray Capacitance Effects due to electric fields b/w conductors at different potentials.

→ Residues.

Precautions & Techniques Used for reducing Errors:-

→ Use of high Quality Components.

→ Bridge layout must be proper.

→ Sensitivity must be Sufficiant in bridge Circuits.

→ Stray Conductance effects may be reduced by mounting the Components on insulating stands.

→ Eddy Current Errors are reduced by avoiding large Conducting masses near the bridge Network.

→ Residual Errors are Eliminating by determining their values.

→ Frequency and waveform Errors are reduced by using wave filters.

———— x ————

Maxwell's Bridge: (Measurement of Inductance)

→ These Maxwell's bridge measures an Unknown inductance interms of a Known Capacitor.

→ The Capacitor is almost a loss less Component.

→ One arm has a resistance 'R_1' in parallel with 'C_1' and hence it is easier to write the balance Eq using the admittance of arm 1. instead of the impedance.

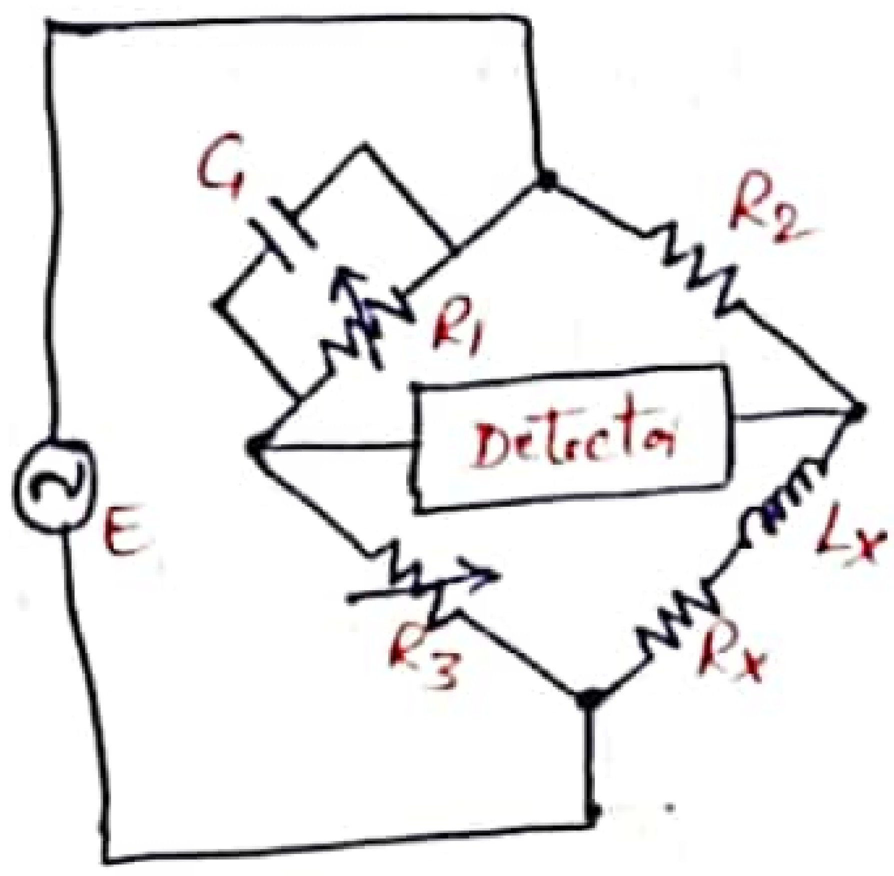


fig: Maxwell's Bridge

→ The general Eq for bridge balance is

$$Z_1 Z_x = Z_2 Z_3$$

$$Z_x = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 \cdot Y_1 \rightarrow ①$$

Here $Y_1 = \frac{1}{R_1} + j\omega C_1$

$Z_2 = R_2$

$Z_3 = R_3$

$Z_x = R_x + j\omega L_x$

Sub. in Eq ①

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

$$R_x + j\omega L_x = \frac{R_2 R_3}{R_1} + j\omega C_1 R_2 R_3 \rightarrow ②$$

by equating real & imaginary terms

$$R_x = \frac{R_2 R_3}{R_1} \qquad L_x = C_1 R_2 R_3$$

→ Maxwells bridge is limited to the measurement of low 'Q' values

→ This measurement is independent of the excitation frequency.

———— x ————

Anderson's Bridge: (Measurement of Inductance)

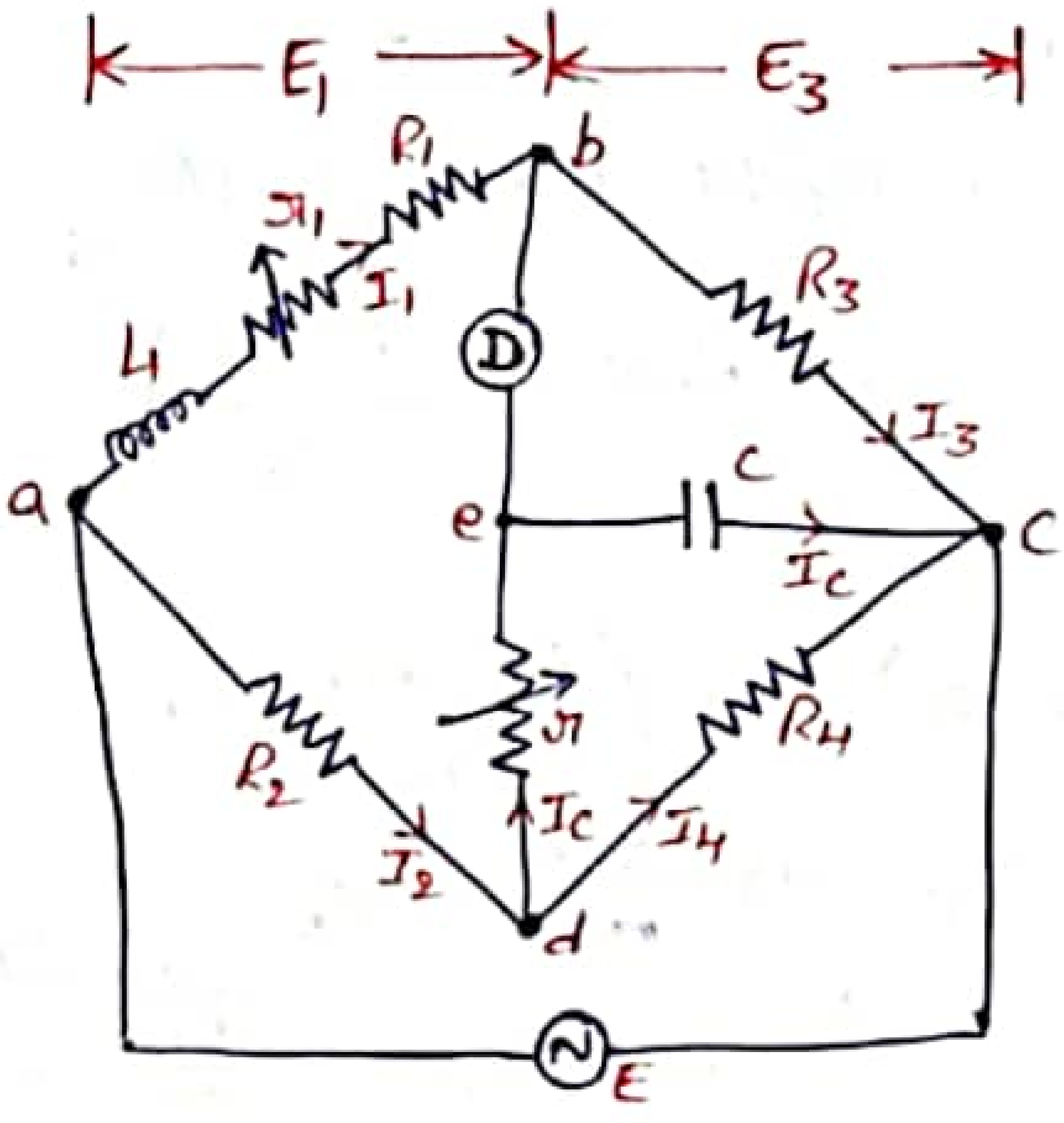


fig: Anderson's bridge.

→ This bridge is a Modification of the Maxwell's bridge.

→ In this Method inductance is Measured interms of a standard Capacitance.

→ This Method is applicable for Precise Measurement of 'L' over a wide range of Values.

→ At Balance Condition,

$$I_1 = I_3 \quad \text{and} \quad I_2 = I_c + I_4 \longrightarrow (1)$$

$$\rightarrow I_3 R_3 = I_c \times \left(\frac{1}{j\omega C}\right)$$

$$I_1 R_3 = \frac{I_c}{j\omega C}$$

$$\therefore I_c = I_1 j\omega C R_3 \longrightarrow (2)$$

→ Other Balance Conditions are.

for Δabd $$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_c \cdot r \longrightarrow (3)$$

for Δcde $$I_c\left(r + \frac{1}{j\omega C}\right) = I_4 \cdot R_4 \longrightarrow (4)$$

from Eq (1) $I_4 = I_2 - I_c$.

$$I_c\left(r + \frac{1}{j\omega C}\right) = (I_2 - I_c) R_4 \longrightarrow (5)$$

Sub. Eq (2) in Eq (3)

$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_1 j\omega C R_3 \cdot r.$$

$$I_1(r_1 + R_1 + j\omega L_1 - j\omega C R_3 r) = I_2 R_2 \longrightarrow (6)$$

Sub. Eq (2) in Eq (5)

$$(I_1 j\omega C R_3)\left(r + \frac{1}{j\omega C}\right) = (I_2 - I_1 j\omega C R_3) R_4$$

$$I_1(j\omega C R_3 r + j\omega C R_3 R_4 + R_3) = I_2 R_4 \longrightarrow (7)$$

Multiply 'R_2' on both sides

$$R_2 I_1 (j\omega C R_3 r + j\omega C R_3 R_4 + R_3) = (I_2 R_4) R_2$$

$$I_1\left(\frac{j\omega C R_2 R_3 r}{R_4} + j\omega C R_2 R_3 + \frac{R_2 R_3}{R_4}\right) = I_2 R_2 \longrightarrow (8)$$

Equate eq (6) & eq (8)

$$I_1(r_1 + R_1 + j\omega L_1 - j\omega C R_3 r) = I_1\left(\frac{j\omega C R_2 R_3 r}{R_4} + j\omega C R_2 R_3 + \frac{R_2 R_3}{R_4}\right)$$

→ by equating real & imaginary terms

(real terms) $r_1 + R_1 = \frac{R_2 R_3}{R_4}$

$\therefore R_1 = \frac{R_2 R_3}{R_4} - r_1$

Assume $R_1 + r_1 = R_x$ (Unknown)

$R_1 + r_1 = \frac{R_2 R_3}{R_4}$

$$\boxed{R_x = \frac{R_2 R_3}{R_4}}$$

(Imaginary terms)

$L_1 - C R_3 r = \frac{C R_2 R_3 r}{R_4} + C R_2 R_3$

$L_1 = \frac{C R_2 R_3 r}{R_4} + C R_2 R_3 + C R_3 r$

$L_1 = \frac{C R_3}{R_4}[r R_2 + R_2 R_4 + r R_4]$

$L_1 = \frac{C R_3}{R_4}[r(R_2 + R_4) + R_2 R_4]$

Here $L_1 = L_x$ (Unknown)

$$\boxed{L_x = \frac{C R_3}{R_4}[r(R_2 + R_4) + R_2 R_4]}$$

Schearing's Bridge :- (Measurement of Capacitance)

→ A very important bridge used for the precision measurement of capacitor and their insulating properties is the "Schering's Bridge".

→ The standard capacitor 'C_3' is a high quality mica capacitor (Low-loss) for general measurements (or) an Air Capacitor for insulation measurements.

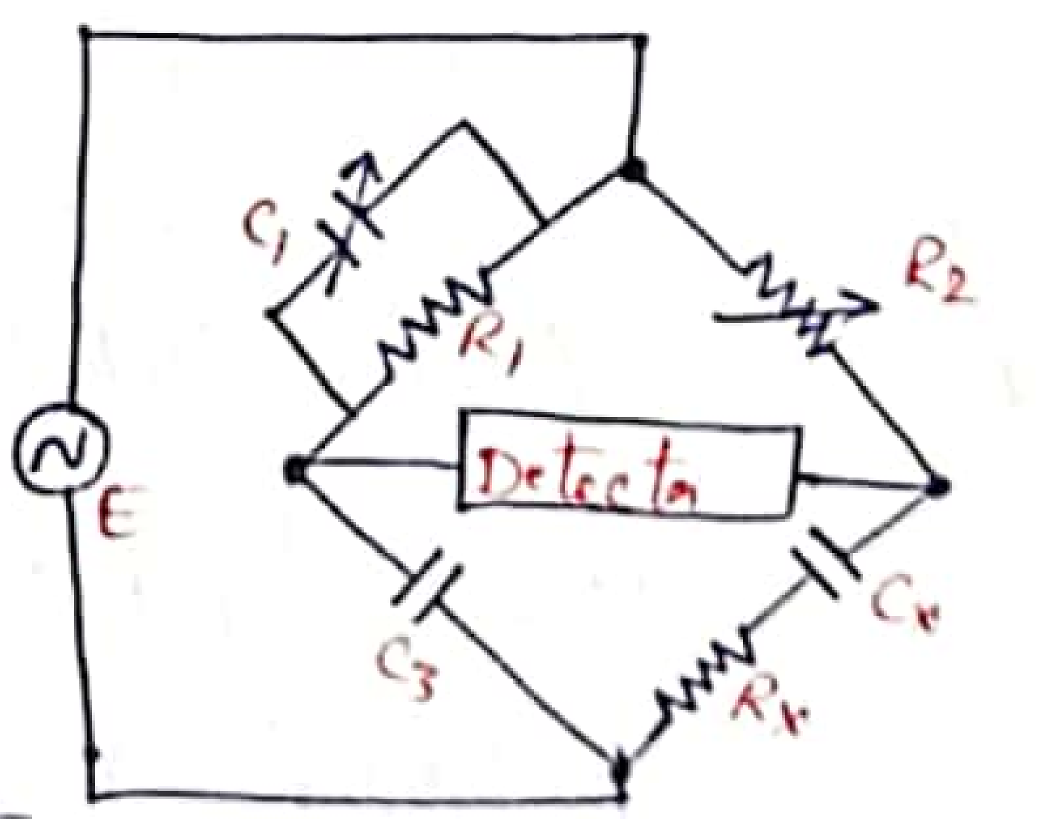


fig: Schering's Bridge

→ Under bridge Balanced Condition.

$$Z_1 Z_x = Z_2 Z_3$$

$$Z_x = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 Y_1 \longrightarrow (1)$$

Here $Z_x = R_x - \frac{j}{\omega C_x}$

$Z_2 = R_2$

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

$Y_1 = \frac{1}{R_1} + j\omega C_1$

Sub. in Eq ①

$$\left(R_x - \frac{j}{\omega C_x}\right) = (R_2)\left(\frac{-j}{\omega C_3}\right)\left(\frac{1}{R_1} + j\omega C_1\right)$$

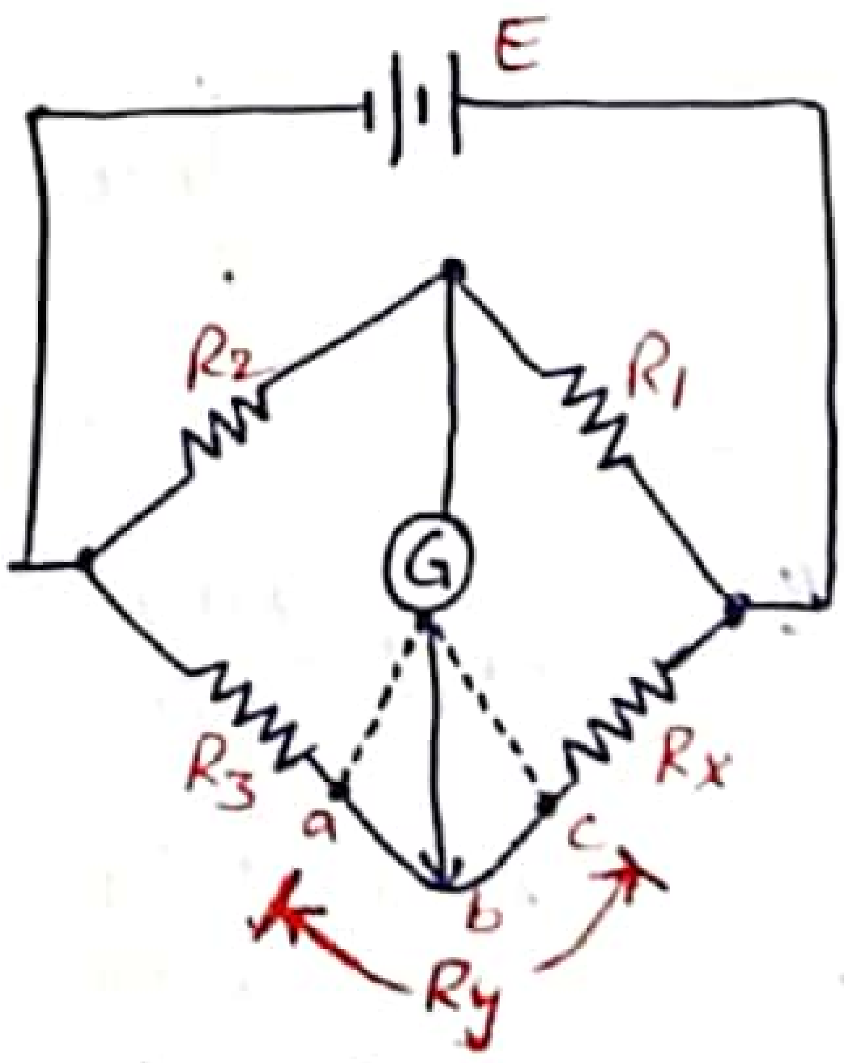
$$R_x - \frac{j}{\omega C_x} = \frac{(-j)R_2}{\omega R_1 C_3} + \frac{R_2 C_1}{C_3}$$

by equating real & imaginary terms

Real terms : $\boxed{R_x = \frac{R_2 C_1}{C_3}}$

Imaginary terms : $\boxed{C_x = \frac{R_1 C_3}{R_2}}$

Kelvin's Bridge :-



→ Kelvin's bridge is a Modification of wheatstone's bridge and is Used to Measure Values of resistance below 1Ω.

→ In fig 'R_y' represents the resistance of the Connecting leads from R_3 to R_x.

→ The Galvanometer Can be Connected to either to Point 'a' (or) point 'c'.

→ when it is Connected to point 'a', the resistance 'R_y' of the Connecting lead is added to the UnKnown resistance 'R_x'.

→ when it is Connected to Point 'c', 'R_y' is added to 'R_3'.

→ If the galvanometer is Connected to Point 'b' in between points 'c' and 'a', in such a way that the ratio of the resistance from 'c' to 'b' and that from 'a' to 'b' equals the ratio of resistances R_1 and R_2 then, $R_{cb} \cdot R_2 = R_{ab} \cdot R_1$

$$\therefore \frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2} \longrightarrow ①$$

→ The usual balance eq for the bridge give the relationship.

$$(R_x + R_{cb}) R_2 = (R_3 + R_{ab}) R_1 \longrightarrow (2)$$

from eq (1) $\frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2}$

$$\frac{R_{cb}}{R_{ab}} + 1 = \frac{R_1}{R_2} + 1$$

$$\frac{R_{cb} + R_{ab}}{R_{ab}} = \frac{R_1 + R_2}{R_2}$$

we know $R_{cb} + R_{ab} = R_y$

$$\therefore \frac{R_y}{R_{ab}} = \frac{R_1 + R_2}{R_2}$$

$$\therefore \boxed{R_{ab} = \frac{R_2 R_y}{R_1 + R_2}} \longrightarrow (3)$$

→ we know $R_{cb} + R_{ab} = R_y$

$$R_{cb} = R_y - R_{ab} = R_y - \frac{R_2 R_y}{R_1 + R_2}$$

$$R_{cb} = \frac{R_1 R_y + R_2 R_y - R_2 R_y}{R_1 + R_2}$$

$$\therefore \boxed{R_{cb} = \frac{R_1 R_y}{R_1 + R_2}} \longrightarrow (4)$$

Sub. eq (3) & (4) in eq (2)

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1}{R_2}\left(R_3 + \frac{R_2 R_y}{R_1 + R_2}\right)$$

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1 R_3}{R_2} + \frac{R_1 R_2 R_y}{R_2 (R_1 + R_2)}$$

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1 R_3}{R_2} + \frac{R_1 R_y}{R_1 + R_2}$$

$$\therefore \boxed{R_x = \frac{R_1 R_3}{R_2}}$$

———— x ————

Q-Meter:-

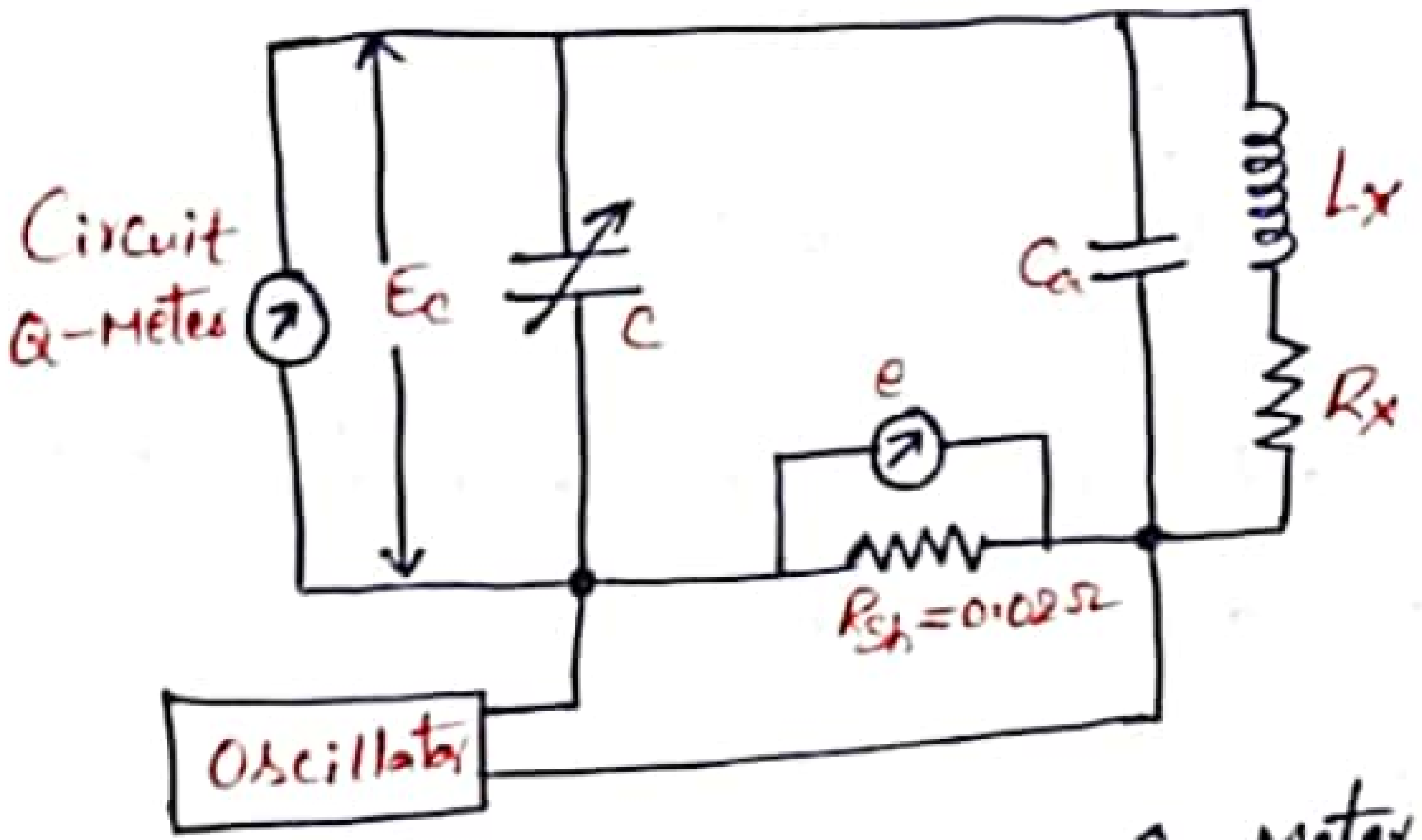


fig: Circuit diagram of a Q-Meter.

→ The Q-Meter is an instrument designed to Measure some electrical properties of coils and Capacitors.

→ The Principle of the Q-Meter is based on Series resonance, the voltage drop across the coil (or) capacitor is Q-times the applied voltage. (where Q is the ratio of reactance to resistance, $\frac{X_L}{R}$)

→ If a fixed voltage is applied to the circuit, a voltmeter across the capacitor can be calibrated to read 'Q' directly.

→ At Resonance $X_L = X_C$ and

$$E_L = I X_L$$
$$E_C = I X_C$$
$$E = IR$$

where

E = applied voltage
E_C = Capacitor voltage
E_L = Inductive voltage

X_L = Inductive reactance.
X_C = Capacitive reactance.
R = coil resistance.
I = circuit current.

$$\therefore Q = \frac{X_L}{R} = \frac{X_C}{R} = \frac{E_C}{E}$$

→ from this eq, if 'E' is kept constant the voltage across the capacitor can be measured by a voltmeter calibrated to read directly in terms of 'Q'.

→ The wide range oscillator, with frequency range from 50KHz to 50MHz delivers current to a resistance R_{sh} having a value of 0.02Ω

→ The circuit is tuned to resonance by varying 'c' until the electronic voltmeter reads the maximum value.

→ The resonance o/p voltage 'E' corresponding to 'Ec' is

$$E = Q \times e$$

i.e. $$Q = \frac{E}{e}$$

→ Since 'e' is known, the electronic voltmeter can be calibrated to read 'Q' directly.

→ The inductance of the coil can be calculated from known values of the coil frequency and resonating capacitor (C).

$X_L = X_C$

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

(or)

$$L = \frac{1}{(2\pi f)^2 C}$$

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(1) Factors that may cause error :-

① → At high frequencies the electronic voltmeters may suffer from losses due to the transit time effect.

→ The effect of 'R_{sh}' is to introduce an additional resistance in the circuit.

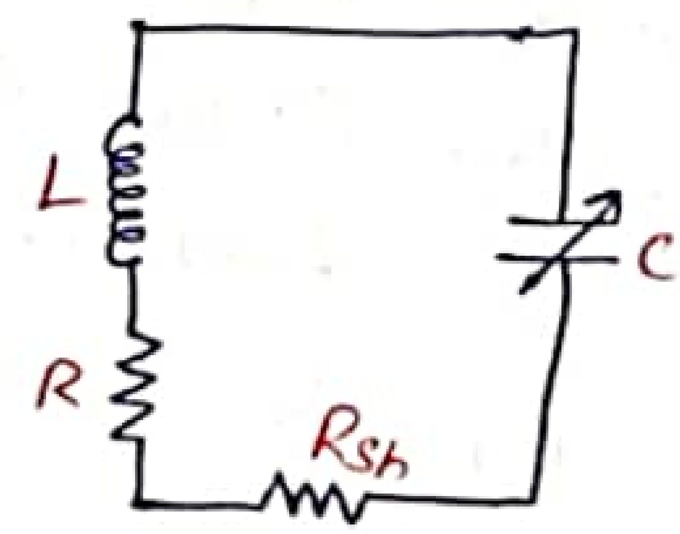

fig: Effect of 'R_{sh}' on 'Q'.

$$Q_{act} = \frac{WL}{R} \quad \text{and} \quad Q_{obs} = \frac{WL}{R+R_{sh}}$$

here Q_{act} = actual 'Q'
Q_{obs} = observed 'Q'.

$$\therefore \frac{Q_{act}}{Q_{obs}} = \frac{R+R_{sh}}{R} = 1 + \frac{R_{sh}}{R}$$

$$\therefore Q_{act} = Q_{obs}\left(1 + \frac{R_{sh}}{R}\right)$$

→ To make the Q_{obs} value as close as possible to Q_{act} ; R_{sh} should be made as small as possible. An R_{sh} value of 0.02 to 0.04 Ω introduces negligible error.

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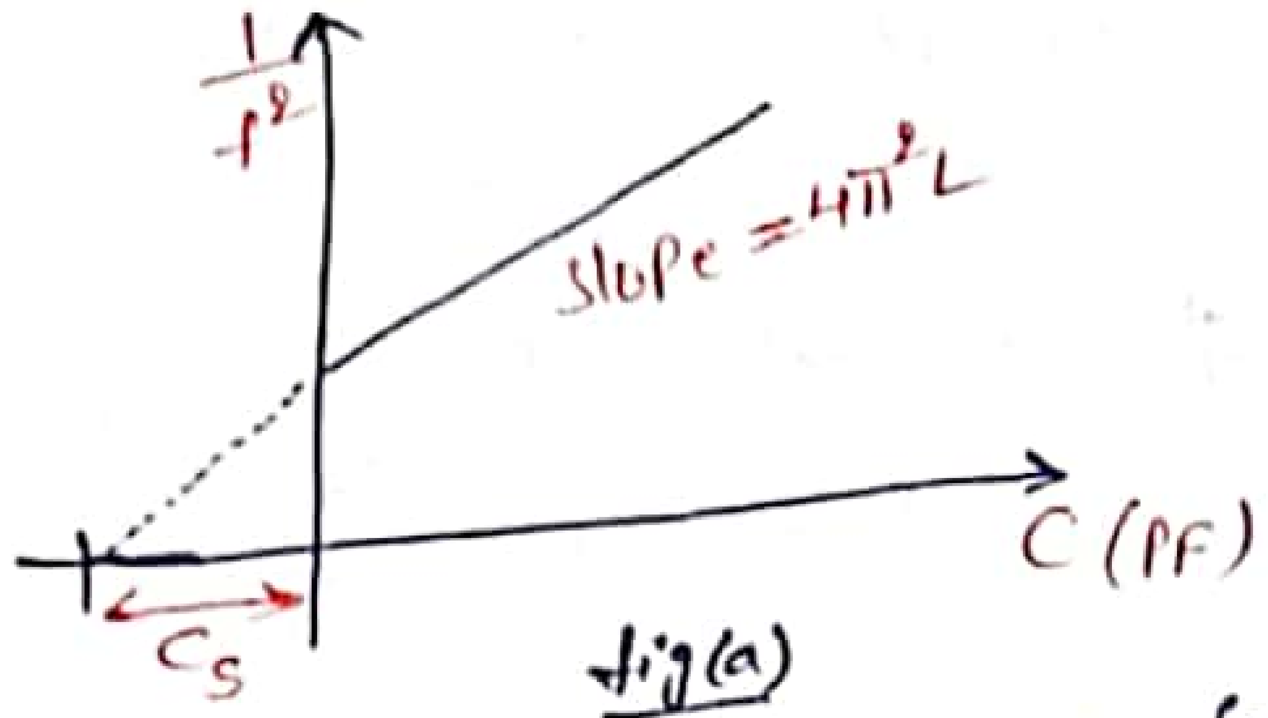
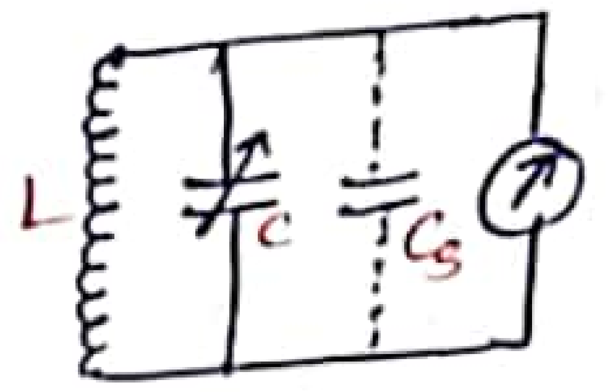
② Another source of error and probably the most important one is the distributed capacitance (or) self (or) stray capacitance of the measuring circuit.



fig(a)



fig(b)

fig: Measurement of stray Capacitance.

→ The presence of stray capacitance modifies the actual 'Q' and the inductance of the coil.

→ One of the simplest methods of determining the stray capacitance of a coil involves the plotting of a graph of '$\frac{1}{f^2}$' against 'C' in (PF).

→ The value of the unknown inductance can be determined from the Eq.

$$L = \frac{\text{slope}}{4\pi^2}$$

$$\therefore \text{slope} = 4\pi^2 L.$$

and

$$f = \frac{1}{2\pi\sqrt{L(C+C_s)}}$$

$$\therefore \frac{1}{f^2} = 4\pi^2 L(C+C_s)$$

If $\frac{1}{f^2} = 0$ then $\boxed{C = -C_s}$

→ Another method of determining the stray (or) distributed capacitance (C_s) of a coil involves making two measurements at different frequencies.

→ The tuning capacitor is set to a high value position and the circuit is resonated by varying the oscillator frequency.

→ Suppose the meter indicates resonance and the oscillator frequency is found to be f_1 Hz and the capacitor value to be 'C_1'.

→ The oscillator frequency of the Q-meter is now increased to twice the original frequency, that is $f_2 = 2f_1$ and the capacitor is varied until resonance occurs at 'C_2'.

→ The resonance frequency of an LC circuit is given by

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

∴ for the initial resonance condition, the total capacitance of the circuit is $(C_1 + C_S)$ and the resonance frequency equals to

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

→ After the oscillator and tuning capacitor are varied for the new value of resonance, the capacitance is $(C_2 + C_S)$

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

But $f_2 = 2 f_1$

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

$$L(C_1+C_S) = 4L(C_2+C_S)$$

$$C_1 + C_S = 4C_2 + 4C_S$$

$$3C_S = C_1 - 4C_2$$

$$\boxed{C_S = \frac{C_1 - 4C_2}{3}}$$

---

(2) Impedance Measurement Using Q-Meter :-

→ An unknown impedance can be measured using a Q-Meter either by series (or) shunt substitution method.

→ In the Q-Meter method of measurement of 'Z', the unknown impedance 'Zx' is determined by individually determining its components Rx and Lx. The technique utilizes an LC tank of a Q-Meter, 'L' being an externally connected standard coil.

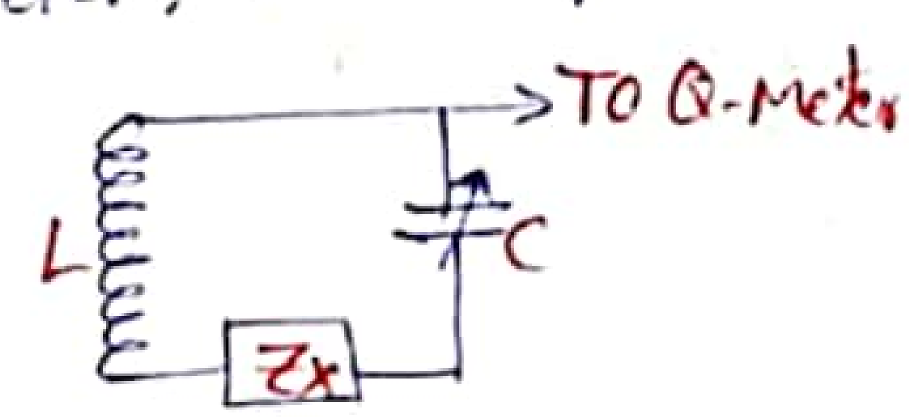


fig (a): Series Substitution

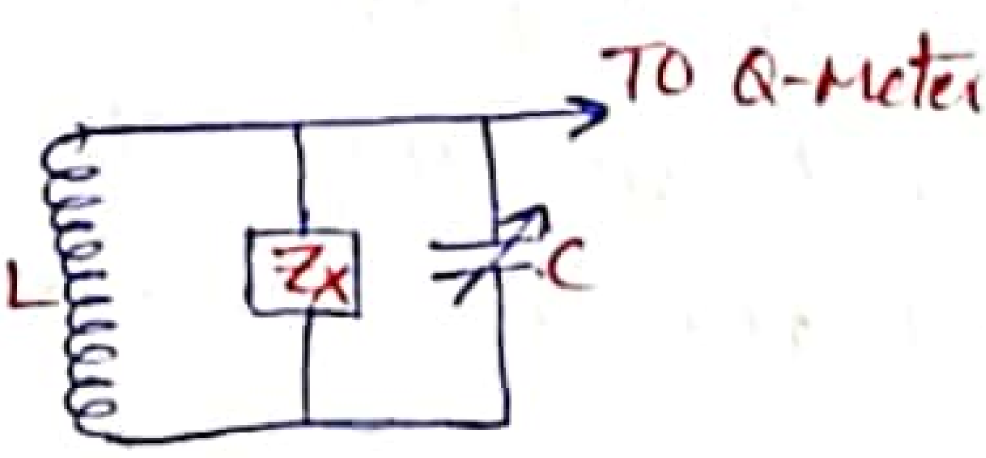


fig (b): Shunt Substitution

→ From fig(a), the Unknown impedance is shorted and the tuned circuit is adjusted for resonance at the oscillator frequency. The value of 'Q' and 'C' are noted. The unknown impedance is then connected, the capacitor is varied for resonance and the new values Q' and C' are noted.

from part 1 we have, $\omega L = \frac{1}{\omega C}$

from part 2 we have, $\omega L + X_x = \frac{1}{\omega C'}$

$$\therefore \frac{1}{\omega C} + X_x = \frac{1}{\omega C'}$$

$$X_x = \frac{1}{\omega C'} - \frac{1}{\omega C} = \frac{1}{\omega}\left(\frac{1}{C'} - \frac{1}{C}\right) = \frac{1}{\omega}\left(\frac{C-C'}{CC'}\right)$$

→ Since $R' = R + R_x$

$\therefore R_x = R' - R$ where 'R' is the resistance of the Auxillari coil

$$R_x = R' - R = \frac{\omega L}{Q'} - \frac{\omega L}{Q} = \omega L\left(\frac{1}{Q'} - \frac{1}{Q}\right) = \omega L\left(\frac{Q-Q'}{QQ'}\right)$$

→ The Unknown impedance 'Z_x' can be calculated from the eq

$$Z_x = R_x + jX_x$$

$$\boxed{Z_x = \omega L\left(\frac{Q-Q'}{QQ'}\right) + j\frac{1}{\omega}\left(\frac{C-C'}{CC'}\right)}$$

→ If 'Z_x' is considerably greater than 'X_L' the Unknown impedance is shunted across the coil and the capacitor shown in fig(b).

is shunted across the coil and the Capacitor shown in fig(b). Y_x represents the shunt admittance of the unknown impedance.

→ Y_x represents the shunt admittance of the unknown impedance. It consists of two shunt elements, Conductance (G_x) and susceptance (B_x)

→ In this method 'Y_x' is disconnected and the Capacitor (C) is tuned to the resonant value. at the oscillator frequency, the value of 'Q' and 'C' are noted with Y_x connected, the capacitor is tuned again for resonance at a oscillator frequency and the new values Q' and C' are noted.

Hence $Y_x = G_x + jB_x$

Here $B_x = \omega C - \omega C'$ and $G_x = \frac{1}{\omega L}\left(\frac{Q-Q'}{QQ'}\right)$

$$\therefore \boxed{Y_x = \frac{1}{\omega L}\left(\frac{Q-Q'}{QQ'}\right) + j\omega(C-C')}$$

(3) Measurement of 'Q' by Susceptance Method :-

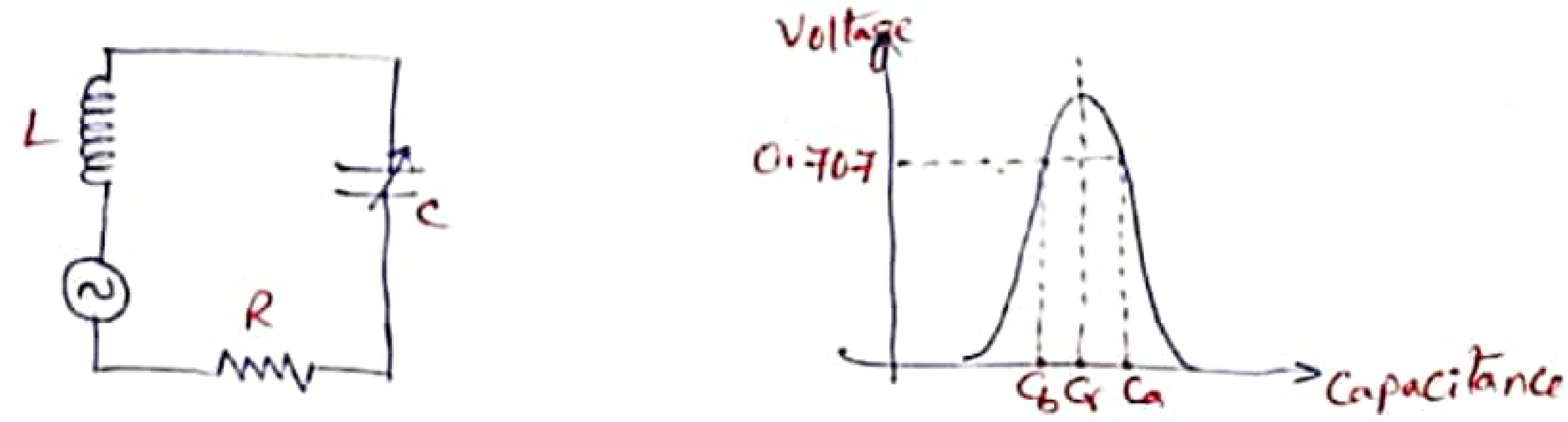


fig: Susceptance Method of Q- Measurement & response Curve.

→ The Coil under test is Connected in series with a calibrated low loss Variable Capacitor.

→ The circuit is tuned for resonance to the oscillator frequency by tuning the Variable Capacitor to a Value 'C_r'.

→ The capacitor is then detuned to a Value 'C_b' on the low Capacitance side of resonance at which the meter reading falls to 70.7% of the resonant voltage.

→ Next the Capacitor is set on the higher Capacitance side of resonance to a value 'C_a', where the Voltmeter deflection is again drops to 70.7% of the resonant voltage.

→ The points C_a, C_b and C_r are closer together when coil 'Q' is high and far apart when 'Q' is low.

→ 'C_a' and 'C_b' are the Values of Capacitances at the half power point and 'C_r' is the Value of the Capacitance at resonance.

$$X_{C_a} = \frac{1}{\omega C_a} \quad \text{and} \quad X_{C_b} = \frac{1}{\omega C_b}.$$

at Half power points

$$\omega L - \frac{1}{\omega C_a} = R \quad \text{and} \quad \frac{1}{\omega C_b} - \omega L = R$$

by adding the two equations we have.

$$\frac{1}{\omega C_b} - \frac{1}{\omega C_a} = 2R \longrightarrow \frac{\omega C_a - \omega C_b}{\omega^2 C_a \cdot C_b} = 2R$$

i.e. $\dfrac{C_a - C_b}{\omega C_a \cdot C_b} = 2R$ but $C_r^2 = C_a \cdot C_b$.

$$\frac{C_a - C_b}{\omega C_r \cdot R \cdot C_r} = 2 \qquad \text{But } Q = \frac{1}{\omega C_r \cdot R} \qquad \left(\because Q = \frac{X_C}{R}\right)$$

$$\frac{Q(C_a - C_b)}{C_r} = 2 \qquad \therefore \boxed{Q = \frac{2C_r}{(C_a - C_b)}}$$

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EMI and EMC :-

① EMI (Electro Magnetic Interference) :-

→ For any Electronic equipment (or) for any instrument, its Performance is degraded by electromagnetic disturbances (or) noise (or) Unwanted Signals.

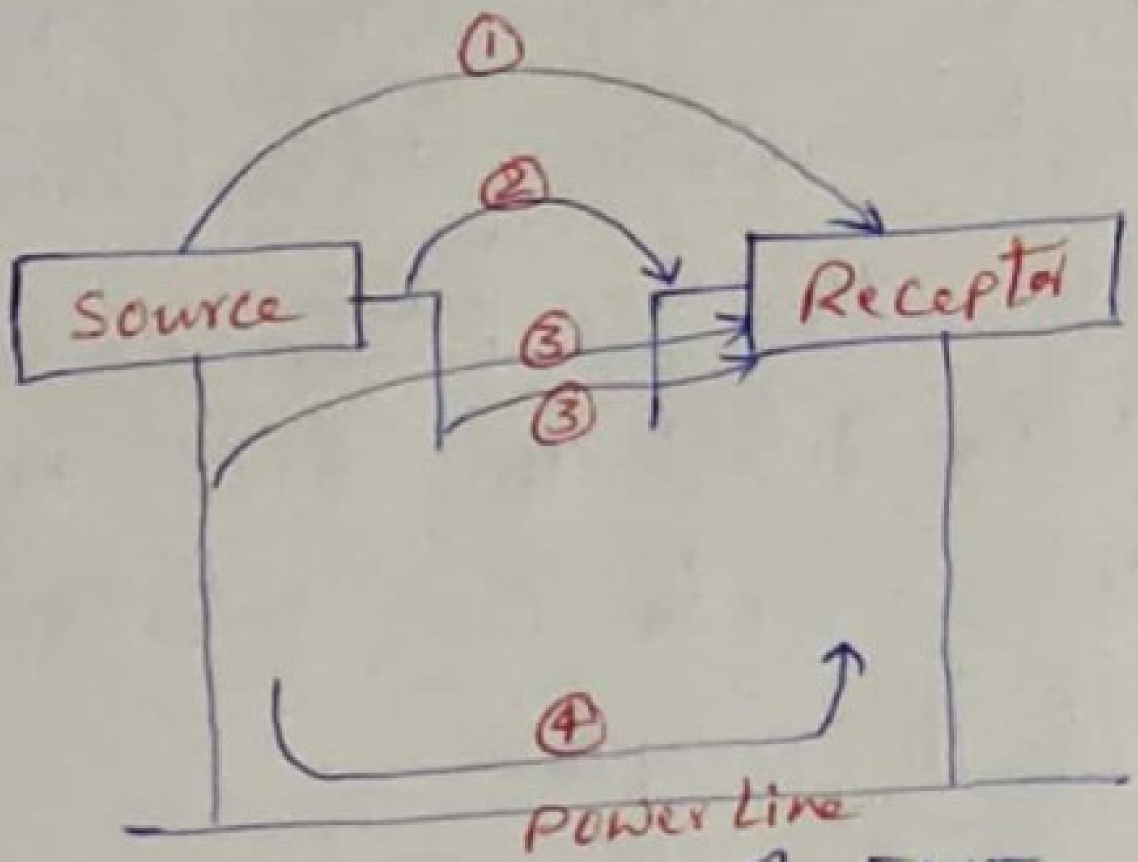

fig: Mechanism of EMI

→ EMI is defined as the degradation in the Performance of a device (or) an equipment (or) a System by electromagnetic disturbances.

→ EMI is also called as "Radio frequency Interference (RFI)"

→ EMI should travel from 'Source' to 'receptor' i.e. receptor is one which receives electro Magnetic Interference (EMI)

→ The Mechanism of EMI is as follows.

→ The Mechanism of Serial transmission from Source to Receptor. There are four Paths of Serial transmission from Source to receptor.

Path 1: Direct radiation from Source to receptor.

Path 2: Direct radiation from Source picked up by electrical Power Cables or the Signals / Control Cables Connected to receptor.

Path 3: EMI radiated by electrical Power, Signal (or) Control Cables of Source.

Path 4: EMI directly Conducted from its Source to receptor Via Common electrical Power Supply Lines (or) Via Common Signal (or) Control Cables.

→ The EMI Carried by Various Power / Signal / Control Cables of the Source, which gets Coupled to the Power / Signal / Control Cables of the receptor, especially when Cable harnesses are bundled such interference reaches the receptor Via Conduction, even when Common Power / Signal / Control Cables do not Exist.

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② EMC (Electro Magnetic Compatability):

→ The ability of a device equipment (or) System to function satisfactorily in its electromagnetic environment without introducing intolerance electromagnetic disturbances to anything in that Environment is called as "EMC".

→ In detail the EMI so Coupled from its Source (or) Sources to the recepter can interface with the normal (or) Satisfactory Operation of the recepter.

→ A recepter becomes a Victim when the intensity of the EMI is above tolerable Unit.

→ To void this, we Made Use of EMC Values of an particular equipment (or) device (or) System.

Interference and Noise Reduction Techniques:-

→ EM Interference devides into several categories to the Source and the Signal Characteristics.

① Continous Interference:

→ Continous (or) Continous wave (CW) Interference arises where Source regularly Exist a given range of frequency.

→ This type is naturally devided into Sub-categories according to frequency range.

(i) Audio frequency from very low frequencies up to around 20 KHz frequencies up to 100KHz may sometimes be classified as audio.

(ii) Radio frequency Interference (RFI) from typically 20KHz to an upper limit which Constantly increases as technology pushes it higher.

② Pulse (or) transiant Interference:-

→ EM Pulse, it is also called as Transiant disturbances arises where the Source Emits a short-duration Pulse of Energy. The energy is Usually broad band by nature.

→ Sources are broadly devided into 2 types.

(1) Sources of Isolated EMP events.

(2) Sources of repetitive EMP events, sometimes as regular Pulse train.

Noise Reduction Techniques:-

→ Here Noise is one type of Interference. so Interference can be minimized if not completly Eliminated. A System is electromagnetically Compatible. if it satisfies 3 criteria.

(1) It does not Cause interference with other Systems.

(2) It is not Susceptable to Emissions from other Systems.

(3) It does not Cause interference with itself.

→ Three ways to prevent Interference are:

(1) Suppress the Emission at its Source.

(2) Make the Coupling paths as efficient as possible.

(3) Make the receptor less Susceptable to Emission.

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UNIT-V

Transducers

Transducer: A Transducer is defined as a device that receives Energy from one System and transmits it to another System, often in a different form.

① **Active Transducer:-** It generates an Electrical Signal directly in response to the physical Parameter and does not require an External Power Source for its operation.

Ex: Piezo electric Sensors, Photo voltaic Cells.

② **Passive Transducers:-** Operates Under energy Controlling principles, which makes it necessary to use an external electrical Source with them. they depend up on the Change in an electrical Parameter (R, L, & C)

Ex: Strain gauges, Thermistors.

Parameters:-

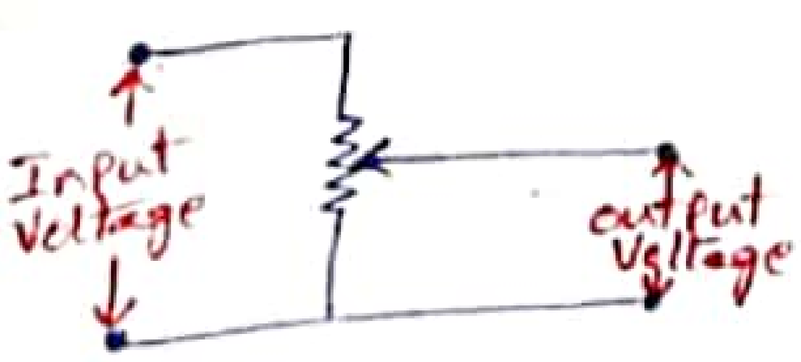
→ An electrical Transducer must have the following Parameters.

1) Linearity
2) Sensitivity
3) Dynamic Range
4) Repeatability
5) physical size.

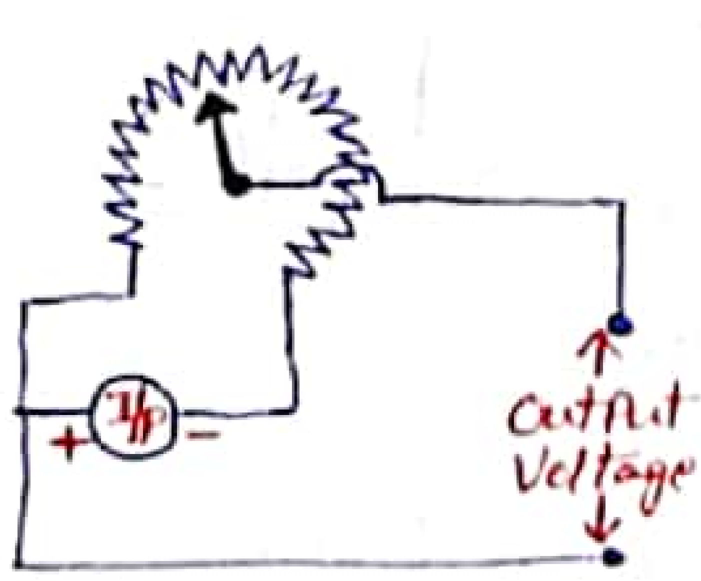
Resistive Transducer:- (Measurement of Displacement)

→ Resistive Transducers are those in which the resistance changes due to a change in some physical Quantity.

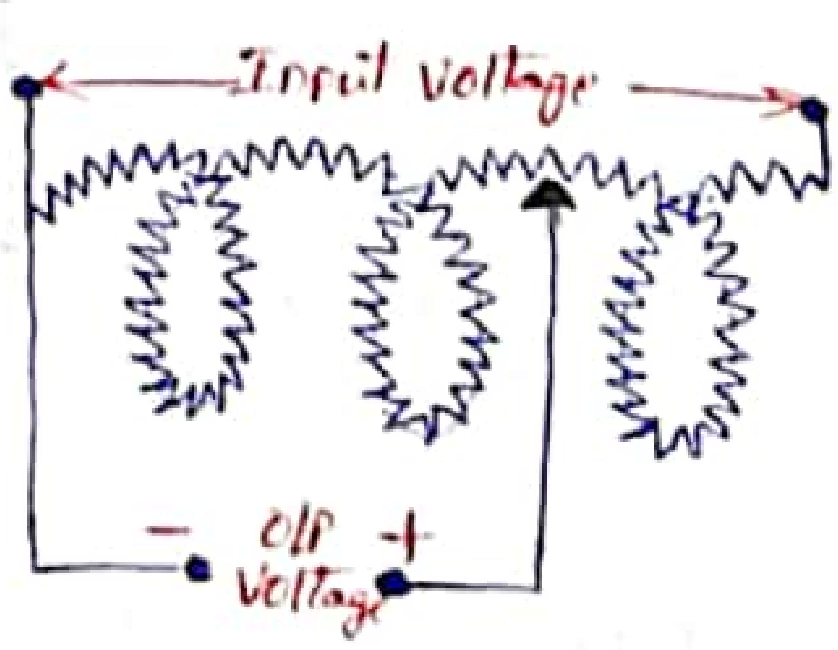
① **Potentiometer:**



fig(a): Translatory Type



fig(b): Rotational Type



fig(c): Helipot Type.

→ A Resistive Potentiometer (Pot) Consists of a resistance element provided with a sliding Contact Called as "Wiper".

→ The Motion of the sliding Contact May be translatory (or) rotational.

→ Some have a Combination of both, with resistive Elements in the form of Helix as shown in fig(c). They are known as "Helipots".

→ Translatory resistive elements as shown in fig(a) are linear (straight) devices.

→ Rotational resistive devices are circular and are used for the measurement of angular displacement as shown in fig(b).

→ Helical resistive Elements are Multiturn rotational devices, which can be used for the measurement of either translatory (or) rotational Motion.

→ A potentiometer is a passive transducer since it requires External power source for its operation.

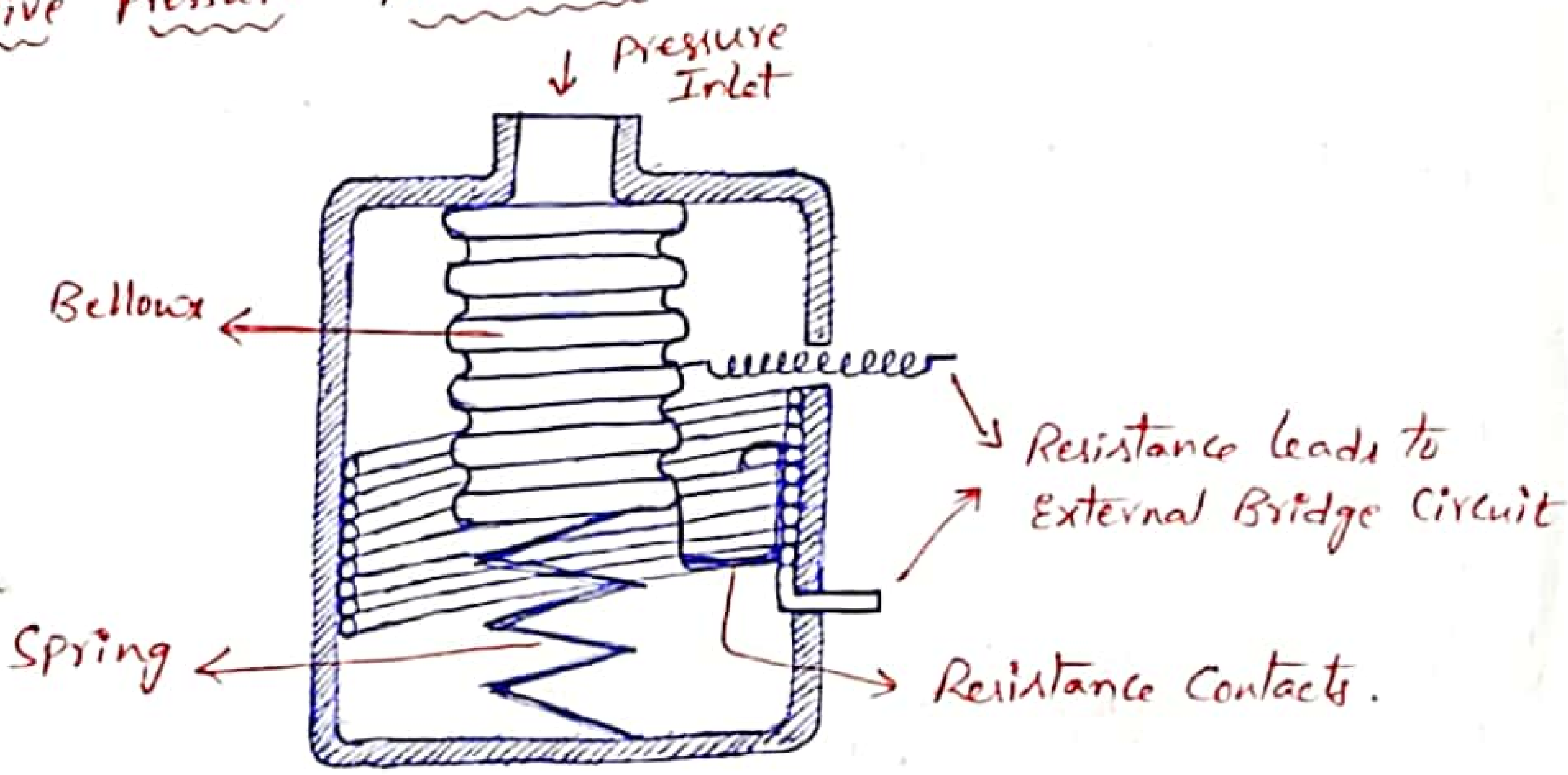
Advantages:

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

Disadvantages:

1) When using a linear potentiometer, a large force is required to move the sliding Contact.
2) The sliding Contacts Can wear out, become misaligned, generate Noise.

② Resistive Pressure Transducer:-



fig(a). Resistance Pressure Transducer Using Bellows.

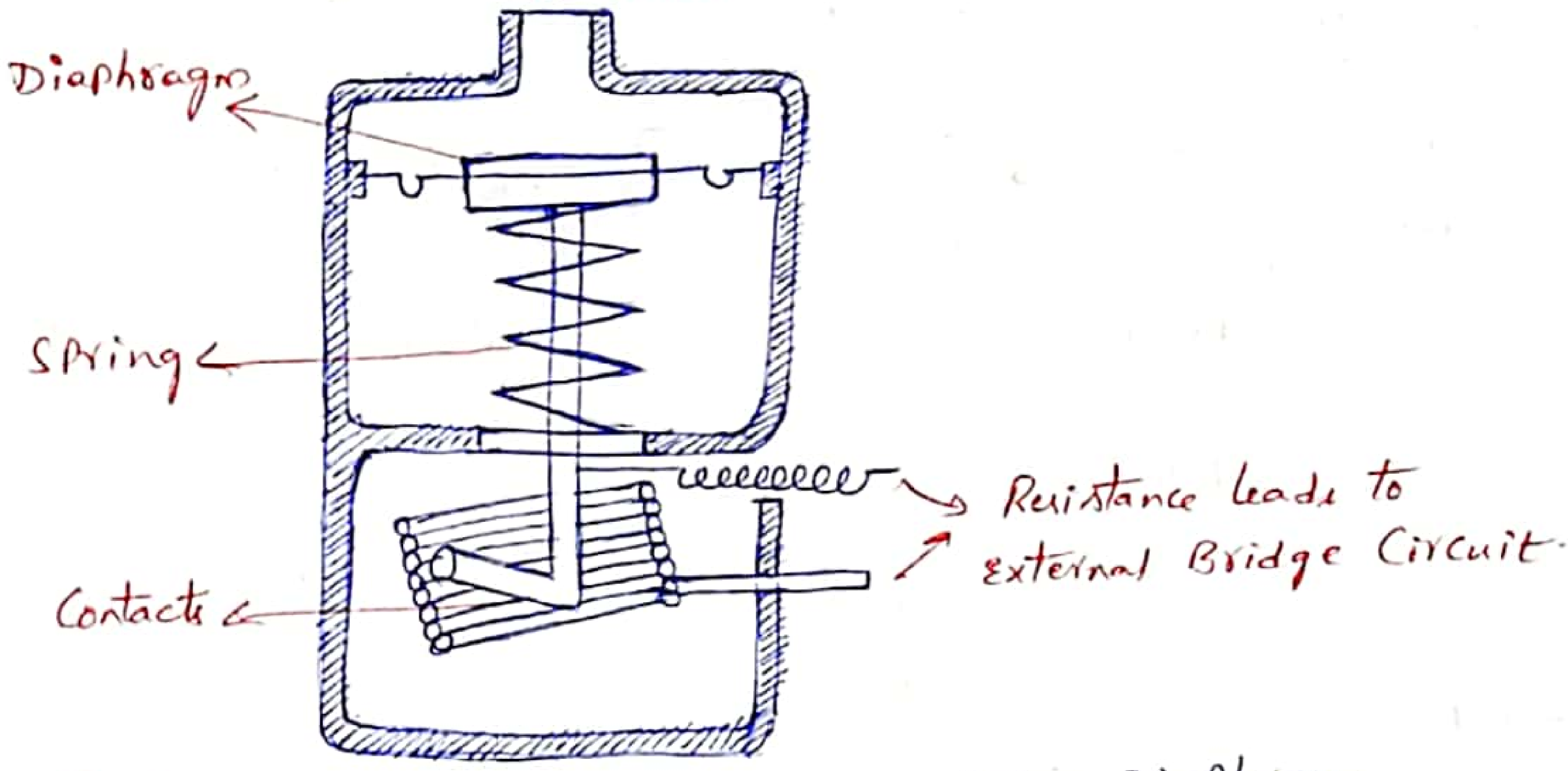


fig (b): Resistive Pressure Transducer Using Diaphragm.

→ Resistive Pressure Transducer are of two Main Types.

(1) The Electro Mechanical resistance Transducer, in which a change of pressure, stress, position, displacement (or) other Mechanical variation is applied to a variable resistor.

(2) The other resistance Transducer is the strain guage, where the stress acts directly on the resistance. It is very commonly used for stress and displacement measurement in Instrumentation.

→ In fig (a) & fig (b) shows two ways by which the pressure acts to Influence the sensitive resistance element, i.e. by which pressure varies the resistance element. They are the "Bellow Type" and the "Diaphragm Type".

→ In each of these cases, the element moved by the pressure change is made to cause a change in resistance. This resistance change can be made part of a bridge circuit and then taken as either ac (or) dc o/p signal to determine the pressure indication.

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Capacitive Transducer: (Measurement of Displacement)

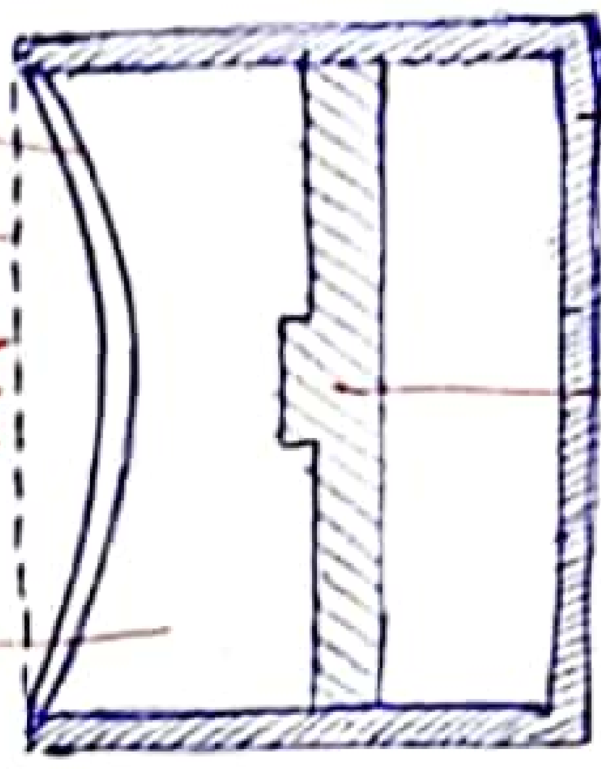

fig: Capacitive Pressure Transducer.

→ Figure shows a transducer that makes use of the variation in Capacitance resulting from a change in spacing between the plates. This particular transducer is designed to measure pressure.

→ A Metallic Diaphragm is Enclosed in an airtight Container, which moves to the right when pressure is applied to the chamber.

→ This "diaphragm" is Used as one plate of a Variable Capacitor.

→ It's distance from the stationary plate, to its left as determined by the pressure applied to the unit determines the capacitance between the two plates.

→ Changes in pressure may be easily detected by the variation of Capacity between a fixed plate and another plate to move as the pressure changes.

→ The resulting variation follows the basic Capacity formule

$$C = 0.885 \frac{K(n-1)A}{t} \quad (PF)$$

Where A = Area of One Side of One Plate (Cm^2)

n = No. of plates.

t = Thickness of dielectric (cm)

K = dielectric Constant.

→ The Capacitive Transducer, used in the Capacitive Microphone, is simple to Construct and inexpensive to Produce. It is particularly effective for HF Variations.

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Inductive Transducer: (Measurement of Displacement)

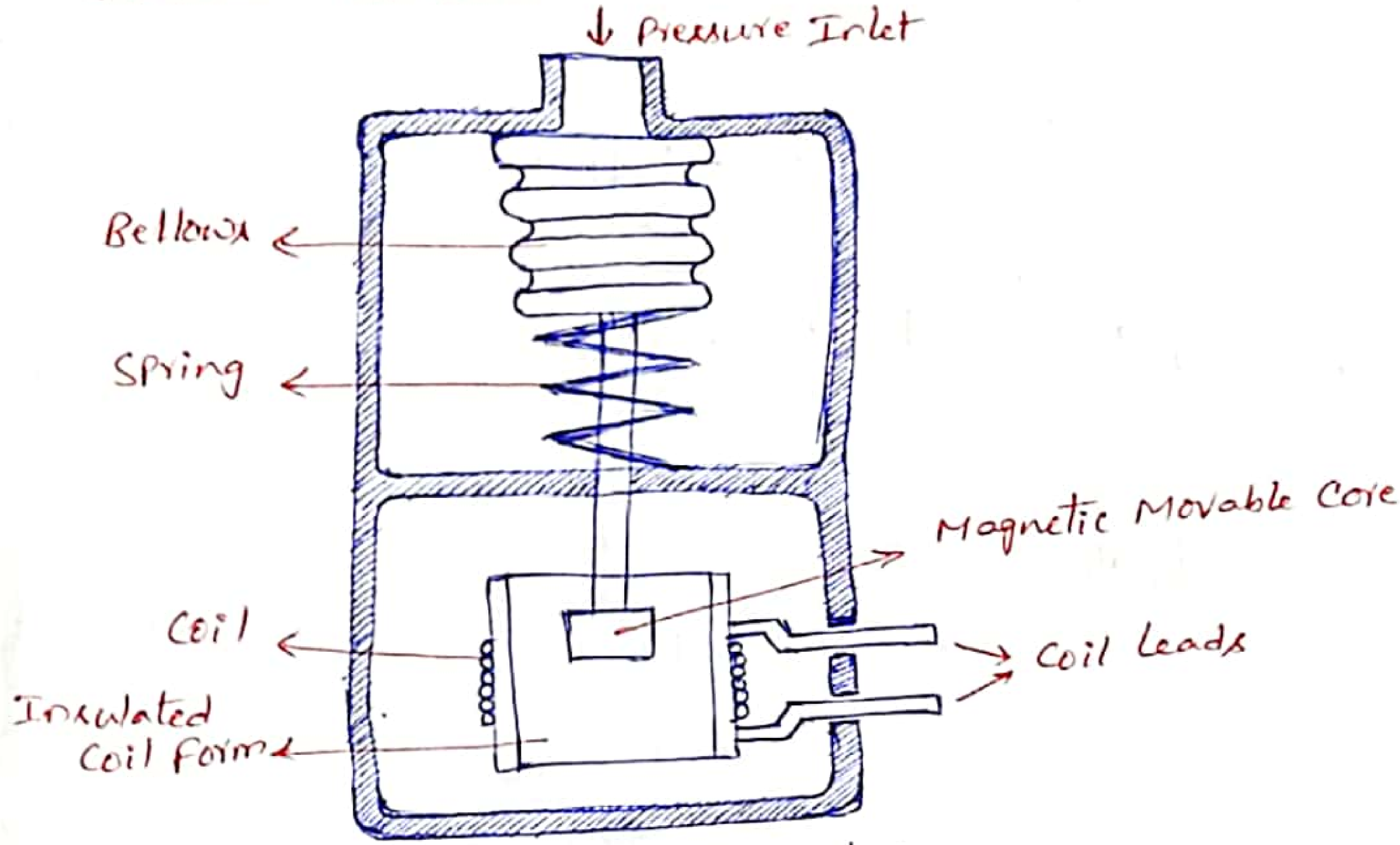

fig: Inductive Pressure Transducer.

→ A simple arrangement, where in a Change in the inductance of a Sensing Element is Produced by a pressure change.

→ Here the pressure acting on a Movable Magnetic Core Causes an increase in the Coil inductance corresponding to the acting pressure.

→ The Change in inductance Can again be made on the basis of an electrical Signal Using an 'ac' bridge.

→ In a slightly Modified form, this principle is used to obtain a change in Mutual inductance between "Magnetically Coupled Coils" rather than in the Self inductance of a Single Coil.

→ When a change in an induced Voltage is involved the transducer is Sometimes called a Variable reluctance sensor (or) Magnetic Pick up. A very important Example of the Mutual type is the 'LVDT'.

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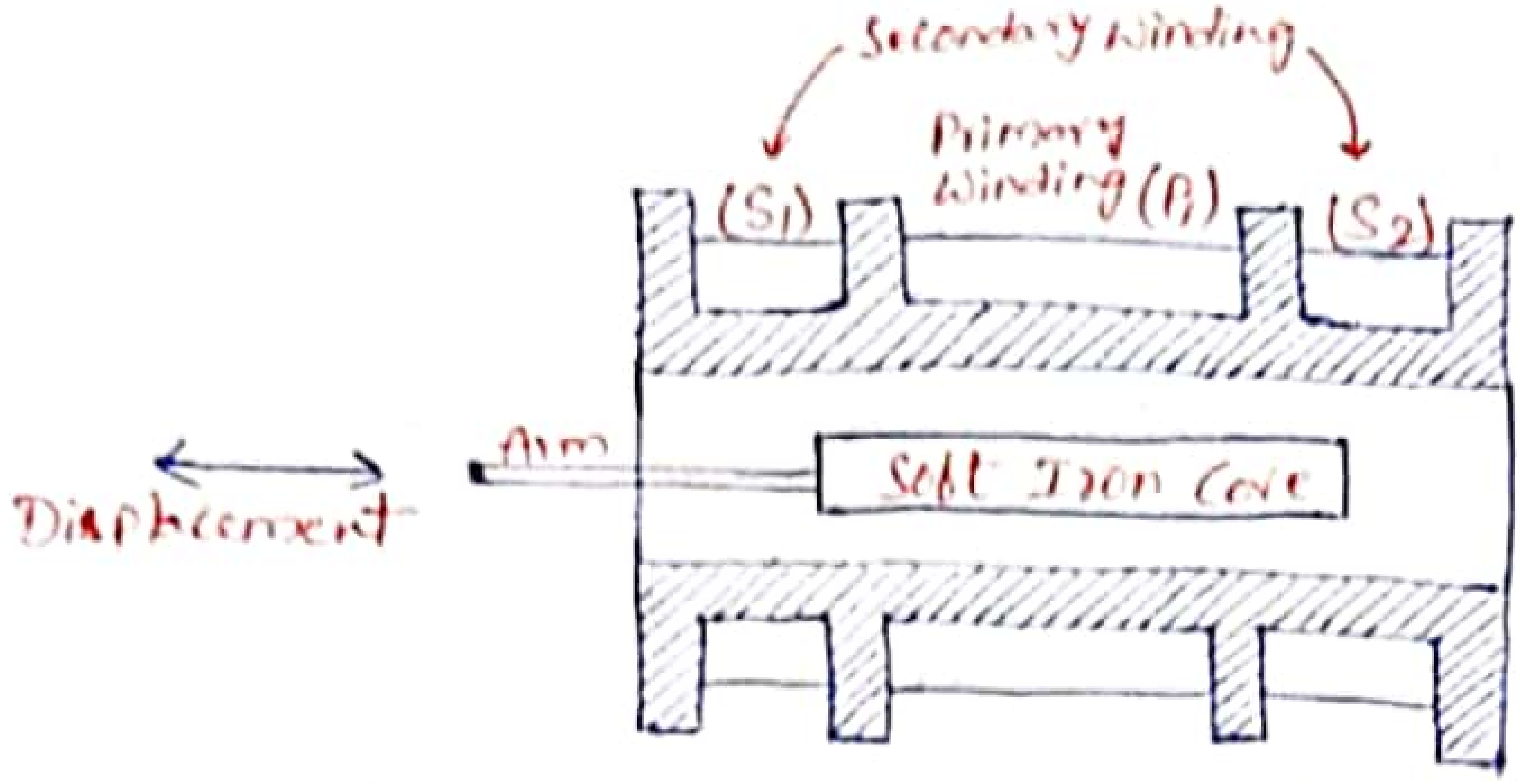
Linear Variable Differential Transducer (LVDT) :-



fig(a): Construction of a LVDT

→ The differential transformer is a passive inductive transformer. It is known as "LVDT".

→ The transformer consists of a single primary winding 'P_1' and two secondary windings 'S_1' and 'S_2' wound on a hollow cylindrical former.

→ The secondary windings have an equal no. of turns and are identically placed on either side of the primary windings.

→ The primary winding is connected to an ac source.

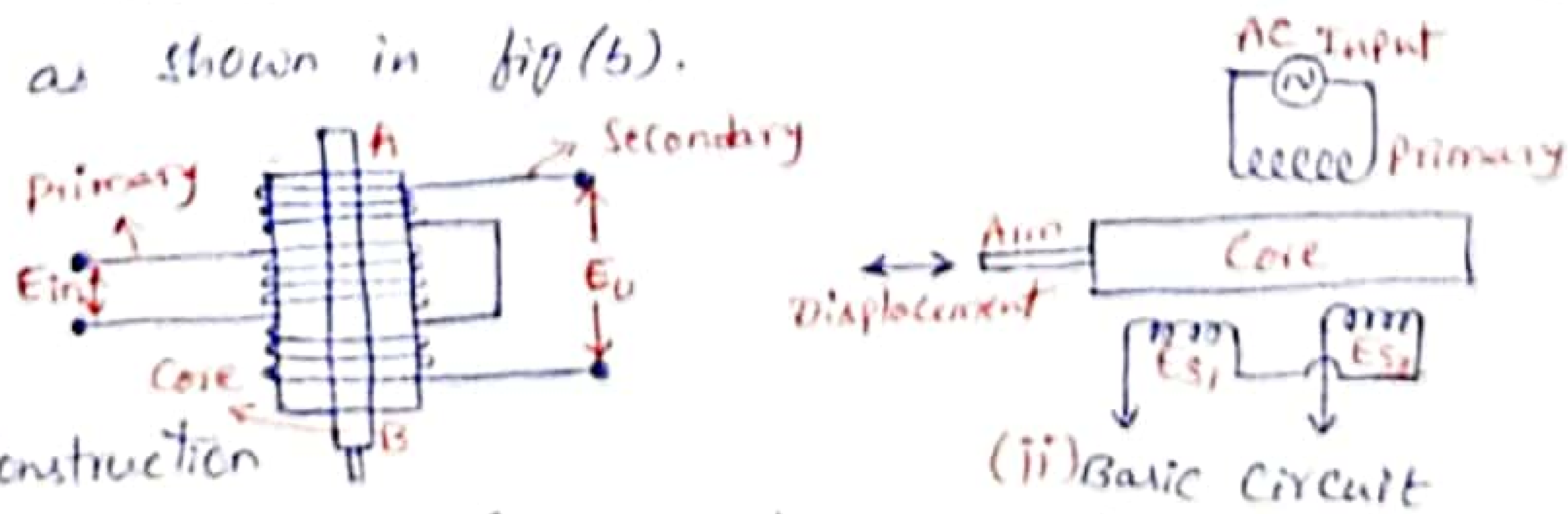
→ The movable soft iron core slides with in the hollow former and therefore affects the magnetic coupling between the primary and the two secondaries.

→ The displacement to be measured is applied to an arm attached to the soft iron core.

→ When the core is in its normal (Null) position, equal voltages are induced in the two secondary windings. The frequency of the ac applied to the primary winding range from 50 Hz to 20 kHz.

→ The o/p voltage of secondary windings S_1 is ES_1 and S_2 is ES_2.

→ In order to convert the o/p from S_1 to S_2 into a single voltage signal, the two secondaries S_1 and S_2 are connected in series position as shown in fig (b).



(i) Construction (ii) Basic circuit

fig(b): Secondary winding connected to differential output.

→ Hence the o/p voltage of the transducer is the difference of the two voltages.

∴ The differential o/p voltage $E_0 = E_{S_1} \sim E_{S_2}$

→ When the core is at its normal position, the flux linking with both secondary windings is equal, and then equal emf's are induced in them. Hence at Null position $E_{S_1} = E_{S_2}$.

so o/p voltage 'E_0' is zero at Null position.

→ Now, if the core is moved to the left of the Null position, more flux links with winding 'S₁' and less with winding 'S₂'.

Hence $E_{S_1} > E_{S_2}$

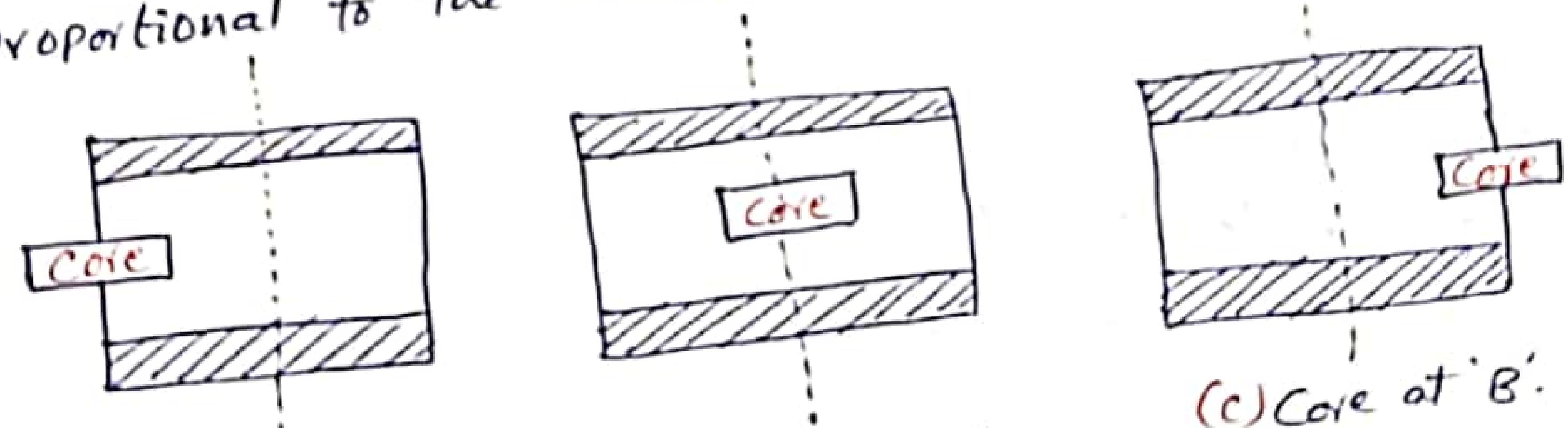
∴ The magnitude of the o/p voltage of the secondary is then $E_{S_1} - E_{S_2}$ in phase with E_{S_1}.

→ Similarly if the core is moved to the right of the Null position, the flux linking with winding 'S₂' becomes greater than that linked with winding 'S₁'.

Hence $E_{S_2} > E_{S_1}$.

∴ The o/p voltage in this case is $E_0 = E_{S_2} - E_{S_1}$ and in phase with E_{S_2}.

→ The amount of voltage change in either secondary winding is proportional to the amount of movement of the core.



(a) Core at 'A'   (b) Core at 'O'   (c) Core at 'B'.

→ LVDT's are available with ranges as low as ±0.05 in. to as high as ±25 in. and are sensitive enough to be used to measure displacements of well below 0.001 in.

→ They can be obtained for operation at temperatures as low as −265°C and as high as +600°C and are also available in radiation resistance designs for nuclear operations.

91

Advantages:-

1) Linearity
2) Infinite Resolution
3) High o/p
4) High Sensitivity
5) less friction
6) Low power Consumption

Disadvantages:

1) Temperature also affects the transducer.
2) large displacements are required for differential o/p.
3) They are sensitive to stray Magnetic fields.

Strain Gauges:- (Measurement of Force)

$$\text{Strain} = \frac{\text{Compression}}{\text{Unit Length}}$$

→ Straingauges work on the Principle that the resistance of a Conductor (or) Semi Conductor is Varied when strained. This Can be Used for the Measurement of displacement, force and Pressure.

→ The following types of strain gauges are the Most important.

(1) wire straingauges
(2) foil straingauges.
(3) Semi Conductor straingauges.

① Resistance wire guages:-

2 Types
① Unbonded Type
② Bonded Type.

(i) Unbonded Resistance wire strain gauges:-

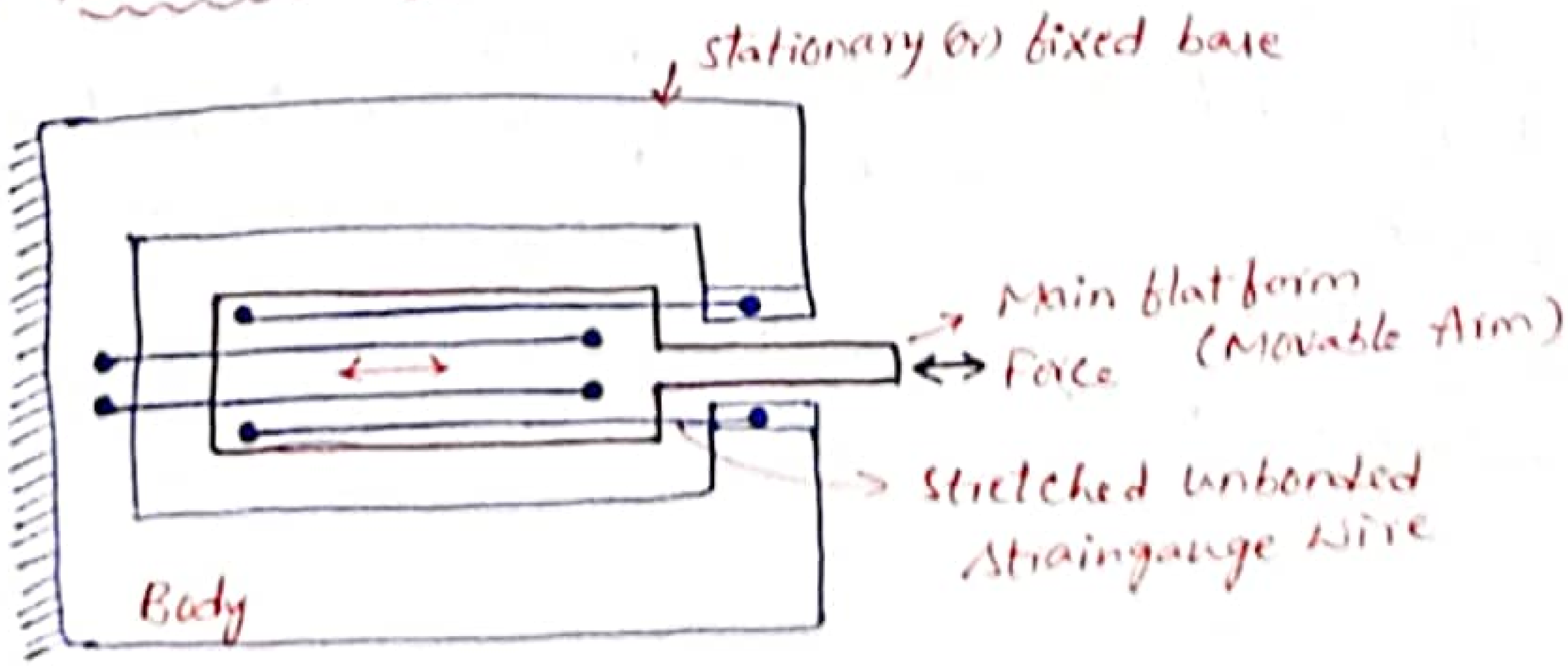


fig: Unbonded Strain gauge

→ An Unbonded strain gauge Consists of a wire streched b/w two points in an insulating medium, such as air.

→ The diameter of the wire used as about "25μm".

→ Unbonded straingauges are usually connected in a bridge circuit.

→ When an External load is applied, the resistance of the strain gauge changes, causing an unbalance of the bridge circuit resulting in an output voltage.

→ This voltage is proportional to the strain.

→ A displacement of the order of 50 μm can be detected with these strain gauges.

(ii) Bonded Resistance wire Strain gauges :-

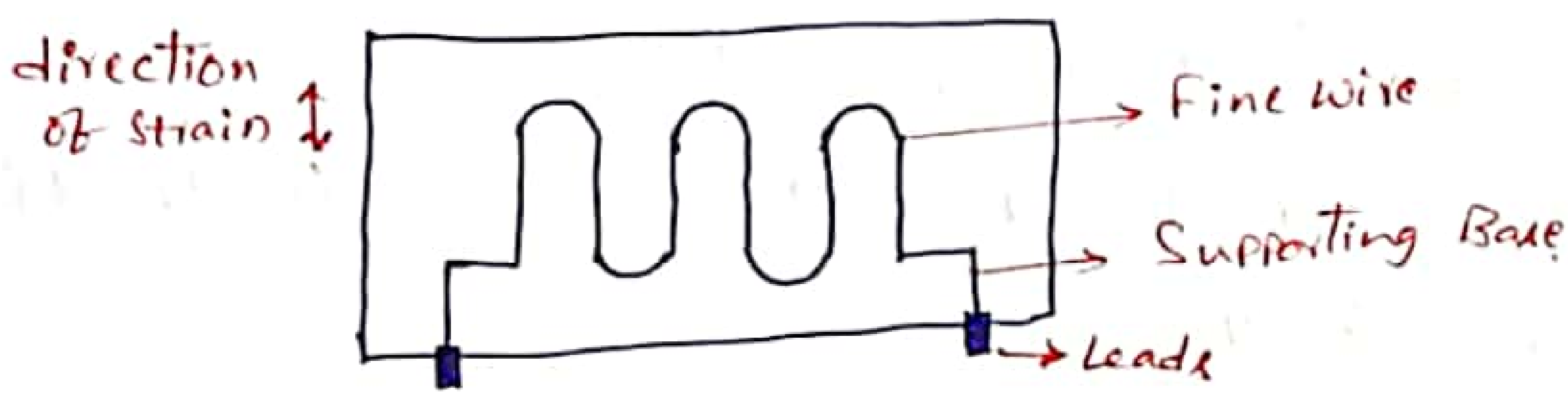


fig: Bonded Resistance Wire Strain gauge.

→ A fine wire element about 25μm (or) less diameter is looped back and forth on a carrier (or) Base (or) Mounting plate

→ The wire is covered on the top with a thin material, so that it is not damaged mechanically.

→ The spreading of the wire permits uniform distribution of stress.

→ A stress tends to elongate the wire and there by increase its length and decrease its cross sectional Area.

→ The combined effect is an increase in resistance, as seen from the following Equation.

$$R = \frac{\rho l}{A}$$

l = length of the conductor in 'm'
A = Area of the conductor in 'm²'
ρ = specific Resistance of the material in 'Ω'.

→ As a result of strain, two physical parameters are of particular interest.

(i) The change in gauge resistance.

(ii) The change in length.

→ The measurement of the sensitivity of a material to strain is called as "Gauge Factor" (GF).

→ It is the ratio of the change in resistance to the change in the length.

i.e. $$G.F\ (K) = \frac{\Delta R/R}{\Delta l/l} \longrightarrow ①$$

here
- K = Gauge Factor
- ΔR = Change in the initial resistance in 'Ω'.
- R = Initial resistance 'Ω' (without strain)
- Δl = Change in the length in 'm'.
- l = Initial length in 'm' (without strain)

→ Since strain is defined as the change in length divided by the original length.

i.e. $$a = \frac{\Delta l}{l} \longrightarrow ②$$

Sub Eq ② in Eq ① $$\therefore\ K = \frac{\Delta R/R}{a} \longrightarrow ③$$

→ The Resistance of a Conductor of Uniform Cross Section is

$$R = \rho \frac{\text{Length}}{\text{area}}$$

$$R = \rho \frac{l}{\pi r^2}$$

Since $r = \frac{d}{2}$

$\therefore r^2 = \left(\frac{d^2}{4}\right)$

$$= \rho \frac{l}{\pi\left(\frac{d^2}{4}\right)}$$

$$R = \frac{\rho . l}{\left(\frac{\pi}{4}\right) d^2} \longrightarrow ④$$

here
- ρ = specific resistance of the conductor
- l = length of the conductor
- d = diameter of conductor.

→ When the conductor is stressed, due to the strain, the length of the conductor increased by 'Δl' and the diameter is decreased by 'Δd'. Hence the resistance of the conductor can now be written as

$$R_S = \rho \frac{(l+\Delta l)}{\frac{\pi}{4}(d-\Delta d)^2} = \frac{\rho(l+\Delta l)}{\frac{\pi}{4}(d^2-2d\,\Delta d+\Delta d^2)}$$

Since 'Δd' is small, Δd^2 is neglected

$$R_S = \frac{\rho(l+\Delta l)}{\frac{\pi}{4}(d^2-2d\,\Delta d)} = \frac{\rho l\cdot\left(1+\frac{\Delta l}{l}\right)}{\frac{\pi}{4}d^2\left(1-\frac{2\Delta d}{d}\right)} \rightarrow (5)$$

→ Now "Poisson's ratio (μ)" is defined as the ratio of strain in the lateral direction to strain in the axial direction, that is

$$\mu = \frac{\Delta d/d}{\Delta l/l} \rightarrow (6)$$

$$\left(\frac{\Delta d}{d}\right) = \mu\left(\frac{\Delta l}{l}\right) \rightarrow (7)$$

Sub. eq (7) in eq (5)

$$\therefore\ R_S = \frac{\rho l\left(1+\frac{\Delta l}{l}\right)}{\left(\frac{\pi}{4}\right)d^2\left(1-2\mu\frac{\Delta l}{l}\right)}$$

Rationalising, we get

$$R_S = \frac{\rho l\left(1+\frac{\Delta l}{l}\right)}{\frac{\pi}{4}d^2\left(1-2\mu\frac{\Delta l}{l}\right)} \frac{\left(1+2\mu\frac{\Delta l}{l}\right)}{\left(1+2\mu\frac{\Delta l}{l}\right)}$$

$$R_S = \frac{\rho l}{\left(\frac{\pi}{4}\right)d^2}\left[\frac{1+2\mu\frac{\Delta l}{l}+\frac{\Delta l}{l}+2\mu\left(\frac{\Delta l}{l}\right)^2}{1-4\mu^2\left(\frac{\Delta l}{l}\right)^2}\right]$$

Since 'Δl' is small, we can neglect higher powers of 'Δl'.

$$R_S = \frac{\rho l}{\left(\frac{\pi}{4}\right)d^2}\left[1+2\mu\left(\frac{\Delta l}{l}\right)+\frac{\Delta l}{l}\right]$$

$$R_S = \frac{\rho l}{\left(\frac{\pi}{4}\right)d^2}\left[1+(2\mu+1)\frac{\Delta l}{l}\right]$$

$$\rightarrow \quad R_S = \frac{\rho l}{\left(\frac{\pi}{4}\right) d^2} + \frac{\rho l}{\left(\frac{\pi}{4}\right) d^2}\left(\frac{\Delta l}{l}\right)(1+2\mu)$$

from Eq ④ we know $R = \frac{\rho l}{\left(\frac{\pi}{4}\right) d^2}$

$$\therefore \quad R_S = R + \Delta R$$

Where

$$\Delta R = \frac{\rho l}{\left(\frac{\pi}{4}\right) d^2}\left(\frac{\Delta l}{l}\right)(1+2\mu)$$

∴ The gauge factor will now be

$$K = \frac{(\Delta R/R)}{(\Delta l/l)} = \frac{\left(\frac{\Delta l}{l}\right)(1+2\mu)}{\left(\frac{\Delta l}{l}\right)} = 1+2\mu.$$

$$\therefore \quad \boxed{K = 1+2\mu.}$$

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② Foil Strain Gauges :-

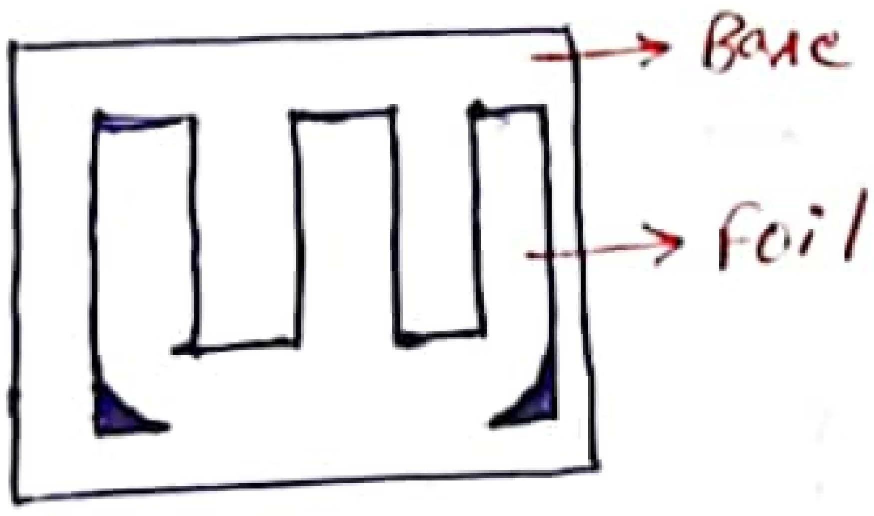

fig: Foil Type straingauge.

→ This class of Straingauge is an extension of the resistance wire straingauge.

→ The strain is sensed with the help of a Metal foil.

→ The Metals and alloys used for the foil and wire are Nichrome, Constantan, Isoelastic, Nickel and platinum.

→ Foil gauges have a much greater dissipation Capacity than wire wound gauges.

→ Foil type straingauge have similar characteristics to wire straingauges. Their gauge factors are typically the same.

→ The advantage of foil type strain gauge is that they can be fabricated on a large scale, and in any shape.

→ The longitudinal sensitivity of the foil gauge is approximately 5% greater than that of similar wire elements.

→ The resistance film formed is typically 0.2 mm thick.

→ The resistance value of commercially available foil gauges between 50 and 1000 Ω.

→ The resistance films are vaccum coated with ceramic film and deposited on a plastic backing for Insulation

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③ **Semi Conductor Strain gauges :-**

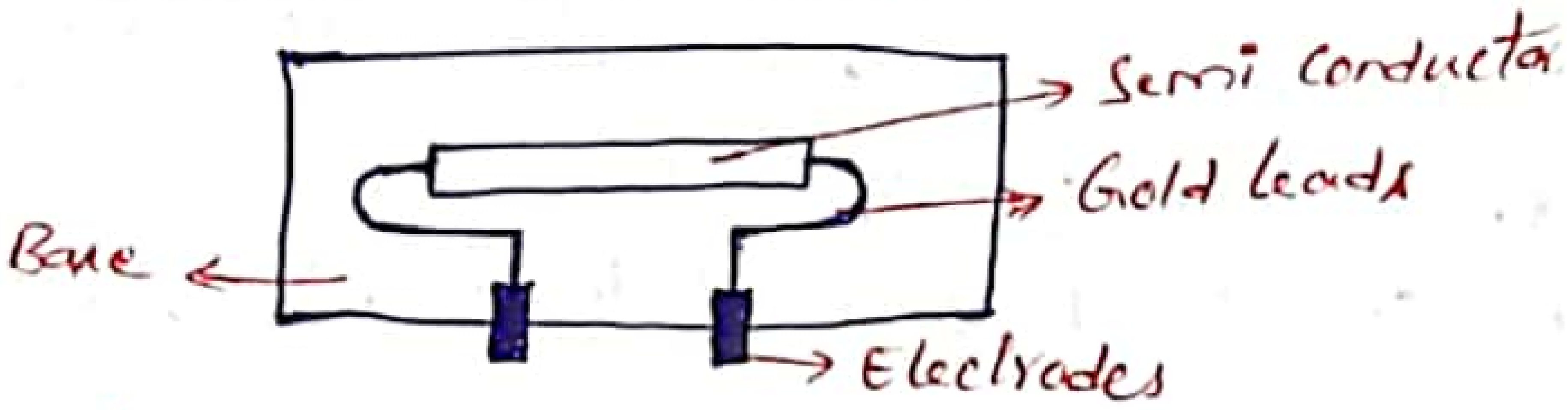

fig: Semi Conductor Strain gauges.

→ To have a high sensitivity, a high value of gauge factor is desirable. A High gauge factor means relatively higher change in resistance, which can be easily measured with a good degree of accuracy.

→ Semi Conductor Strain gauges are Used when a Very high gauge factor is required.

→ They have a gauge factor 50 times as high as wire strain gauges

→ The resistance of the Semi Conductor changes with change in applied strain.

→ Semi Conductor Materials such as germanium and silicon are Used as resistive materials.

→ A typical strain gauge consists of a strain Material and leads that are placed in a protective Box as shown in fig.

→ Semi Conductor wafer (or) filament which have a thickness of 0.05 mm are Used.

→ Gold leads are generally Used for making Contacts.

→ Simple temperature Compensation methods Can be applied to Semi Conductor strain gauges, so that small values of strain that is microstrain Can also be measured.

→ The gauge factor of this type of Semi Conductor strain gauge is 130 ± 10% for a Unit of 350 Ω, 1" Long, ½" wide, 0.005" thickness.

→ The Semi Conductor Straingauge has proved itself to be a stable and practical device for operation with Conventional indicating and recording systems to measure small strains from 0.1 – 500 Microstrain.

Advantages:–

1) These gauges have a high gauge factor of about +130. This allows very small strain measurements of the order of 0.01 Micro strain.

2) Hysterisis characteristics of Semi conductor straingauge are excellent. i.e. lessthan 0.05%.

3) This gauges can be very small in size, ranging in length from 0.7 to 7mm.

Disadvantages:

1) They are very sensitive to changes in temperature.

2) Linearity of Semi Conductor Strain gauges is poor.

3) They are more expensive.

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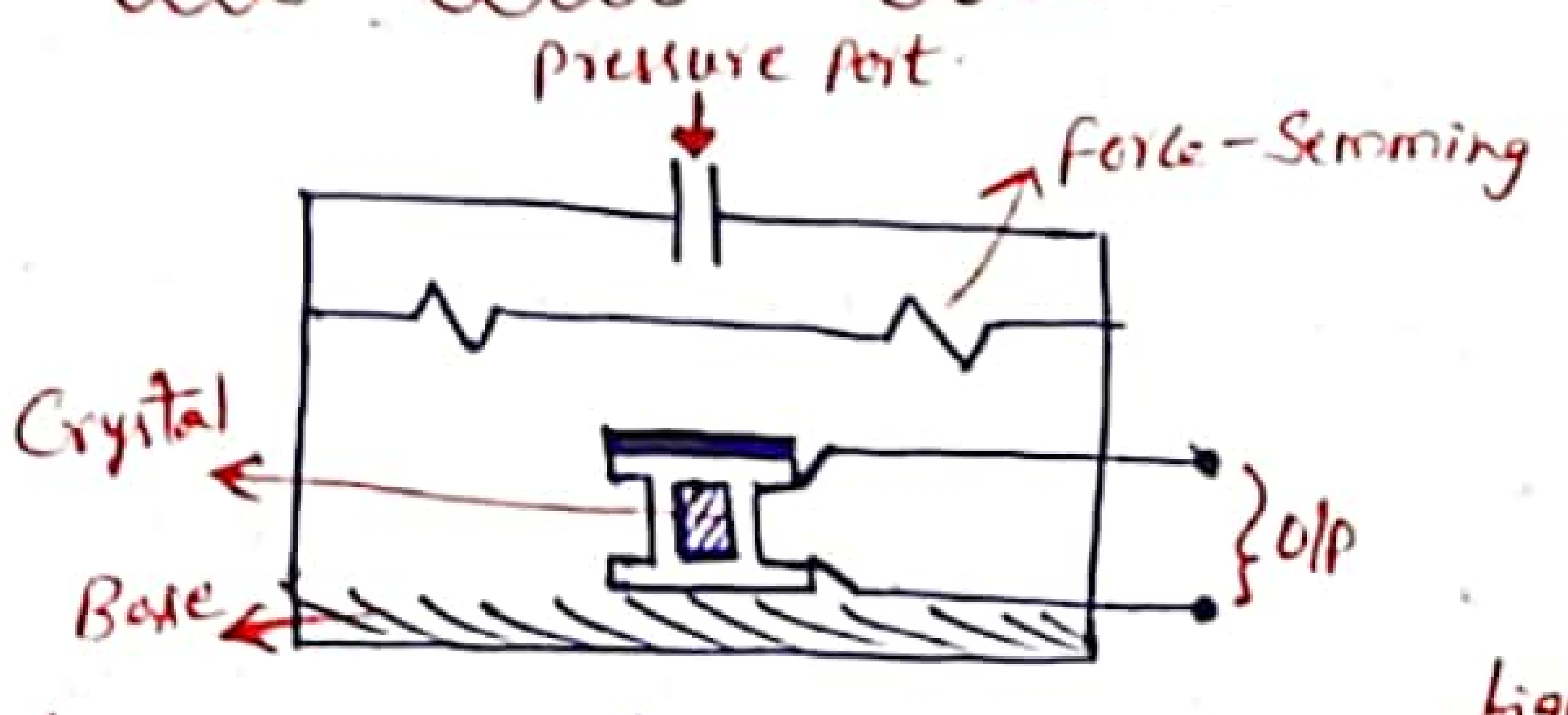
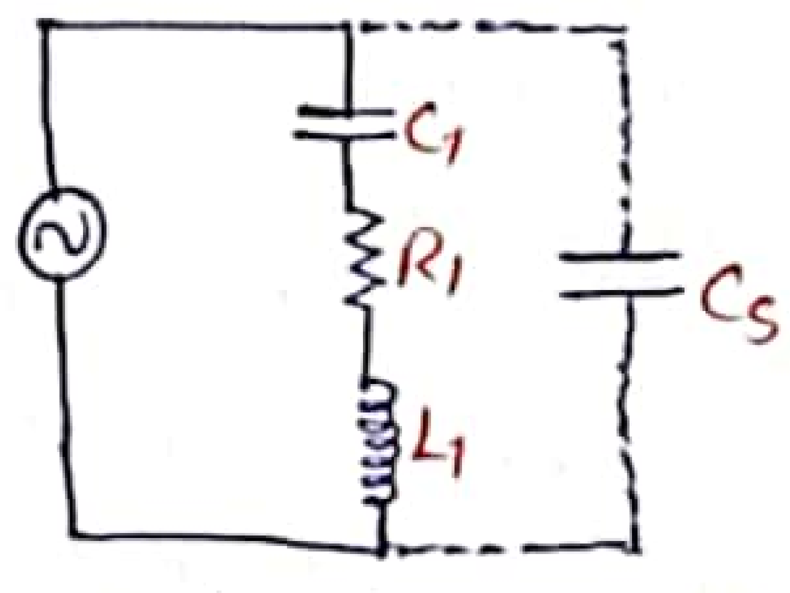
Piezo Electric Transducers: (Measurement of Pressure)



fig(a): Piezo Electric Transducer



fig(b): Equivalent Circuit of a Crystal

→ A Symmetrical Crystalline Materials such as Quartz, Rochelle Salt, and Barium titanate produce an Emf when they are placed under stress. This property is used in Piezo Electric Transducers.

→ Where a crystal is placed between a solid base and the force-summing Members.

→ An externally applied force, Entering the transducer through its pressure port, applied pressure to the top of a crystal.

→ This produces an Emf across the crystal proportional to the Magnitude of applied pressure.

→ Since the transducer has a very good HF response, its principle used in HF accelerometer.

→ In this application, its o/p voltage is typically of the order of 1-30 mV per gm of acceleration.

→ The o/p voltage is also affected by temperature variation of the crystal. The basic expression for o/p voltage 'E' is given by.

$$E = \frac{Q}{C_S}$$ Q = generated charge. C_S = Shunt capacitance.

→ The applied energy is converted to mechanical energy, analogous to a compressed spring. When the pressure is removed, it returns to its original shape and loses its electric charge.

→ From these relationships, the following formulas have been derived for the Coupling Coefficient 'K'.

$$K = \frac{\text{Mechanical energy converted to electrical energy}}{\text{Applied Mechanical energy.}}$$

(or)

$$K = \frac{\text{Electrical energy converted to Mechanical energy}}{\text{Applied electrical energy.}}$$

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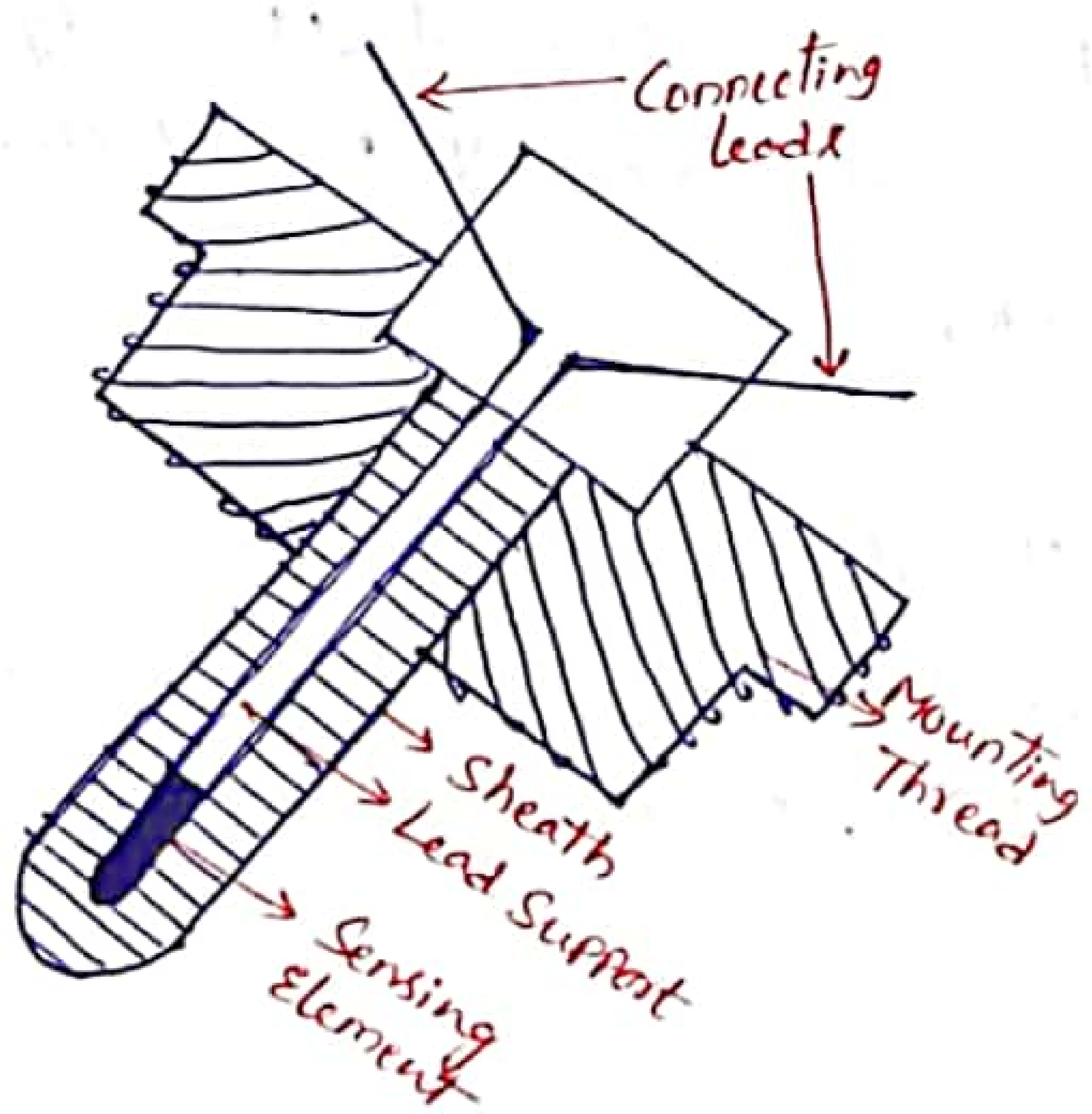
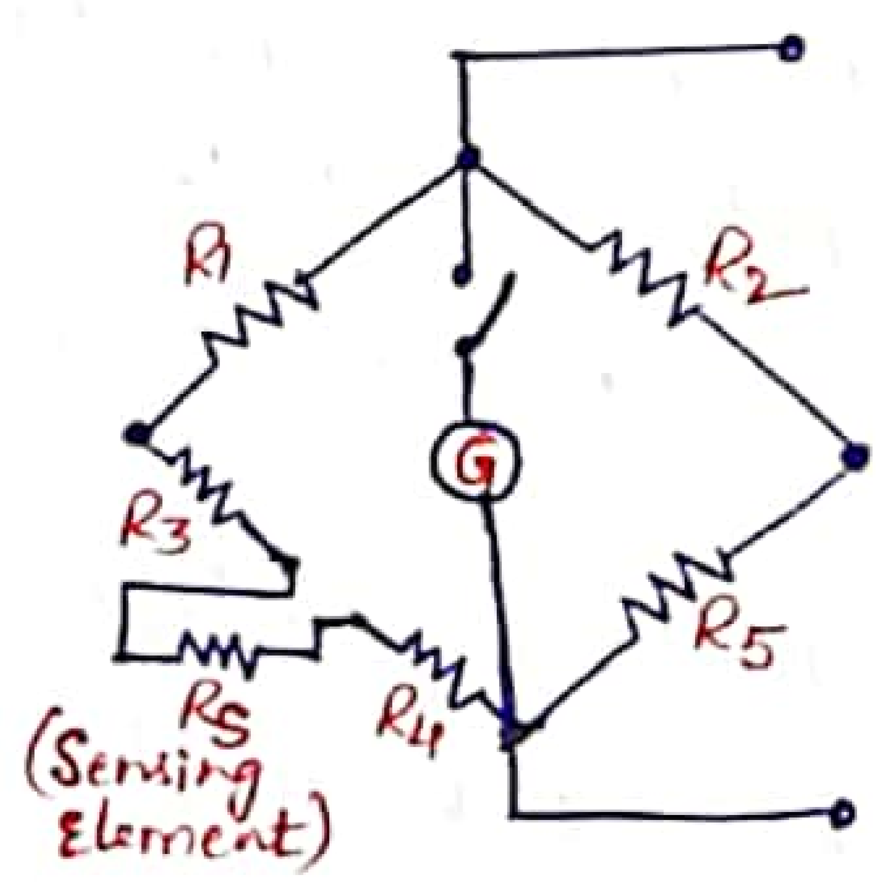
Resistance Thermometer :- (Measurement of Temperature)



fig(a): Resistance Thermometer.



fig(b): Bridge Circuit

→ The resistance of a conductor changes when its temperature is changed. This property is utilized for the measurement of temperature.

→ The "Resistance Thermometer" is an instrument used to measure electrical resistance interms of temperature. i.e. it uses the change in the electrical resistance of the conductor to determine the temperature.

→ The main part of a resistance thermometer is its "Sensing element".

→ The characteristics of the sensing element determines the sensitivity and operating temperature range of the instrument.

→ The sensing element may be any material that exhibits a relatively large resistance change with change in temperature.

→ Platinum, nickel and copper are the metals most commonly used to measure temperature.

→ The changes in resistance caused by changes in temperature are detected by a "wheat stone bridge".

→ The sensing element 'R_S' is made of a material having a high temperature coefficient, and R_1, R_2 and R_5 are made of resistances that practically constant under normal temperature changes.

→ When no current flows through the galvanometer, the normal principle of wheat stone bridge states the ratio of resistance is

$$\frac{R_1}{R_2} = \frac{R_S}{R_5}$$

→ In normal practice, the sensing element is away from the indicator, and its leads have a resistance say R_3 and R_4.

$$\therefore \frac{R_1}{R_2} = \frac{R_3 + R_S + R_4}{R_5}$$

→ Now if resistance 'R_S' changes, balance can not be maintained and a galvanometer shows a deflection, which can be calibrated to give a suitable temperature scale.

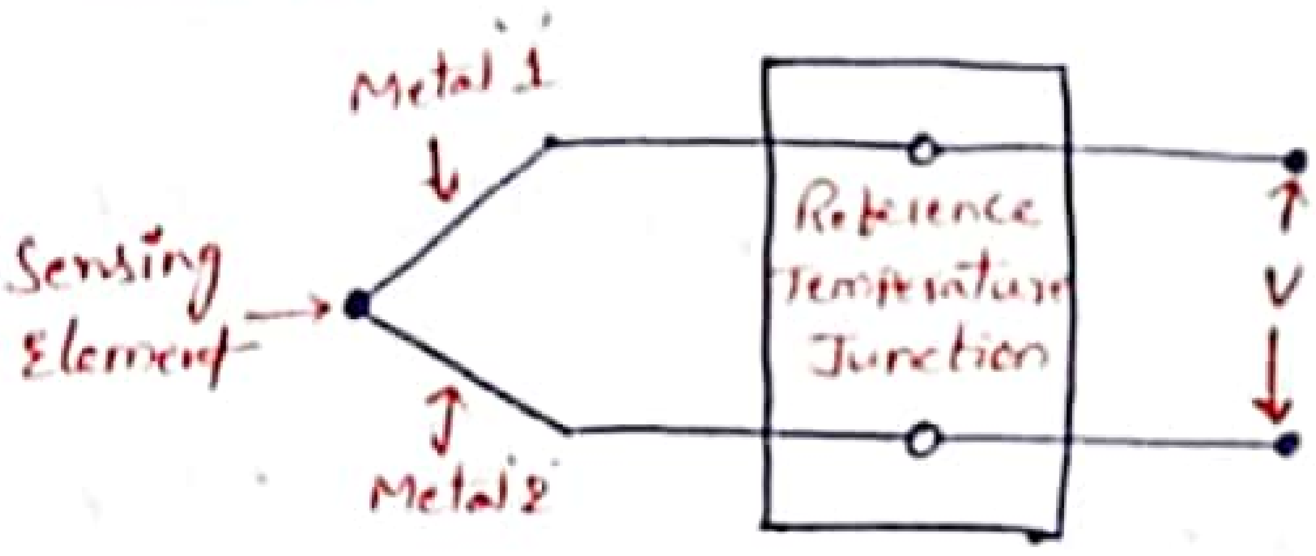
Advantages:-

1) The Measurement is very accurate.
2) The temperature sensitive resistance element can be easily installed and replaced.
3) They are best suited for remote indication.
4) The relative element response time is of the order of 2 to 10 sec.
5) Extremely accurate temperature sensing.

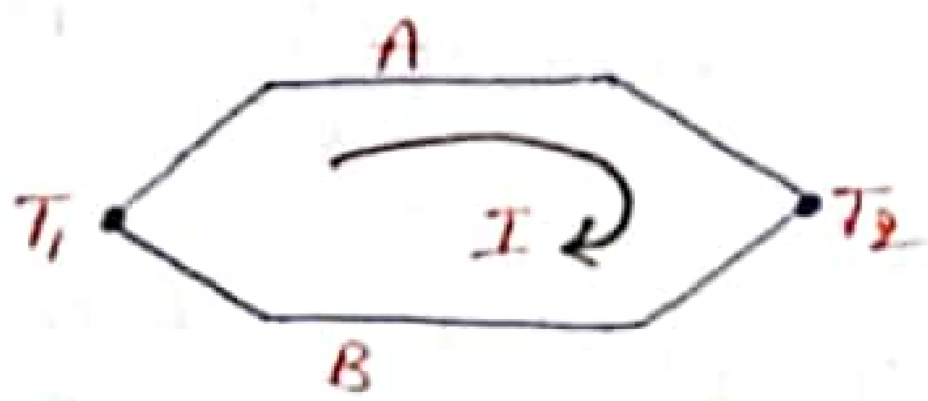
Limitations:-

1) High Cost
2) Need for bridge circuit and power source.
3) possibility of self-heating.

Thermo Couples :- (Measurement of Temperature)



fig(a): Basic ThermoCouple Connection



fig(b): Current through two dissimilar Metals.

→ One of the Most Commonly Used Methods of Measurement of Moderately high temperature is the "thermo Couple Effect."

→ When a pair of wires made up of different Metals is Joined together at one end, a temperature difference between the two ends of the wire produces a voltage between the two wires as shown in fig (a)

→ Temperature Measurement with thermocouple is based on the "Seebeck Effect".

→ A Current will circulate around a loop made up of two dissimilar Metal when the two Junctions are at different temperatures as shown in fig(b).

→ When this circuit is opened, a Voltage appears that is proportional to the Observed "Seebeck Current".

→ There are Voltage Sources, their Sum is the Observed "Seebeck Voltage". Each Junction is a Voltage Source, Known as "Peltier Emf"

→ Each Conductor has a "Self induced Voltage" (or) "Thomson Emf".

→ The thomson and Peltier Emf's Says that with in the Conductor, the density of free charge carriers (Electrons and holes) increases with temperature.

⇒ When a Junction is heated a voltage is generated. this is Known as "See beck Effect".

→ The Seebeck Voltage is Linearly proportional for Small Changes in temperature. Various Combinations of Metals Used in thermocouples.

→ The Magnitude of See beck Voltage depends on the Material Used for the wires and the amount of temperature difference between the Joined ends and the other Ends.

→ The Junction of the wires of the thermocouple is called the "Sensing Junction".

→ The Temperature difference between the Sensing Junction and the other Ends is called as "Critical factor".

→ Suppose the other Ends at constant reference temperature, Called as "Cold Junction".

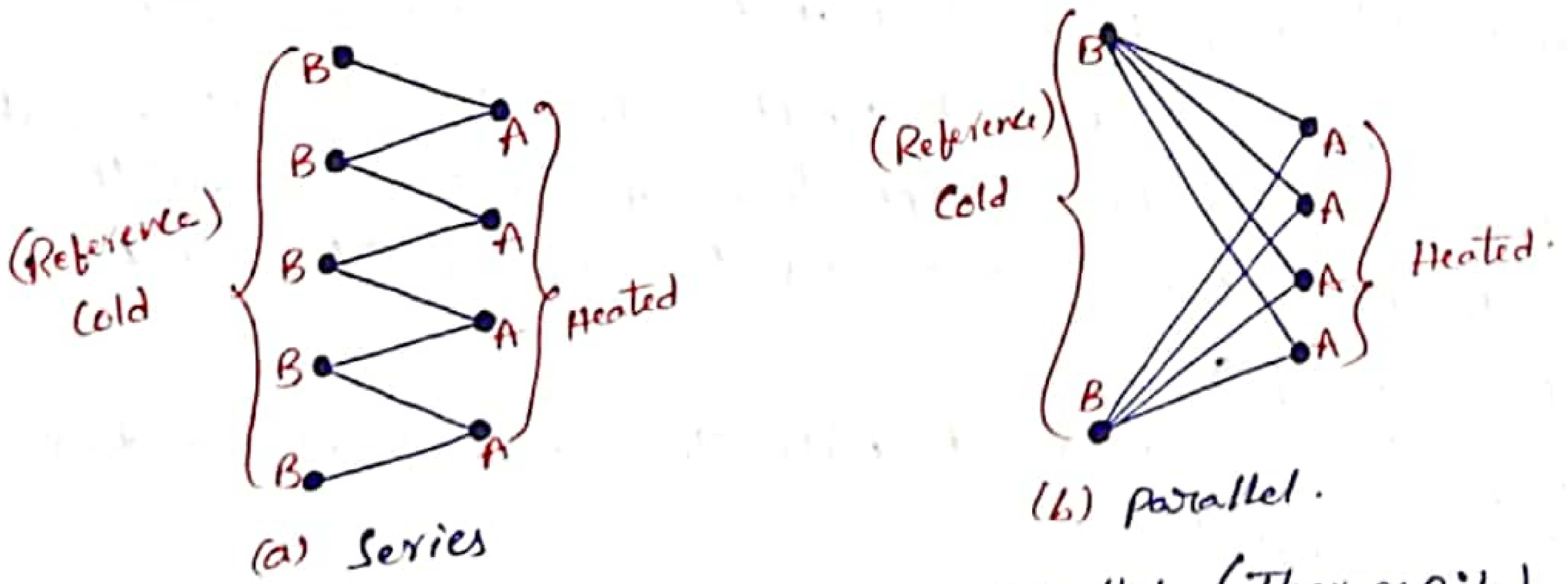


fig: Thermo couples in Series and parallel (Thermopile)

→ In fig (a) Four thermocouples are Connected in Series, with wire 'A' being positive and 'B' being negative in Each thermocouple.

→ The total Emf between points 1 to 5 is the sum of individual thermocouple Emf. An Arrangement of this type is called a "Thermopile" and it is used to obtain increased sensitivity and greater obsolute Emf.

→ Fig(b) shows four thermocouples are in parallel. This arrangement provides a larger current but Emf is same as that of any one thermocouple.

Advantages:

1) Bridge circuits are not required for temperature measurements.
2) Cheaper in cost.
3) Thermocouple offer good reproducibility.
4) Speed of response is high.
5) Measurement accuracy is good.

Dis advantages:-

1) In many applications, the signals need to be amplified.
2) To avoid stray electrical signal pick-up. Proper separation of extension leads from thermocouple wire is essential.
3) They exibit Non Linearity in the Emf (vs) Temp. Characteristics.
4) Cold Junction and other compensation is essential for accurate measurements.

Thermistors :- (Measurement of Temperature)

→ The Electrical Resistance of Most Materials changes with temperature.

→ Thermister (THERMally sensitive resISTOR) are non-metallic resistors (semi conducter material), made by sintering mixtures of metallic oxides such as Manganese, nickel, Cobalt, copper and Uranium.

→ Thermistors have a "Negative Temperature Coefficient" (NTC) i.e. resistance decreases as temperature rises.

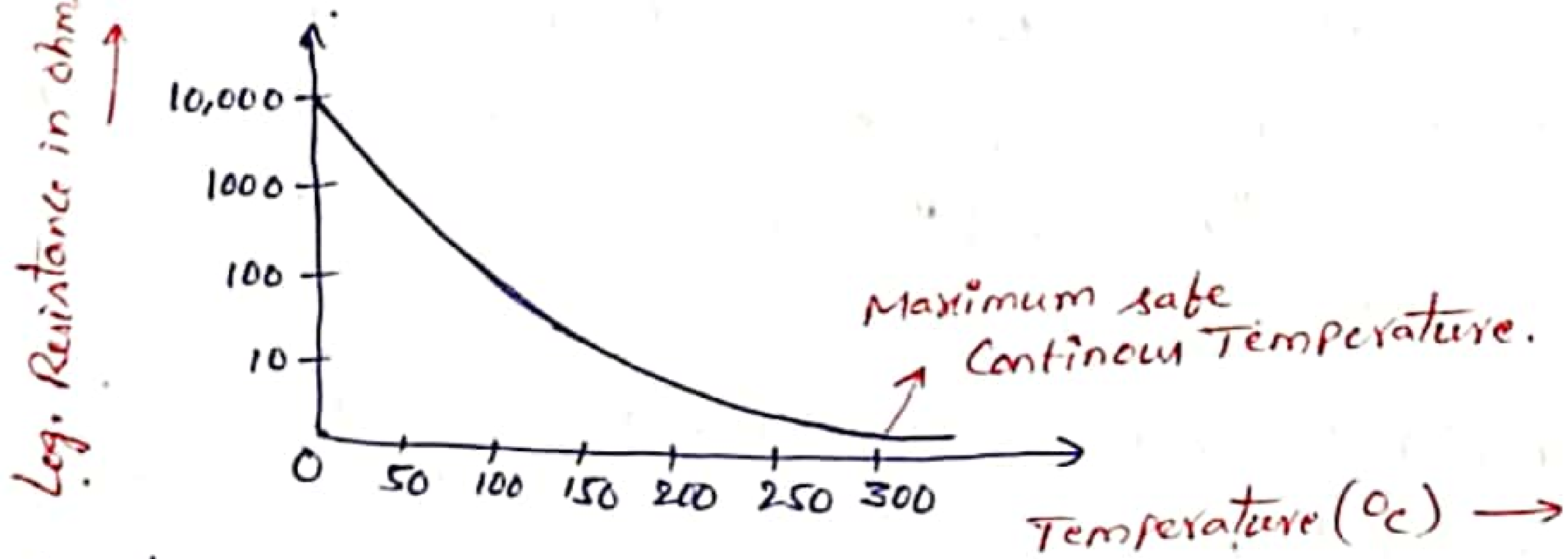


fig: Resistance (Vs) Temperature graph of a Thermistor.

→

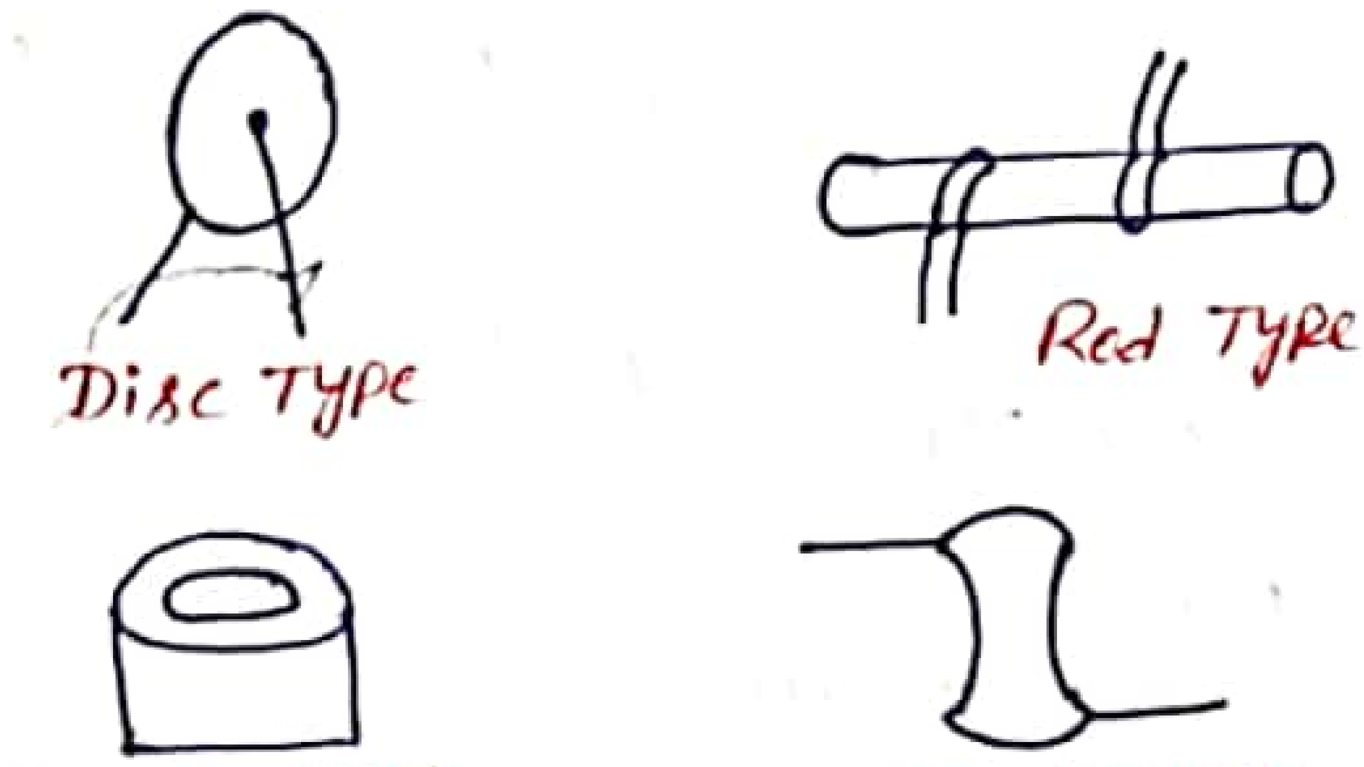


fig: Various Configurations of Thermistors.

→ The Smallest thermistors are made in the form of "Beads". some are as Small as 0.15mm (0.006 In.) in diameter.

→ Thermistors may be Obtained in disc, washer (or) rod forms Disc thermistors about 10mm. in diameter.

→ Rod thermistors are extended through dies to make long Cylindrical Units of 1.25mm, 2.75mm and 4.25mm in diameter and 12.5 – 50mm long. leads are attached to the end of the rods. Their resistance Usually Varies from 1 – 50 KΩ.

→ The advantage of Rod thermistors over other Configurations is the ability to Produce high resistance Units with Moderately high power handling Capability.

→ Thermistors Can be Connected in Series/parallel Combination for applications requiring increased power handling Capability.

→ Thermistors are Non-Linear devices over a temperature range although now units with better than 0.2% Linearity over the 0-100°c temperature range are available.

Advantages:-

1) Small size
2) Low cost
3) Good sensitivity in the NTC region.
4) Fast response over narrow temperature range.

Limitations:-

1) Non-linearity in resistance (Vs) Temperature Characteristics.
2) Unsuitable for wide temperature range.
3) Need of shielded power lines, filters etc. due to high resistance.

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Measurement of Velocity / Speed :-

→ The following types of transducers are used for measurement of linear velocity.

(1) Electro Magnetic Transducers:
  (i) Moving-Magnet Type.
  (ii) Moving Coil Type.
(2) Seismic Type Transducers

Electro Magnetic Transducers:-

→ An Electro Magnetic Transducer utilizes the voltage produced in a coil on account of change in flux linkages resulting from change in reluctance. This is the most commonly used Transducer for measurement of linear velocity.

(i) Moving Magnet type:-

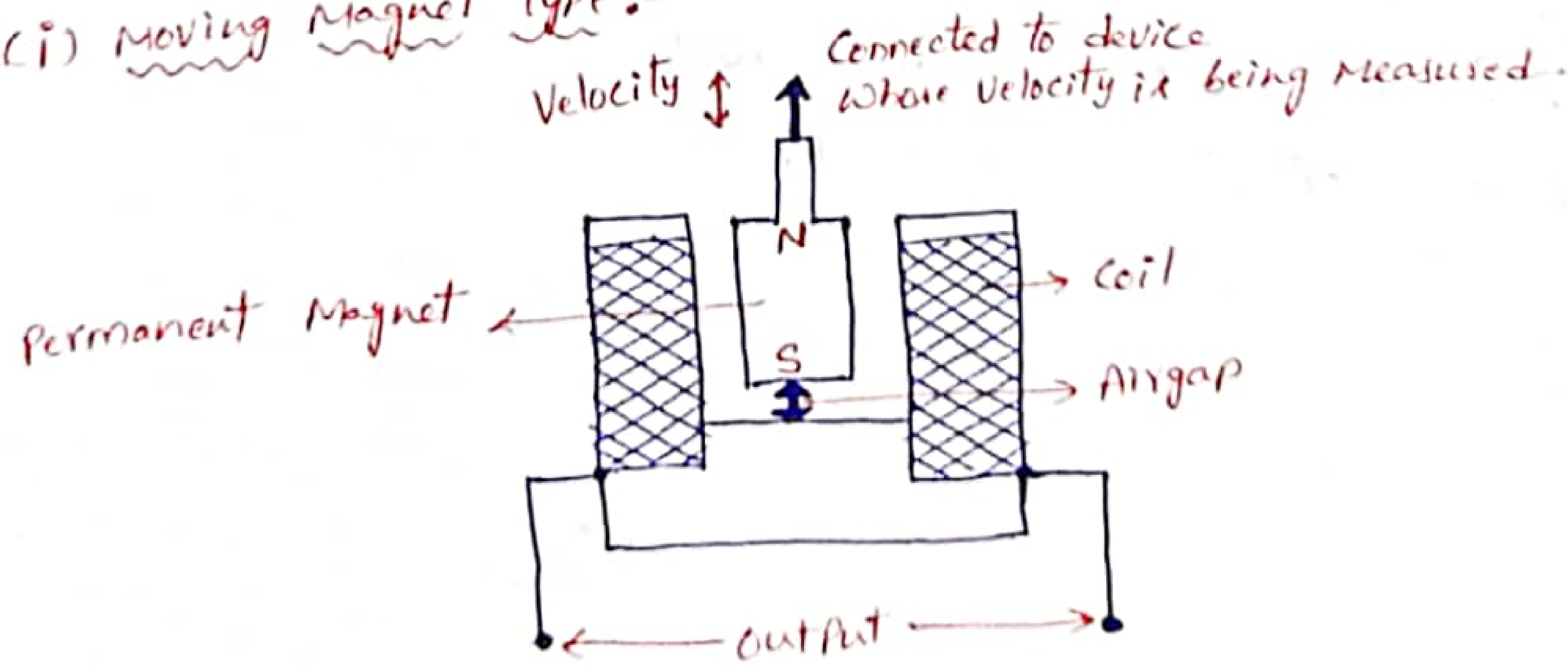

fig: Moving Magnet-type Transducer.

→ A Moving type electro Magnetic Transducer Uses Permanent Magnet which Provides a Constant Polarizing field.

→ It Consists of Rod, which is coupled to the device whose velocity is being measured. The Rod is a permanent Magnet which is Surrounded by a coil.

→ When the Magnet moves a voltage is induced in the coil which is directly proportional to the velocity.

→ The voltage induced in the coil is given by

$$\boxed{e = BANV}$$

where B = flux density (wb/m^2)
A = Area of coil (m^2)
N = No. of turns of coil
V = Relative velocity of Magnet.

i.e. $e \propto V$

→ The direction of Motion is determined by the Polarity of the o/p voltage.

Advantages:

1) The o/p voltage is Linearly proportional to the velocity.
2) Negligible Maintenance.
3) Inexpensive to Manufacture.

Disadvantages:-

1) Limited frequency Response.
2) Unsuitable for Measurement of vibrations.
3) Stray magnetic fields are affects their Performance.

(ii) Moving coil type:

→ This type of Transducer operates essentially through the action of a coil moving in a Magnetic fields. The voltage generated in the coil being proportional to the velocity of the coil.

Advantages:

1) Reduced stray Magnetic field effects.
2) More Satisfactory arrangement.

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Measurement of Acceleration :-

→ The Acceleration of a Moving body is generally measured by means of sensors called "Accelerometers".

→ Types :-
1) Piezo Electric Type
2) Seismic Type

(i) Piezo Electric Accelerometer :-

→ It Consists of a Piezoelectric Crystal Sandwiched b/w two electrodes and has Mass placed on it.

→ According to newtons Second law of Motion "force = Mass x Acceleration" (F=ma) since the Mass is fixed Quantity, force is proportional to the acceleration.

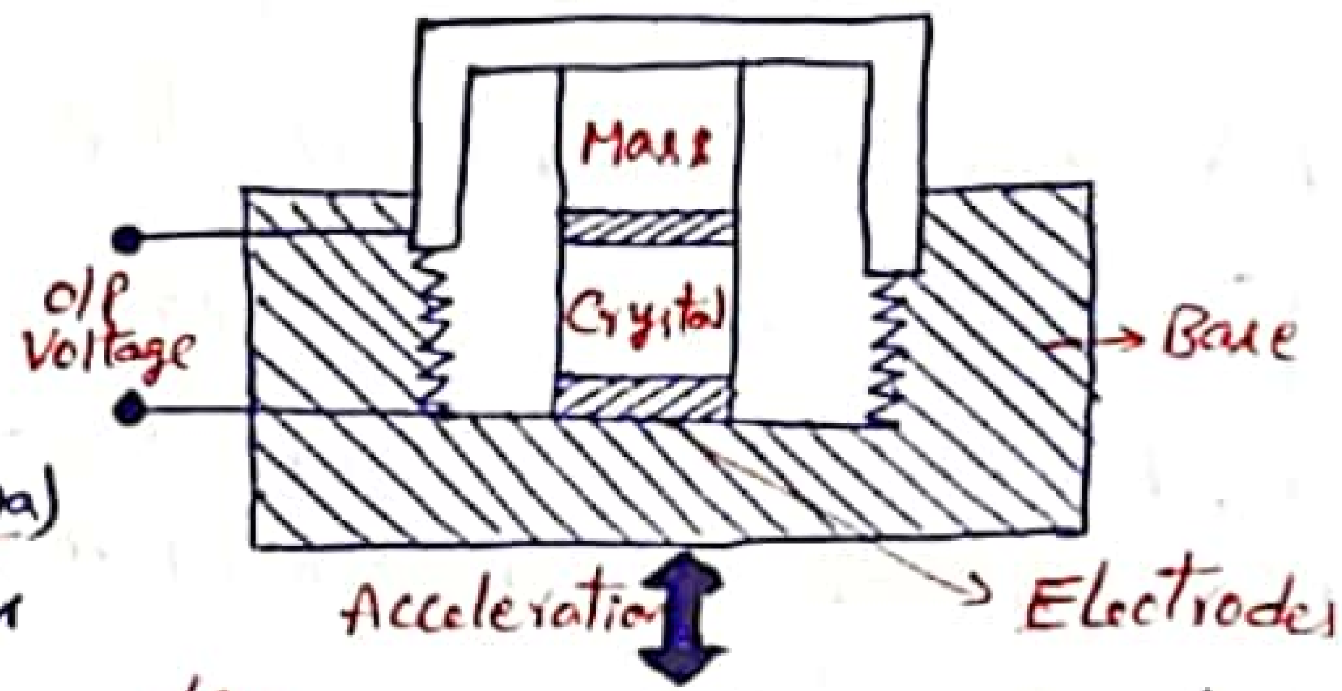

fig: Piezo Electric Accelerometer.

→ An Acceleration in the upward direction would increase the force on the crystal in proportion to the acceleration. This releaves stress on the Crystal. The resulting is change in output voltage because crystals may produce some emf when they are under stress. This o/p voltage is recorded and correlated to the acceleration imposed on the base.

Advantages:
1) Small size & a Small Weight
2) High o/p Impedance.
3) High sensitivity.
4) High frequency response.

Disadvantages :-
1) Unsuitable for applications where the i/p frequency is lower than 10 Hz.
2) Sensitive to temperature changes.

(ii) Seismic Accelerometer :-

→ In a seismic (Displacement Sensing) accelerometer, the displacement of a mass resulting from an applied force is measured and correlated to the acceleration.

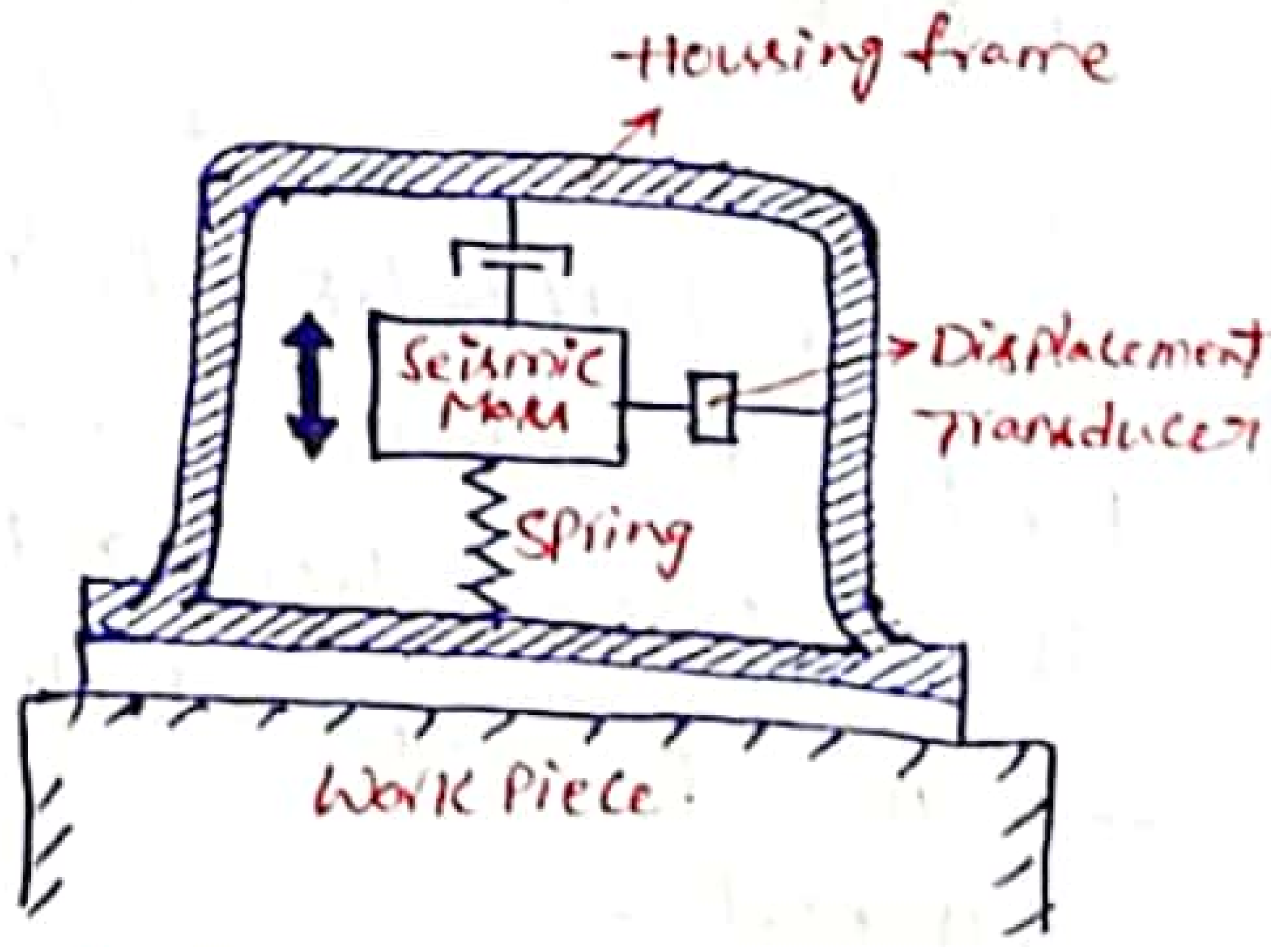

fig: Seismic Accelerometer

→ The Mass is Connected through the Parallel Spring and damper arrangement to the Housing frame.

→ The Housing frame is connected to the source of vibrations whose characteristics are to be measured.

→ The Mass has tendency to remain fixed in its spacial position so that the vibrational motion is registered as a relative displacement b/w Mass and housing frame. This displacement is sensed and indicated by an appropriate Transducer.

→ This accelerometer may also be used as a "Vibration sensor" (vibration refers to the repeated cyclic oscillations of a system).

Measurement of Vibration:-

[Using permanent Magnet Moving coil (PMMC)]

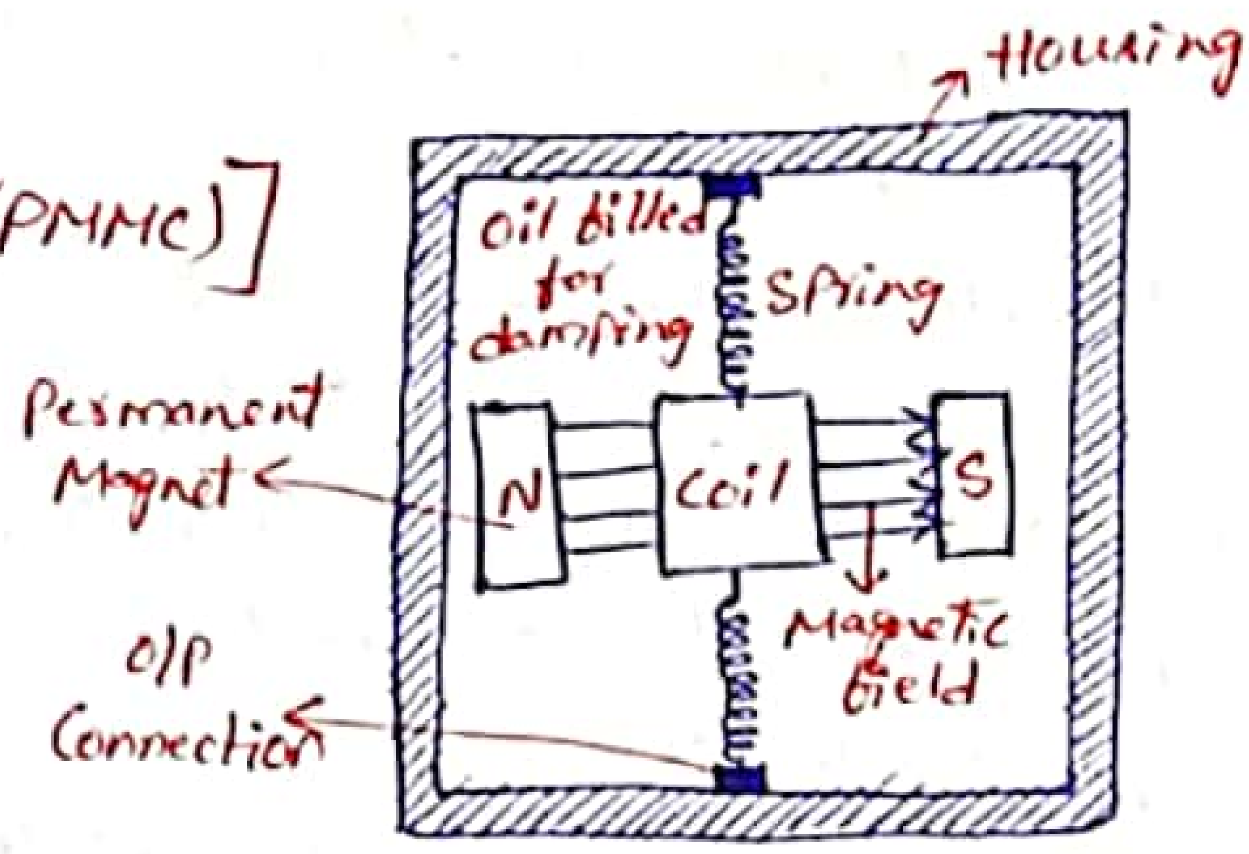

fig: Measurement of Vibration

→ This Method is employed when the Vibrations are to be measured in the form of velocity.

→ The system consists of an electrical coil suspended by a spring in the Magnetic field of a permanent Magnet.

→ The whole assembly is mounted in a housing, which is placed in contact with the vibrating surface. The coil has low natural frequency by which it moves with housing.

→ When vibration velocity is applied to the coil, a voltage is induced in it. The amplitude of voltage is proportional to vibration velocity with frequency equal to the vibration frequency.

→ The Induced voltage is monitored (or) displayed on a read-out.

Measurement of PH Value:-

→ Since acids and bases are of significant importance in various fields like biology, Medicine, food Technology, water sewage treatment and the chemical industry, therefore measurement of their concentration and strength are most common.

→ The scale on which acidity (or) alkalinity is measured in pH scale.

→ The degree of acidity (or) Alkalinity of solution is determined by the relative concentration of Hydrogen (H^+) ions and Hydroxyl (H^-) ions in the solution.

→ The Solution is "acidic" when Hydrogen (H^+) ions are dominate.
The solution is "alkaline" when Hydroxyl(OH^-) ions are dominate.

→ In any such Solution the product of (H^+) and (OH^-) has a Constant value which is always equal to 10^{-14}.

→ Hydrogen (H^+) ion Concentration is Measured on PH Scale.

→ PH Value of a Solution is defined as the negative logarithm of the Hydrogen ion Concentration.

$$pH = -\log_{10}(H^+)$$

→ This Scale ranges from '0' to '14'.

→ In Neutral Solution, the Concentration of both (H^+) and (OH^-) ions are equal i.e. both are 10^{-7}.

$$pH = -\log_{10}(10^{-7}) = 7$$

∴ for a Neutral solution pH = 7

→ Thus a Neutral solution like Pure water has a PH Value of '7'.

→ For "Acidic solutions" the PH Value lies b/w '0' to '7'. In Case of "Alkaline Solutions" PH Value lies in b/w '7' to '14'.

→ PH measurement involves the break down of Certain chemical Components when Combined with water. When these compounds breakdown, tiny Electrically charged Particals are released. Some of these are negatively Charged particals – Hydroxyl ions (OH^-) and some are positively Charged particals – Hydrogen ions (H^+)

→ The pH of a Solution can be accurately measured by means of an electronic "PH meter". PH meter Usually covers a range of '0 to 14' PH Units.

PH Cell (or) PH Meter:–

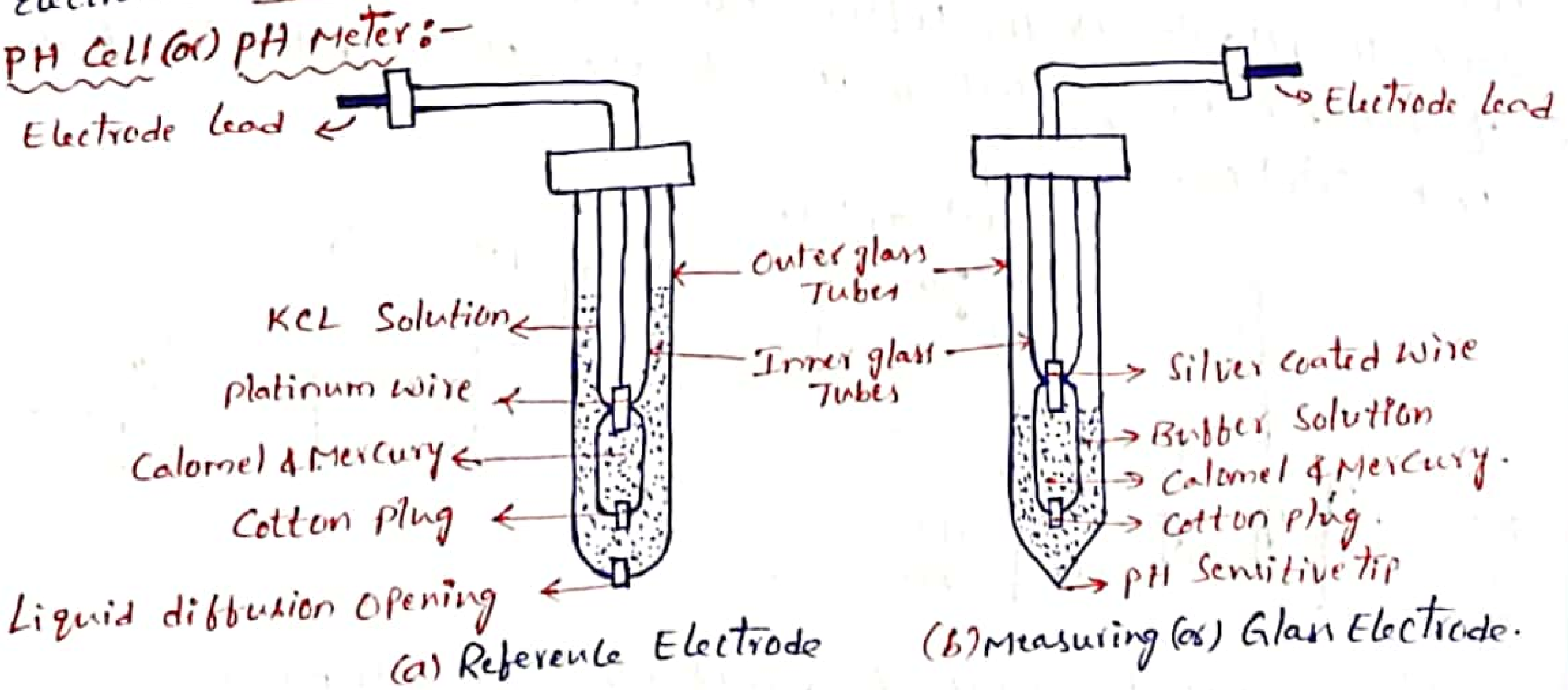

fig: PH Meter

→ The PH Cell Consists of two Electrodes.

1) Reference Electrode – at a Constant Potential regardless of the PH Value of the solution under Test.

2) Measuring Electrode – The Potential of this electrode is determined by the PH Value of Solution.

→ Thus the potential difference b/w the two electrodes depends upon the PH value of the Test Solution.

→ The "Reference Electrode" is Made of glass and Consists of an inner assembly containing a solution Calomel "(Mercury Chloride) and "Mercury". This assembly is Surrounded by a larger glass tube, and the space b/w the two Contains an accurate solution of KCL (Potassium cloride).

→ A Tiny opening in the bottom of the electrode permits KCl to diffuse very slowly into the test solution.

→ In this way the electrical contact is Made b/w this Solution and Calomel solution of the reference Electrode. Thus the test solution acts the potential level of the reference Electrode.

→ In the Measuring Electrode the mercury Calomel element is Surrounded by a buffer solution of. Known and Constant PH.

→ There is no opening at the bottom of the outer Tube, instead tapers down to a tip Made of thin glass of Special Composition.

→ At this tip a Potential difference b/w the buffer solution and the test solution because of difference in the PH Value of the two Solutions since the PH value of the buffer solution is Constant the net Potential of this measuring electrode is a function of the PH Value of the Test Solution.

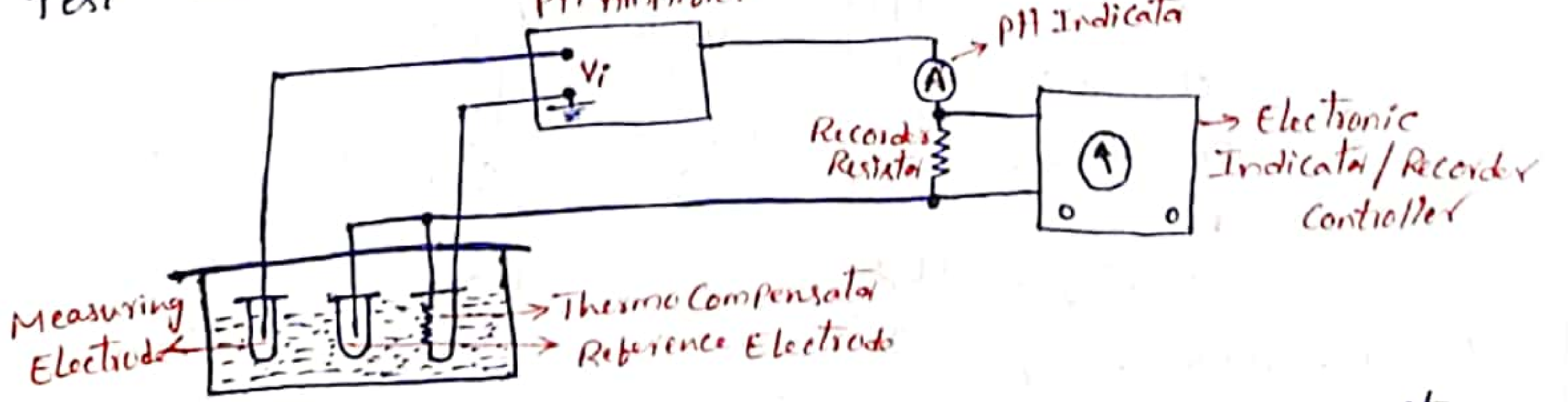

Fig: Simplified Circuit diagram of Electronic PH Measurement.

→ The voltage developed b/w the measuring electrode and the reference electrode is applied as the i/p voltage. 'V_i' to a null balance millimeter

→ The temperature compensating resistor immersed in the test solution is included in the test circuit. Its resistance varies with the variation in temperature of the test solution, so that the PH measurement is correct at the working temperature.

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