Introduction to instrumentation system measurement.

value of quantity under measurement. → I/P → [System] → O/P measured value of quantity

Measurement ⇒ It is the process by which one can convert physical parameters to meaningfull number.
In others words it can be defined as the comprasion of some quantity with respect to other. for measurement the quantity under measurement is fed into the system and output is as it's value in the visual display unit.

Measurement System

measurement system is the means used to carry out the measurement from the input of the quantity to be measured to the output there consist of various components performing different tasks.

I/P → [Sensor / Transducer] → [Signal conditioner] → [Signal Processor] → [Data transmission] → [Data Presentation]

Components

I Sensor / Transducer

It's convert one form of energy into another form. The quantity to be measured may be in any form of energy ~~to~~ so the energy to be converted into the form which is suitable for the component used afterwards. The known electrical energy can be converted into electrical and vice versa. The sensor of this type is transducer. Eg: Thermalcouple photodecter etc.

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Signal conditionar

Signal obtain from the transducer may be required to change it's property this is done by using signal conditionar It may involve amplification, attanution, intergration, differentation, addition etc.

Signal processor

A signal processor produce the output signal which is suitable for intregration, recording or transmission to a long distance. It may involve A.C to D.C analog to degital etc.

Data transmission

It transmits the data from signal processor to the data present in it. It may be wired or wireless.

Data presentation

The information about the quantity under measurement has to be easy to handling the instrument or the system for monitoring, control or analysis propose It may be include register, counter, seven Sigment display, digital computer, recorder etc.

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Extension of Instrument Range

- Shunts and CTs (Current Transformer) are used to extend the range of ammeter.
- multipliers and PTs (potential Transformer) are used to extend the range of voltmeter.

Ammeter shunts

- It is a low resistance that is placed in parallel with coil ckt of instrument.

Here $I = I_m + I_s$

$I_s = I - I_m$

Now, $I_s R_s = I_m R_m$

$$R_s = \frac{I_m R_m}{I_s} = \frac{I_m R_m}{I - I_m}$$

$$= \frac{R_m}{\frac{I}{I_m} - 1}$$

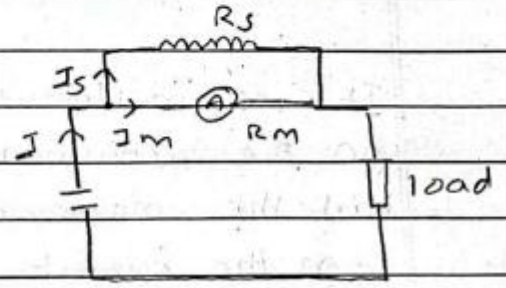


fig: ckt diagram

$$R_s = \frac{R_m}{N - 1}$$ where $N \Rightarrow$ multiplying factor $\Rightarrow \frac{I}{I_m}$

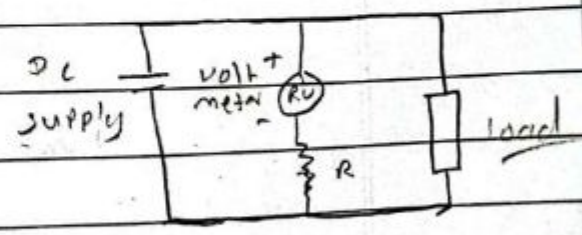
Voltmeter multiplier

It is a high non-inductive resistance connected in series with the voltmeter coil and is used for increasing the range of the voltmeter.

Here, $V = IR_v + IR$

$= I(R_v + R)$

or $R = \frac{V}{I} - R_v$



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Multirange Ammeters :

Let N_1, N_2, N_3, N_4, N_5 be the multiplying power of the shunts.

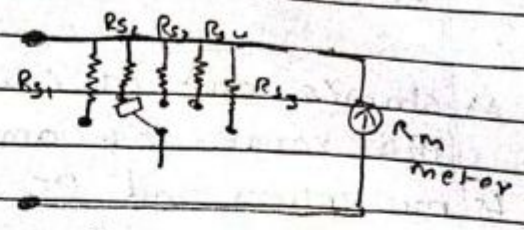


fig: multirange Ammeter.

NOW; $R_{s_1} = \frac{R_m}{N_1 - 1}$;

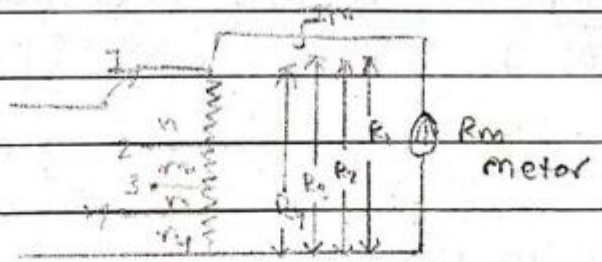
$R_{s_2} = \frac{R_m}{N_2 - 1}$;

$R_{s_3} = \frac{R_m}{N_3 - 1}$; $R_{s_4} = \frac{R_m}{N_4 - 1}$; $R_{s_5} = \frac{R_m}{N_5 - 1}$

It use multiposition make-before break switch provided on the instrument case. such switch is essential so that the meter movement is not damaged when changing from the current range one to another.

Universal shunt or Ayrton shunt

It eliminates the possibility of meter being in the ckt without a shunt.



for position 1: $\frac{R_m}{N_1 - 1}$

for position 2: $I_m (R_1 - R_2 + R_m) = (I_2 - I_m) R_2$

or $I_m R_1 - I_m R_2 + I_m R_m = I_2 R_2 - I_m R_2$

or $I_m (R_1 + R_m) = I_2 R_2$

or $R_2 = \frac{(R_1 + R_m) I_m}{I_2} = \frac{R_1 + R_m}{I_2 / I_m} = \frac{R_1 + R_m}{N_2}$

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for position 3 : $I_m(R_1 - R_3 + R_m) = (I_3 - I_m)R_3$

or, $N_3 = \frac{R_1 + R_m}{R_3}$

for position 4:

$I_m(R_1 + R_4 + R_m) = (I_4 - I_m)R_4$

or $R_4 = \frac{R_1 + R_m}{N_4}$

Thus values of different sections of resistance i.e

$r_1 = R_1 - R_2$ $\quad r_2 = R_2 - R_3$

$r_3 = R_3 - R_4$ $\quad r_4 = r_4$ may be determined.

IMP QN Design an Ayrton shunt to provide an ammeter with current ranges of 1A, 5A and 10A. The movement with internal resistance of 50Ω and full scale deflection current of 1mA is used in the configuration.

soln

meter resistance $(R_m) = 50\Omega$

meter current for full scale deflection (I_m)

$1mA = 1 \times 10^{-3}$

i) for range of 1A (position 1)

multiplying factor $N_1 = \frac{I}{I_m} = \frac{1}{1 \times 10^{-3}} = 10^3$

ii) for range of 5A (position 2nd)

$N_2 = \frac{I}{I_m} = \frac{5A}{1mA} = 5 \times 10^3$

$R_2 = \frac{R_1 + R_m}{N_2} = \frac{0.05 + 50}{5 \times 10^3} = 0.01\Omega$

iii) for range of 10A (position 3rd)

$N_3 = \frac{I}{I_m} = \frac{10A}{1mA} = 10 \times 10^3$

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$R_3 = \frac{R_3 R_m}{N_3} = \frac{0.05 \times 50}{10 \times 10^3} = 0.005\,\Omega$ and

section resistance

$r_1 = R_1 - R_2 = 0.04\,\Omega$

$r_2 = R_2 - R_3 = 0.0045\,\Omega$

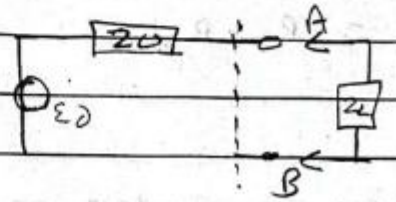
$r_3 = R_3 = 0.005$

loading effect due to shunt connected instrument.

$\because E_0 = I_L Z_L + I_L Z_0$

$I_L (Z_L + Z_0)$

$\therefore E_L = I_L Z_L$



$$\frac{E_L}{E_0} = \frac{I_L Z_L}{I_L (Z_L + Z_0)} = \frac{1}{\frac{Z_L}{Z_L} + \frac{Z_0}{Z_L}}$$

$$= \frac{1}{1 + \frac{Z_0}{Z_L}}$$

$\therefore$ Actual voltage measured, $E_L = \frac{E_0}{1 + \frac{Z_0}{Z_L}}$

The meter takes appreciable current and indicates a lower reading than what existed before the meter was connected. This effect of the voltmeter is called the loading effect.

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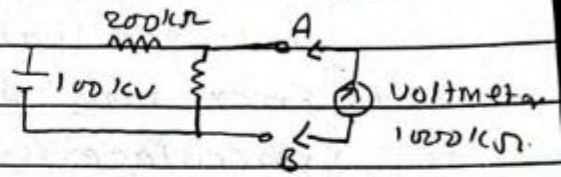
Ex: A 100V range voltmeter is connected across the terminals A and B of the ckt shown in figure. find the reading of the voltmeter under open ckt and loader conditions - find the accuracy and the loading error. The voltmeter has resistance of 1000kΩ



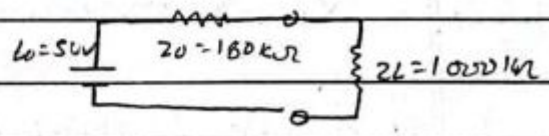
i) open ckt voltage across A and B is

$$t_0 = 100 \times \frac{200}{200+200} = 50V$$

O/P impedance $(z_0) = \frac{200 \times 200}{200+200} = 100k\Omega$

∴ Trevenin's eqn ckt under loaded conditions

$$t_1 = \frac{t_0}{1+\frac{z_0}{z_1}} = \frac{50}{1+\frac{100}{1000}}$$



$= 45.45V.$

∴ loading error $= \frac{45.45-50}{50} \times 100 = 9.1\%$ (100)

Accuracy = 100 - % loading error

= 100 - 9.1

= 90.9%

Note: meter resistance (z) = Sensitivity * scale

$= \frac{\Omega}{V} \times V$

$= \Omega$

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~~Types~~

Errors in measurement

- Error is the deviation of the true value from the measured value
- Error may be expressed either as absolute or as percentage

Absolute error

$e = |Y_n - X_n|$

$Y_n \Rightarrow$ True value

$X_n \Rightarrow$ measured value

$$\% \text{ Error} = \frac{\text{Absolute value}}{\text{True value}} = \left| \frac{Y_n - X_n}{Y_n} \right| \times 100\%$$

Types of errors

- Gross Errors
- Systematic errors
  - → Instrumental Error
  - → Environmental error
- Random Errors

1. Gross Errors
- Carelessness in reading
- poor Selection of measuring instruments
- Adjustment of instrument

Minimization of errors

- Great care should be taken in reading and recording the data
- more reading should be taken.

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A # Instrumental Errors

1) Due to inertia of instrument parts.
2) Due to misuse of instruments
3) Due to leading effect of instruments.

minimization of Errors.

1) Selecting a suitable instrument for the particular measurement application.
2) Applying correction factors

B Environmental Errors

1) Poor shielding of instrument
2) Due to change in environmental conditions such as tempr, magnetic fields etc.

minimization of Errors

1) using proper shielding
2) using correction factor

C Random Errors

1) Occurs due to unknown causes or due to the cause that are difficult to find out.

Minimization of Errors

1) Can be minimized by taking many different readings and using statistical analysis approach.

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Statical Analysis

i) Arithematic mean ($\bar{x}$)

4) Average of the data taken

$$\bar{x} = \frac{x_1 + x_1 + \cdots + x_n}{n}$$

ii) Deviation from the mean (d):-

4) Deviation of each reading from the mean value

i.e $d_1 = x_1 - \bar{x}$

$d_2 = x_2 - \bar{x}$ } may be +ve or -ve

$d_n = x_n - \bar{x}$

iii) Average deviation (D)

4) Average of the absolute sum of individual deviation

$$D = \frac{|d_1| + |d_2| + \cdots + |d_n|}{n}$$

iv) standard deviation

It is also known as Rms deviation

$$\sigma = \sqrt{\frac{d_1^2 + d_2^2 + \cdots + d_n^2}{n}} \quad \text{if } n > 20$$

$$\sigma = \sqrt{\frac{d_1^2 + d_2^2 + \cdots + d_n^2}{n-1}} \quad \text{if } n \leq 20$$

v) Variance (V)

square of standard deviation

$$V = \sigma^2 = \frac{d_1^2 + d_2^2 + \cdots + d_n^2}{n} \quad \text{if } n > 20$$

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$$V = \sigma^2 = \frac{d_1^2 + d_2^2 + \cdots + d_n^2}{n} \quad \text{if } n \leq 20$$

QN A ckt was tuned by ten different students and the values of resonant frequency in KHz were recorded as 525, 526, 524, 527, 523, 527, 525, 524, 528 & 527. Assume that only random errors are present. calculate

i) Arithematic mean
ii) Average deviation
iii) Standard deviation
iv) Probable error

Soln

Table

x	$d(x_1 - \bar{x})$	d^2
525	-0.6	0.36
526	$+0.4$	0.16
⋮		
$\Sigma x = 5256$		

i Arithematic mean $= \frac{x_1 + x_2 + \cdots + x_n}{n}$

$= 5256 / 10$

$= 525.6$ KHz.

ii Average deviation (D)

$$\frac{|d_1| + |d_2| + \cdots + |d_n|}{n}$$

$= 1.4$ KHz

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iii standard deviation (σ):-

$$\frac{\sqrt{d_1^2+d_2^2+\cdots}}{n}$$

$= 2.44$ kH.

iv probable error $= 0.6745 \times \sigma$

$= 1.64578$

Concept of Bridges:-

wheatstone Bridge
maxwell's Bridge
maxwell's wien bridge
schering Bridge
kelvin Bridge
Hay's Bridge
capacitance Bridge
wien's Bridge (freq. measurement)

{ * DC Bridge
others AC Bridges }

Bridge ckt:-

Bridge ckts are the simple electrical n/w that are extensively used for measuring the component values such as
Resistor (R), Inductor (L) and capacitance (C)

Wheatstone Bridge:-

i) used in measurement of medium resistance
ii) accurate and reliable used in industry

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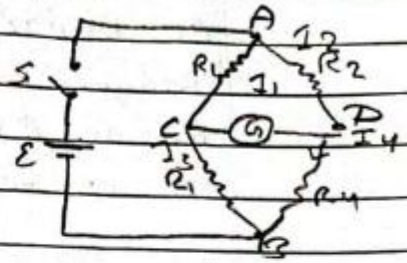
4) It operates on null indication principle

1) R_1, R_2, R_3, R_4 → Resistors

G = Galvanometer

S = switch

$\mathcal{E}$ = source emf



when switch is closed, current flows and divides into two arms at point A. The bridge is balanced when there is no current through the galvanometer when the p.d at point C and D is equal.

4) from figure $I_1R_1 = I_2R_2$ — (i) for bridge balance. for galvanometer current to be zero, the following condition should be satisfied.

$$I_1 = I_3 = \frac{\mathcal{E}}{R_1 + R_3} \quad \text{--- (II)}$$

$$I_2 = I_4 = \frac{\mathcal{E}}{R_2 + R_4} \quad \text{--- (III)}$$

substituting eqn (II) and (III) in eqn (i) we get,

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

$$R_1R_2 + R_1R_4 = R_1R_2 + R_2R_3$$

$$R_1R_4 = R_2R_3$$

$$\therefore R_4 = \frac{R_2R_3}{R_1} \quad \text{--- (IV)}$$

This is the equation for the bridge to be balanced. The unknown resistance (R_x) normally connected to R_4

$$\therefore R_x = \frac{R_2R_3}{R_1}$$

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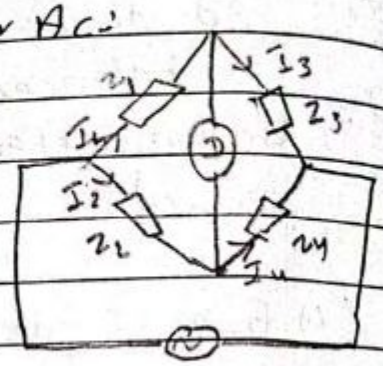
AC Bridges

AC bridges is similar to D.C bridge expect that bridges arms are impedance. The bridge is exitated by an A-C source rather than D.C and the galvanometer is replaced by a ~~dectro~~ detector.

General Eq^n for bridge Balance for AC:



At bridge balance condition

$I_1 Z_1 = I_2 Z_2$ and

$I_3 Z_3 = I_4 Z_4$

and from figure; $I_1 = I_3$

$I_2 = I_4$

$$\frac{I_1 Z_1}{I_3 Z_3} = \frac{I_2 Z_1}{I_4 Z_4}$$

$$Z_1 Z_4 = Z_2 Z_3$$

In polor form; $(Z_1 \angle \theta_1)(Z_4 \angle \theta_4)$

or $Z_1 Z_4 \angle(\theta_1 + \theta_4) = Z_2 Z_3 \angle(\theta_2 + \theta_3)$

when baldcing an a-c bridge

The 1st condition is that the magnitude of impedance satisfy the relationship:

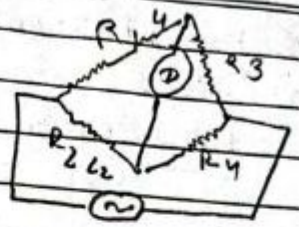
$$Z_1 Z_4 = Z_2 Z_3 \quad -- (1)$$

The 2nd condition is that the phase angle of impedances satisfy the relationship:

$$\angle\theta_1 + \theta_4 = \angle\theta_2 + \theta_3 \quad -- (2)$$

If it is represented in the reactangular form then Real part and imagmary part of both sides

must be equal.



Maxwell's Bridge

$Z_1 Z_4 = Z_2 Z_3$

Here; $Z_1 = R_1 + j\omega L_1$

$Z_2 = R_2 + j\omega L_2$

$Z_3 = R_3$

$Z_4 = R_4$

$(R_1 + j\omega L_1) R_4 = (R_2 + j\omega L_2) R_3$

$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega L_2 R_3$

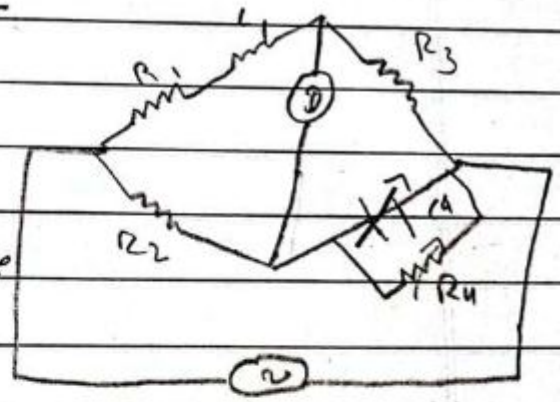
on equating;

$R_1 R_4 = R_2 R_3$ and $L_1 R_4 = L_2 R_3$

$R_1 = \frac{R_2 R_3}{R_4}$ $\quad L_1 = \frac{R_3}{R_4} L_2$

Thus value of unknown self inductance L_1 can be determined.

Maxwell's Wien Bridge :-



$L_1 \Rightarrow$ unknown inductance

$R_1 \Rightarrow$ effective resistance of inductor L_1

$R_2, R_3, R_4 \Rightarrow$ known non-inductive resistances

$C_4 =$ variable standard capacitor

$Z_1 = R_1 + j\omega L_1$

$Z_2 = R_2$

$Z_3 = R_3$

$Z_4 = \frac{R_4}{1 + j\omega C_4 R_4}$ $\quad \therefore \left(R_4 \,//\, \frac{1}{j\omega C_4}\right) = \frac{1}{Z_4} = \frac{1}{R_4} + \frac{1}{\frac{1}{j\omega C}}$

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

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

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

$$Z_1 Z_4 = Z_2 Z_3$$

$$(R_1 + j\omega L_1) \cdot \left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = R_2 R_3$$

$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega R_2 R_3 C_4 R_4$$

Equating real and imaginary parts

$$R_1 R_4 = R_2 R_3 \qquad \therefore L_1 R_4 = R_2 R_3 C_4 R_4$$

$$R_1 = \frac{R_2 R_3}{R_4} \qquad L_1 = C_4 R_2 R_3$$

$$\text{Quality factor} = \frac{\omega L_1}{R_1} = \frac{\omega C_4 R_2 R_3 R_4}{R_2 R_3}$$

$$= \omega C_4 R_4$$

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1 A 1000Hz bridge has the following constant
armab $R_1 = 1000\Omega$ in parallel with $C_1 = 0.5\mu f$
arm bc $R_3 = 1000\Omega$ in series with $C_3 = 0.5\mu f$
arm cd $L_4 = 30mH$ in series with $R_4 = 200\Omega$.
find the constant of armda to balance the bridge. Express the result as a pure resistance R in series with a L or C.

Soln

$R_1 = 1000\Omega$

$R_3 = 1000\Omega$

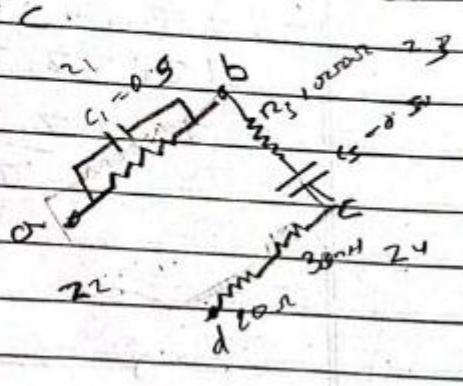
$R_4 = 200\Omega$

$C_1 = 0.5\mu f = 0.5\times10^{-6}$

$C_3 = 0.5\mu f$

$L_4 = 30mH$

$Z_1, Z_2 = ?$



Now,

$$Z_1 = \frac{R_1 \times C_1}{R_1 + C_1}$$

$$= \frac{1000 \times 0.5}{1000 + 0.5}$$

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

$$= \frac{1000}{1 + j \times 100 \times 0.54 \times 1000}$$

$$=$$

$Z_1 = R_1 + j\omega L_1$

$= 1000 +$

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

$$= \frac{1000}{1 + j \times 100\,2\pi\, 0.54\times10^{-6} \times 1000}$$

$91.93 - 288.93j$

$92 \angle 289$

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

$$= 1000 - j318.31$$

$$= 1000 - j318.31$$

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

$$Z_2 Z_3 = Z_1 Z_4$$

$$Z_2 = \frac{Z_1 Z_4}{Z_3} = \frac{(92.3289)(200 + j188.5)}{(1000 - j318.31)}$$

$$= 77.87 - j15.672$$

$$R - jX_C$$

$$X_C = 15.672$$

$$\frac{1}{2\pi f C} = \frac{1}{2\pi \, 1000 \times 15.672}$$

$$= 10.2 mf$$

$$\therefore Z_4 = \frac{R_4}{1 + j\omega L_4 R_4}$$

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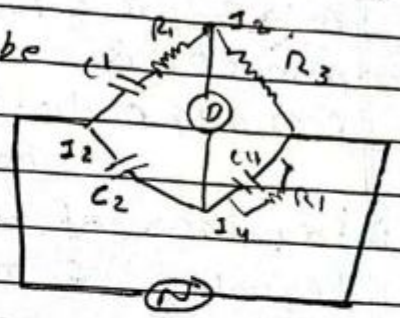
Schering Bridge:

1) Useful ckt for measurement of capacitance and dielectric loss



2) C_1 => where capacitance is to be determined

R_1 = series Resistance representing the loss in capacitor C_1

C_2 => standard capacitor

R_3 => A non inductive resistance

C_4 => variable capacitor

R_4 => a variable non-inducting resistance.

$$Z_1 = R_1 + \frac{1}{j\omega C_1} \qquad Z_3 = R_3$$

$$Z_2 = \frac{1}{j\omega C_2} \qquad Z_4 = \frac{R_4}{1 + j\omega C_4 R_4}$$

now; $Z_1 Z_4 = Z_2 Z_3$

$$\left(R_1 + \frac{1}{j\omega C_1}\right)\left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = \frac{1}{j\omega C_2} R_3$$

$$\left(R_1 + \frac{1}{j\omega C_1}\right) R_4 = \frac{R_3}{j\omega C_2}(1 + j\omega C_4 R_4)$$

$$R_1 R_4 - \frac{j R_4}{\omega C_1} = \frac{-j R_3}{\omega C_2} + \frac{R_3 R_4 C_4}{C_2}$$

equating Real and imaginary terms we get

$$R_1 R_4 = \frac{R_3 R_4 C_4}{C_2} \qquad \frac{R_4}{C_1} = \frac{R_3}{C_2}$$

$$R_1 = \frac{R_3 C_4}{C_2} \qquad C_1 = \frac{R_4 C_2}{R_3}$$

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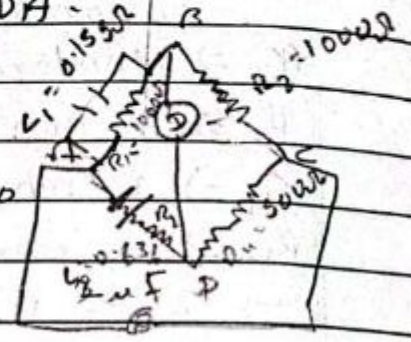
1 An ac bridge has following constants ~~armab~~ is
Arm AB ; R = 1000Ω In parallel with C = 0.159μF
Arm BC ; R = 1000Ω
Arm CD ; R = 500Ω
Arm DA ; C = 0.636 μf in series with an unknown Resistance : calculate

i) Frequency at which bridge becomes at balance
ii) The value of resistance in Arm DA.



Soln

$Z_1 = 0.159 \times 10^{-6} \,//\, 1000$

$Z_1 = \frac{R_1}{1+j\omega C_1 R_1} = \frac{1000}{1+j\omega \times 0.159 \times 10^{-6} \times 1000}$

$= \frac{1000}{1+j\omega \times 1.59 \times 10^{-4}}$

$= 1 + j\omega \times 1.59 \times 10^{-4}$

$Z_2 = R_2 - \frac{j}{\omega C_2}$

$Z_1 Z_4 = Z_2 Z_3$

$\frac{R_1}{(1+j\omega C_1 R_1)} R_4 = \left(R_2 - \frac{1}{\omega C_2}\right) R_3$

or $\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2} + j\left(\omega C_1 R_2 - \frac{1}{\omega C_2 R_1}\right)$

Equating Real and imaginary part

$\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2}$

and $\omega C_1 R_2 - \frac{1}{\omega C_2 R_1} = 0$

$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$

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

$\therefore R_2 = \left(\frac{R_4}{R_3} - \frac{C_1}{C_2}\right)$

$R_1 = \frac{500}{1000} - \frac{0.159 \times 10^{-6}}{0.636 \times 10^{-6}} \times 1000$

$= 250\Omega$ Ans

$f = \frac{1}{2\pi\sqrt{1000 \times 250 \times 0.159 \times 10^{-6} \times 0.636 \times 10^{-6}}}$

$= \cancel{1000 Hz}$ 1000 HZ

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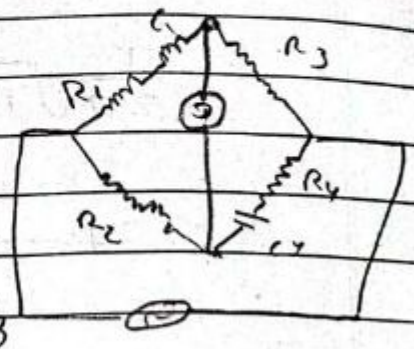
Hay's Bridge

- This is the modification of the maxwell's-wien Bridge
- This bridge uses a resistance in series with the standard capacitor.
- $L_1 \Rightarrow$ unknown inductance having resistance R_1
  $R_2, R_3, R_4 \Rightarrow$ known non-inductive resistance
  $C_4 \Rightarrow$ standard capacitor.



- Balance $Z_1 Z_4 = Z_2 Z_3$

$$(R_1 + j\omega L_1)\left(R_4 - j\frac{1}{\omega C_4}\right) = R_2 R_3$$

$$R_1 R_4 + \frac{L_1}{C_4} + j\omega L_1 R_4 - \frac{jR_1}{\omega C_4} = R_2 R_3$$

Separating real and imaginary parts:

$$R_1 R_4 + \frac{L_1}{C_4} = R_2 R_3 \quad \text{and} \quad L_1 = \frac{+R_1}{\omega^2 R_4 C_4}$$

Solving the above two equations, we have

$$L_1 = \frac{R_2 R_3 C_4}{1 + \omega^2 C_4^2 R_4^2}$$

$$R_1 = \frac{\omega^2 R_2 R_3 R_4 C_4^2}{1 + \omega^2 C_4^2 R_4^2}$$

The Q factor of the coil is; $Q = \frac{\omega L_1}{R_1} = \frac{1}{\omega C_4 R_4}$

- Now, $L_1 = \frac{R_2 R_3 C_4}{1 + \omega^2 C_4^2 R_4^2}$ but $Q = \frac{1}{\omega C_4 R_4}$

and therefore $L_1 = \frac{R_2 R_3 C_4}{1 + (Q)^2}$

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For a value of Q greater than 10, the term $\left(\frac{1}{Q}\right)^2$ will be smaller than $\frac{1}{100}$ and can be neglected.

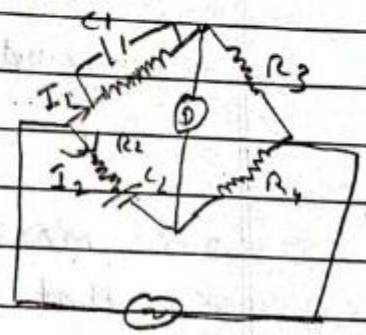
∴ Therefore eqn (A) reduces to

$$L_1 = R_2 R_3 C_4$$

which is the same as for a maxwell's wien bridge.

Wien's bridge for frequency measurement:

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



$$Z_2 = R_2 - \frac{1}{\omega C_2}$$

$$Z_3 = R_3$$

$$Z_4 = R_4$$

At Balance condition

$$Z_1 Z_4 = Z_2 Z_3$$

$$\frac{R_1}{(1 + j\omega C_1 R_1)} \cdot R_4 = \left(R_2 - \frac{1}{\omega C_2}\right) \cdot R_3$$

$$\frac{R_4}{R_3} = \left(R_2 - \frac{1}{\omega C_2}\right) \cdot \left(\frac{1 + j\omega C_1 R_1}{R_1}\right) = \left(R_2 - \frac{1}{\omega C_2}\right)\left(\frac{1}{R_1} + \frac{j\omega C_1 R_1}{R_1}\right)$$

$$= \frac{R_2}{R_1} + j\omega C_1 R_2 - \frac{1}{\omega C_2 R_1} + \frac{\omega C_1}{\omega C_2}$$

$$\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2} + j\left(\omega C_1 R_2 - \frac{1}{\omega C_2 R_1}\right)$$

Equating real and imaginary parts, we get,

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$$\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2} \quad \text{or,} \quad \omega C_1 R_2 - \frac{1}{\omega C_2 R_1} = 0$$

$$\text{or, } \omega^2 C_1 R_2 C_2 R_1 - 1 = 0$$

$$\omega^2 = \frac{1}{R_1 R_2 C_1 C_2}$$

$$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

and $f = \dfrac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$ Hz

In most of the cases the components are choosen so that

$R_1 = R_2 = R$ and $C_1 = C_2 = C$

$$\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2} \quad \text{and} \quad f = \frac{1}{2\pi RC}$$

$$\frac{R_4}{R_3} = 2$$

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1 The Arms of a four ~~or~~ Arms bridge ABCD. supplied with sinosodial voltage have the following value

Armab:- a resistance of 200Ω in parallel with a capactance 1uf.

Armbc:- a 400Ω resistance

Arm CD:- 100Ω resistance

Arm DA:- a resistance R_2 in series with a ~~the~~ 2uf capactance.

Determine the value of R_2 and the frequency at which the bridge will balanced. Ans: R_2 400Ω, f = 397 Hz

2 An A.C bridge has an arm ab of pure capactance 0.2uf, in Arm bc a pure resistule of 500Ω in Arm CD a series combination of R_2 50Ω and l = 0.1H. Arm DA consist of a capactor c = 0.4uf in series with a variable Resistor Rs find the value of Rs to obtain bridge balance. Given that ω = 5000 radian/sec. Ans = 1000Ω

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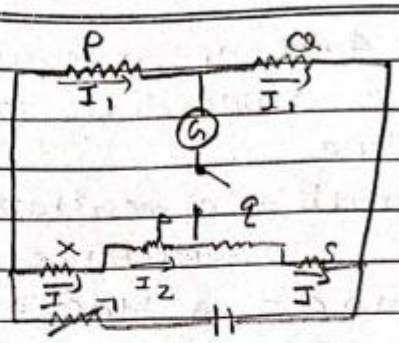
Kelvin's Bridge

The ratio $\frac{P}{Q}$ is kept the same as $\frac{p}{q}$, these ratio varied until the galvanometer reads zero.



Applying Kirchoff's second law:

for mesh (I) $I_1 P - I_2 p - I x = 0$

or, $I x = I_1 P$ -- (i)

for mesh (II) $I_1 Q - I_2 q - I s = 0$

or, $I s = I_1 Q - I_2 q$ -- (ii)

Dividing eqn (i) by (ii) we get

$$\frac{x}{s} = \frac{I_1 P - I_2 p}{I_1 Q - I_2 q} = \frac{P\left(I_1 - \frac{p}{P} I_2\right)}{Q\left(I_1 - \frac{q}{Q} I_2\right)} = \frac{P}{Q}$$

$$\because \frac{P}{Q} = \frac{p}{q} \text{ or } \frac{p}{P} = \frac{q}{Q}$$

$\therefore$ Unknown Resistance $(x) = s \times \frac{P}{Q}$

LVDT = Linear variable different transformer

Physical variables and Transducers

* Sensor and transducers:
Sensor are the device which is used for energy conversion. It takes information about physical quantity and turns it into a signal which can be measured.

Transducers are the sensor that converts the non-electrical energy into electrical and vice-versa. The transducer may be mechanical, electrical, magnetic and ~~fo~~ thermal etc.

II Classification of sensor: (on the basis of principle involved)

1 Resistive Sensor
The input being measured is transpered into change in resistance. Eg: Potentiometer, strain gauge etc.

2 Capacitive sensor:
The input being measured is transfered into change in capacitance Eg: displacement sensor, Liquid lever sensor etc.

3 Inductive sensor:
The input being measured is transfered in inductive
Ex: LVDT

4 Electromagnetic:
works on the principle of faraday's law of Electromagnetic Induction. Ex Tacho generator.

5 Thermoelectric sensor:
The input being thermal energy and the output is emfs. Ex: Thermocouple.

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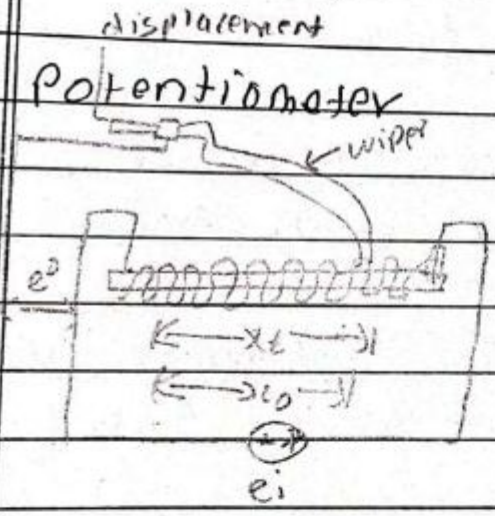
6 Piezo-electric sensor
force applied to a crystal displace in the atoms in the crystal and results in the crystal acquiring a surface charge. Ex; measurement of pressure.

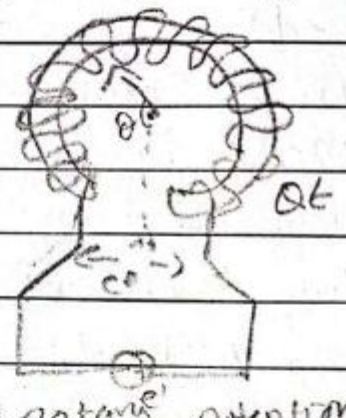
7 Photovoltic sensor
These are the P-N junction which produce a charge in current when electromagnetic radiation is incident on the junction.

8 Hall effect sensor:
The action of magnetic field on potential difference which measures the strength of magnetic field.

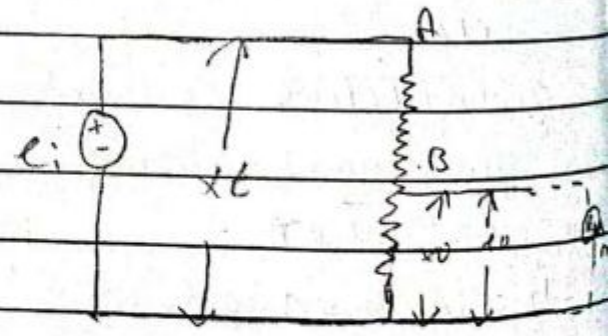
Potentiometer



b) linear potentiometer



a) rotary potentiometer



c) linear potentiometer

used for the measurement of displacement.
e_i e_o => i/p and o/p voltage respectively
R_p => total resistance of potentiometer
x_t => total length of resistance element

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Resistance per unit length $= \frac{R_p}{x_t}$

The resistance of the displacement is given by

$$R_{BC} = \frac{R_p}{x_t} \times x_{AD} = \frac{x_0}{x_t} \cdot R_p = kR_p \text{ where } k = \frac{x_0}{x_t}$$

$$e_0 = \frac{R_{BC}}{(R_{AB} + R_{BC})} \times e_i = \frac{kR_p}{R_p} \times e_i$$

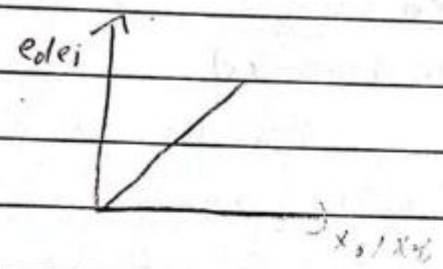
$$\therefore e_0 = ke_i \quad \text{-- (i)}$$

Hence eqn (i) shows that there exist a linear relationship betn o/p and i/p

4) The same expression (i) is used for rotary pot also. we have to replace $x_0 \to \theta_0$ and $x_t \to \theta_t$. Hence the expression is given by

$$e_0 = ke_i = \frac{\theta_0}{\theta_t} \cdot e_i \quad \text{-- (2)}$$

$$\text{sensitivity (s)} = \frac{o/p}{i/p} = \frac{e_0}{x_0} \cdot \frac{e_i}{x_t} \quad \text{(constant -- (3))}$$



Loading effect :-

↳ For ideal case $e_o = \frac{x_s}{x_t} * e_i = ke_i$ -- (1) linear relationship. However in practice the o/p of potentiometer is connected to a device whose impedance R_m is finite. Thus when the instrument is connected across the o/p terminal, the indicated voltage is less than that given by above equation. This is known as loading effect.

↳ This causes a non-linear relationship betw^n the o/p and i/p voltage.

↳ from linear relationship ; $e_o = ke_i$ and $R_{eq} = kR_p$

when meter is connected, $R_{BC} = \frac{kR_p * R_m}{kR_p + R_m}$ --(2)

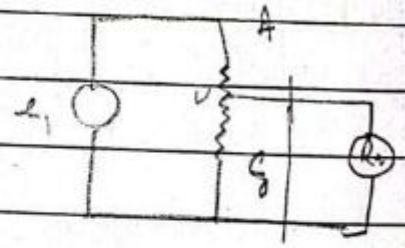
Again, using voltage divider rule

$$e_o = \frac{R_{BC}}{R_{AB} + R_{BC}} * e_i \quad --(3)$$

also, $R_{AB} = R_p - R_{BC} = R_p - kR_p$

$$= R_p(1-k) \quad --(4)$$

using (1) (2) (3)



$$e_o = \frac{\frac{kR_p * R_m}{(kR_p + R_m)}}{R_p(1-k) + \frac{kR_p + R}{kR_p + R}} * e_i$$

$$= \frac{kR_p * R_m}{R_p(1-k)(kR_p + R_m) + kR_pR_m} * e_i$$

$$= \frac{kR_p * R_m}{R_p}$$

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$$\frac{KR_pR_m}{KR_p^2 + R_pR_m - K^2R_p^2 - KR_pR_m + KR_pR_m} * e_i$$

$$\frac{KR_pR_m}{KR_p^2 + R_pR_m - K^2R_p^2} * e_i$$

$$e_o = \frac{K}{K\frac{R_p^2}{R_pR_m} + \frac{R_pR_m}{R_pR_m} - \frac{K^2R_p^2}{R_pR_m}} * e_i$$

$$\frac{K}{K\frac{R_p}{R_m} + 1 - K^2\frac{R_p}{R_m}} * e_i$$

$$\frac{K}{\frac{K}{\alpha} + 1 - \frac{K^2}{\alpha}} * e_i \qquad \text{where, } \alpha = \frac{R_m}{R_p}$$

$$\therefore e_o = \frac{\alpha K}{\alpha + K - K^2}$$

$$\therefore = \frac{\alpha K e_i}{\alpha + K(1-K)} \quad \text{--- (iv)}$$

Therefore the equation (4) shows that there exists non-linear relationship between the o/p and the i/p due to loading effect

If $R_m \to \infty$, $\alpha \to \infty$

Then $e_o = \frac{\alpha K e_i}{\alpha} = Ke_i$ which is ideal relationship

Relative Error:-

Relative error $(\varepsilon_r) = \frac{TV - MV}{TV}$

~~Cr = o/p voltage without loading~~

Cr. = o/p voltage without Loading effect − o/p voltage with Loading effect

o/p voltage without loading effect

$$= \frac{ke - \frac{\alpha k e_i}{\alpha + k(1-k)}}{k e_i}$$

$$= \frac{1 - \alpha}{\alpha + k(1-k)}$$

$$= \frac{\cancel{\alpha} + k - k^2 - \cancel{\alpha}}{\alpha + k(1-k)}$$

$$= \frac{k(1-k)}{\alpha + k(1-k)}$$

To find the value of k at which the error is maximum.

$$\frac{d\varepsilon_r}{dk} = 0$$

$$\frac{d}{dk}\left[\frac{k(1-k)}{\alpha + k(1-k)}\right] = 0$$

$$\frac{d}{dk}\left(\frac{k - k^2}{\alpha + k - k^2}\right) = 0$$

$$\frac{(\alpha + k - k^2)(1-2k) - (k-k^2)(1-2k)}{(\alpha + k - k^2)^2} = 0$$

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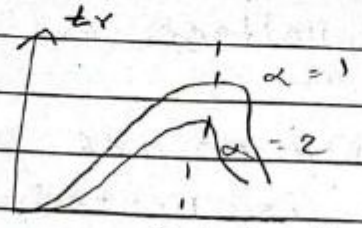
$= (1-2k)(\alpha + k - k^2 - k + k^2) = 0$

$\therefore \alpha(1-2k) = 0$

since $\alpha \neq 0$; $1-2k = 0$

$k = \frac{1}{2} = 0.5$

This shows the error is max^m when the wiper or slider is at the midpoint of the potentiometer. But in actual practise the max^m error occurs when slider travels 67% of total length.



0.5 for theoritical plot

0.67 for practical plot

methods of Reducing loading effect

1) Use of the digital meter insted of analog meter, as the digital meter have higher input resistance as compared to analog meter.
2) Use the buffer circuit or voltage follower circuit
3) Connect the compensating resistor equal to the input resistance of a output device across the remaining of potential different.

Show that linearity and sensitivity are two conflicting requirement of potentio meter.

Hint :- for good linearity : $\alpha = \infty$ or $\frac{R_p \downarrow}{R_m} = 0$

for high sensitivity : $S = \frac{e_o \uparrow}{x_o}$ but the

$e_o \uparrow \propto e_i \uparrow$

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power dissipation $(p) \uparrow = \frac{e_i^2 \uparrow}{R_p \downarrow}$

In order to achive a good linearity the resistance of potention-meter should be as low as possible for a fixed value of input resistance Rm.

In order to achive a high sensitivity the output voltage ~~e~~ e_o should be high which in turn requires a high input voltage e_i.

Due to limitation of power dissipation, the input voltage is limited by the resistance of the potentiometer.

In order to keep the power dissipation at a low level the input voltage should be small and resistance of potentiometer should be high

Thus for high sensitivity* the input voltage should be large and this calls for a high value of resistance Rp. On the other hand if we consider the linearity the resistance of potentiometer Rp should be as low as possible. The resistance of the potentiometer Rp should be as low as possible. The resistance of the potentiometer Rp cannot be make low because if we do so the power dissipation goes up with the result that we have to make the input voltage small to keep the power dissipation to the acceptable level. This results in lower sensitivity.

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Thus, linearity and sensitivity are two conflicting requirements.

Strain Gauge

1) If a metal conductor is ~~streath~~ streched or compresed it's resistance changes on account of the fact that both length and diameter of conductor change Also their is a change in the value of resistivity of the conductor when it is strained and this property is called peizo resistive effect.

4) The Strain Gauge are used for measurement for strain and associated stress in experimental space analysis.

Theory:-

If a strip of plastic material is subjected to tension it's longtidunal dimension will increase while their will be the reduction in the laterial dimension. Since the resistance of conductor is proportional to it's length and inversely proportional to it's area of cross-section, the resistance of the gauge increase with positive strain.

Let us consider, a strain gauge made of circular wire. The wire has the dimension 'length l', Area 'A' diameter 'D' before being strained. The material of the wire has a resistivity ρ.

$\therefore$ Resistance of unstrained gauge $R = \rho \frac{L}{A}$ ...

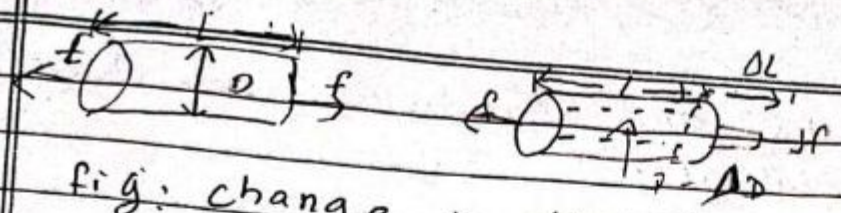

fig: change in dimension of strain.

Let a tensile stress 's' be applied to the wire. This produces a +ve strain causing the length to increase and area to decrease.

let, $\Delta L \Rightarrow$ change in length

$\Delta A \Rightarrow$ change in area

$\Delta D \Rightarrow$ change in diameter

$\Delta R \Rightarrow$ change in resistance.

Diff. eq^n (1) w.r.t. 's' we get,

$$\frac{dR}{\partial S} = \frac{\partial}{\partial S}\left(\frac{\rho L}{A}\right)$$

$$= \frac{\rho}{A} \cdot \frac{\partial L}{\partial S} - \frac{\rho L}{A^2}\frac{\partial A}{\partial S} + \frac{\partial \rho}{\partial S}\frac{L}{A} \quad \text{--- (2)}$$

Dividing eq^n (2)

$$\frac{1}{R}\frac{\partial R}{\partial S} = \frac{1}{L}\frac{\partial L}{\partial S} - \frac{1}{A}\frac{\partial A}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S} \quad \text{--- (3)}$$

Also, $A = \frac{\pi D^2}{4}$ --- (4)

$$\frac{\partial A}{\partial S} = \frac{\pi}{4} \cdot 2D \cdot \frac{\partial D}{\partial S}$$

$$= \frac{\pi D}{2} \cdot \frac{\partial D}{\partial S} \quad \text{--- (5)}$$

dividing

$$\cancel{\frac{1}{A} \cdot \frac{\partial A}{\partial S} = \frac{2}{D}\frac{\partial D}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S} \quad \text{--- (7)}}$$

$$\frac{1}{A} \cdot \frac{\partial A}{\partial S} = \frac{2}{D}\frac{\partial D}{\partial S} \quad \text{--- (6)}$$

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using eqn (6) in eqn (3)

$$\frac{1}{R}\cdot\frac{\partial R}{\partial S} = \frac{1}{L}\frac{\partial L}{\partial S} - \frac{2}{D}\frac{\partial D}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S} \quad \text{--- (7)}$$

For small variations, the above relationship can be written as:

$$\frac{\Delta R}{R} = \frac{\Delta L}{L} - \frac{2\Delta D}{D} + \frac{\Delta \rho}{\rho} \quad \text{--- (8)}$$

Now, poisson's ratio

$$\mu = \frac{\text{Laterian strain}}{\text{longitudinal strain}} = \frac{-\frac{\Delta D}{D}}{\frac{\Delta L}{L}}$$

$$\frac{\Delta D}{D} = -m\frac{\Delta L}{L} = -\mu\epsilon \quad \text{where } \epsilon = \text{strain} = \frac{\Delta L}{L}$$

$$\therefore \frac{\Delta D}{D} = -\mu\epsilon \quad \text{--- (9)}$$

using eqn (9) in eqn (8)

$$\frac{\Delta R}{R} = \frac{\Delta L}{L} + 2\mu\epsilon + \frac{\Delta \rho}{\rho\mu} \quad \text{--- (10)}$$

The gauge factor is defined as the ratio of per unit change in resistance to ~~pre~~ per unit change in length

i.e $$G = \frac{\frac{\Delta R}{R}}{\frac{\Delta L}{L}} = \frac{\Delta R/R}{\epsilon}$$

$$\therefore \frac{\Delta R}{R} = G\epsilon \quad \text{--- (11)}$$

from eqn (10) and (11)

$$G\epsilon = \frac{\Delta L}{L} + 2m\epsilon + \frac{\Delta \rho}{\rho}$$

$$\cdot\epsilon + 2\mu\epsilon + \frac{\Delta \rho}{\rho}$$

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$G = 1 + 2\mu + \frac{\Delta\rho/\rho}{\varepsilon}$

can be neglected

$\therefore G = 1 + 2\mu$

req^d expression for strain gauge

Q) A strain gauge having a resistance of 600 Ω and gauge factor 2.0 ohm and is connected in series with blast resistance of 1000 ohm across 50V. Determine the change in output when a stress of 150 MN/m² is applied. The modulus of elasticity is 250 GN/m².

Sol^n

Resistance $(R_S) = 600\Omega$, $R_B = 1000\Omega$

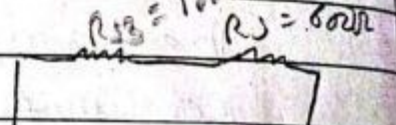
Gauge factor $(G) = 2.0$

Stress $(S) = 150 \times 10^6$ N/m²

Elasticity $(E) = 150 \times 10^9$ N/m²

Strain $(\varepsilon) = \frac{S}{E} = \frac{150 \times 10^6}{250 \times 10^9} = \frac{3}{5000} = 0.0006$

Voltage across the strain gauge



supply voltage $= \frac{R_S}{R_S + R_B}$

$= 50 \times \frac{600}{600 + 1000} = 18.75$

change in resistance $\Delta R = R_S \times \varepsilon G = 600 \times 0.006 \times 2$

$= 0.72\Omega$

voltage across the gauge under strained condition $= \frac{600 + 0.72}{600 + 1000 + 0.72} \times 50$

$= 18.78408$ volt.

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difference betn the output voltage = 18.76406
= 18.75
= 0.01406

Q.N A compressive force is applied to a structural membe
the strain of selstrain two seperate strain gauges are
attached to the structral membem. one is nickal wire
strain gauge having a gauge factor of -12.1 and
the other is nichrome wire strain gauge having a
gauge factor of 2.0. calculate the value of resistance
of the gauges after they are strained. The resistanc
of strain gauges before being strain is 120 Ω.

i = 7.26 mm
ii = 1.2 mm

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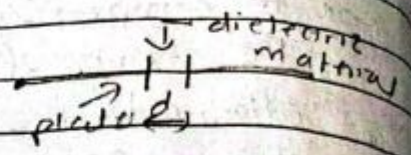
Capacitive Transducer:

The principle of operation of capacitive transducer is based upon the familiar equation for capacitance of a parallel plate capacitor.

capacitance $(C) = \epsilon \frac{A}{d}$



$= \epsilon_0 \epsilon_r \frac{A}{d}$

where, $A \Rightarrow$ overlapping area : (m^2)

$d \Rightarrow$ distance betn two plates : m

$\epsilon \Rightarrow \epsilon_r \epsilon_0$ = permittivity of medium : F/m

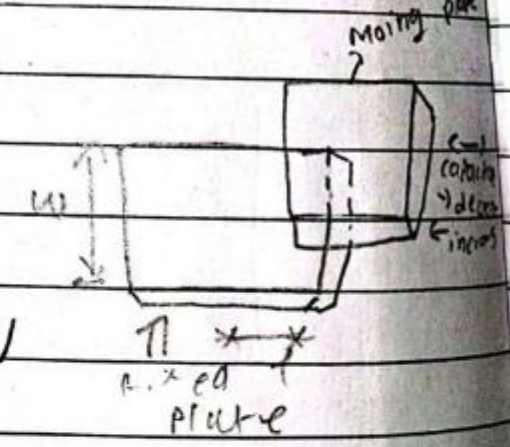
$\epsilon_0 \Rightarrow$ Permittivity of ~~medium~~ free space : 8.85×10^{-12} F/m

The capacitive transducer works on the principle of change of capacitance which may be caused by i) change in overlapping area A, ii) change in distance 'd' betn the plates and iii) change in dielectric constant

i) capacitive sensor working on principle of change in Area (A):-

a) for linear displacement

* parallel plate :-



$\Rightarrow$ capacitance, $(C) = \epsilon \frac{A}{d}$

$\Rightarrow C = \epsilon \frac{A}{d} = \epsilon \frac{l * w}{d}$ farad

where, $l \Rightarrow$ overlapping pard

$w \Rightarrow$ width

Sensitivity (S) = $\frac{\Delta C_p}{\Delta x_p} = \frac{dC}{dx} = \frac{d}{dx}\left(\frac{\epsilon w l}{d}\right) = \frac{\epsilon w}{d}$ (constant)

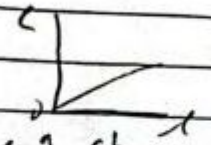
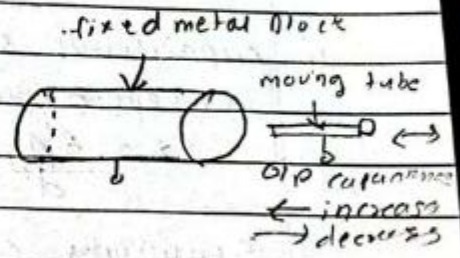


fig characteristics

b # for cylindrical capacitor:

$$C = \frac{2\pi \epsilon l}{\log_e\left(\frac{D_2}{D_1}\right)} \text{ farad}$$



l => length of overlapping part
D_2 => inner diameter of outer cylindrical electrode;
D_1 => outer " " inner " " ; m

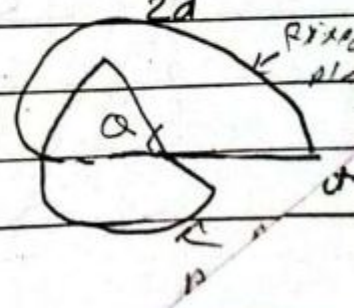
sensitivity (S) = $\frac{dC}{dl} = \frac{2\pi\epsilon}{\log_e(D_2/D_1)}$ F/m

Hence,
the sensitivity is constant & the relationship betw capacitance & displacement is linear.

c # for ~~Analo~~ Angular displacement:
The angular displacement changes the capacitance. The capacitance is max^m when the two plates completely overlap each other i.e when $\theta = 180°$

∴ max^m value of capacitance $C_{max} = \frac{\epsilon A}{d} = \frac{\epsilon \pi r^2}{2d}$

capacitance at angle 'θ' is $C_\theta = \frac{\epsilon \theta r^2}{2d}$



where θ => angular displacement in radian.

sensitivity (S) = $\frac{dC_\theta}{d\theta}$

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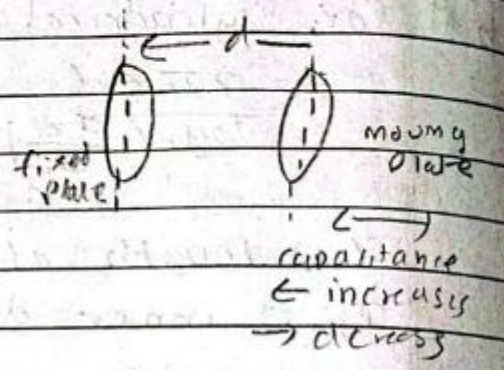
$$\frac{d}{dQ}\left(\frac{\epsilon Q r^2}{2d}\right)$$

$\frac{\epsilon r^2}{2d}$ Constant ⇐ linear

i) capacitive sensor working on principle of change in seperation distance.

10-(5)
(2)

$$C = \frac{\epsilon A}{d}$$



Sensitivity $(S) = \frac{dc}{dd}$

$$= \frac{d\left(\frac{\epsilon A}{d}\right)}{dd} = -\frac{\epsilon A}{d^2}$$

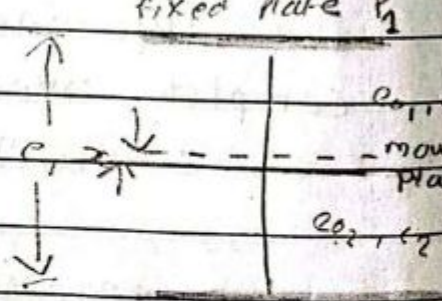
(not linear)

only used for measurement of extremely small displacement.

The linear relationship betw^n the input and output can be obtained by using a differential arrangement.

Differential Arrangement:

i) when m is midway between the fixed plates P_1 & P_2



$$C_1 = \frac{\epsilon A}{d} = C_2 \quad \text{--- (1)}$$

$$e_{o_1} = e_{o_2} = \frac{e_i}{2}$$

$$e_{o_2} = \frac{C_2}{C_1 + C_2} \times e_i = \frac{e_i}{2}$$

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$\therefore \Delta e_0 = e_{o2} - e_{o1} = 0.$

4) If the center m is moved by a distance 'x' upward as shown in figure:

$$C_1 = \frac{\epsilon A}{d-x} \quad \text{and} \quad C_2 = \frac{\epsilon A}{d+x}$$

$\therefore \Delta e_0 = e_{o2} - e_{o1}$

where; $e_{o1} = \frac{C_2}{C_1+C_2} \cdot e_i$, $e_{o2} = \frac{C_1}{C_1+C_2} \cdot e_i$

Now. $\Delta e_0 = \frac{C_1}{C_1+C_2} e_i - \frac{C_2}{C_1+C_2} \cdot e_i$

$$= \frac{C_1 - C_2}{C_1 + C_2} \cdot e_i$$

$$= \frac{\frac{\epsilon A}{d-x} - \frac{\epsilon A}{d+x}}{\frac{\epsilon A}{d-x} + \frac{\epsilon A}{d+x}} \cdot e_i$$

$$\Delta e_0 = \frac{d+x - d+x}{d+x+d-x} \times e_i$$

$$= \frac{2x}{2d} \times e_i$$

$$= \frac{x}{d} \times e_i$$

$\therefore \Delta e_0 \propto x$ i.e the voltage varies linearly as the displacement of x.

$$\text{Sensitivity } (S) = \frac{\Delta E}{\Delta x} = \frac{\frac{x}{d} e_i}{x} = \frac{e_i}{d} \rightarrow \text{constant}$$

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capacitive sensor working as a liquid level sensor:

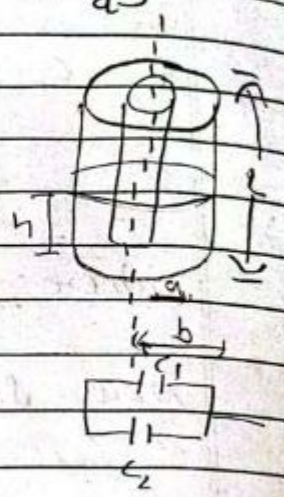
The capacitance is given by $C = \frac{2\pi \epsilon_0 \epsilon_r l}{\log(\frac{b}{a})}$ --(1)

Now,

$$C_{total} = \frac{2\pi \epsilon_0 \epsilon_r h}{\ln(\frac{b}{a})} + \frac{2\pi \epsilon_0 (l-h)}{\ln(\frac{b}{a})}$$

$$\frac{2\pi \epsilon_0}{\ln(\frac{b}{a})} [\epsilon_r h + (l-h)]$$

$$\frac{2\pi \epsilon_0}{\ln(\frac{b}{a})} [l + h(\epsilon_r - 1)] \quad \text{--(2)}$$



Qn A capacitive transducer is made up of two concentric cylindrical electrode. The outer diameter of inner cylindrical electrode is 3mm and the dielectric medium is air. The inner diameter of outer electrod is 3.1 mm. calculate directiz stress when the voltage of 100 volt is applied across the electrodes. Is it within safe limit? The length of electrodes is 20 mm calculate change in capacitance if inner electrode is move through distance of 2mm. The breakdown strength of air is 3kV/mm

Ans =

Soln

Length of air gap betw^n the two electrodes $\frac{(3.1-3)}{2}$ 0.05

$\therefore$ dielectric stress $= \frac{100}{0.05} = 2000$ V/mm

$= 2$ kV/mm

The breakdown strength of air is 3kV/mm and

the dielectric is safe.

Capacitance of the transducer

$$C = \frac{2\pi\epsilon l}{\log_e\left(\frac{D_2}{D_1}\right)} = \frac{2\pi \times 8.85 \times 10^{-12} \times 20 \times 10^{-3}}{\log_e\left(\frac{3.1}{3}\right)} f$$

$$= 33.9 \text{ pf}$$

The moving in electrode is shifted through a distance of 2mm.

$$\therefore l = 20 - 2 = 18\text{mm}$$
$$= 18 \times 10^{-3} \text{m}$$

New value of capacitance $= \frac{2\pi \times 8.85 \times 10^{-12} \times 18 \times 10^{-3}}{\log_e\left(\frac{3.1}{3}\right)}$

$$= 30.5 \text{ pf}$$

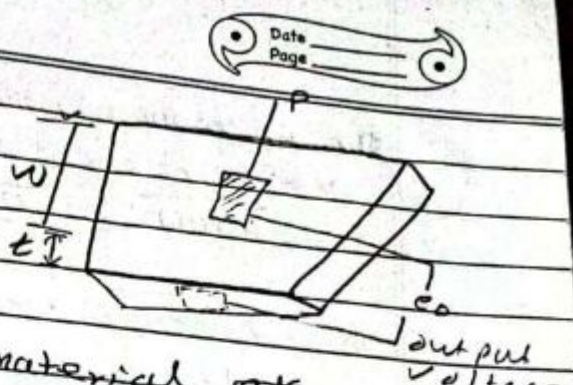
$\therefore$ change in value of capacitance $(\Delta C) = 33.9 - 30.5$

$$= 3.4 \text{ pf.}$$

Ans = 450.5 pf

A capacitive transducer uses two quartz diaphragms of area 750 mm² seperated by the distance of 3.5mm. A pressure of 900 kN/m² when applied to the top diaphragms produces the ~~difference~~ deflection of 0.6mm. The capacitance is 370 pf when on pressure is applied to the diaphragm. find value of capacitance after the application of pressure of 900kN

Piezoelectric Transducers:



In some crystal line or ceramic materials, a potential difference appers across the opposite faces of the material as a result of dimensional changes when a mechanical force is applied to it. This is called the piezoelectric effect and such material are called piezoelectric materials.

This effect is reversiable also that is when the potiental difference is applied accross the opposite faces of material it changes its physical dimension.

There are three types of piezoelectric materials.

1. Natural : eg: quartz, rochelle salt.
2. synthetic : eg : lithium sulphate ammonium hydrogen phosphate
3. polarized ferroelectric ceramic : eg); barium titanate

4) The piezoelectric effect is direction sensitive. A tensile force produce a voltage of one polarity while a compressive force produces a voltage of opposite polarity. when a force 'f' is applied charge 'Q' is generated:

$$Q \propto f$$

$$\therefore Q = df \quad \ldots \text{ii)}$$

where 'd' is the crystal charge sensitivity in coulomb and is constant for a given crystal.

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The ~~yo~~ youngs modulus is given by

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{\frac{f}{A}}{\frac{\Delta t}{t}}$$

$t \Rightarrow$ thickness

$\Delta t \Rightarrow$ change in thickness

The force 'f' causes a change in thickness of crystal.

$$f = Y \cdot \frac{\Delta t}{t} \cdot A \quad -- (2)$$

using eq^n (2) and eq^n (1)

$$Q = d \cdot Y \cdot \frac{\Delta t}{t} \cdot A \quad -- (3)$$

The capacitance bet^n electrodes is

$$C_p = \frac{\epsilon_0 \epsilon_r A}{t} \quad -- (4)$$

If e_0 is the ~~op~~ OCP voltage developed. then

$$e_0 = \frac{Q}{C_p} = d \cdot Y \cdot \frac{\Delta t}{t} \cdot A \cdot \frac{t}{\epsilon_0 \epsilon_r A}$$

$$e_0 = \frac{dY\Delta t}{\epsilon_0 \epsilon_r}$$

or, $$e_0 = \frac{d}{\epsilon_0 \epsilon_r} \frac{\frac{f}{A}}{\frac{\Delta t}{t}} \cdot \Delta t$$

$$= \frac{dft}{\epsilon_0 \epsilon_r A} = \frac{dt}{\epsilon_0 \epsilon_r} \cdot \frac{f}{A}$$

$$= \frac{dtp}{\epsilon_0 \epsilon_r}$$

or, $$e_0 = \frac{dpt}{\epsilon_0 \epsilon_r} \qquad \therefore p = \frac{f}{A}$$

$\therefore e_0 = gpt$ where g is voltage sensitivity

$$= \frac{1}{\epsilon_0 \epsilon_r}$$

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Q/N A barium titanate Pickup have the dimension of 5mm x 5mm x 1.25mm. The force acting on it is 5N. The charge sensitivity of barium titanat is 150 pC/N and it's permitivity is 12.5×10^{-9} F/m. If the modulus of elasticity of barium tiranat is 12×10^{6} N/m². calculate the strain, charged and ~~capacit~~ capactains.

Area of plates (A) = $5 \times 5 \times 10^{-6} = 25 \times 10^{-6} m^2$

pressure (p) = $\frac{5}{(25 \times 10^{-6})} = 0.2 MN/m^2$

voltage generated $e_0 = g t p$

$= 12 \times 10^{-3} \times 1.25 \times 10^{-3} \times 0.2 \times 10^{6}$

$= 3V$

where $g = \frac{d}{\varepsilon_0 \varepsilon_r} = \frac{150 \times 10^{-12}}{12.5 \times 10^{-9}}$

$= 12 \times 10^{-3}$ Vm/N

Strain $\epsilon = \frac{\Delta t}{t}$

$= \frac{\text{stress}}{\text{Young's modulus}} = \frac{0.2 \times 10^{6}}{12 \times 10^{6}} = 0.0167$

charge $Q = dF = 150 \times 10^{-12} \times 5$

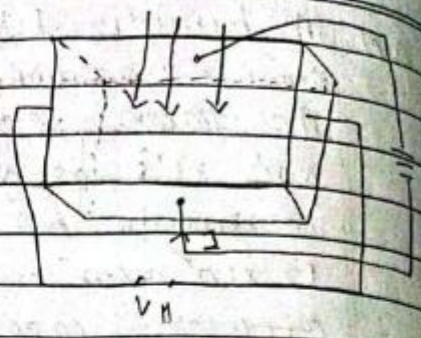
$= 750$ pc.

capacitance $C_p = \frac{Q}{e_0} = \frac{750 \times 10^{-12}}{3}$

$= 250$ pF

Hall effect sensor

$$V_H = \frac{K_H B I}{t} \text{ volts}$$



where $K_H \Rightarrow$ Hall's coefficient

$B \Rightarrow$ magnetic field (wb/m^2)

$I \Rightarrow$ current (Amp)

$t \Rightarrow$ thickness of plate (m).

when a conductor is kept perpendicular to the magnetic field and a direct current is passed through it, it results in an electric field perpendicular to the direction of both the magnetic field and current with a magnitude proportional to the product of the magnetic field strain and current. This phenomenon is called Hall effect.

Q) A hall effect element used for measuring a megnetic field strength gives an output voltage of $10.5\,mV$. The element is made up silicon and is 2.5mm thick and carries a current of 4 Amp. The hall coefficient is 4.1×10^{-6} $\frac{Vm}{(A\text{-}wb/m^2)}$ [1.6 wb/m²] calculate megnetic field strength.

Soln

$$B = \frac{V_H \times t}{K_H I} = \frac{10.5 \times 10^{-6} \times 2.5 \times 10^{-3}}{4.1 \times 10^{-6} \times 4}$$

$$= 1.6\ wb/m^2$$

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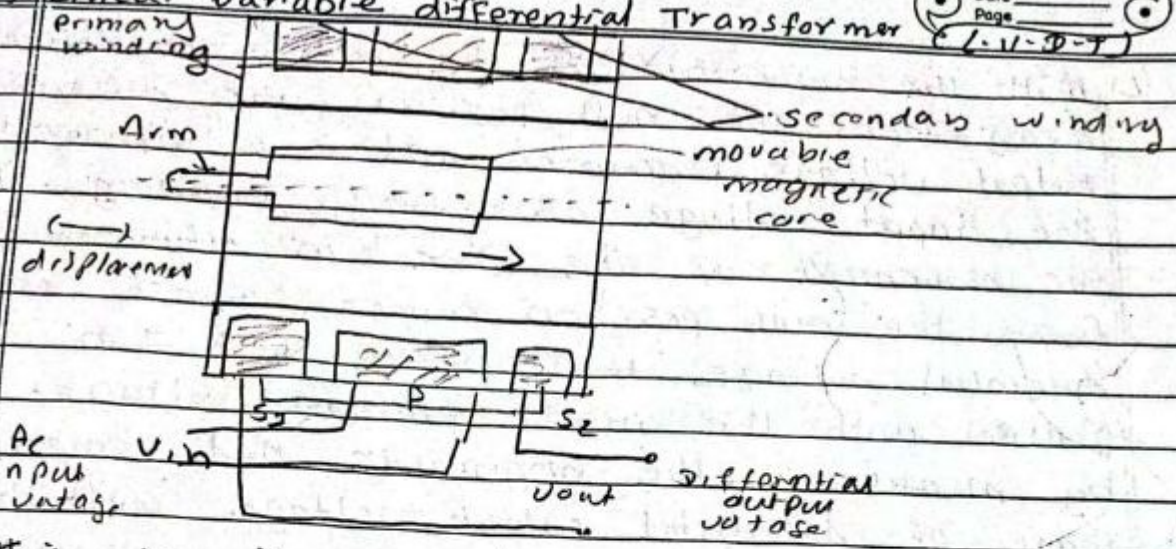
Linear variable differential Transformer (L.V.D.T)



- This is the most widely used inductive transducer for translating the linear motion into an electrical signal.
- L.V.D.T is a differential transformer consisting of one primary winding 'P' and two identical secondary winding S_1 and S_2. The secondary windings S_1 and S_2, which have equal numbers of turns and placed either side of the primary winding 'P'.
- Null position: O/P voltage induced in S_1 & S_2 are equal.
- moved toward lef: Magnetic linkages to S_1 increases and S_2 decreases so O/P voltage induced in S_1 increases whereas S_2 decreases.
- moved toward right: O/P voltage induced in S_1 decreases whereas S_2 increases
- Secondary winding S_1 and S_2 are connected in series opposition show that the different of output voltage of secondary winding gives the measurement of displacement.

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b) With the movement of the pole in one direction away from the null position, the differential output voltage increases and it is inphase with the input voltage of primary winding. whereas the movement of the core in other direction from the null position causes ~~against~~ again differential voltage to increase but 180° out of phase with the input primary voltage. now by measuring the magnitude and comparing the phase of differental output voltage with the input primary voltage amount and direction of displacement of core may be determined.

Q.N) The output of an L.V.D.T is connected to the 5V through an amplifier with a gain of 850. The voltmeter scale has 100 divisions and the scale can be ~~left~~ read upto $\frac{1}{5}$th of a division. An output of 2 millivolt appears across the terminals of LVDT when core is displaced through the distance of ~~zero~~ 0.5mm calculate and determine

i) sensistivity of L.V.D.T and entire setup.

ii) The resolution of ~~instrument~~ estimate.

Soln

The O/P of L.V.D.T $V_{out} = 2mV$

Displacement $= 0.5mm$

sensistivity of L.V.D.T $= \frac{V_{out}}{\text{Displacement}} = \frac{2mV}{0.5mm}$

$= 4mV/mm$

sensitivity of entire set up = Amplification factor × sensitivity of L.V.D.T

$= 850 \times 4mV/mm$

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$= 1000\ mV/mm$

$= 1\ V/mm$ #

Full-Scale of voltmeter = 0-5V

Number of divisions on voltmeter scale = 100

1 scale division $= \frac{5}{100} = 0.05V$ or $50mV$

min^m voltage that can be read on voltmeter $= \frac{50mV}{5}$

$= 10mV$

Resolution of instrument = $\frac{\text{min}^m \text{ voltage that can be read on voltmeter}}{\text{sensitivity of entire setup}}$

$= \frac{10mV}{1000\ mV/mm}$

$= 0.01\ mm$

Resistance Thermometer:-

1. metal Resistance Thermometer.
2. Thirmister (thermally sensitive Resistor)

1. metal Resistance Thermometer

The resistance of a conductor changes when temperature is changed. This property is utilised for measurement of temperature.

The variation of resistance 'R' with temp^r T°K can be represented by the following relationship

$$R = R_0 [1 + \alpha_1 T + \alpha_2 T^2 + \dots]$$

where α_1, α_2 -- are Constants.

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The resistive material used in resistance thermometer is made from either of ~~pt~~ platinum, copper or nickel

- Platinum has a closely linear relationship betwn resistance and temperature. It has a tempr range of -200 to 850°c and is relatively inert. It is more expensive then the other metal but is however the most widely used nickel and copper are less expensive but have more interaction with environment and cannot be used over such large range of temperature. nickel have range about -80°c to 300°c and copper of range -200°c to 250°c.

2 Thermister

The mathematical expression for the thermister:

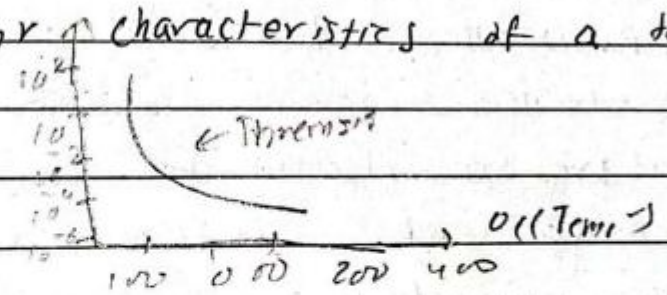
$$R_T = R_0 \exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right] \quad --(1)$$

where; R_T = Resistance of the thermister at absolute Tempr T; °k

R_0 = Resistance of the thermister at absolute T_0; °k

β = a constant depending upon the material of thermister, typically 3500 to 4500°k

Resistor tempr characteristics of a typical thermistor



Thermister are mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron or uranium

Thermister has a very high -ve temp^r coefficient of resistance.

Application - Temp^r measurement, Temp^r control, Temp^r compensation etc.

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Chapter: 4

Signal conditioning and processing

Date
Page

~~Signal conditioning~~
~~OP Amp~~

OP Amp (operational Amplifier)

* Properties of ideal ~~op-a~~ Op-amp are:

1) It should have an infinite input impedance
~~ie~~ ie $Z_{in} = \infty$

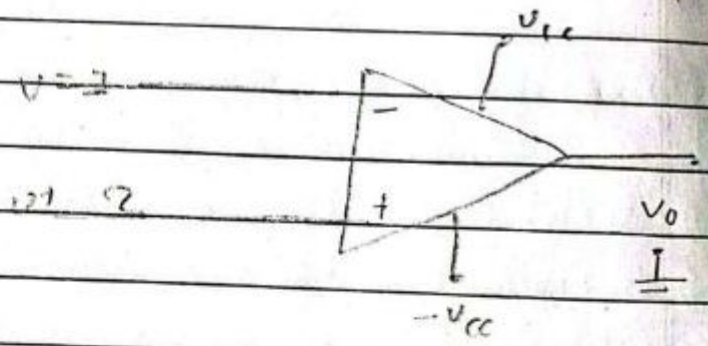
2) It should have a zero output impedance $Z_o = 0$

3) It should have an infinite open loop gain
$A_{vol} = -\infty$

4) It should have an infinite bandwidth
ie it has flat frequency response over a wide range of frequency.

5) common mode rejection ratio (CMRR) is infinite ie $CMRR = \infty$

II OP Amp symbol



Configuration :- (mode)

i) inverting mode
ii) non - inverting mode
iii) unity follower

I Inverting Amplifier or Negative scale:

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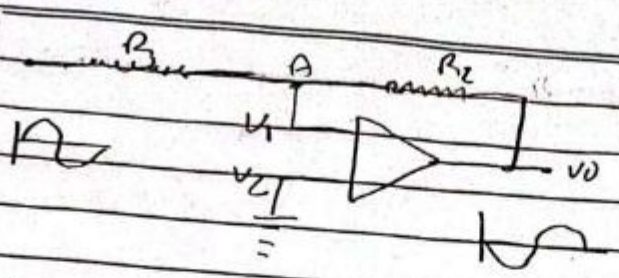


R_2 = feedback Resistor

from figure;

$i_1 = \frac{V_{in} - V_1}{R_1}$ and $i_2 = \frac{V_1 - V_o}{R_2}$

Since point V_2 is grounded $V_1 - V_2 = 0$ (virtual short ckt)

$i_1 = \frac{V_{in}}{R_1}$ and $i_2 = \frac{-V_o}{R_2}$

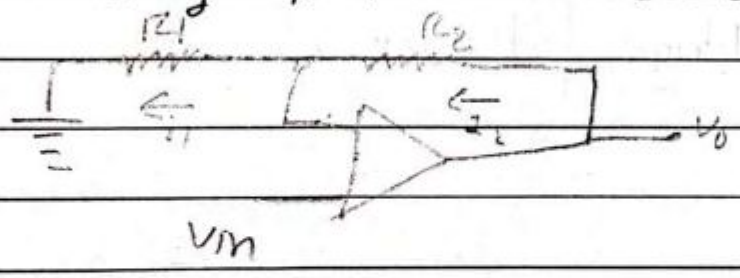
At point A, $i_2 = i_1$

$$\frac{-V_o}{R_2} = \frac{V_{in}}{R_1}$$

$$\frac{V_o}{V_{in}} = -\frac{R_2}{R_1} = -K$$

$$\therefore V_o = -\frac{R_2}{R_1} \cdot V_{in}$$

2 Non-inverting Amplifier or +ve scaler



from figure

$i_1 = \frac{v_{in}}{R_1}$ and

$i_2 = \frac{V_0 - v_{in}}{R_2}$

since point v_2 act as input

$v_1 = V_2 = v_{in}$ (virtual short circuited)

At point A, $i_2 = i_1$

$$\frac{V_0 - v_{in}}{R_2} = \frac{v_{in}}{R_1}$$

$$V_0 - v_{in} = \frac{R_2}{R_1} \cdot v_{in}$$

$$V_0 = \left(1 + \frac{R_2}{R_1}\right) v_{in}$$

3 Unity follower:

If $R_2 = 0$ and $R_1 = \infty$ keeping it open circuited

$$V_0 = \left(1 + \frac{R_2}{R_1}\right) v_{in}$$

$$V_0 = v_{in}$$

i.e. the ~~out~~ output voltage of the OPM exactly tracks the input voltage both in sign and magnitude. This is the reason that this circuit is called a voltage follower circuit.

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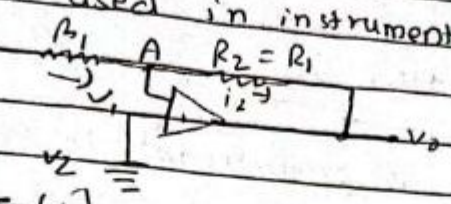
Op-Amp ckts used in instrumentation:

1. Inverter



From figure (1)

$i_1 = \frac{V_{in} - V_1}{R_1}$ and $i_2 = \frac{V_1 - V_o}{R_2 = R_1}$

Since, V_2 is grounded $V_2 = V_1 = 0$

$i_1 = \frac{V_{in}}{R_1}$, $i_2 = \frac{-V_o}{R_1}$

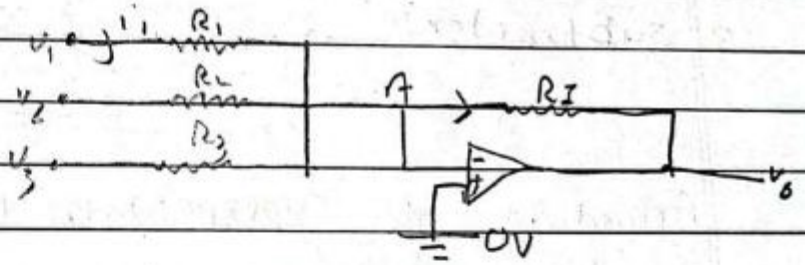
At point A,

$i_1 = i_2$

$\frac{V_{in}}{R_1} = \frac{-V_o}{R_1}$

$\therefore V_o = -V_{in}$

2. Adder or summer



now, point 'A' is at virtual ground.

$i_1 = \frac{V_1}{R_1}$, $i_2 = \frac{V_2}{R_2}$

$i_3 = \frac{V_3}{R_3}$, $i_f = \frac{-V_o}{R_f}$

At point 'A' $i_f = i_1 + i_2 + i_3$

$\frac{-V_o}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$

$V_o = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$

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If $R_1 = R_2 = R_3 = R$

$$V_0 = \frac{-R_f}{R}(V_1 + V_2 + V_3)$$

Hence, o/p voltage is proportional to the algebric sum of the three input voltages.

Case (I): If $R_f = R$; Then o/p is exactly equal to the sum of inputs.

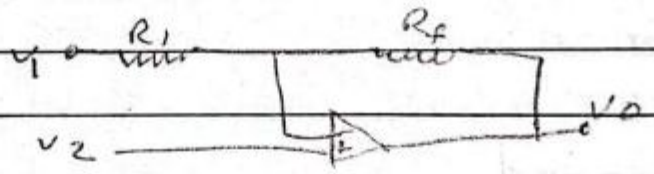
Case (II): If $R_f = \frac{R}{3}$;

$$V_0 = \frac{-R/3}{R}(V_1 + V_2 + V_3)$$

$$= \frac{-1}{3}(V_1 + V_2 + V_3)$$

The o/p is equal to the average of three inputs.

3 Subtractor:-



According to superposition theorem.

$$V_0 = V_0' + V_0''$$

where V_0' is the o/p produced by V_1 and V_0'' is that produced by V_2

Now,

$$V_0' = -\frac{R_f}{R_1} \cdot V_1$$

$$V_0'' = \left(1 + \frac{R_f}{R_1}\right) V_1$$

$$V_0 = \left(1 + \frac{R_f}{R_1}\right) \cdot V_2 - \frac{R_f}{R_1} V_1$$

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Since, $R_f \gg R_1$

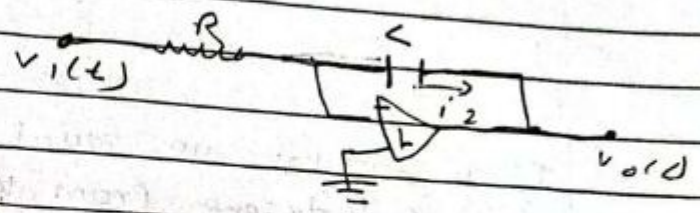
$$V_0 = \frac{R_f}{R_1}(V_2 - V_1)$$

If $R_f = R_1$ then

$$V_0 = V_2 - V_1$$

4) As Integrator:

Now, $i_1 = \frac{V_1(t)}{R}$



$$i_2 = -C\frac{dV_0(t)}{dt}$$

$$i_1 = i_2$$

$$\frac{V_1(t)}{R} = -C\frac{dV_0(t)}{dt}$$

$$-\frac{1}{RC}V_1(t)\,dt = dV_0(t)$$

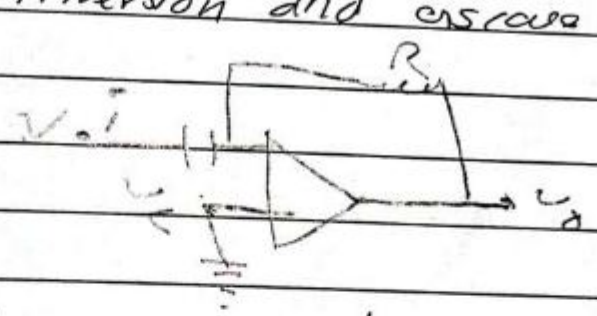
Integrating on both sides,

$$V_0(t) = -\frac{1}{RC}\int V_1(t)\,dt$$

It is seen that o/p is an integral of the input with an inversion and a scale factor of $\frac{1}{CR}$

5) Differentiator

$$i = C\frac{dV_c}{dt}$$



Taking investing input terminal as virtual ground.

4) O/P voltage $V_{out} = -iR$

$$= -\left[C\frac{dV_c}{dt}\right]R$$

$$= -CR\frac{dV}{dt}$$

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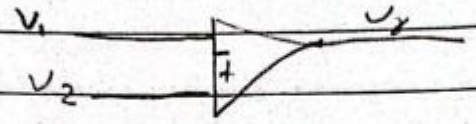
i.e o/p voltage is proportional to the derivative of the input voltage, the constant of proportionality being $-CR$

6 Comparator:



If v_1 and v_2 are equal the V_0 should ideally be 0. even if V_1 differs from V_2 by a very small amount, V_0 is large ckt can detect very small level changes which is another way of saying that it compares two signal.

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Instrumentation Amplifier:

1) It is a dedicated differential amplifier with extremely high input impedance.

2) It's gain can be set by a single internal or external resistor.

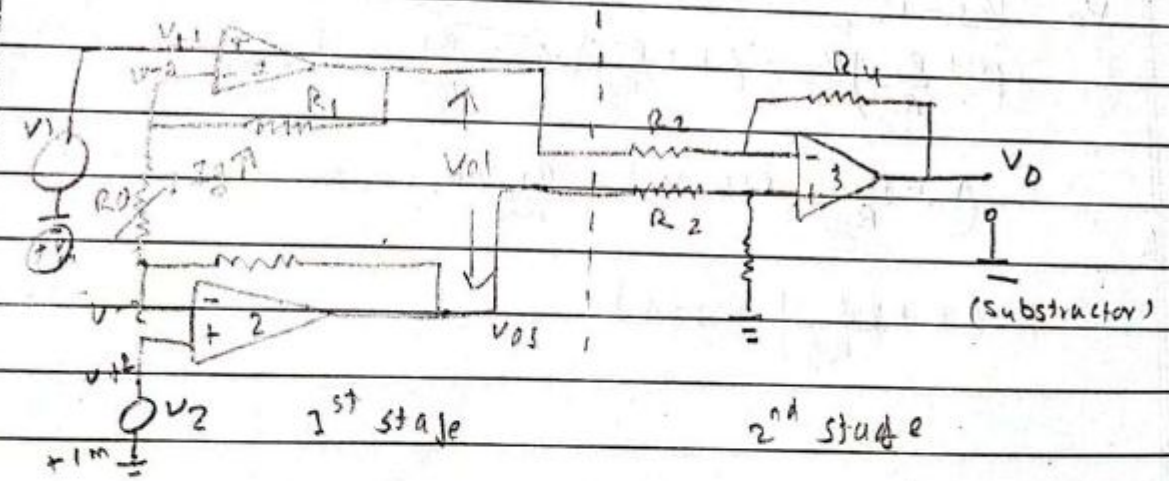
3) It has high common mode resistor.

4) The instrumentation amplifier is not a general building block like a op-amp. It is a closed loop device with carefully set gain.

Instrumentation amplifier consists of two stages. The first stage offers very high input impedance to both input signal and always set of the gain with a single resistor.

The second stage is a differential amplifier with the output, negative feedback and ground connections are brought out.

Imp



$V_{+1} = V_{-1} = V_1$

$V_{+2} = V_{-2} = V_2$

Also $v_{-2} - v_{-1} = v_g = I_g R_g$

$v_2 - v_1 = I_g R_g$

$\therefore I_g = \frac{v_2 - v_1}{R_g}$ --- (i)

The o/p of the 1st stage is given by

$v_{o1} = I_g (R_1 + R_g + R_1)$

$= I_g (R_g + 2R_1)$

$v_{o1} = \left(\frac{v_2 - v_1}{R_g}\right)(R_g + 2R_1)$

$\frac{v_{o1}}{v_2 - v_1} = \left(1 + 2\frac{R_1}{R_g}\right)$ --- (ii) $\therefore v_{o1} = \left(1 + \frac{2R_1}{R_g}\right)(v_2 - v_1)$

The 2nd stage of the instrumentation amplifier is a unity gain different amplifier.

$v_{o2} = \left(1 + \frac{R_1}{g}\right) v_1 - \frac{R_1}{R_g} v_2 + v_{cm}$

$v_{o3} = \left(1 + \frac{R_1}{g}\right) v_2 - \frac{R_1}{R_g} v_1 + v_{cm}$

$v_o = v_{o3} - v_{o2}$

$= \left(1 + \frac{R_1}{R_g}\right) v_2 - \left(1 + \frac{R_1}{R_g}\right) v_1 - \frac{R_1}{R_g} v_1 + \frac{R_1}{R_g} v_2$

$= \left(1 + \frac{R_1}{R_g}\right)(v_2 - v_1) + \frac{R_1}{R_g}(v_2 - v_1)$

$= \left(1 + \frac{2R_1}{R_g}\right)(v_2 - v_1)$

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Isolation Amplifier

- Applicable where processing circuits must be protected from faults and power transient and interferance from motors, powerlines etc.

- A two part isolator has it's signal input circuit isolated from signal output and power input circuits. The ultimate in isolation is provided by 3 part isolator which has in addition isolation between signal output and power input.

- Isolation can be achieved by several means such as by use of transformer, photo resistor thermocouplers etc.

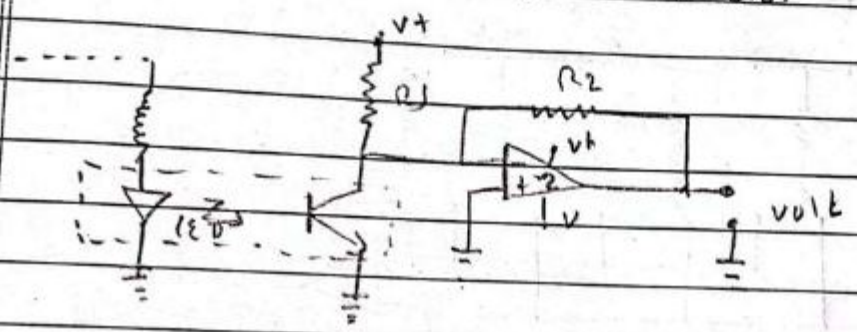


fig: LED Phototransistor linearized isolation Amplifier.

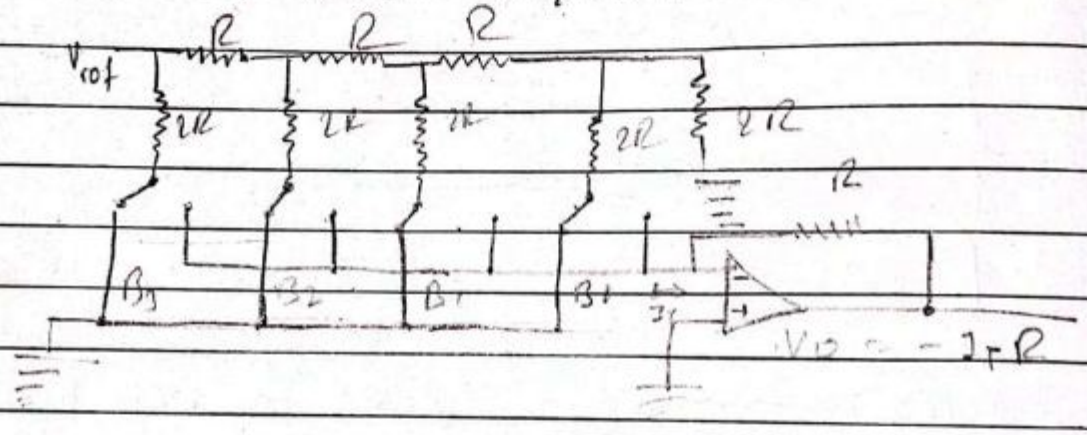
Signal input → signal o/p → power input.

Digital to Analog conversion:

Basically digital to analog conversion is the process of taking a value represented in digital code and converting it into a voltage or current which is proportional to the digital value. There are various techniques which can be used to realise a digital to analog conversion

1 Binary ladder or R-2R ladder DAC:

The network is design in such a way that the equivalent resistor is R. The number of nodes can be increased according to the number of bits required.



$$I_3 = \frac{V_{ref}}{2R}, \quad I_2 = \frac{V_{ref}}{4R}, \quad I_1 = \frac{V_{ref}}{8R}$$

$$I_0 = \frac{V_{ref}}{16R}$$

$$I_T = (I_3 B_3 + I_2 B_2 + I_1 B_1 + I_0 B_0)$$

$$= \frac{V_{ref}}{R}\left(\frac{1}{2} B_2 + \frac{1}{4} B_2 + \frac{1}{8} B_1 + \frac{1}{16} B_0\right)$$

$$V_0 = -I_T \cdot R$$

$$= V_{ref}\left[\frac{1}{2} B_3 + \frac{1}{4} B_2 + \frac{1}{8} B_1 + \frac{1}{16} B_0\right]$$

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$$= -V_{ref}\left[\frac{1}{2}B_{n-1} + \frac{1}{4}B_{n-2} + \dots + 1 \cdot \frac{B_0}{2^n}\right]$$

$$= \frac{V_{ref}}{2^n}\left[2^{n-1}B_{n-1} + 2^{n-1}B_{n-2} + \dots + 2B_0\right]$$

$$= \frac{-V_{ref}}{2^n} \cdot D$$

D → Decimal equivalent of input bits.

An 8 bit DAC has reference voltage of 16 vol. It uses of R-2R ladder network. Find min value of R ~~which~~ each that output current of ladder doesn't exist 10mA. Also find the smallest value of quantized current

Soln

$n = 8$ bit

$V_{ref} = 16$ volt

$i_0 = 10mA$

We know, (for ~~max~~ max^m value all bits are one)

$$V_0 = \frac{V_{ref}}{2^n}\left[2^{n-1}B_{n-1} + 2^{n-2}B_{n-2} + \dots + 2^0 B_0\right]$$

$$I_0 \times R = \frac{V_{ref}}{2^8}\left[2^7 + 2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0\right]$$

$$R = \frac{16}{10 \times 10^{-8} \times 2^8}$$

$$\sim 1593.75\,\Omega$$

The small value of the quantized current is given by the LSB

$$\frac{V_{ref}}{2^n R}\left[B_0 \times 2^0\right]$$

$$= \frac{16}{2^8 \times 1593.75}$$

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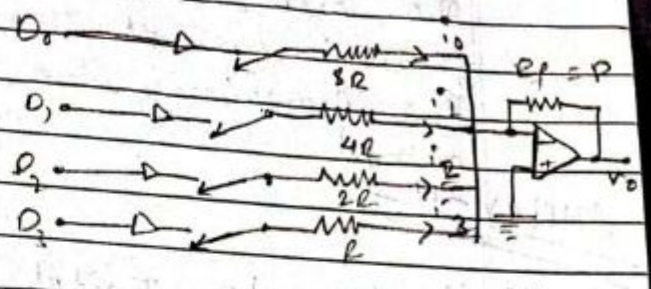
2 weighted Resistor D/A network:

If all input is high;

$i_T = i_0 + i_1 + i_2 + i_3$

$= \frac{V_{ref}}{2^3 R} + \frac{V_{ref}}{2^2 R} + \frac{V_{ref}}{R}$



Now,

$V_0 = i_T \cdot R_f$

$= -\left(\frac{V_{ref}}{2^3 R} + \frac{V_{ref}}{2^2 R} + \frac{V_{ref}}{2R} + \frac{V_{ref}}{R}\right) \cdot R_f$

but $R_f = R$ so,

$V_0 = -\left(\frac{V_{ref}}{2^3 R} + \frac{V_{ref}}{2^2 R} + \frac{V_{ref}}{2R} + \frac{V_{ref}}{R}\right) \cdot R$

$= -V_{ref}\left(\frac{1}{2^3} + \frac{1}{2^2} + \frac{1}{2} + 1\right)$

$= -\frac{V_{ref}}{2^3}\left(d_3 \cdot 2^3 + d_2 \cdot 2^2 + d_1 2^1 + d_0 2^0\right)$

if $R_f \neq R$ then

$V_0 = -\frac{V_{ref}}{2^{n-1}} \cdot \frac{R_f}{R}\left(d_{n-1} 2^{n-1} + d_{n-2} 2^{n-2} + d_0 2^0\right)$

Drawbacks

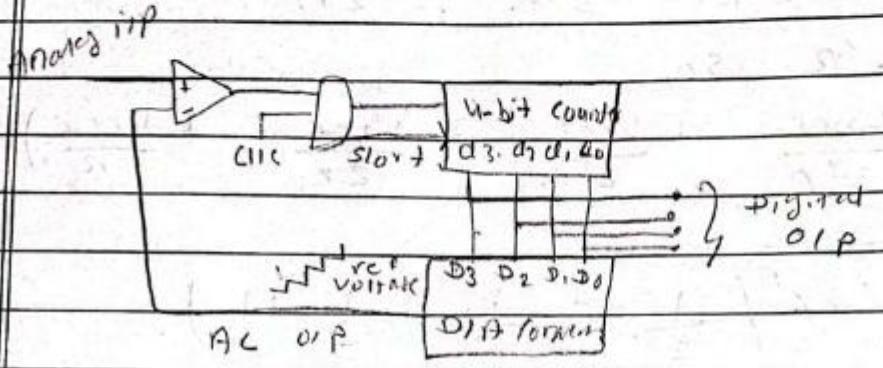
The biggest problem is the large difference in resistor values between LSB (least significant bit) and MSB (most significant bit) specially in high resolution or many bit DAC. In IC fabrication it is very difficult to produce resistor of values over a wide resistance range

- The MSB resistor is required to handle a much greater current then that used or LSB resistor. This drawbacks are overcome by R-2R ladder method

Chapter - 4

Analog to Digital conversion:

1. Ramp A/D converter: Counter type A/D converter



Operation

First the counter is reset to all zeros (0s) when a convert signal appears on the start line the gate opens and clocpulses are unload to pass through to the input of the counter. The counter ~~advantages~~ advances through it's normal binary count sequences and the stare case waveform is generate at the output of the DAC. This wave form is applied to oneside of the comparator and the analog input voltage is applied to the other side. When the reference voltage equal or exceed the input analog voltage the gate is close the counter stops and the conversion is complete. The stored ~~in the~~ value in the counter is now the digital equivalent of the analog input voltage

$= \frac{1}{25500}$

$= 0.00004$

$= 40\mu A$

What will be the analog output for the digital word of 1010 if the referance voltage is 8 volt

Soln

$$V_0 = -\frac{V_{ref}}{2^n}\left[2^{n-1} B_{n-1} + 2^{n-2} B_{n-2} + \cdots + 2^0 B_0\right]$$

$$= \frac{8}{2^4}\left[2^3 B_3 + 2^n B_2 + 2^1 B_1 + 2^0 B_0\right]$$

$$= \frac{8}{2^4}\left[2^3 + 2^1\right]$$

$=$

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continuously increase हुँदै जाने voltage → RAMP

- It have high resolution
- Conversion time required is longer. since counter always begins to zero (0) and counts through it's normal binary sequence.

Assignment

Interference signals

a) Internally generated interference signals.

b) Externally " " " .

Dual Slope A/D converter

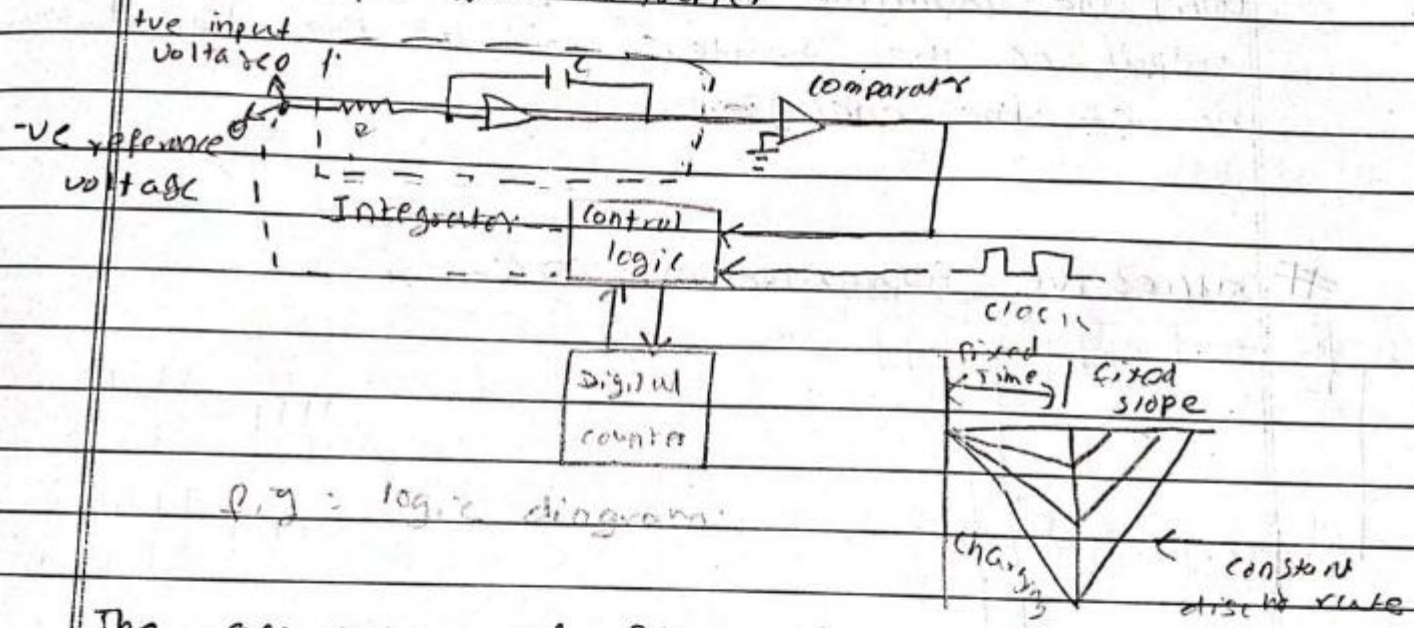


fig: logic diagram

The accuracy of RAMP ADC can be improved with the dual slope method.

The measurement is accomplished in two step:

In the first ~~step~~ step the input voltage is applied to the intregrating circuit which intregrates the input analog signal with respect to time and produces a ramp voltage across the capacitor of the integrator during this time

counter start counting. The capacitor gets charged maximum on a fixed interval of time. Then the control logic sends a message to the switch to drop down to the point connected to the ground.

In the second step, it involves the integration of reference voltage to produce a second ramp voltage that is the capacitor discharge through the resistor. At the beginning of the 2nd step the counter is reset to zero and starts counting until the capacitor completely discharges. The output of the counter will be the digital equivalent of the analog.

Successive Approximation ADC:-

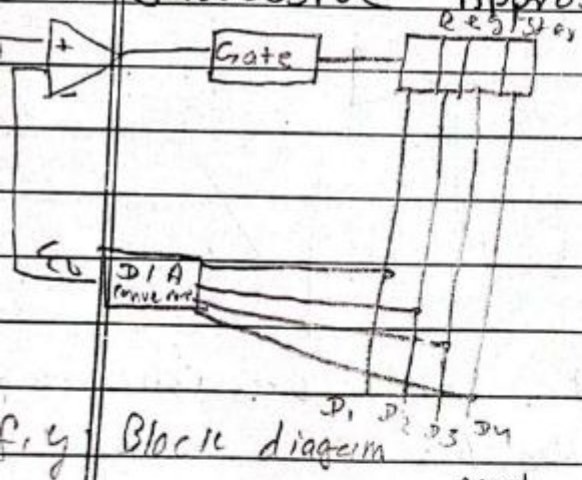
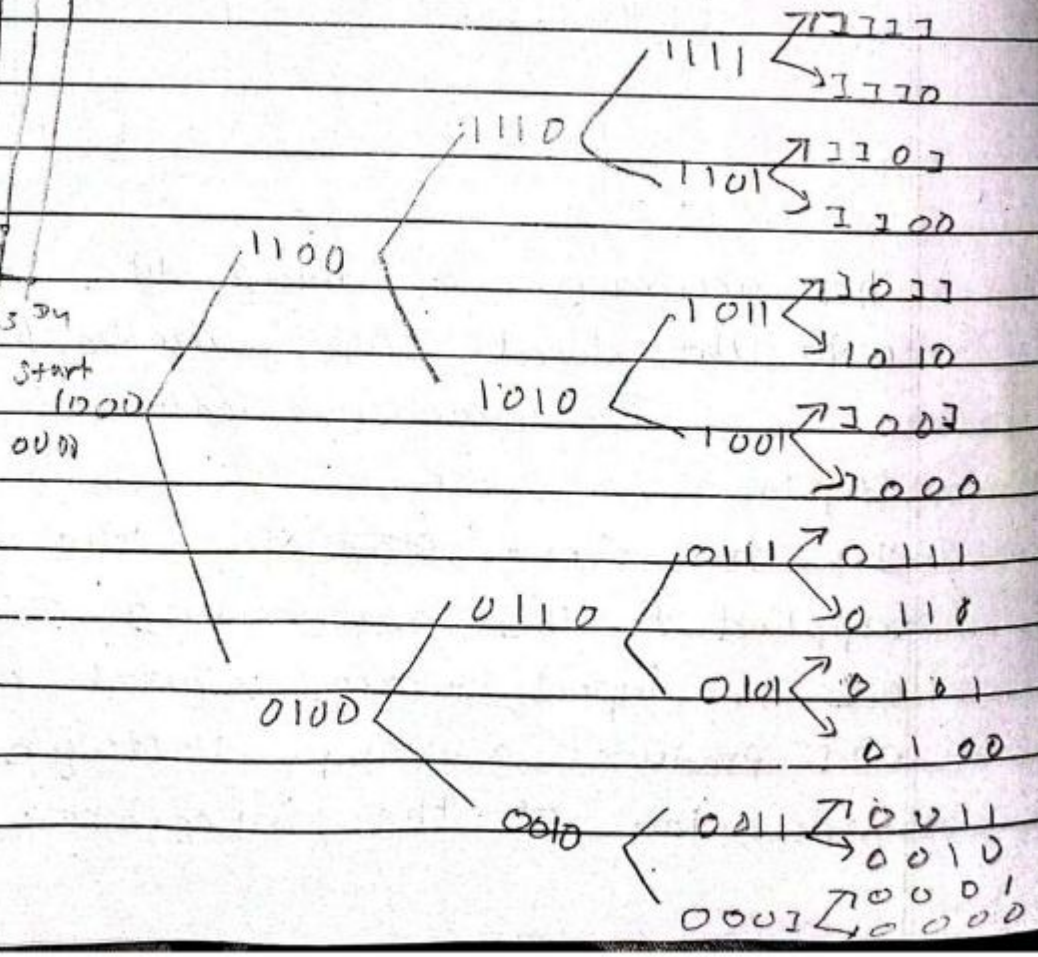


fig Block diagram



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It is the most commonly used ADC. This method is based on the comparision of input analog signal with another feedback analog signal until they are ~~equivale~~ equal.

At the first the input DAC is set with the MSB=(1) and other 0 i.e 1000. for the first approximation* the input analog voltage compared with it. If the input is greater then the referance voltage then next bit from MSB is turned on ie 1100. If the input is less then the referance voltage the MSB bit is turned off and next bit is on i.e 0100

In case 1100 again the digital value 1100 is converted into analog signal and compared with input. If the input is less then that the D_2 bit gets off and D_1 bit gets on i.e 1010. If this is too low then the input signal then next bit is turned on ie 1011, then ~~this~~ next bit will be the nearest value of the input signal. The gates close and the digital output becomes 1011

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Date
Page

Qn. find the successive approximation ~~and~~ analog to digital output to a ~~3.2~~ volt if the reference is 5 volt 3.217

Soln.

i) let $d_3 = 1$

$\therefore$ output $= \frac{5}{2^1} = 2.5$ volt

Now $3.217 > 2.5$ $\therefore$ set $d_3 = 1$

ii) let $d_2 = 1$

$\therefore$ output $= \frac{5}{2^1} + \frac{5}{2^2}$

Now, $3.217 < 3.75$ $\therefore d_2 = 0$

iii) set $d_1 = 1$

$\therefore$ output $= \frac{5}{2^1} + \frac{5}{2^3} = 3.125$

Now,

$3.217 > 3.125$ $\therefore$ set $d_1 = 1$

iv) set $d_0 = 1$

$\therefore$ output $= \frac{5}{2^1} + \frac{5}{2^3} + \frac{5}{2^4} = 3.4375$

Now $3.217 < 3.4375$ $\therefore$ ~~set~~ set $d_0 = 0$

Thus o/p of A/D converter is 1010 ;

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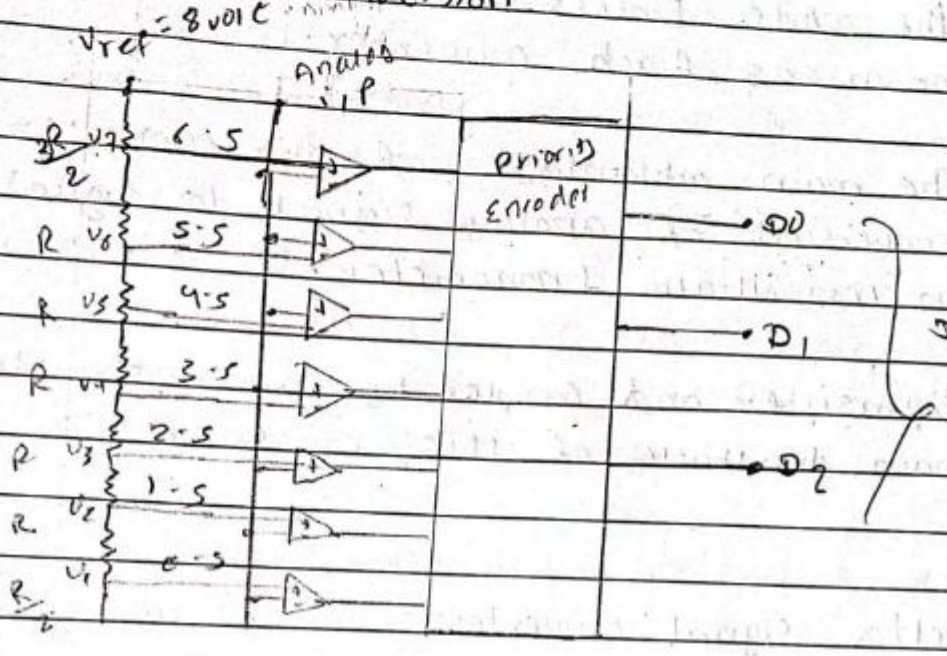
Convert an analog signal having a magnitude 3.62.5 in a four bit digital word successive approximation ADC if the reference voltage is 8 volt.

4 flash (parallel) A/D conversion



Let $V_{ref} = 8$ volt $V_1 = \frac{\frac{R}{2} \times 8}{R_{Total}} = \frac{\frac{R}{2} \times 8V}{8R} = 0.5$ volt

$$V_2 = \frac{\left(R + \frac{R}{2}\right) \times 8}{R_{Total}} = \frac{(2R + R) \times 8}{2 \times R_{Total}} = 1.5 \text{ volt}$$

Similarly, $V_3 = 2.5$ volt Then; $0 \longleftrightarrow 0.5 \rightarrow 000$

$V_4 = 3.5$ " $0.5 \longleftrightarrow 1.5 \rightarrow 001$

$V_5 = 4.5$ " $1.5 \longleftrightarrow 2.5 \rightarrow 010$

$V_6 = 5.5$ " $2.5 \longleftrightarrow 3.5 \rightarrow 011$

$V_7 = 6.5$ " $3.5 \longleftrightarrow 4.5 \rightarrow 100$

$4.5 \longleftrightarrow 5.5 \rightarrow 101$

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5.5 ⟷ 6.5 → 110
6.5 ⟷ → 111

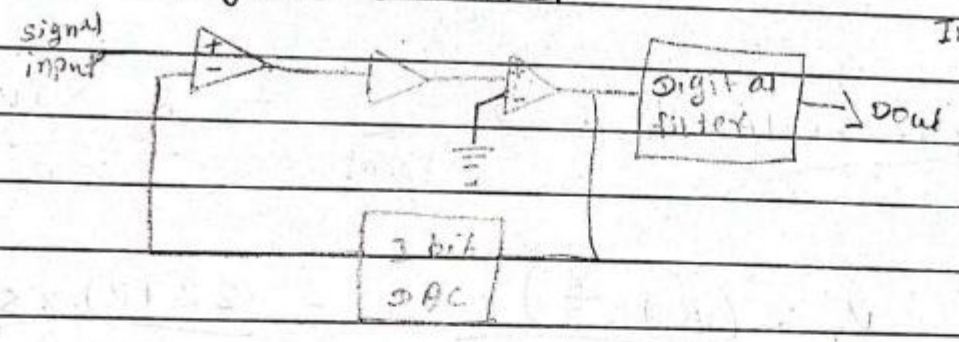
This device is known as parallel converter because the conversion of analog signal to digital signal occurs in parallel rather than sequentially. Thus, the while process occurs in a flash so it is known as flash converter.

The main advantage of this converter is that the conversion of analog signal to digital signal occurs in less than 1 nanometer.

Expensive and complexcity in construction is the main drawback of this converter.

Delta signal converter

Σ = Integration 1bit ADC / comparator



One of the more advanced ADC

Δ ⇒ difference

Σ ⇒ sommator

- The analog input voltage and output of the DAC are differenciating providing an analog voltage.

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- This voltage is present to the intregrater whose output progresses in a negative or positive direction.

- If output of intgrator is greater then zero then output of comprator is 1 and if output of integrator is less then zero (0) then output of comprator is zero. The output of comprator is feedback into 1 bit DAC as well as clocked out to the digital filter stage.

- The one bit DAC response by changing the analog output voltage of the difference amplifier. This creates a different output voltage causing the intregrator to progress.

- If the output ~~pause~~ pulse train is average, it equals the value of the input signal.

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PWM (Pulse width modulation) Type DAC:

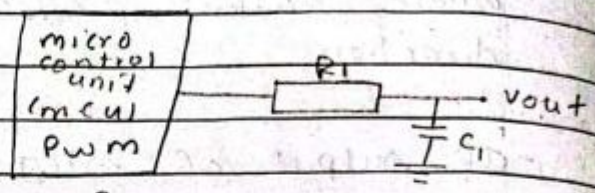


fig: Ckt. diagram

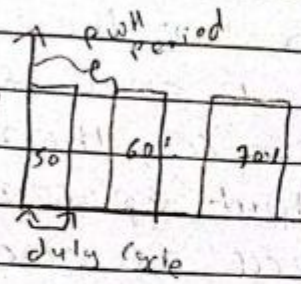


fig: PWM signal

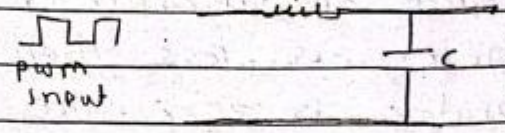


fig:- Low Pass filter

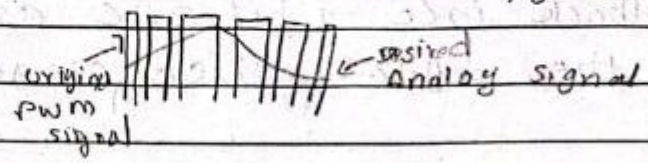


fig:- I/p and O/p signal

- The common way of producing an analog control signal from a micro control is to used a PWM output and an RC filter

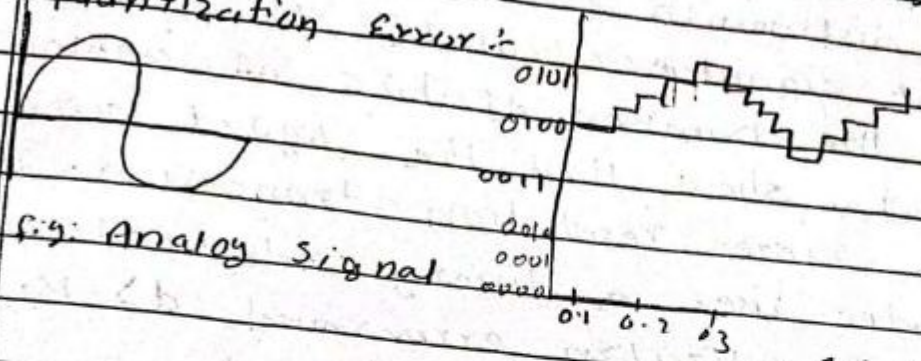
- This can be much cheaper than external DAC for non-critical application.

- The pulse width also refers to it's duty cycle is directly proportional to the amplitude of the orginal unmodulated signal

- The idea behind the PWM DAC is quite simple, it's to filter out all of the harmonic ~~signal~~ content of PWM signal and be left with only the DC component of it's. To achive this the PWM signal is low passed filter. Cheap, low power consuption, less interferance of noise, high power handling capacity are the advantages

and complexity in circuit is disadvantage.

Quantization Error :-



f.g: Analog signal

f.g : Quantized signal

- The difference between an input value and it's quantized value is called a quantization ~~energy~~ energy
- The memod of sampling chooses a fed point joint to round off the value to a near stabilized value such a process is called quantization.
- Quantization is representing the simple values of the amplitude by a finite set of levels, which means converting a amplitude analog into a discrete time signal.

$$(E_q) = \frac{Q}{2\sqrt{3}}$$ where Q : quantization interval

Numerical

Qn An analog transducer with a 0 to 10 volt input is able to distinguish a change of 10 milivolt in it's input signal. a) calculate the resolution b) calculate the number of bits of analog to digital convertor show that the digital output has almost the same resolution transducer. The analog digital converter uses a binary code. Calculate also c) the quantization error and d) the number of decision levels.

Soln

a) Resolution $= \frac{10\,mV}{10\,V} = \frac{1}{1000}$

b) Resolution $= \frac{1}{2^n} = \frac{1}{1000}$

$n = 10$

as $2^{10} = 1024$ (nearly equal to 1000)

c) Quantization interval $(Q) = \frac{10\,V}{2^n}$

$= \frac{10}{1024} \approx$

Quantization error or noise $= E_q = \frac{Q}{2\sqrt{3}} = \frac{1 \times 10^{-3}}{2 \times \sqrt{3}}$

$= 0.29\,mV$

d) The no. of decision levels $= 2^n - 1$

$= 1024 - 1$

$= 1023$

Note: Descret levels $= 2^n$

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Test probe:

i simple test leads
ii High voltage probes
iii shielded cables
iv connectors
v current probes.

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Wave Analyzers and digital instruments.

Wave Analyzer

- It is an instrument design to measure relative amplitude of a ~~sig~~ single frequency component in a complex wave form.

- The instrument acts as as frequency selective volt meter which is tuned to the frequency of one signal while rejecting all other signal components.

wave analyzer are of two type :-

- frequecy selective wave analyzer
- Heterodyned wave analyzer

i frequency selective wave analyzer

- used for measurements in the audio frequency range (i.e 20 Hz to 20 kHz)

- It has a filter section with a very narrow pass band.

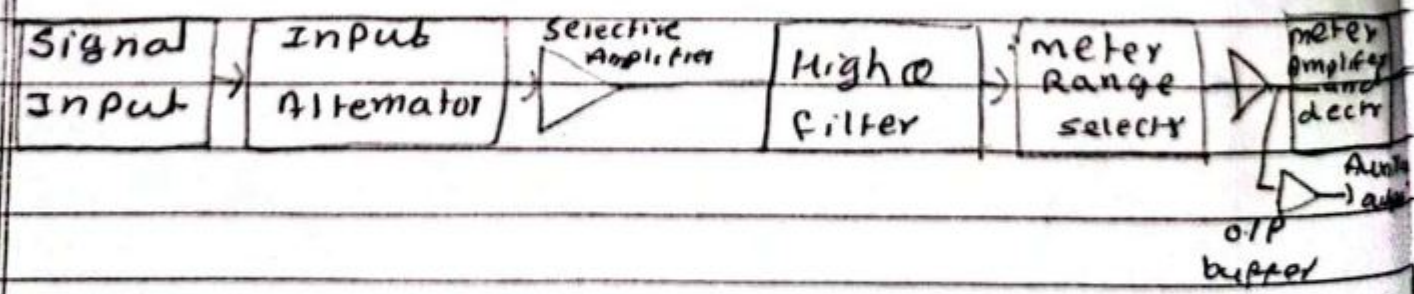

fig:- frequency selective wave Analyzer

4) The output of the alternator is fed to a selective amplifier which amplifies the selective frequency.

4) The high Q filter is a low pass filter which allows the frequency which is selected to pass and reject all others.

4) The magnitude of this selected frequency is indicated by the meter and the filter section identified of the frequency of the component.

ii) Heterodyned wave Analyzer

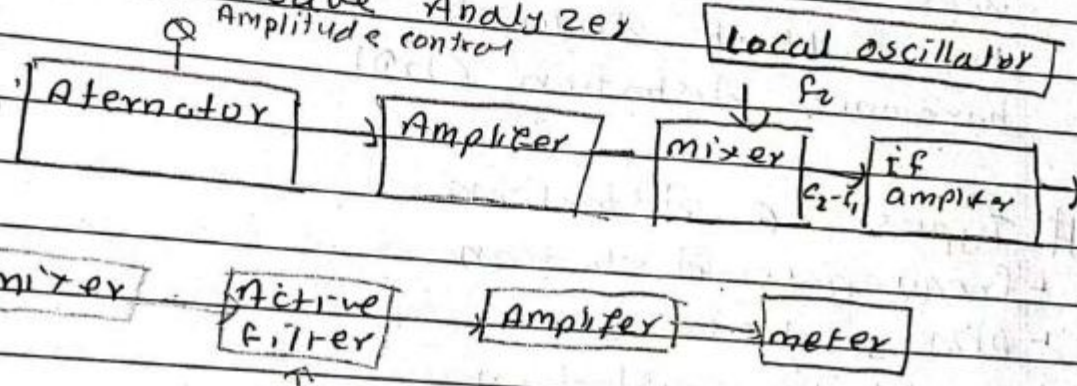

fig: Block diagram

If - intermiddle frequency

The frequency of the local oscillator is adjusted to give a fixed frequency output which is in the pass band of the I.f amplifier.

This signal is then mixed with a second crystal control oscilator. The subsequent active filter has a controlable bandwidth and passes the selected component of the frequency to the indicating meter.

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Application :- sound measurement, electrical measurement and vibration measurement.

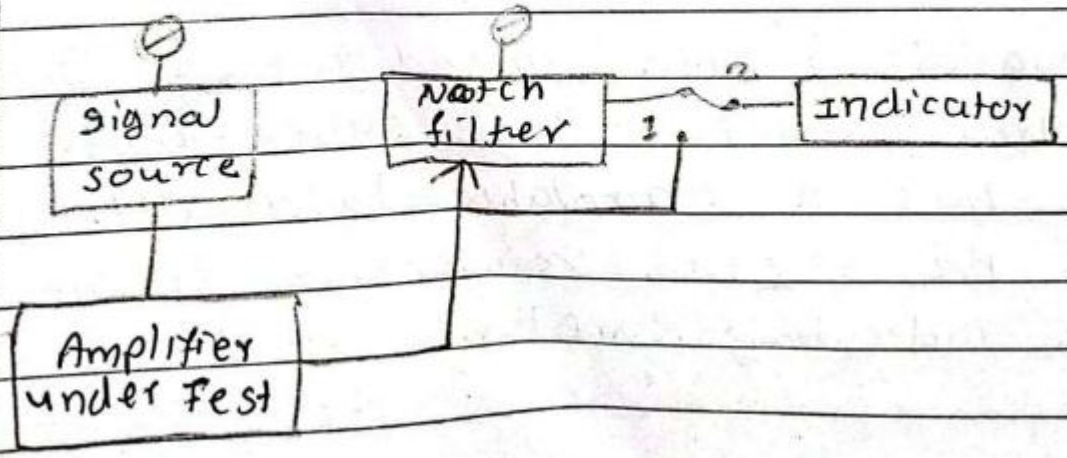
Distortion Analyzer

- The output wave form is not an exect replica of the input waveform because of various types of distortion that may occur.
- Non-linear behaviour of circuit elements introduces harmonis in the output waveform and the resultant distortion is often refer to as harmonic distortion (HD)

Types of distortion

- frequency distortion
- phase distortion
- Amplitude distortion
- Inter-modulation distortion
- cross-over distortion

fundamental Harmonic Distortion Analyses:



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4) The signal from the source is fed into the amplifier under test. This generate the harmonic and orginal fundamental frequency. The fundamental frequency is removed by the notch filter.

4) The switch is first place in position one and the total content of fundamental and harmonic (ET) is measured. Then the switch is moved to position two to measure just the harmonic (Ex). The value of total harmonic distortion (THD) is then found from:

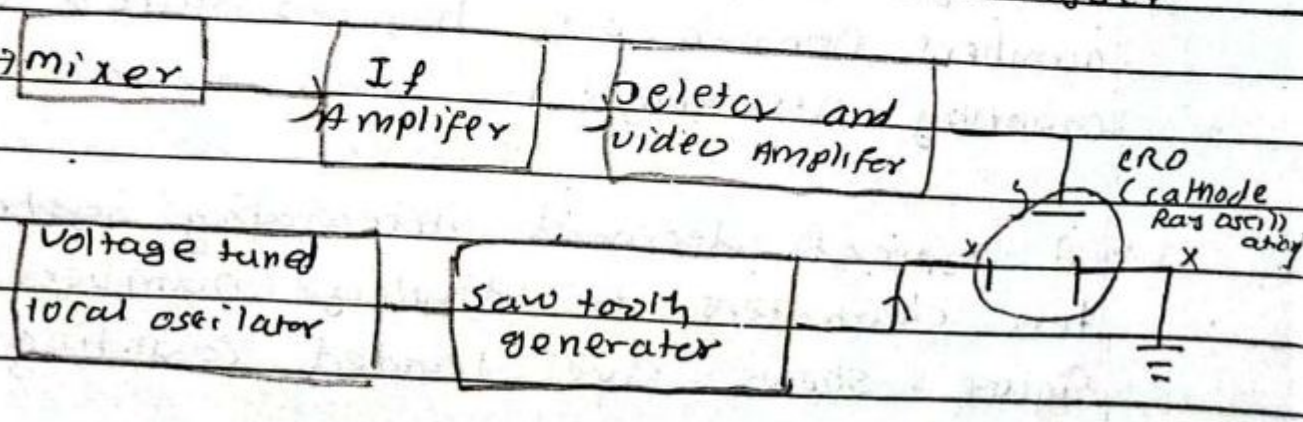
$$THD = \frac{EH}{ET} \times 100\%$$

Spectrum Analyser:

4) Spectrum Analyser is defined as the study of energy distribution across the frequency spectrum of a given electrical signal.

4) study gives valuable information about band width, effect of different types of modulation and spurious signal generation.

i Basic swept receiver spectrum Analyser.



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It is design to represent a plot of amplitude versus frequency. saw tooth generator supplies a ramp voltage to the voltage tuned local oscillator. saw tooth voltage is simultaneously applied to the horizontal place of the CRO. The horizontal signal to be tuned is applied to the mixture stage. The resuting IF signals are amplifiers and then detected. After that they are applied to the vertical deflection plate of the CRO. Thereby producing a display of amplitude versus frequency on the screen.

Decade counting Assembles (DCAs):

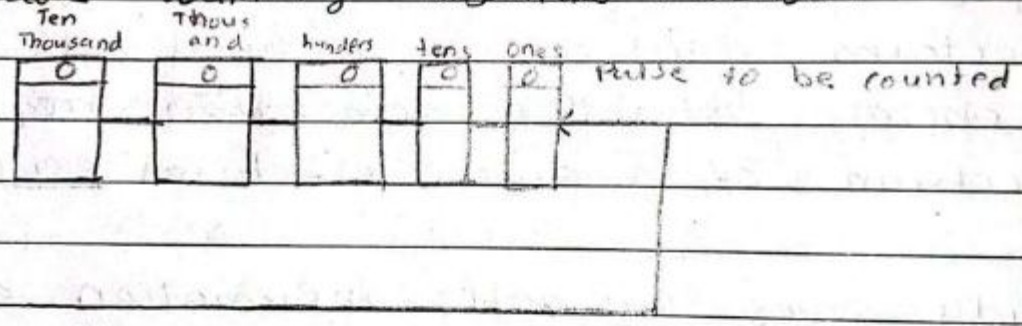

fig:- DCAs with their readout

~~A Sig~~ Silicon.

A single display neumeric unit can display numbers from 0 to 9 this is called a decade counting assembly.

A typical decimal integrating system uses ten characters to display numbers 0 to 9. figure shows five decaded counting assembles

Connected in cassed. They can count upto 99999. when the first unit count up to 9 it returns to zero (0) on the ~~ten~~ 10th count and activates one of the second DCA indicating a count of 10.

- When the tens recycle it activates 1 of the third DCA. As each decades recycle and activate the higest DCA.

Frequency counter:

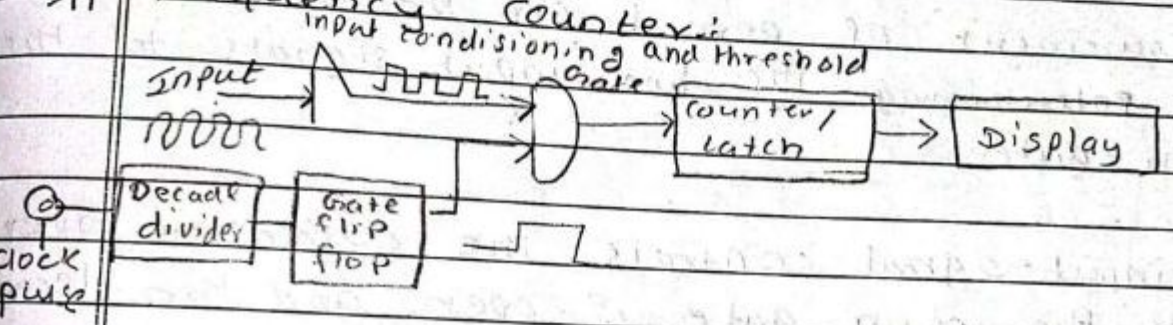

fig: Block diagram

- Amplifer convert the signal into square or rectangular wave for processing.
- Clock produce for verious timing.
- Decade divider devided the clock signal and output is given to flipflop.
- flipflop produces for AND Gate
- AND Gate produce a series of pulses at a presise time interval
- Counter counts the number of pulses that occurs from the input signal.
- The latch is used to hold the output signal while displaying the figuers.

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Period counter

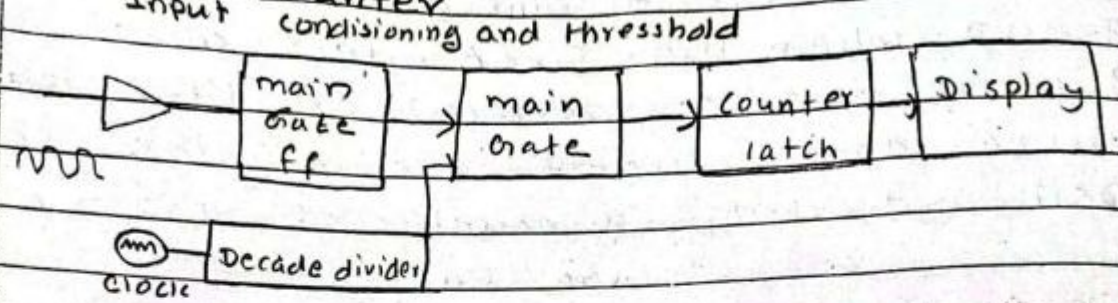

fig:- Block diagram

Period of unknown frequency $t = \frac{1}{f}$, Thus

- measurement of period can be done directly by interchanging the two input signals to the main gate.

- The input signal controls the duritation over which the main gate is open and the decade divider output is counted by the counter. The duration of the count is one cycle or period of the input signal.

Digital voltmeter (comparision to analog)

- Increases speed
- output of digital voltmeters can be fit to memory devices for storage.
- versatile and accurate
- reduced size, power and cost

Types:-

i. Ramp type DVM (Digital voltmeter)
ii. Integrating Type DVM

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iii) potentiometric type DVM
iv) succesive approximation type DVM

1) Ramp type digital voltmeter

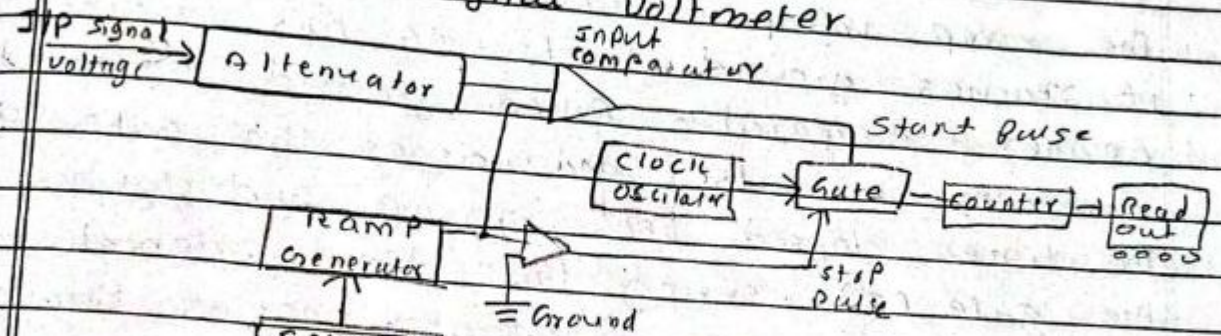


fig: Block diagram

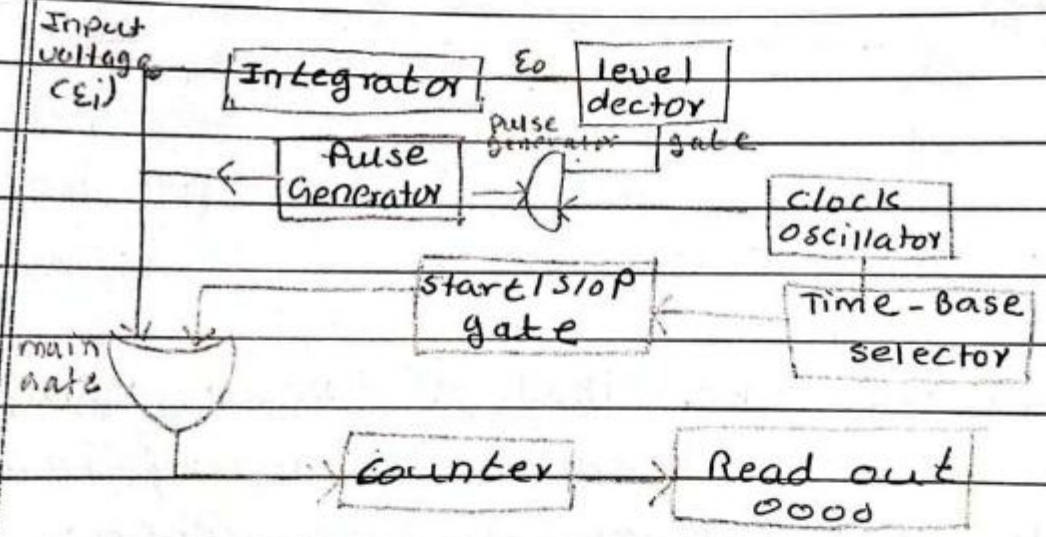
4) It measure a time that a linear Ramp voltage tends to change from a level of input voltage to zero voltage or vise versa. The time interval is measurd with time interval counter and count is displayed.

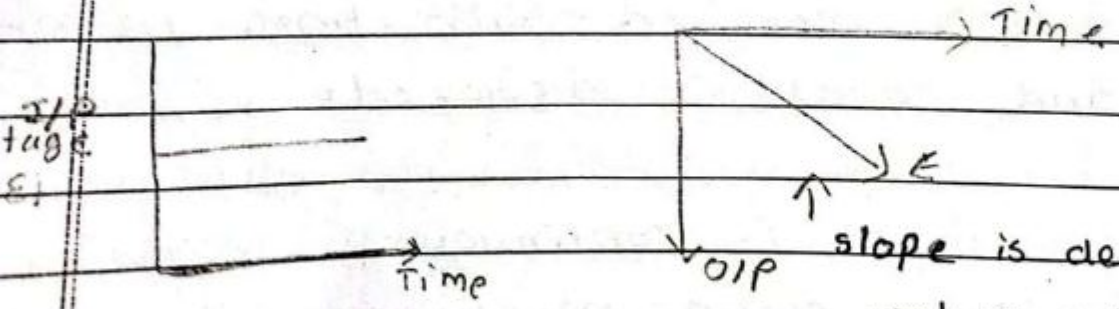
4) The ramp voltage is continuously compared with the voltage being measured (unknown voltage). At the ~~stra~~ instant the value of ramp voltage is equal to that of unknown

voltage a coincidence circuit called an input comparator generates a pulse which open circuits.

- The ramp voltage continues to decrease till it reaches ground levels. At this instant another comparator called ground comparator generates a pulse and closes the gate. The time elapsed betn opening and closing of the gate (T). During this time interval pulses from a clock pulse generator passes through the gate and are counted and displayed.

2 Integrating type digital voltmeter:





slope is determined by the value of input voltage

This voltmeter employees an interation technique which uses the voltage to frequency converter and frequency is measured. A voltage to frequency feedback converter control system which governs the rate of pulse generation in proportional to the magnitude to the input voltage. The unkno-wn input voltage is fit to the integrator and the output voltage tends to rise which is then applied to the level ~~detector~~ detector. The o/p voltage from integrator is compared with the fixed voltage of an internal referance when E_0 reaches the level of the detector produces an output pulse.

4) The greater the value of input voltage E_i the shaper will be the slope of output voltage E_0 and quicker the output voltage E_0 will reach it's referance levels.

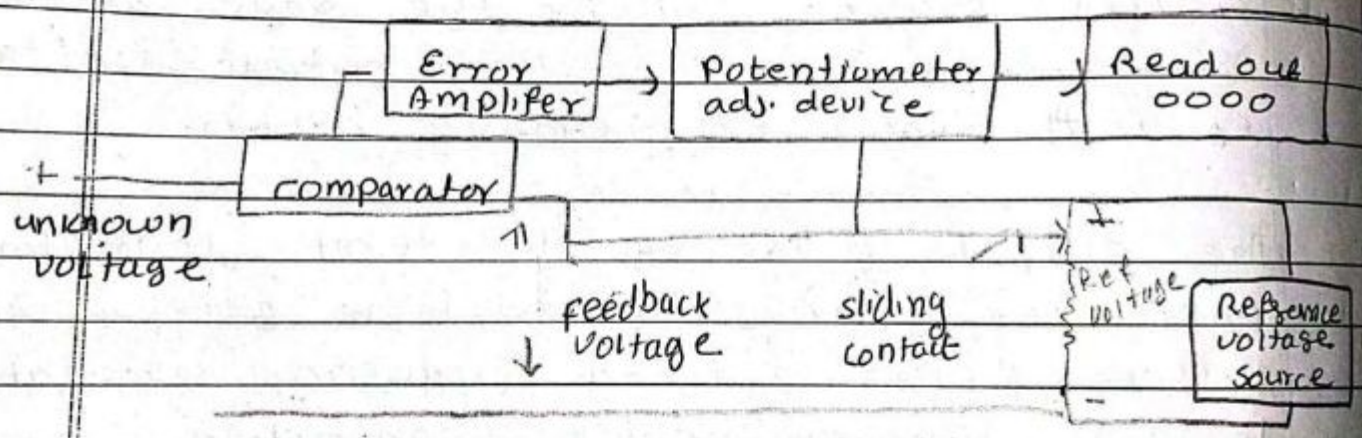
4) The output pulse of the level detector open the pulse generation gate permiting pulses from a fixed frequency clock oscillator to pass through pulse generation.

- This output pulse which polarity is opposite and has a greater amplitude is feedback to the input of the integrator. As a result of this reverse input the output drops to it's original levels. Since ~~inert~~ E_0 is now below the referance level of the level detector Prei

is no o/p from the detector to the pulse generator gate and gate gates close. when the output voltage pulse has passed E_0 start it's rise again and the intercycle is repeated again and again.

- One pulse from the pulse generator is produced from the each cycle of the o/p, the number of o/p produced in a period of time interval ~~and~~ hence the frequency is an indication of the voltage being measured.

3 Potentiometric (servo) type digital voltmeter

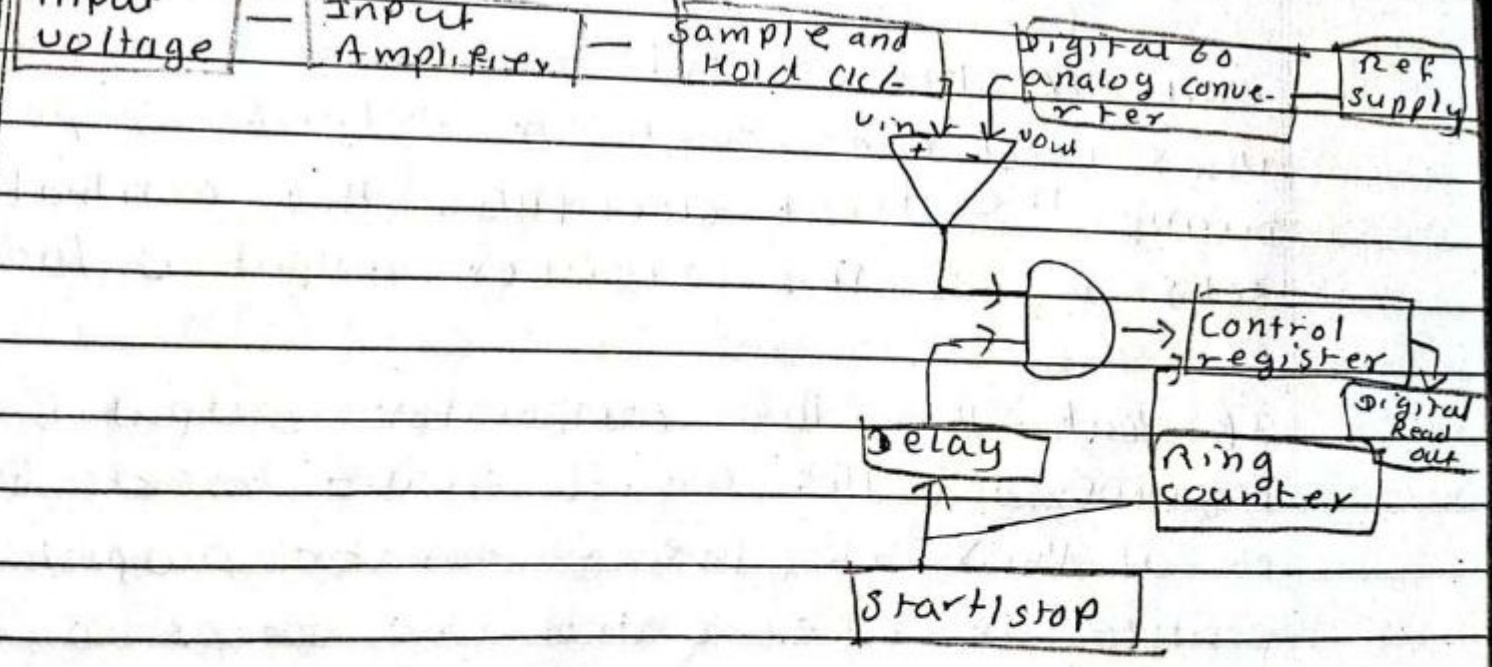


The unknown voltage and the feedback voltage are compared in the comparator. The difference of the voltage (error) signal is amplified and fit to the potentiometer adjustment device which moves sliding contact. The direction of movement of slider is depends upon whether the

Feedback voltage is larger or input voltage is larger. The sliding contact moves to such a place where a feedback voltage equals the unknown voltage. In that case there will not be any error voltage and hence their will be no input to the device adjusting the position of the sliding contact and therefore it will come to rest. The position of the potentiometer* at this point is indicated in ~~an~~ numerical form in digital readout device.

The potentiometer adjustment device that is which moves the sliding contact is a servo motor

4 Successive Approximation type digital voltmeter,



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- The output generated from digital to analog converter is compared with respect to the unknown voltage.
- from the amplifier section, the input is fed to the comparator using an sample and hold circuit
- The control register receives 8 bits as input which is then counter clk. After every clockpulse which is then provided to DAC that converts the recieved signal into an energy signal.
- The output of AND Gate becomes logic 1 when the comprator output is recieved from the control register.
- when the start pulse signal activates the control clk, the successive approximation register is cleared. ~~the~~ The output of the register is 00000000

Vout of the digital to analog is 0. now if Vin > Vout the comprator output is positive. During the first clockpulse the control ckt sets D_7 to the register output is 10000000

If Vout > Vin, the comparator output is negative and the control circuit resets D_7. However if Vin > Vout, the comparator output is positive and the control ckt keeps D_7 set. similarly the rest of the bits begining from D_7 to D_0 are set and tested. Therefore the measurement is completed in 8 clockpulse

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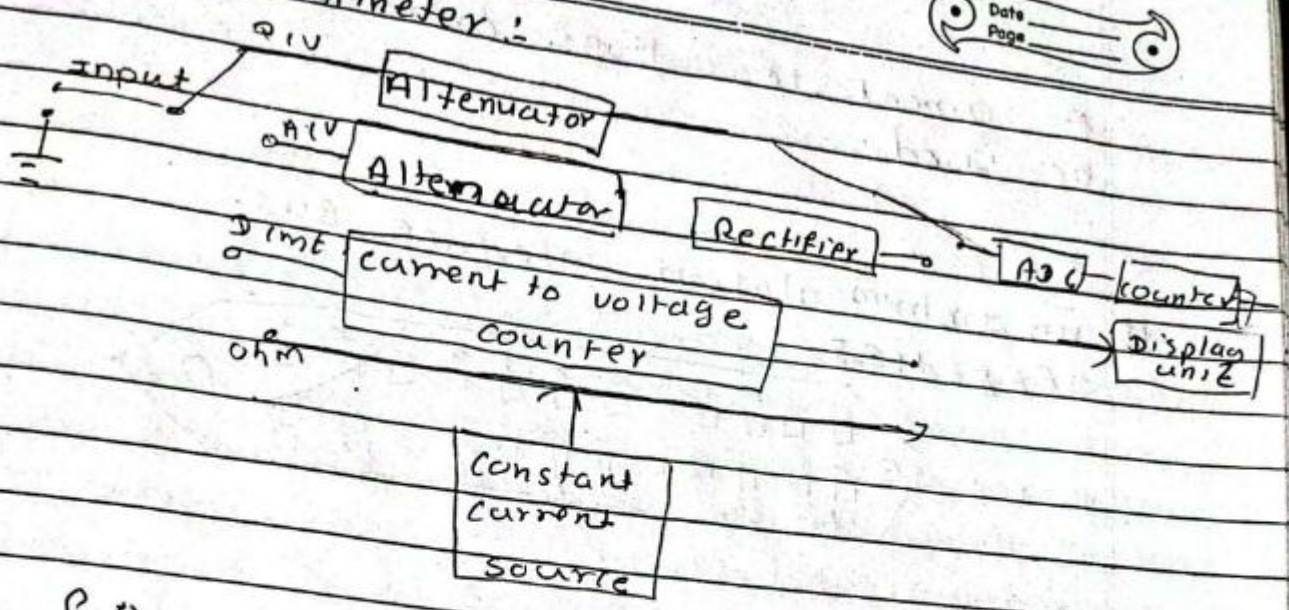
Digital multimeter :-

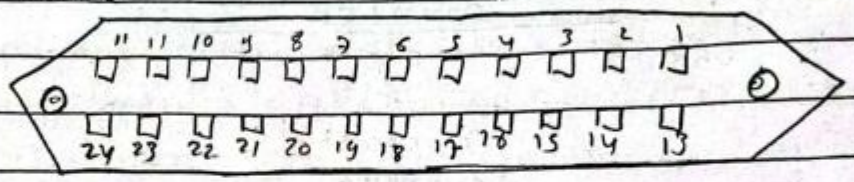


f.g: Block diagram of digital multimeter.

- It is basically a digital voltmeter may be used for the measurement ~~for~~ of voltage, current and resistance.
- All quanties other then DC voltage are first converted into an equivalent D.C voltage by some device.
- for AC voltage :- Input is converted into Low frequency (DC voltage) by means of rectifier.
- for Resistance :- A constant current source is passed through the resistance and the voltage developed across it is measured. The resistance value is displaye in ohm.
- for current :- The unknown current is passed through the resistor and the voltage developed across the resistor is measured. The current value is displaced in mA (milliamper)

A current to voltage controlar may also be used.

II Instrumentation interface Bus:
IEEE. 488



Pin	signal	
1	Data 1	Data i/p o/p
2	Data 2	
3	Data 3	
4	Data 4	
5	EOI → end or identify	
6	DAV → data valid	
7	NARD → Not Ready for Data	
8	NDAC → Not data accepted	
9	IFC → Interface clear	
10	SRQ → service Request	
11	ATN → Attention	
12	SHIELD → shield	
13	Data 5	Data Ip-OIP
14	Data 6	
15	Data 7	
16	Data 8	
17	REN → Remote Enable	
18	GND	Grounded twisted pair
19	GND	
20	GND	

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21 GND
22 GND } Grounded twisted pair
23 GND
24 logic GND -> signal ground

- The purpose of IEEE 488 Bus is to provide digital interfacing between programable instrument for a set of instrument to be interface with a ~~sig~~ singal computer a general bus system has been develop to which the number of instrument can be attached so that communication between the computer and instrument are possible over a common cable. This is known as IEEE-488

Vector Voltmeter:

- Vector voltmeter measure the amplitude of a signal at two points in a circuit and simitanously measures the phase different between the voltage waveforms at this two points. Rf to If convertor and the phase control ~~sect~~ Section produce two twenty kHz sign waves with the same amplitude and the same phase relationship as the fundamental component of the rf signal applied to channel ~~and~~ A and V.
- The phase meter section contineously monitors this two 20Hz sign waves and indicates the phase angle between them.
- The voltmeter section can be switched to channel ~~A~~ and B to provide a meter display of amplitude.

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- To determine the phase difference between the two If signals the tuned amplifier is followed by the phase meter cirkuit. If channel is first amplified and then limited.
- channel a is shifts to the phase of square signal by +60° the circuit in channel be shifts the phase of it's signal by -120°
- The output of the ~~outsh~~ phase shift ~~ckt~~ are amplified and clipped to producing square waveform and applied to the trigger amplifier.
- By stable multivibrator is trigger by pulses from both channels. Channel's A is connected to the set input of the multivibrator, channel B is connected to the reset input of the multivibrator. The switch connect the constant supply to the phase meter.

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Output device

Recorder

A recorder is a device which function is to record the value of quantity as it is being measured

i magnetic tape Recorders
ii ship chart Recorder
iii Galvonometer type recorder
iv Potentiometer type recorder

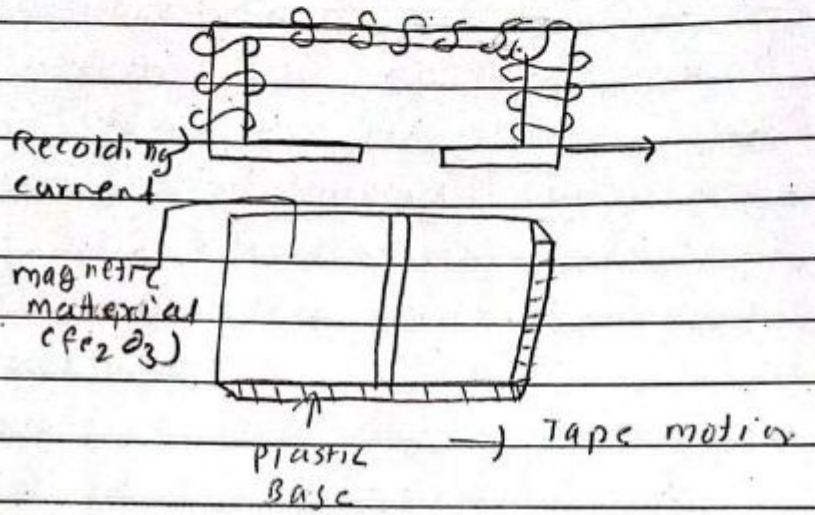

fig: magnetic tape recording Head

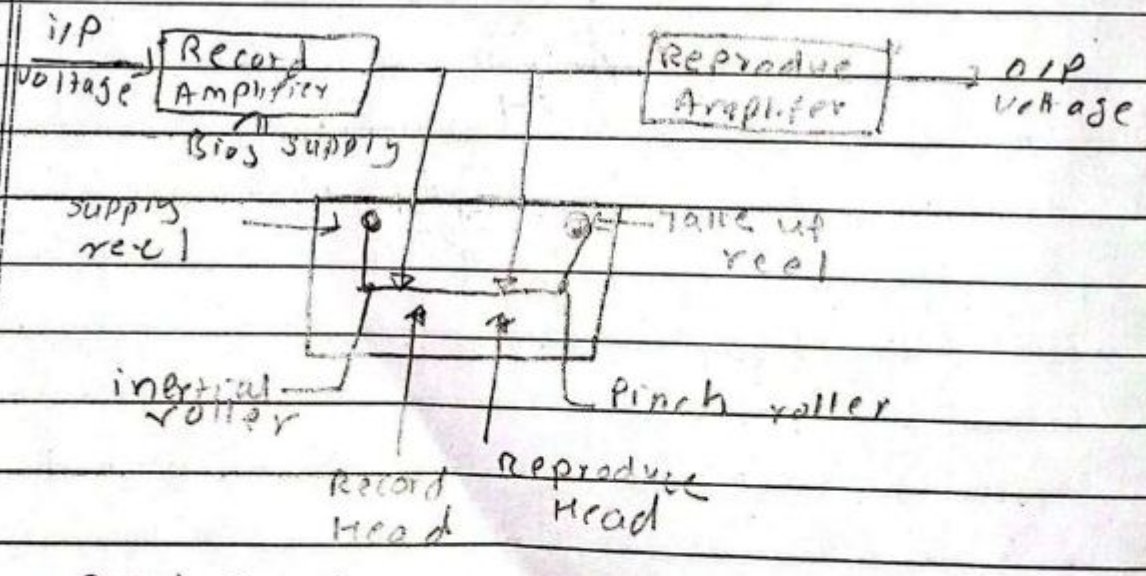

fig: Simple magnetic recording System

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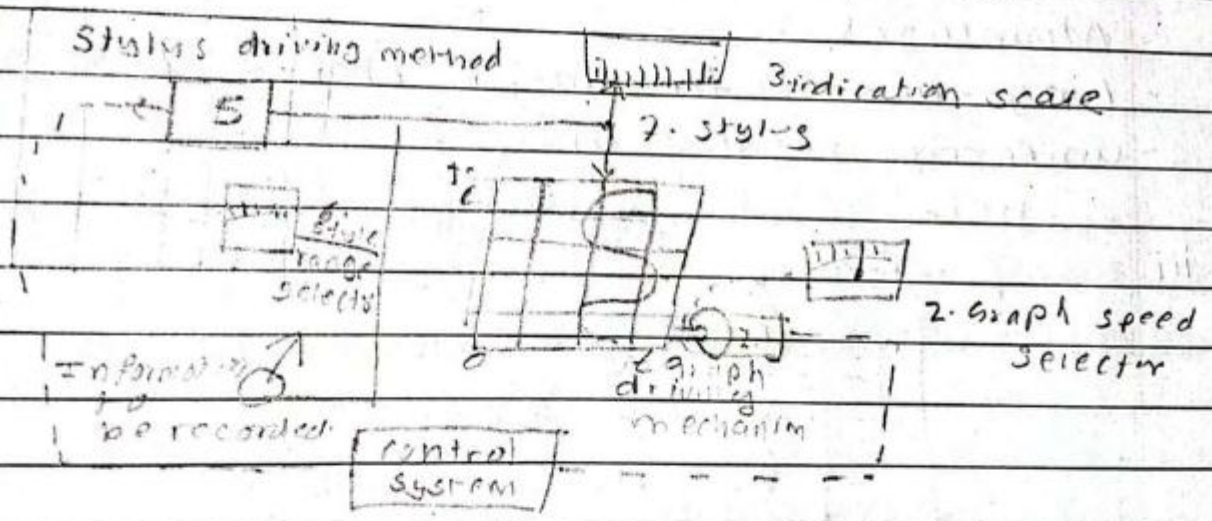
⇒ when magnetic tape is passed through a recording head, any signal recorded from the tape appears as magnetic pattern disperse in space along the tape similar to the orginal coil current variation with time

- ~~when~~ The same tape passed through or recorded head, emf is induced in the coil due to the rate of change of flux linkage so corresponding current is passing through the circuit whose magnitude is proportional to the magnetic pattern of the tape

Applications

- works on wide frequency range
- low distortion
- The tape can be erased and reuse

ii



This type of recorder records one or more variable with respect to time so it is also called the x-t recorder.

- paper driving ~~ma~~ machanism is usually constant speed motor (Synchronous motor)

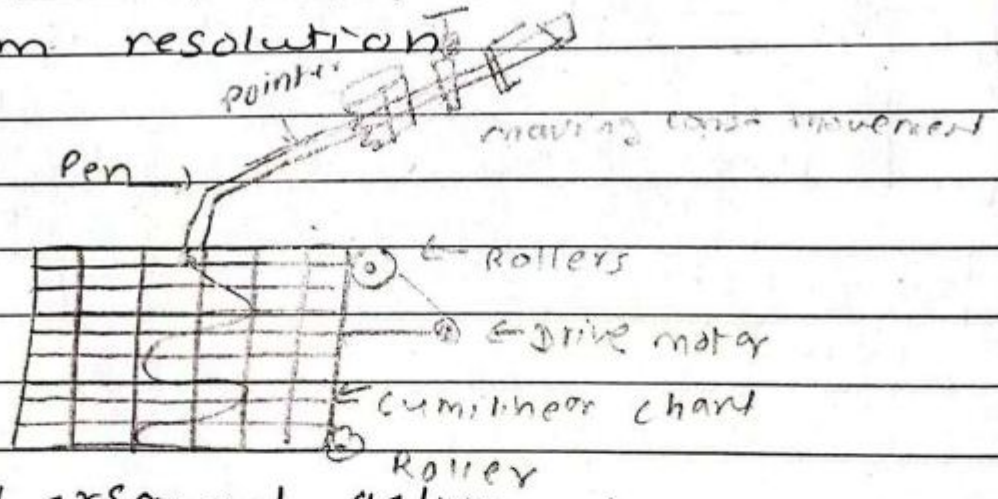
marking machanism is done by pen and ink, thermal ~~or writing~~ writing, light beam method etc. stylus gives current reading.

- Strip charge gives current reading ~~recording~~ y. It shows the variation or recorder with respect to time.
- It consist of a long role of graph paper moving vertically proportionally to the output of control system. A system for driving the paper at some selected speed which is generally in range of 1 to 100 mm per second. A stylus make marks on the moving graph paper. The stylus move horizontally in proportional to the quantity to be measured.

Advantages

- Long period ~~for~~ run; A chart lenght of 36m
- uniform resolution

iii



4 use D' arson and galvanometer

The pointer is equipt with the recording pen machanism as the current ~~fotte~~ flows through the coil it deflects. The greater the amplitude of incomming signal, the

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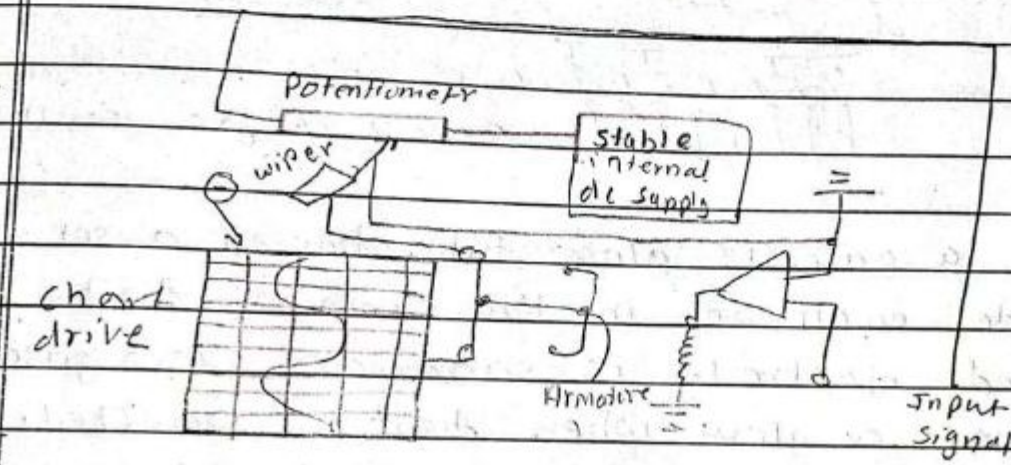
greater is the deflection. When the pointer comes to rest on account of controlling torque exerted by springs. The stylus also comes to rest thus the value of quantity is recorded. The movement of instrument requires an appriciable torque, to obtain this torque. The D'arsonual movement consists on large moving coil situated in a strong magnetic field.

iv) Potentiometer type Recorder:



The accuracy can be improved if the input signal is compared with a reference voltage by using a potentiometer circuit.

The error signal which is the difference between the input signal and the potiometer voltage is amplified and is used to energized the field of dc motor. A wiper is machinacally connected to the armature of DC motor. This wiper moves over the potentiometer in the appropriate direction to reduced the magnitude of the error signal and to obtain balance.

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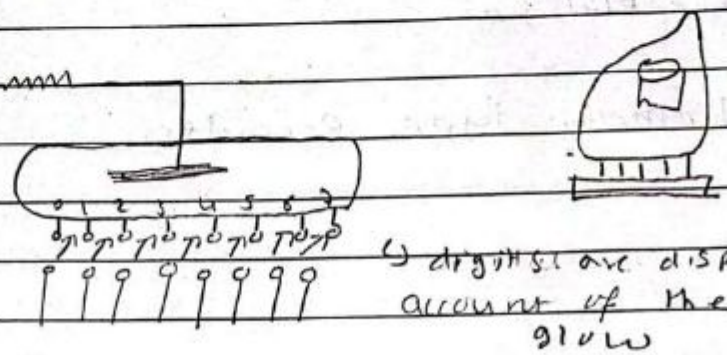
The wiper comes to rest when the unknown signal voltage is balanced against the voltage of the potentiometer.

Indication and displays

In digital ~~instrument~~ device the output devices indicates the value in decimal digits. This is done by using a digital display device.

Nixie



↳ digits are displayed on account of the resulting glow

It is a gaseous glow tube having a set of electrode each set in the form of digit. The selected electrode is surrounded by gaseous discharge or glow when digit is selected. The electrode are stacked one behind another and hence, the various digits appered in different plans in the readout.

LED (Light Emitting Diode):

when a LED is a PN junction device which emit light when a current passes through it in the forward direction.

Charge carrier recombination occurs at a PN junction as a electrons cross form N side and recombines with holes in the P side.

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when recombination takes place the charge carrier give up the energy in the form of heat and light. If the some conducting material is ~~trans~~ translucent the light is emitted and the Junction is source of light

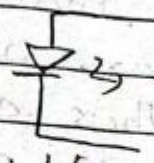
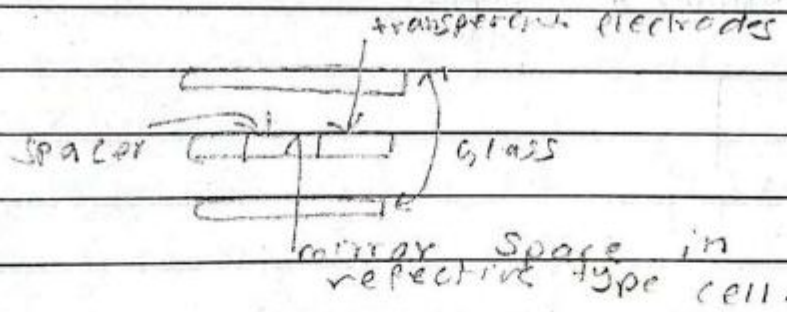


fig: LED

material: Gallium Arsenide phosphide ~~(GA~~ (GaAsP) => emits yellow light.
Gallion Arsenide (GaAs) => emits green or red light.

Liquid crystal diode (LCDs):

a) dynamic Scattering type
b) field effect type



When potential is applied across the cell charge carrier following through the liquid distrupt the molicular allignment and produce ~~tu~~ turbulance. When the liquid is not activated it is transparent.

when a liquid is activated molecular turbulance causes light to be

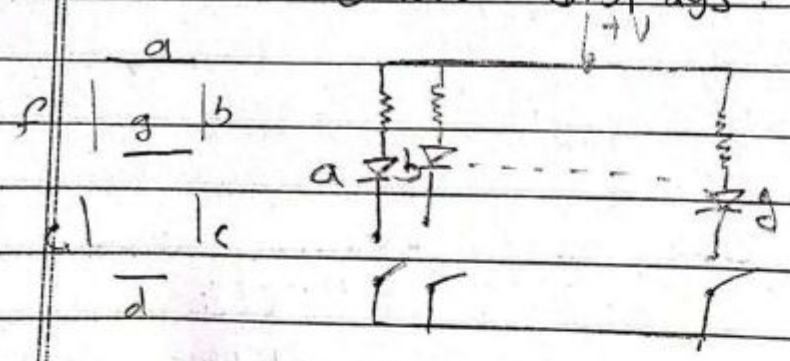
Strutter in all direction and the cell appers to be bright. This phenomena is called dynamic ~~stratering~~ scattering.

In field effect liquid crystal display is similar to that of dynamic ~~sca~~ scattering type with the exception that two thin polarizing optical filters are placed at the inside of glass sheet. This allows the light to pass through the optical filters and the self appers bright.

Advantages
low power consuption, low cost

disadvantages
slow devices, occupy large area

seven segment Displays:



In this case of segmental display one or more than one light sources may be involved in the display of a particular character. suppose digit 0 is to be displayed by a seven segment display, this requires the segment A, B, C, D, E, F should be light up.

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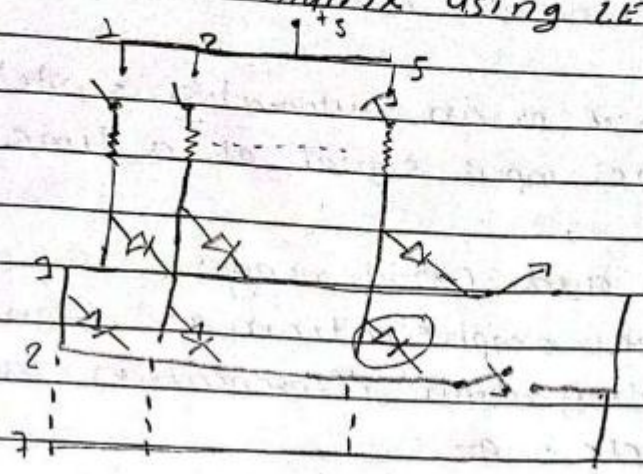
A common supply voltage derives the anodes of the leds and when the switch closes the corresponding ~~leds~~ led is forward bias and emits light.

Dot matrix Displays

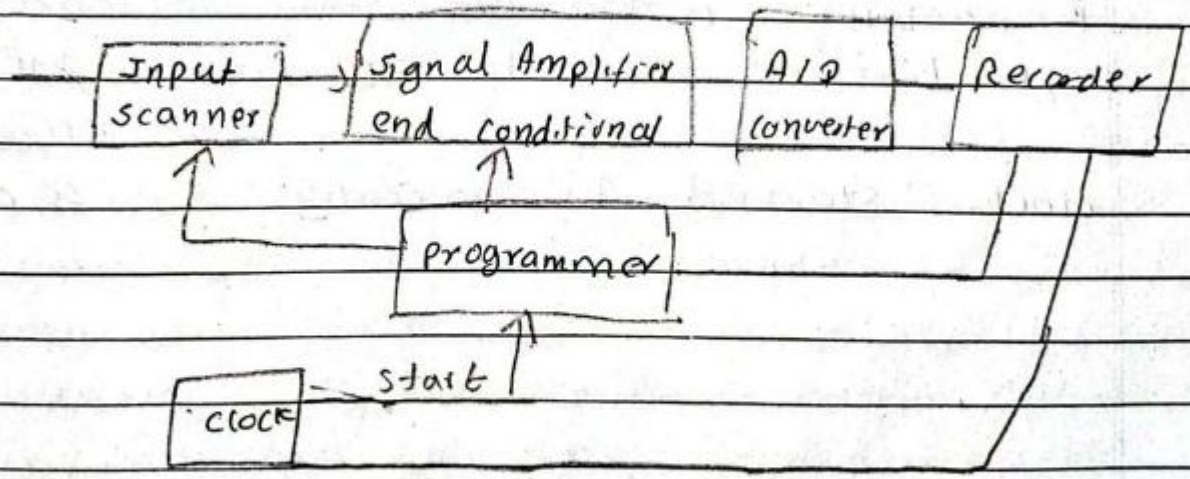
Ex: 5x7 dot matrix using LEDs.



The circle led light up because voltage is applied to 3rd row and 5th column.

By applying voltage to more then one column and grounding ~~one~~ more then one row a decimal digit or alphabet can be display.

Data loggers:-



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Data loggers are electronic devices which automatically monitor and record environmental parameter over time, allowing condition to be measured, documented, analysis and validated.

It is used to measured and stored the reading of instruments without any loss of accuracy

Input scanner:- it is an automatic switch that can select only one input signal at a time.

Signal amplifier and conditioning
It may involve amplification and signal conditioning light intregration differencation addition substraction etc.

Analog to digital Converter
It converts the analog signal to ditial signal because data loggers only handel digital data.

Recorder
Example:- typwriter, punch paper tape etc.

Programmer : control the ~~situ~~ sequence of operation of all units of data logger.

clock : started automatically by a clock

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Oscilloscope:-
It is used for display, measurement and analysis of waveforms and other phenomena in electrical and electronic ckts.

Cathod ray oscilloscope are ~~an~~ infact very fast xy product display an input signal verses another signal or verses time.

Application
- Display the wave form of signal
- measurement of voltage, current, frequency, timeperiod and phase angle.
- Comparison of two frequency, two waveforms etc
- Study of pulse width, pulse ~~display~~ amplitude etc.

Specification of osscilloscope:-
1) Bandwith
- Governs the maximum frequency of the signal that it can capture and analysis.
- As the frequency of the signal gets closer to the maximum frequency. It's accuracy drops.

2) Sample rate
- It is the number of sample that the osscilloscope is capable of capturing per second.

memory size / depth
- It describe the total number of samples that an ossilloscope can hold for ~~lette~~ later processing.

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~~Right~~ time

Rise time

- It describe the ability of the instrument to detect and capture rapidely raising and falling signals

Channels

Two to four channels

2 ↔ 4 channels

↑ Allow two input signals

↑ Allow four inputs signals.

Cathode Ray oscilloscope (CRO):-

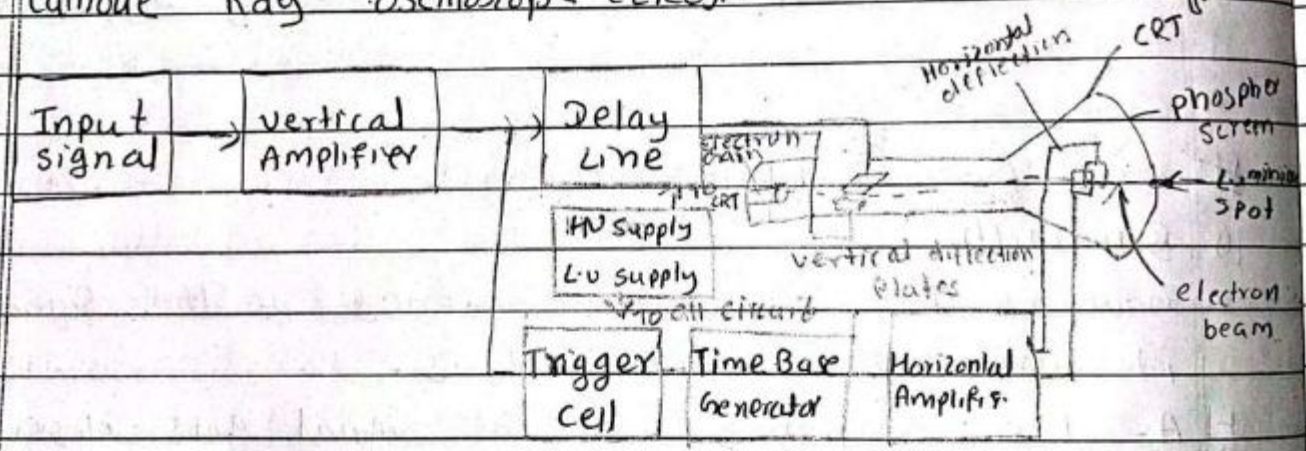

fig: Block diagram.

In cathode Ray oscilloscope the output signal voltage of the vertical amplifier is fit to the vertical place of CRT and some of it's portion is used for triggering the time based generator ckt, whose output is supply to the horizontal deflection plate through horizontal amplifier. The whole process which include generating and

shapping of a trigger pulse and starting of a time base generator and it's amplification takes time of order of 100 nanosecond or so. So, the input signal of the vertical deflection of a CRT is to be delayed by at least the same or little more amount of time to allow the operator to see the leading each of the signal waveform under study on the screen. For this purpose delay circuit is introduce between vertical amplifier and the plate of CRT.

Cathode Ray tube (CRT)

- It is the heard of the oscilloscope
- Low voltage supply is required for the heater of the electric gun for generation of electron beam and high voltage of order of the few thousand volt is required for cathode Ray tube to accelerate the beam.
- The electron gone assembly produces a sharply focused beam of electrons which are accelerated to high velocity. This focused beam of electrons the fluorscent screen with sufficient energy to cause a luminous spot on the screen.
- voltage applied to one pair of plates ~~of~~ moves the beam vertically up and down and the voltage applied to the other pairs of plates move the beam horizontally from one side to another. These two movement horizontal and vertical are independent of each other and thus the beam may be position anywhere on the screen.

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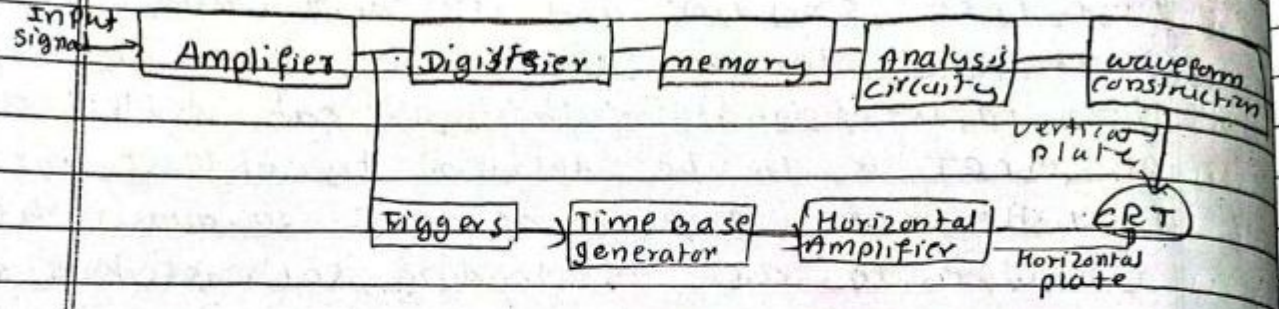
Digital storage oscilloscope:



- It stores and analysis the signal digitally
- It takes and input signal, store them and display it on the screen.
- It display the signal visually as well as numerically.
- The maximum frequency of the signal which is measured by the digital oscilloscope depend on the two factor: sampling state
  Nature of converter
- The sampling theory states that the sampling rate of the signal must be twice as fast as the highest frequency.
- Because of the sampling rate the bandwidth and resolution of the oscilloscope are limited
- The need of the analog to digital signal converter can also be overcome by using the shift register.

Disadvantage

- It doesn't accept data during digitization so it had a blind spot at that time.

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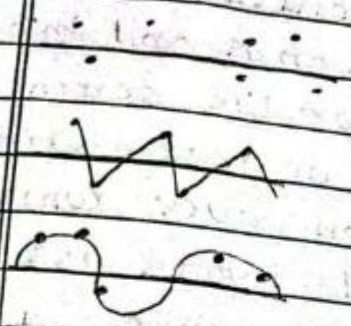
waveform Reconstruction



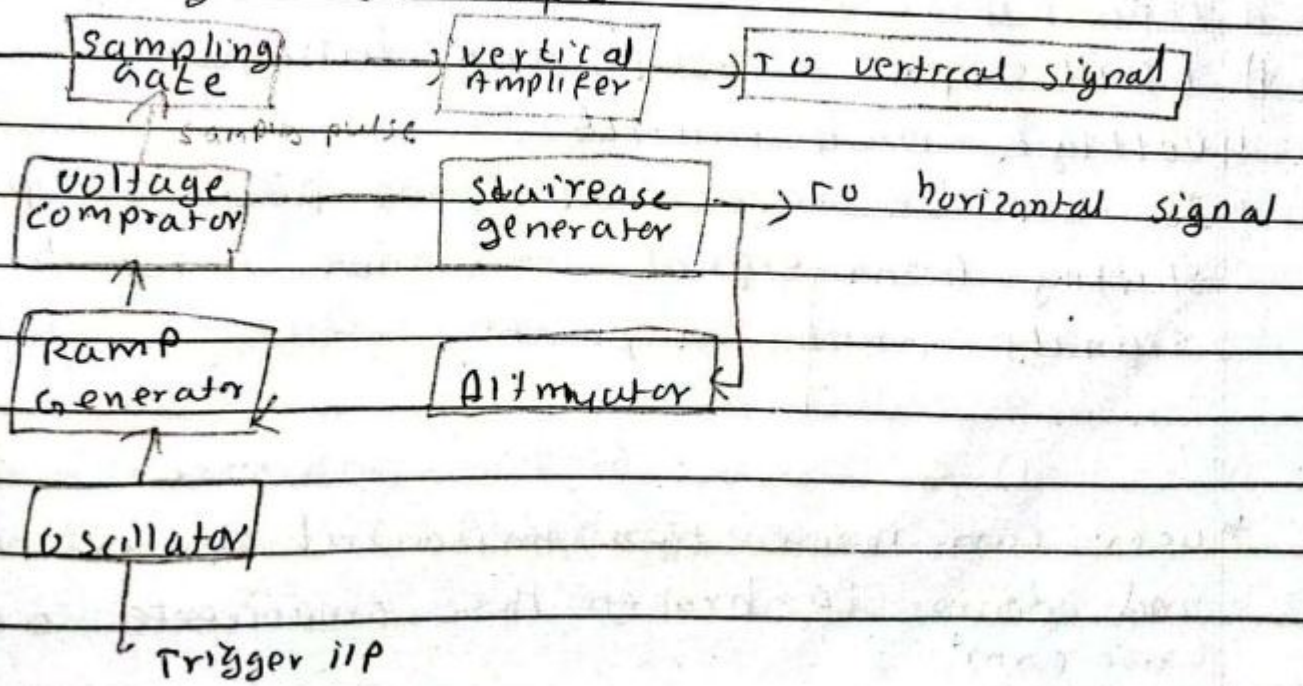
a) without interpolation

b) linear interpolation

c) sinusoidal interpolation

for visualizing the final wave, the oscilloscope used the technique of interpolation. It is the Process of creating new data points with the help of known variable data points. Linear and sinusoidal interpolation are two process of connecting the points together. Linear interpolation is used for creating the pulse or square waveform is ultilized in the oscilloscope.

sampling oscilloscope



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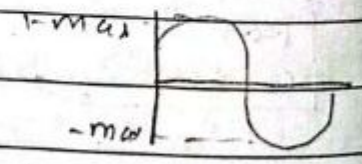
- It is a special type of digital sampling oscilloscope which is used to examine to very fast signal.
- It receives various electrical signal and then togetherally display the signal on the screen.
- In sampling oscilloscope, from various portion different sample are ~~over~~ taken over conjugation cycles and then ~~overcom~~ overall image is shown on the screen as the contineous wave.
- when the sampling cycle begin, the oscillators gets activated by the trigger circuit due to which Ramp output voltage is produced. The signal generated from the ramp generator is fit to the voltage comparator unit. The Ramp voltage compared with the staircase signal generated by the staircase generator.
- During comparision when the amplitude of the two signals equal it advance the stair case by one step. Thus generating a sample pulse. This again opens the sampling gate and the cycle is repeated in a similar manner.

Oscilloscope measurement techniques

- voltage measurement
- It can be measured from peak to peaks starting from signal maximum point to the signals minimum points



- user can move two horizontal crusur lines up and down to braket the amplitude of the wave form

2) Time measurement / Period
- Two vertical lines can be move left and right for time measurement.

3) frequency measurement
since the frequency is reciperical of time period knowing the timp period will enables users to easily determine the frequency.

4) Phase shift measurement
The x, y mode can be utlized to determine the phase shift measurement which is the diff in timing of two identical two periodic signals

Accessories of cathode ray oscillascope:
1) calibrators
Enables the oscilloscope amplifier and time based generator to be calibrated and checked for accuracy.

2) Probes
connecting the circuit to the oscilloscope without altering, loading or otherwise disturbing the test circuit.
a: direct reading probes
b circuit isolation probes
c detector probes

a) Direct reading probes
- ~~used~~ uses a shielding coxial cable
- used for low frequency and low impedance ckt

b circuit isolation probes
- use inorder to avoid the undesirable circuit loading effect on the shielded probes.

c Detector probes
- when analysing the response to modulation signal used in communicated equiptment like AM, FM and TV receivers. The detector probes function to seperate the low ~~mo~~ frequency modulation component to high frequency carrier

D Electronic switch
- used for displaying two signals simultaniously on ~~signa~~ single phrase oscilloscope.

E Camera
The best method of permanent record of oscilloscope phruses for analysis is the use of photography. special camera are used for this purpose.

1 Comprasion of Analog and digital oscilloscope
2 Laser printer
3 Compact disc / optical disc recoder

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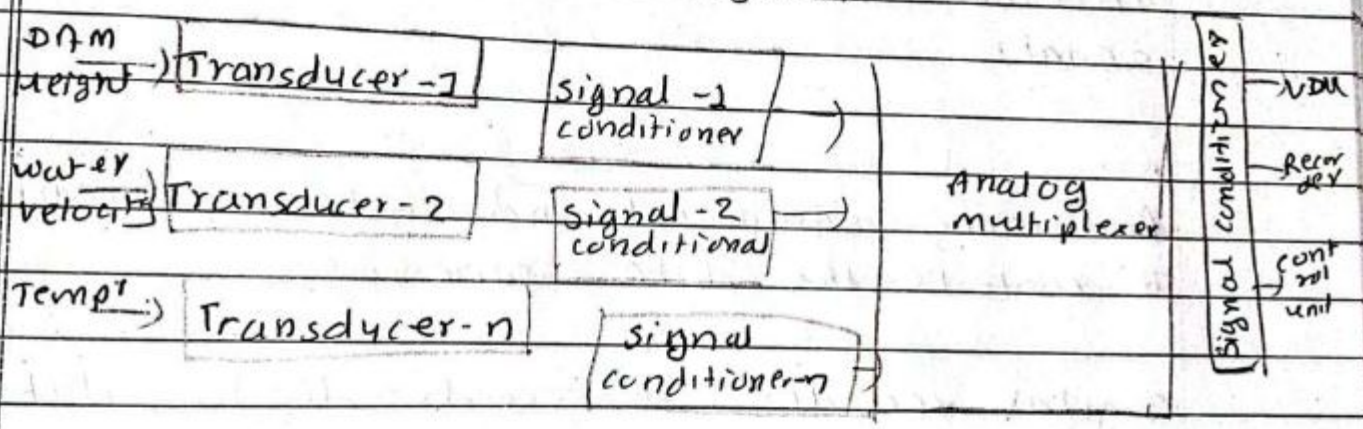
Data acquisition system:-

- objectives

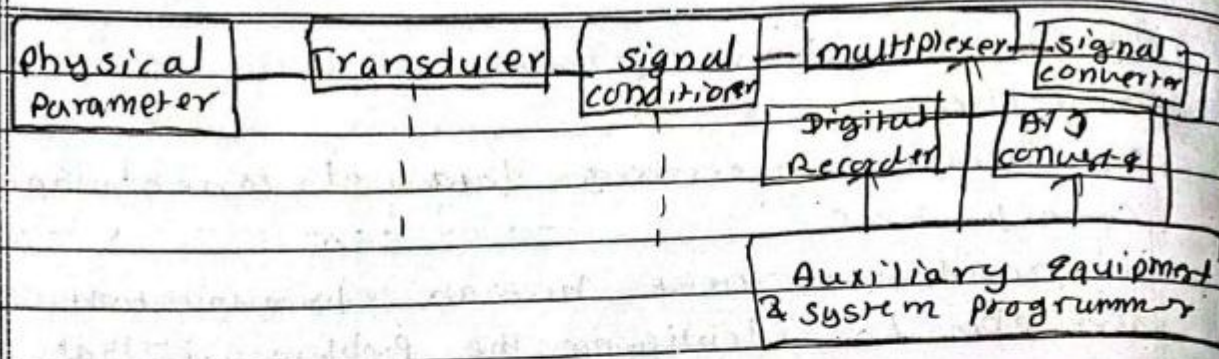
1) To acquire necessary data at correct speed and correct time.
2) To provide efficient human communication system and able to identifying the problem of that area.
3) Be able to collect summarize and store data for diagnosis operation and record purpose.

Analog DAS - width frequency and low accuracy
Digital DAS - narraw bandwidth & high accuracy more complex

Analog Data Acquistion System:



- Transducers to convert physical parameters to electrical signals.
- Signal conditioner for amplifying modifying or selecting certain person of portions of these signals.
- multiplexer accepts multiple analog input and sequentially connect them to the output.
- signal converter translate the analog signal to a form acceptable by the output devices



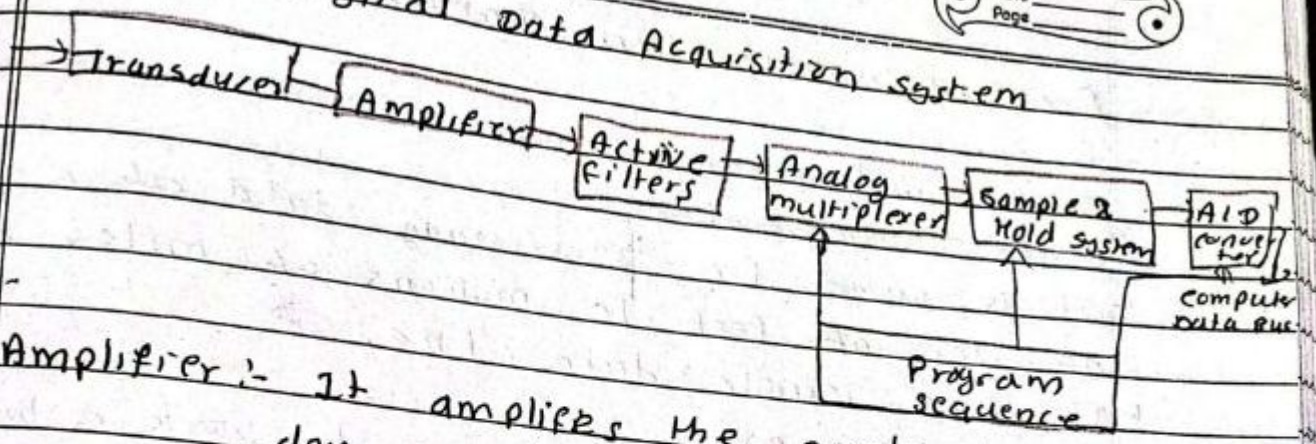
Signal conditioner
It translates analog signal to a form acceptable by the analog to digital converter.

Analog to digital converter
It translate the analog signal to digital signal.

Auxiliary equipment and system programmer.
It controls the data processing

Digital recorder : It records digital data
example :- floppy, disk

modern Digital Data Acquisition system



Amplifier :- It amplifies the amplitude of transducer output signal may be in the range of micro volt or minivolt.

Active filters / low pass
It reduces high frequency signal intereerance, unwanted noise etc.

Sample and Hold system
It aquares the signal voltage, ~~and~~ sampled them and then hold's it's value.

Analog to digital converter
It converts the analog value to digital form. The resultant digital word goes to a computer data bus or to the input of a digital circuit.

Data Transmission

In modern management system the various component of the system ~~of~~ are usually located at a distance from each other. It ~~therefore~~ becomes necessary to transmit the data or an information between them through some

form of communication channel.

series and parallel transmission

Series Transmission:

- It is used for transferring data at a distance of 100s of feet to millions of miles apart
- It uses single data line
- It is cheaper
- for sirial data communication to work a bit of data must be converted to serial bits using parallel in serial out shift registery then it can be transmitted over a ~~signal~~ single data line. This also means that at the receiving end their must be a serial in parallel out shift register to receive the serial data and packed them into a bit.
- Serial data communication uses
  - ~~serial~~ - Asynchronous data communication
  - synchronous data communication

A Asynchronous data communication

stop bit	0	1	00000	1	start bit
	MSB			LSB	

- 8 bit data are placed between start and stop bit
- start bit is ~~always~~ equal to zero (0), stop bit equal to 1 / high
- LSB sends out first
- It is so name because the timing of the signal is unimportant, instead information is

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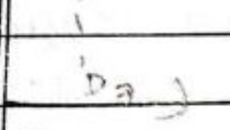
recived ~~by~~ and transmitted by data partems

B Synchronous data communication

sender | 01001000 10011000 00010101 | reciver

- The bit stream is combine into a longer frame which may contain multiple bits
- The receiver seperates that string into bits or characters that is needed to reconstruct the information
- The advantage is it's speed with no extra bit or gap
- faster
- useful for high speed intregration such as one computer to another computer.

parallel Transmission.



- It use 'n' wire or transmission lines to send 'n' bit of data at a time.
- speed is very high
- works only short distance
- & but data path is expensive

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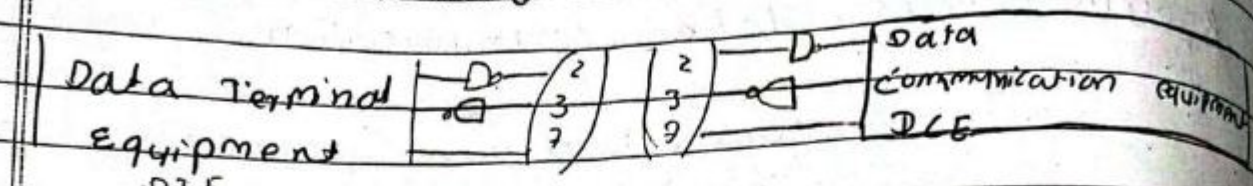
Interface convention:
Rs 232 c standard



- It is developed to interface between DTE and DCE employing serial binary data.
- most common uses is the connection of computer terminals to computers.
- It is the interface standard developed by electronic industries associated by CEIA in response to need for signal and handshake standards betwn DTE & DCE
- This standard describes the function of 25 signals and handshake pins for serial dat transfer. It also describes the voltage levels, impedance level rise and fall times, maximum bit rate and maximum capacitance for these signal lines.
- It also specifies that the DTE connector should be male and DCE connector should be female

Voltage level

High (1) - betwn -3v and -15V
low (0) - betwn +3v and +15V

- The signal levels of RS 232 are not compatable with that of the DTE and DCE which are TTL signals. Hence TTL to Rs 232 c and RS 232 c to TTL conversion are required

because TTL uses nominal 0 volt for logical 0, nominal +5v for logical 1

1. Difference betn Asynchronous & synchronous } Assignment
2. " " series and parallel commn

IEEE 12488 standard.

Computer (PC) ⟶ Printer

USB
Universal serial BUS

IEEE 12488 is a standard that defines bidirectional combination between computers and other devices. It is fully bidirectional to ensure compatibility with todays latest printer.

- The USB type A connector for standard USB cable connection
- IC-36 parallel connector
- It is a USB to parallel code converter
- It converts the USB on personal computers notebook computers and handle computing devices into a parallel code for printer connection.

OS support :- windows 2000, windows 7
windows xp, windows vista

Specification
USB port : 1 x USB type A male

Printer: IEC-36 male, ~~1.2 mbs~~
data rate: 1.2 megabit per second
cable length: 1.8 m
LED's ~~not~~ not available
powermode: Bus powering
Housing: plastics

Optical Communication:

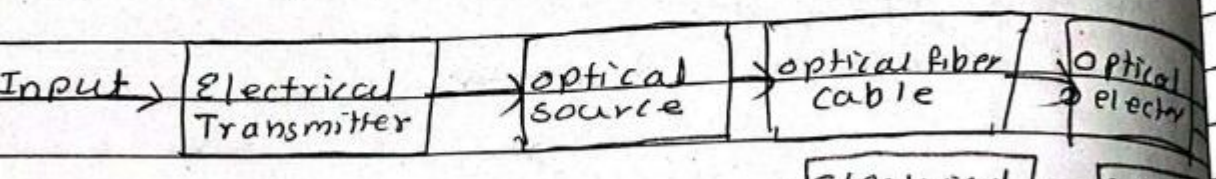


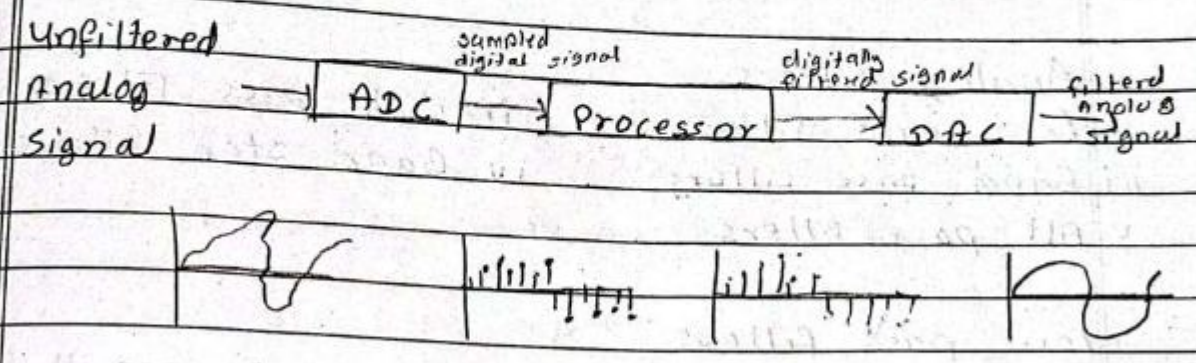
fig: Block Diagram

The optical source is a device which converts the electrical signal into optical signal it may be either semiconductor leaser or light emitting diode. The transmission medium consist of an optical fiber and receiver consist of optical detector which converts the optical signal into electrical signal. It may consist of photodiode, phototransistor or photo conductor. Thus, there is a requirement for electrical interfacing at either end of the optical link, for signal processing the optical signal through optical fibre.

Advantage:
- Low transmission loss
- Low repair and ~~mechanism~~ maintance cost
- High degree of signal security

- Electrical isolation between transmitting and receiving end small size and weight more flexible

Digital filters



- It uses a digital processor to perform numerical calculations on sampled valued of the signal. A processor may be a general purpose computer or a digital signal processor (DSP chip)

The analog input signal first be sampled and digitized using an ADC. The resulting binary numbers representing successive input signal are transfered to the processor which carries out numerical calculation on them. This calculations typically involves multiplying the input values by constant and adding the products together. If necessary the result of this calculations which now represent sampled values of the filtered signal are output through an DAC.

Advantages

It is programable

- Are easily designed, tested and implemented on general purpose computer or work station.
- Are very much versatile
- Hardware requirement relatively simple.

Analog filters:-

i) Low pass filters
ii) High pass filters
iii) Band pass filters
iv) Band stop filters
v) All pass filters

i) Low pass filters

- It allows only low frequencies to pass through but attenuates all higher frequencies.

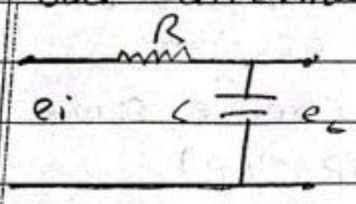


fig: ckt diagram

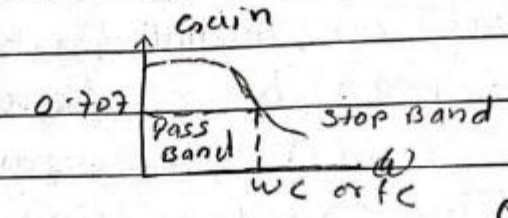


fig: frequency response

- The max^m frequency which it allows to pass through is called cutoff frequency 'f_c'.
- If $\omega = 0 \Rightarrow X_c = \infty$ then capacitor acts as open ckt i.e. Gain = 1. If $\omega \uparrow\uparrow = X_c \downarrow\downarrow$ then capacitor acts as nearly short ckt i.e Gain < 1.
- To calculate Gain

$$e_o = \frac{e_i}{R + \frac{1}{j\omega C}} \cdot \frac{1}{j\omega C} = \frac{e_i}{(1 + j\omega CR)}$$

$$\frac{e_o}{e_i} = \frac{1}{1 + j\omega CR}$$

$$A = \frac{1}{1 + (\omega CR)^2}$$

magnitude $\left|\frac{e_o}{e_i}\right| = \frac{1}{\sqrt{1+(\omega_c RC)^2}}$

$\therefore A = \frac{1}{\sqrt{1+(\omega_c RC)^2}}$

At cutoff frequency ; $f = f_c$ $A = 0.707$

$0.707 = \frac{1}{\sqrt{1+(\omega_c RC)^2}}$

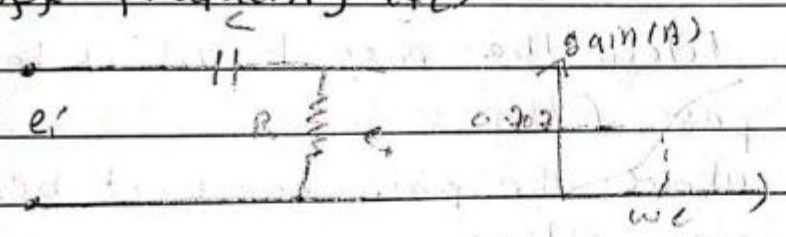
$1+(\omega_c RC)^2 = \left(\frac{1}{0.707}\right)^2 = 2$

$\omega_c = \frac{1}{CR}$ rad/sec

$\therefore f_c = \frac{1}{2\pi RC}$ Hz

ii High pass filters

- It allows signals with higher frequencies to pass and reject lower frequency.
- The min^m frequency it allows to pass is called cut off frequency (f_c)



- If $\omega \to \infty$, $X_c = 0$ output will be equal to input

Gain (A) = 1

- If $\omega \downarrow\downarrow \Rightarrow X_c \uparrow\uparrow$ rejects the lower frequencies
- To calculate gain $e_o = \frac{e_i}{R + \frac{1}{j\omega C}} \cdot R$

$$\frac{e_o}{e_i} = \frac{1}{1+\frac{1}{j\omega CR}}$$

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$$\therefore A = \left|\frac{e_o}{e_i}\right| = \frac{1}{\sqrt{1+\frac{1}{(\omega CR)^2}}}$$

Then, $\omega = \omega_c$ $A = 0.707$

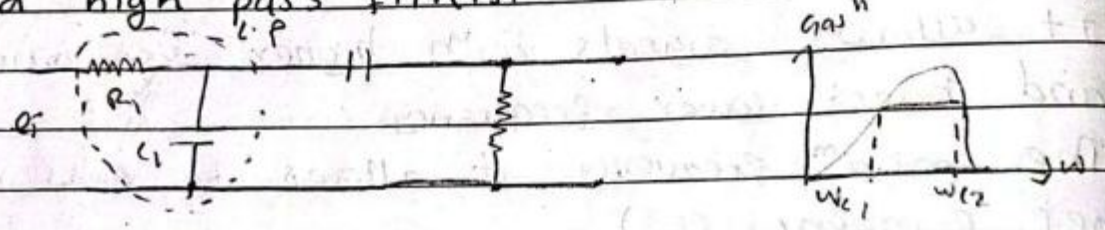
$$0.707 = \frac{1}{\sqrt{1+\frac{1}{(\omega_c CR)^2}}}$$

$$\omega_c = \frac{1}{RC} \text{ Rad/sec}$$

$$\boxed{f_c = \frac{1}{2\pi RC}} \text{ Hz}$$

iii Band pass filters

- can be constructed by cascading a low pass and high pass filters.



- At frequences below the pass band it between like a high pass filter
- At frequeinces above the pass band it between like a low pass filter
- The lower cutoff frequency is $f_{c1} = \frac{1}{2\pi R_2 C_2}$
- The upper cutoff frequency is $f_{c2} = \frac{1}{2\pi R_1 C_1}$

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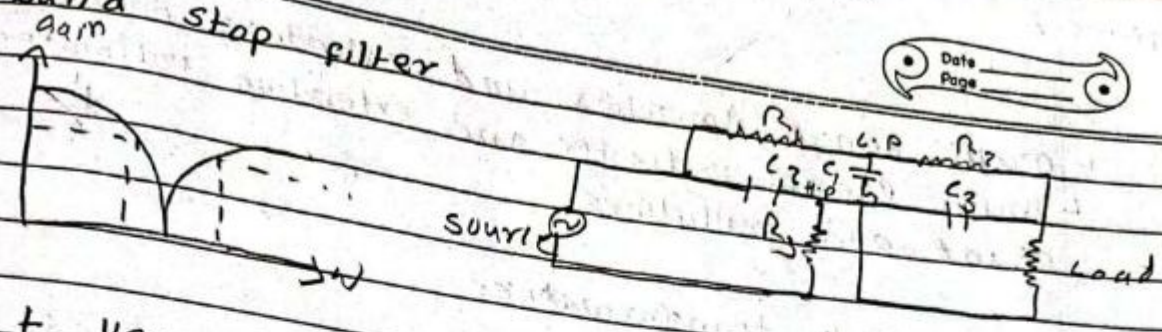
Band stop filter



- At very low and very high frequencies, the gain is almost unity. This type of filter is after called a notch filter because it completely rejects a particular frequency this particular frequency is known as notch frequency.
- A low pass section is comprised of R_1, R_2 and C_1 in "T" configuration. The high-pass filter section is comprised of C_2, C_3 and R_3 in a "T" configuration as well. Together this arrangement is commonly known as "Twin-T" filter, giving share response when the components values are choosen in the following ratios

$$R_1 = R_2 = 2(R_3)$$

$$C_2 = C_3 = (0.5)C_1$$

Notch frequency $(f_{notch}) = \frac{1}{4\pi R_3 C_2}$

V. All pass filters

- It shift the phase of input frequency.

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- multi Range Ammeters and extending Ammeter range
- multi Range voltmeter and extending voltmeter range
- shunt and multipliers

Instrument transformer

~~- Current~~

- The transformer used for measurement of current is called a current transformer (CT).
- The transformer used for measurement of voltage is called a potential transformer (PT)

Disadvantage of shunt and multipliers

- Difficult to exist accuracy
- power consume is large
- problem of insulation
- limited capacity
- measuring circuit is not isolated electrically from the power circuit.

Advantage of insturment transformer

- The measuring circuit is isolating from the power circuit.
- Low power consuption in ~~M~~. metering circuit
- several instruments can be operated from a ~~Signal~~ singal instrument transformer.
- current transformer has been standarized at 5 amp secondary winding current and the voltage transformer are at 100, 110 for 100 volt secondary winding current.

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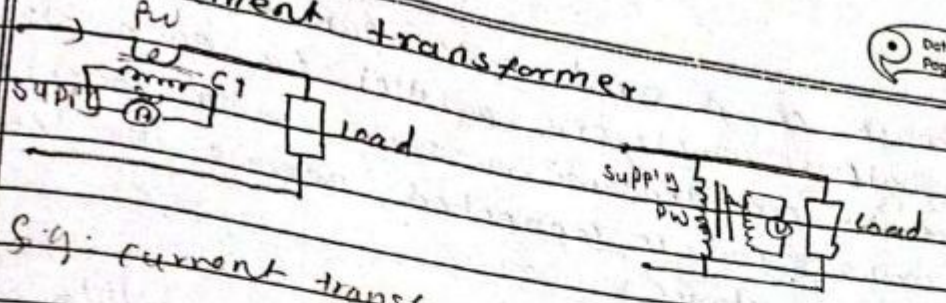
Instrument transformer



S.g: current transformer

S.g: potential transformer

Transformation Ratio (Ki) = $\frac{\text{Primary winding current or voltage}}{\text{Secondary winding current or voltage}}$

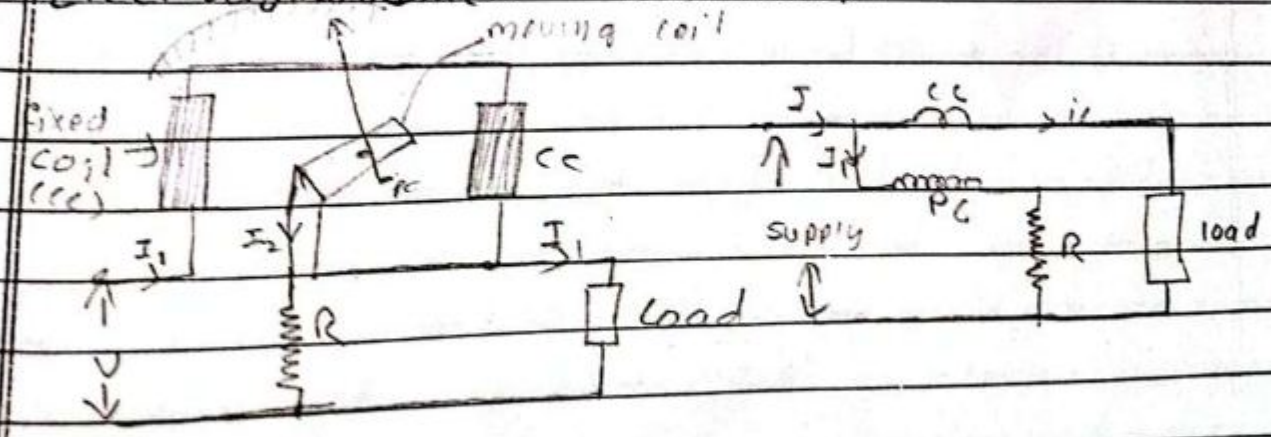
Wattmeter

A wattmeter is an instrument which is used to measure electric power given to or developed by an electric ckt. A wattmeter consist of a current coil and potential coil.

Types of wattmeter

- Electrodynamic wattmeter (for both DC and AC. power measurement)
- Induction wattmeter (for A.C power measurement only).

- Electrodynamometer wattmeter:



It consist of a fixed coil which is divided into two halves which are parallel to each other and ~~each~~ is connected ~~in~~ in series with load. While the moving coil is connected across the load through a resistance.

The fixed coil is called current coil while the moving coil is called potential ~~current~~ coil.

When the wattmeter is connected in a circuit to measure power the current coil carries the load current and potential coil carries a current proportional to the load voltage. Due to the currents in the coil a mechanical force developed between them. The result of this mechanical force deflects the moving coil and pointer over the scale. The pointer comes to the rest when the deflecting torque and controlling torque become equal.

As the reversal of the ckt current reverses the currents in both the current coil and potential coil so that the direction of deflecting torque remain unchanged. Therefore electrodynamometer can measure power in both the DC as well as AC circuit.

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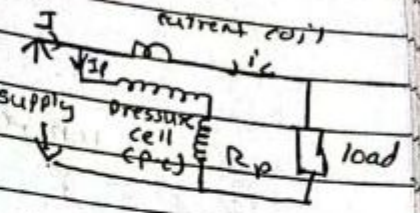
Wattmeter

4 Intentaneous torque $(T_i = i_1 i_2 \frac{dm}{d\theta}$ where i_1 and i_2 are intentaneous value of currents.

4) $V = \sqrt{2}V \sin\omega t$

$i_p = \frac{V}{R_p} = \frac{\sqrt{2}V \sin\omega t}{R_p}$

$\sqrt{2} I_p \sin\omega t$ where $I_p = \frac{V}{R_p}$



2 If the current in the current coil lags the voltage by an angle ϕ.

$i_c = \sqrt{2} I \sin(\omega t - \phi)$

4 $T_i = \sqrt{2} \cdot I_p \sin\omega t$

$= 2 I_p I \sin\omega t \sin(\omega t - \phi) \frac{dm}{d\theta}$

$= I_p I (\cos\phi - \cos(2\omega t - \phi)) \frac{dm}{d\theta}$

4 Average deflecting torque

$T_i = \frac{1}{T} \int_0^T T_i \, d(\omega t)$

$\frac{1}{T} \int_0^T I_p I [\cos\phi - \cos(2\omega t - \phi)] \frac{dm}{d\theta} d(\omega t)$

$I_p I \cos\phi \frac{dm}{d\theta}$

$\frac{V}{R_p} I \cos\phi \frac{dm}{d\theta}$

controlling torque exerted by springs

$T_c = K\theta$

where K = spring constant

θ = deflection

At balance condition;

$K\theta = \frac{V}{R_p} I \cos\phi \frac{dm}{d\theta}$

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or deflection $\theta = \left(\frac{VI\cos\theta}{R_p \cdot K}\right) \cdot \frac{dm}{d\theta}$

$= K_1 VI\cos\theta \frac{dm}{d\theta}$

$\therefore \theta = K_1 \cdot \frac{dm}{d\theta} \cdot P$

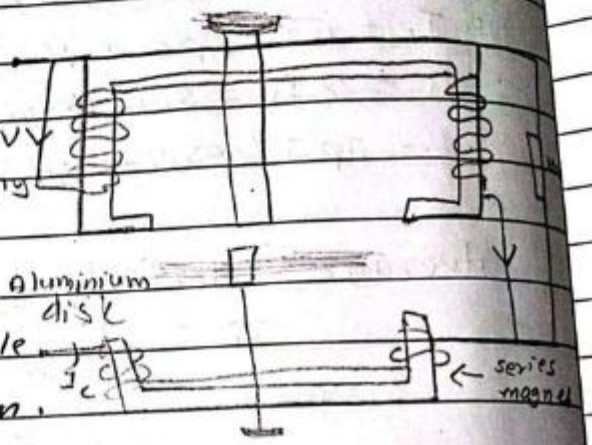
where P = power being measured
$= VI\cos\theta$

and $K_1 = \frac{1}{R_p \cdot K}$

$\therefore \theta \propto P$

i induction type wattmeter:

2) It is a measuring device that can measure electric power in AC ckt



4) It works on the principle of electromagnetic induction.

4) The shunt magnetic is connected across the supply and carries a current proportional to the supply voltage. The coil of shunt magnet is made highly inductive. So that the current in it lacks the supply voltage by 90°. The series magnetic is connected in series with the supply and carries load current. The coil of series magnetic is made highly non-inductive. A thin disc mounted in a spinder is placed between the two magnetic so that it cuts the flux of two magnet.

fluxes produce by the two magnet induce eddy current in the aluminium disc by the action of electromagnetic induction. Due to the interaction between the fluxes and eddy current a deflecting torque is produced on the disc, causing the disc to move. The pointer comes to rest when the deflecting torque become equal to the controlling torque.

E_{sh} ⇒ emf induced in the disc by shunt magnetic flux.

I_{sh} ⇒ eddy current in the disc caused by emf E_{sh}

E_{se} ⇒ emf induced in the disc by series magnetic flux.

I_{se} ⇒ eddy current in the disc caused by emf E_{se}

Torque due to I_{se} and ϕ_{sh} is: $(T_1) = k I_{se} \phi_{sh} \cos\phi$

" " " I_{sh} " ϕ_{se} : $(T_2) = k I_{sh} \phi_{se} \cos(180-\phi)$

Resultant Torque : $k I_{se} \phi_{sh} \cos\phi - k I_{sh} \phi_{se} \cos(180^\circ - \phi)$

$= k[I_{se} \phi_{sh} \cos\phi + k I_{sh} \phi_{se} \cos\phi]$

$= k[k_1 VI \cos\phi + k_2 VI \cos\phi]$

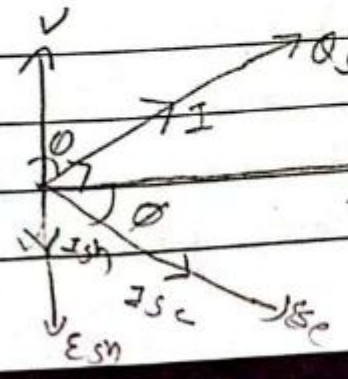
$= k VI \cos\phi [k_1 + k_2]$

$\therefore T_2 \propto VI \cos\phi$

Since : $\phi_{sh} \propto V$; $\phi_{se} \propto I$; $I_{se} \propto I$ and $I_{sh} \propto V$

$\phi_{sh} I_{se} \propto VI = k_1 VI$

$\phi_{se} I_{sh} \propto IV = k_2 VI$



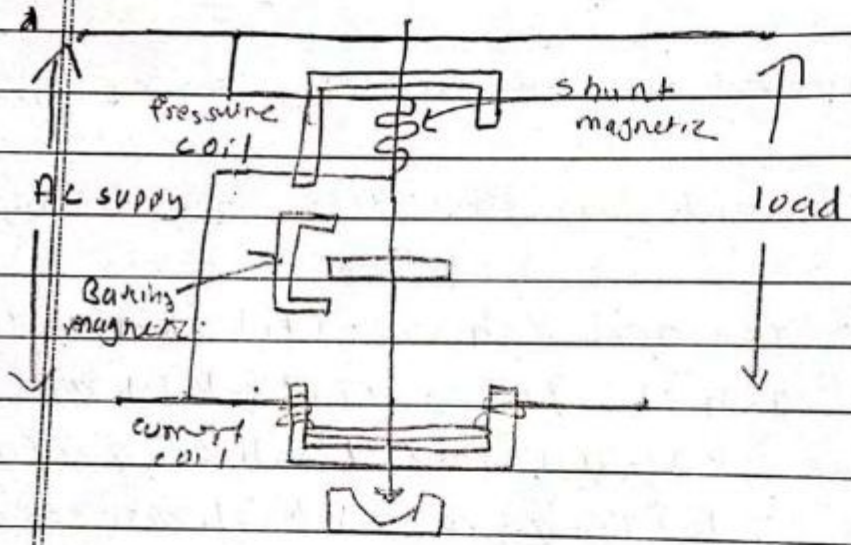
Energy meter / watt hour meter

- It is an electrical instruments that measures the amount of electrical energy used by consumers.
- one uses one kilowatt in one hour duration 1 unit of energy gets conversed.

Type of energy meter

- electro mechanical types induction meter
- Electronic energy meter

Electromechanical type induction meter



It consist of a rotating alumunium disc placed on the Splinder betw^n two Electro magnets. The ~~contact~~ rotation speed of the disc is proportional to the power and this power is integrated by the use of gear tense and counter machanism.

- four main parts

1. smung system
2. moving system

3 Braking system
4 Registering System

The series magnetic is exitted by the load current flow through the current coil. The coil of the shunt magnet is directly connected with the supply and hence carry the current proportional to the shunt voltage

Moving system
The eddy current is induced in the disc because of the change of the magnetic field. The eddy current is caused by the magnetic flux. The interaction of the flux in the disc induced the deflection torque.

when the devices consume power the aluminum disc start rotating after some number of rotation the disc display the unit used by the load.

Braking System
The permanent magnetic is used for the braking system. The eddy current cause the magnetic flux of the permanent magnetic and hence produces the braking torque

Registering system
main function is to record the numbers of rotation of the aluminum disc. Their rotation is directly proportional to the energy consumed

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By the load in the kilowatt hour.

Braking Torque (T_B) $\propto$ speed of the disc (N).

$$T_B \propto N$$

$$T_B = k_3 N$$

since $T \propto VI\cos\phi$

$$T = k[k_1 + k_2] VI\cos\phi$$

At steady state condition

$$T_B = T$$

$$k_3 N = k[k_1 + k_2] VI\cos\phi$$

$$N = \frac{k[k_1 + k_2]}{k_3} VI\cos\phi$$

$\therefore$ $N \propto$ True power of the ckt.

↳ Total no. of revolutions :

$$= \int N\,dt$$

$$= \frac{k[k_1 + k_2]}{k_3} \int VI\cos\phi\,dt$$

$$= \frac{k[k_1 + k_2]}{k_3} (\text{The True power}) \cdot dt$$

$\therefore$ The total no. of revolution is proportional to the integral of true power i.e energy.

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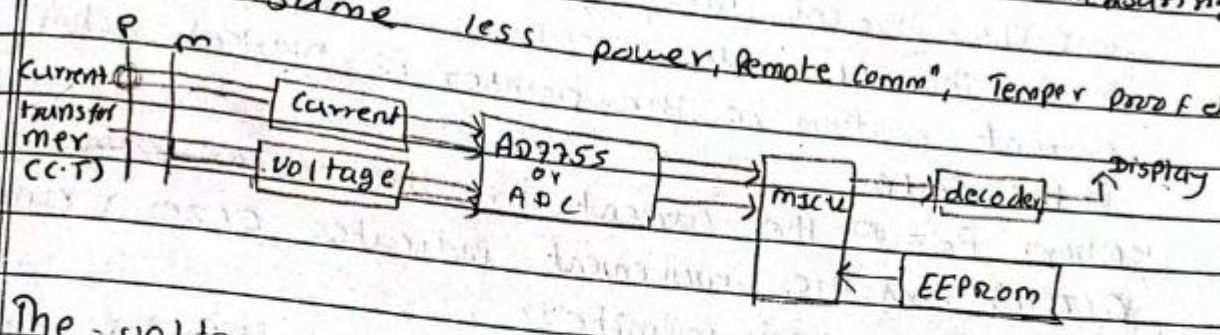
ii Electronic energy meter:

- Are accurate precise and reliable type of measuring instruments.
- They consume less power, Remote comm^n, Temper proof etc



- The voltage and currents of the power lines are rated down to signal level using C.T and P.T. AD77-
- AD7755 : To aquare ~~the~~ and process the input voltage and current parameters sampled and converted into digital
- MICU : It is the Brain of the System. It performs all necessary opperation like storing and reteriving data from EEPROM. The micro-controller is program in such a way that the voltage and current values from ADC are multiply and intregrated over a specify time period
- The decoder decodes the output of MICU data and sends to display unit.

Ohmmeter:

- The meter which measures the resistance and the continunity of the electric circuit.

i Series ohmeter

ii Shunt ohmmeter.

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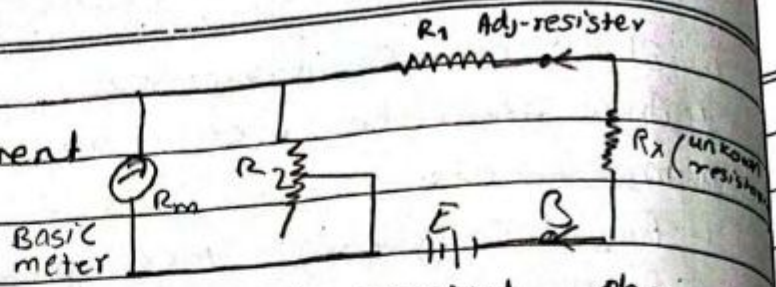
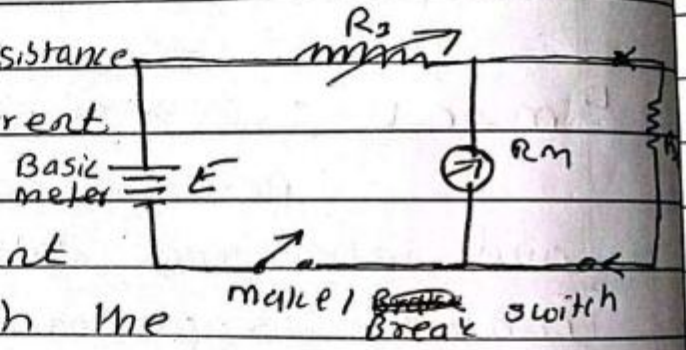
1 series ohmmeter:



- when $R_S = 0$ large current will flow through the meter. The full scale current position of the pointer is marked 0 ohm on the scale
- when $R_S = \infty$ the current in the meter drops to 0 (zero) and the movement indicates 0 (zero) current which is marked infinite.
- Internal Resistance of ohmmeter $(R_x) = \frac{R_1 + R_2 R_m}{R_2 + R_m}$

2 Shunt type ohmmeter



- when the unknown resistance $R_S = 0$ ohm the meter current is 0.
- If the $R_x = \infty$ the current finds path only through the meter and selecting a proper value for resistance R_1 the pointer may be made to read full scale.
- This ohm meter therefore has 0 mark on the left hand side of the scale and infinite mark on the right side of the scale
- Internal resistance $R_n = \frac{R_1 R_m}{R_1 + R_m}$

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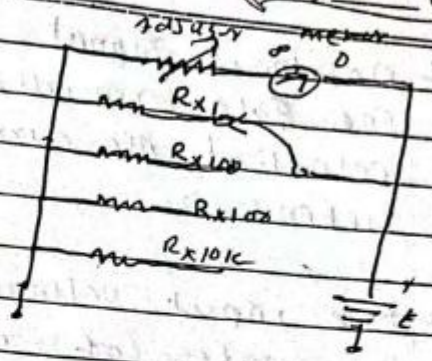
Multirange ohmmeter:-

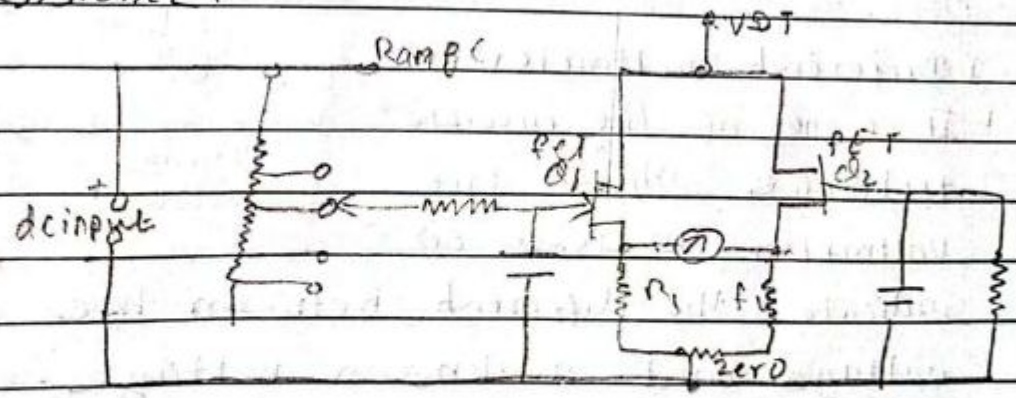
- The range of this type of ohmmeter is very high.
- The meter has adjustor which selects the range according to need.



Electronic multimeters

It is capable of measurent of AC and DC currents, voltage, and resistance. This multimeters generally consists of the following elements

1. A balanced bridge DC amplifiers & PMMC indicating instruments
2. A range switch which is an attenuator to limit the value of input ~~of~~ to the desire value.
3. A rectifier to convert AC to DC value.
4. An internal battery and additional circuit for the measurement of resistance.
5. A function switch to select various measurement function of the instrument like current voltage and resistance.



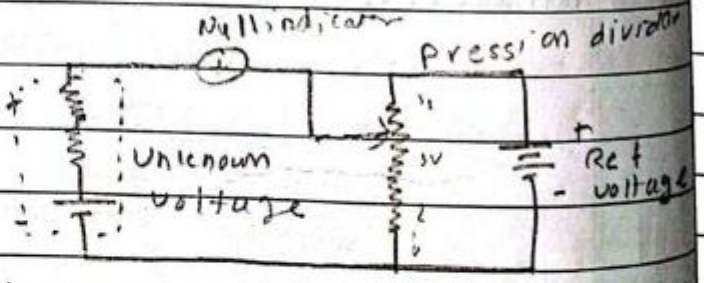
L No input signal
The gate terminals of fets, they are at ground potential. No current will flow through the meter

L +ve input voltage
The gate of input transistor Q_1 it's drain gain current increases which causes the voltage at source terminal to rise. The resulting unbalanced between the Q_1 and Q_2 ~~increase~~ source voltage is indicated by the meter movement, whose scale is calibrated to agree with the magnitude of the applied input voltage

L The range of input voltage can easily be extended by an input alternuater and range switch

(Analog) Type of voltmeter
i Different voltmeter
ii True rms Type

1 Different voltmeter
L It is one of the accurate technique where the voltmeter is used to indicate the different between the unknown voltage and a known voltage.

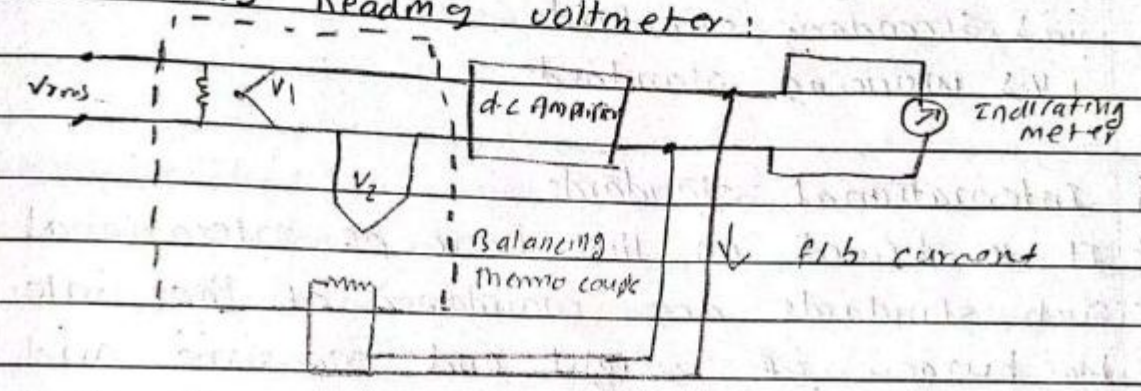


L The null indicator (meter) is connected between the unknown voltage source and the output

terminals of a voltage divider and hence d indicate the difference betn them. This voltage divider is connected across a ref voltage source and can be adjusted to provide known fraction of the reference voltage.

c) For A.C. differential voltmeter contains input attenuator / amplifier and rectifier circuit is used.

ii) True rms Reading voltmeter:



$P = \frac{V_{rms}^2}{R_{Heater}}$

o/p voltage of thermocouple $V_0 = f(P) = f\left(\frac{V_{rms}^2}{R_{Heater}}\right) = kV_{rms}^2$

where k is constant of proportionality

$V_0 = A(V_1 - V_2)$ $\boxed{A = \frac{V_0}{V_1}}$

$V_1 - V_2 = \frac{V_0}{A} = 0$

Since high gain amplifier $A = \infty$

$V_1 = V_2$

$kV_{rms}^2 = kV_0^2$

$V_{rms} = V_0$

i.e o/p is equal to V_{rms}

Chapter = 1

Page

Bridges → Theory + Numerials (all)
Transducer → Theory + Numerical (all)

Remainity:

1. Standards of measurement
- It is a physical representation of a unit of measurement.
- Different types of standard of measurement
  - i) International standards
  - ii) Primary standards
  - iii) Secondary standards
  - iv) Working standards

i. International standards
- It is defined on the basic of interational aggreme
- Such standards are maintained at the internationa bureau of weight and measure and are not available to the ordinary humans

ii. Primary standards
- This standards are maintain by national standard labs in different parts of the world. This standards represent the fundamental units and some of the derived mechanical and electrical unit.
- The main function of primary standards is the verification and calibration of secondary standards.

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iii) secondary standards

- This are the basic reference standards used in industrial measurement lab.
- They are normally ~~sent~~ sent periodically to the national standards labs for calibritation and comprasion against primary standards.

iv) working standards

- This are the major tools of the measurement lab.
- This standards are used to check and callibrate generate lab instruments for their accuracy purpose.

Characteristics of measurement

i) static characteristics
ii) Dynamic characteristics

i) static characteristics

a) Accuracy	b) precissors	c) sensitivity
d) Resolution	e) linearity	f) Reproducibility
G) Hysteresis	h) Deadband	i) Drift
J) Threshold	k) Span	

Accuracy

- It specifies the ~~accuracy~~ difference betw^n measured value
- It is the ~~los~~ closeness to the reading of a measurement system to the few value of the quantity
- It can be express as i) Point accuracy
  ii) Accuracy at % of Scale range

iii Accuracy at pertentage at true value.

ii Precision
- It is the measure of the consistency or repeatability of measurement.
- The instrument is set to be precise if the measurement taken has the reading close to each other.

iii Sensitivity
- It specifies how much output we get per unit change in input

i.e $\frac{\text{change in output}}{\text{change in input}}$

iv Resolution
- It may be defined as the minimum amount of input change that can produce detectable output.

v linearity
- The system is said to be linear if equal change in input signal causes equal change in output signal
- linear relationship : $y = mx + c$

vi Reproducitivity
- It may be specifies interms of units for a given period of time
- perfect Reproducitivity means that the instrument have no drift.

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vii Mystersis

- Mystersis arries due to the fact that all the energy put into the stressparts when loading is not recoverable upon unloading. This is because of the second law of thermodynamics. Second law of thermodynamics rules out any reversable process in the world.

viii Deadband

- It is the region of the signal in which the system doesnot response small changes.

IX Drift

- Environmental condition effect the output and the instrument can be called as drift.

X Threshold

- It is the minimum value of the input sign that is required to make a change or start from zero.

xi Spam / range

- It is the different between the highest reading value and the lowest reading value

Dynamic characterstics

The measurement system specially area space and biological application are subjected to input that are dynamic in nature
i.e input varies with time.

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The behaviour of the system under such condition is described by it's dynamic characteristics.

1) Speed of ~~Re~~ Response
2) measuring lag
3) Fidelity
4) Dynamic error

1 Speed of Response
- It is the rapidity with which the measurement system responds to changes in the measured quantity.

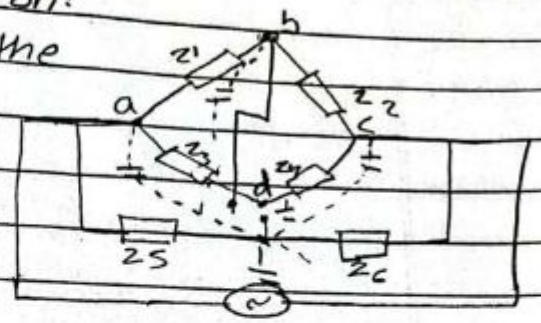
2 measuring lag
- It is the retardation ~~for~~ or ~~detect~~ delay in the response of measurement system to changes in the measured quantity.

3 fidelity
- It is defined as the degree to which a measurement system indicates the change in the measured quantity without ~~any~~ any dynamic error.

4 Dynamic error
It is the different between the true value of the quantity changing with time and the value indicated by the measurenment system

Wagner Ground connection:

- It is used for removing the earth capacitance from the bridges
- It provides high accuracy to the bridges.
- At high frequency stray capacitance is induced betwn the bridge element, ground and arms of the bridges. This stray element causes the error in measurement. One of the way of controlling this capacitance is enclosed the bridge elements into the shield. Another way of elementing this stray capacitance is to place the warmer earth device between this elements of this bridges.
- At balanced condition C_1, C_2, C_3, C_4 are eliminated from the bridge circuit along with the impedance Z_5 and Z_6.



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