R. C. Patel College of Engineering & Polytechnic, Shirpur

Department of Electrical Engineering

Name of Subject: **- Electrical & Electronic Measurement (EEM)**

Course Code: **- 313334**

Scheme:- **EE-3K**

Semester**:- Third**

Unit No. 03- Digital Measuring Instruments.

CO3 - Use digital measuring instruments for different applications.

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
3	Digital Measuring Instruments.	CO3	10	4	6	6	16

THEORY SYLLABUS CONTENT

Fundamentals of Measurement

3.1 Digital measuring instruments-Essentials and advantages.

3.2 Construction and working of digital Meters-Ammeter, Voltmeter and Multimeter, Clamp-on meter, L-C-R meter, Power factor meter and Tachometer (Contact and Non-contact).

3.3 Construction and working of Resistance measurement meters: Ohm meter, Digital Megger, Digital earth tester.

3.4 Construction and working of meter used for synchronization: Frequency meter, Synchro scope and Phase sequence indicator.

3.5 Function generator: Basic block diagram, function of each block and applications.

3.6 CRO: Basic block diagram, function of each block.

3.7 Digital storage Oscilloscope: Basic block diagram, function of each block.

Subject Incharge
Mr. N. S. Borse

Unit - 3

Digital Measuring Instruments.

Digital Instrument:

It measure quantity in digital form

It convert analog signals into digital form

Advantages: More accurate, easy to design, No parallax error, size is portable, store information, power consumption is less.

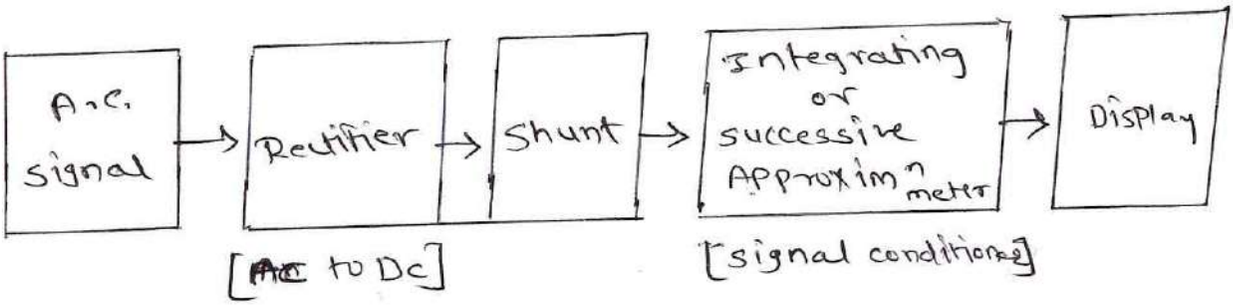
Parameters	Analog instru.	Digital instru.
Represent	quantities in analog form	quantities in digital form
Data storage	Difficult	data storage easily.
Precision	limited to 3-4 digits	More digits.
Accuracy	Less	More
size	Bigger	Compact
cost	Less	More
Parallax error	more possibility	No possibility

Disadvantages:- Overloading capacity is more

- Very sensitive
- Noise affect their operation.
- High initial cost
- Sensitive to electromagnetic Interface
- Complexity of circuit is more
- It reqr external power supply for their operation

* Construction & Working of digital Meters.

* Ammeter:



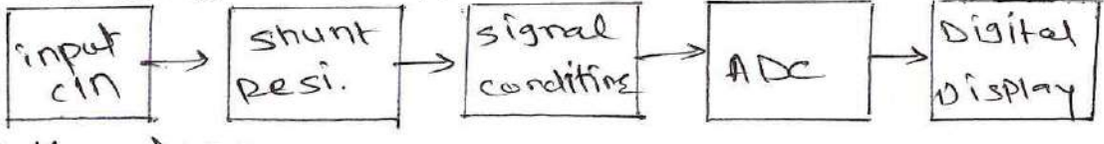
A.C quantity is rectified using rectifier. This is A.C to D.C. conversion.

The cln to be measured passes through a low-resistance shunt resistor.

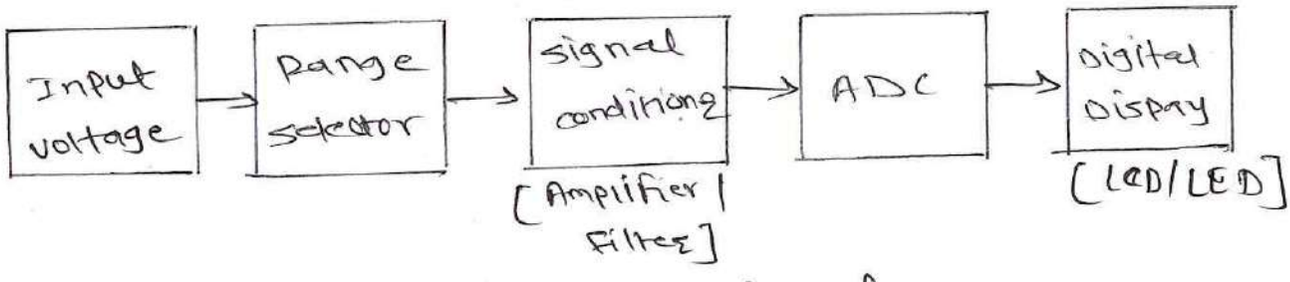
converts the analog signals into a digital value.

Finally display is calibrated in terms of current.

The digital value is processed and displayed as current in amperes (A, mA, μA) on LCD or LED display.



* Voltmeter:



The digital voltmeter consist of

1) Range selector - It reduces high input voltages to a suitable level for measurement.
It provide different voltage ranges.

2) Signal conditioning circuit: The input signals are amplifier & filters. It improves measurement accuracy.

3) Analog to digital converter - Convert the analog voltage into a digital signal.

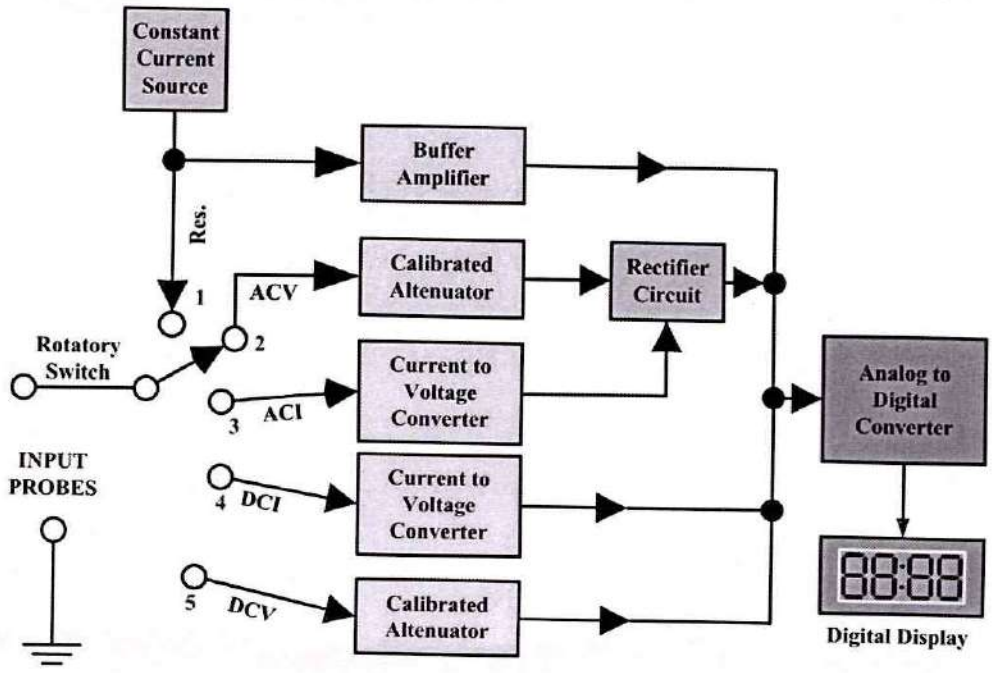
4) Display unit - Displays the measured voltage in digital form

* Multimeter:

1) The digital multimeter (DMM) is used to measure AC/DC voltage, current, Resistance, conductance decible. Thus DMM offers increased versatility.

2) All DMM make use of some type of analog to digital converter (ADC). generally dual slop integration type AD is used for this purpose.

- The block diagram of basic DMM shown below.



3) A commercial DMM consist of several A to D converter, decade counter & display. It is basically de voltmeter.

4) In order to measure unknown cln, cln to vltg converter is used.

a) DC voltage - five vltg ranges are available. The vltg range is from ±200 to ±1000V
- Accuracy is about ± 0.03 %.
- Resolution is about 10 μV.

b) AC voltage - five vltg ranges are available. The vltg range is from 200mV to 750V.
- Accuracy is freq dependant, about 0.5%.
- Resolution is about 10μV.

c) Resistance - generally six resi. ranges are available. The resi range is from 200Ω to 20MΩ
- Accuracy is about ± 0.1 % of reading

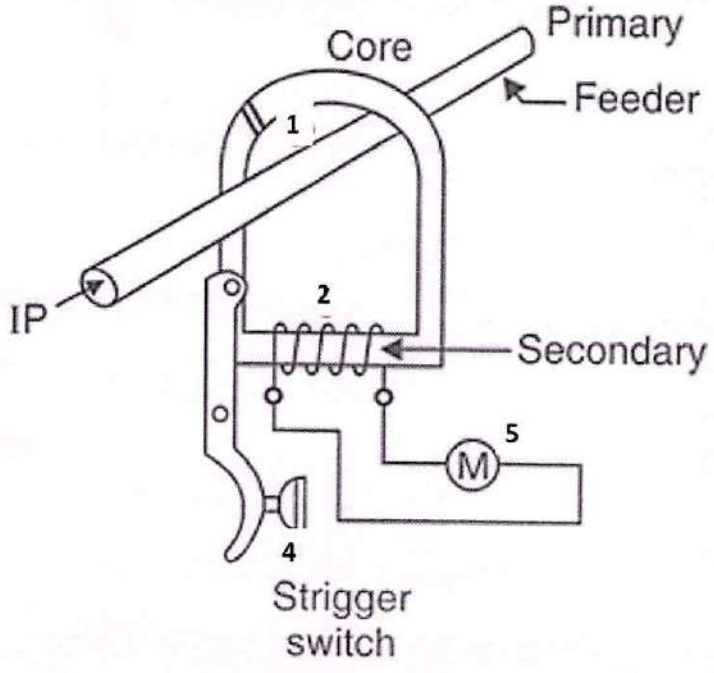
d) D.C. current - five range are available. This range is from ±200μA to 2 Amp
- Accuracy is about ± 0.3%.
- Resolution is about ± 0.01 μA.

e) AC current - range is from 200μ to 2 Amp
- Accuracy is dependent on freq, It is about ± 1%.

Advantages:- Having high i/p impedance hence high accuracy
- Available in small size.
- Measured both AC & DC quantity
- different ranges can be possible.
- High sensitivity.

clamp on meter:

1) Basically it is a cln xmer to measure high cln, without disturbing the circuit.
2) It can be used for instant value measurement with no physical connection with the circuit.
3) It is portable and use in HV or LV line current measurement.
4) clamp on meter consist of split core, secondary winding, trigger switch [for opening the core], Ammeter.
5) The following fig. shows constructional diag. of clamp on meter.



6) The split core hold the conductor, whose cln is measure. conductor work as primary winding
7) At the bottom of core, secondary winding is connected in which emf is ~~ee~~ induced and

then secondary cln shows on display.

8) Basically stepdown xmer circuit is used.

9) With the help of meter connected in secondary, read primary current.

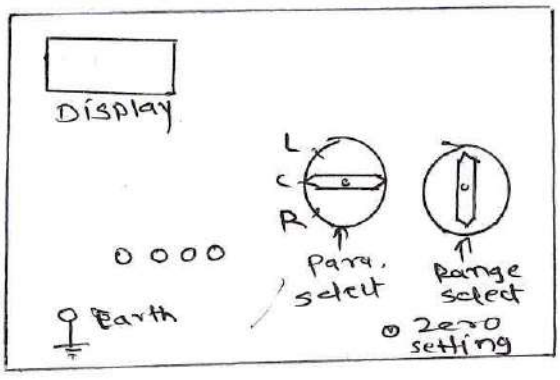
10) Clamp on meter is generally used for H.V. line cln.

11) It is useful for measuring A.C. cln only.

L.C.R. Meter:

1) The LCR meter is used to measure inductor (L), capacitance (C), Resistance (R), quality factor (Q), susceptance (B).

2) The following fig. shows front panel of meter.



3) The following fig. shows Block diagram of LCR meter.

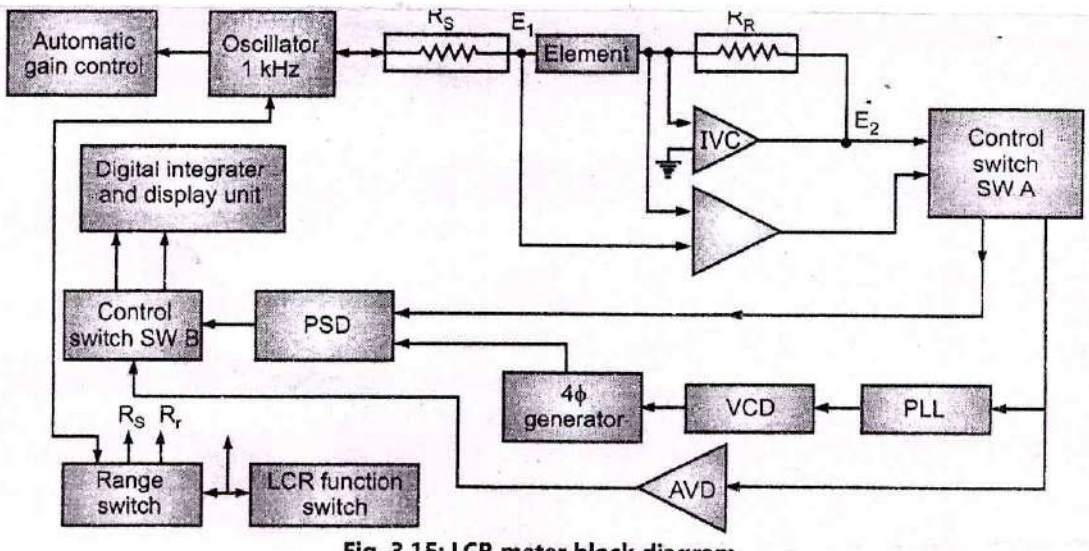


Fig. 3.15: LCR meter block diagram

4) LCR meter based on A.C. Bridge.

5) Test element is placed in bet^n selector resistor R_S & Range resistor R_R

6) The meter provides test freq are 1 kHz.

7) The signal cln flows through cln to vltg converter (IVC) which is operational amplifier with range resistor (Rr) feedback path.

8) E_1 is the vltg across element. The signal cln thro Rr develop vltg E_2 proportional to cln.

9) The E_1 & E_2 are vector quantities, mathematically $E_1 \propto V$, $E_2 \propto I$

10) $\therefore$ capacitance $C \propto \frac{I}{V} \propto \frac{E_2}{E_1}$

Inductance $L \propto \frac{V}{I} \propto \frac{E_1}{E_2}$

11) The values of R_s & Rr selected depending on impedance of unknown device.

12) If device having low impe, R_s is higher and if device having high impe, R_s is lower

13) The signal vltg is routed through differential amplifier. E_1 is then fed to control slw along with signal vltg E_2.

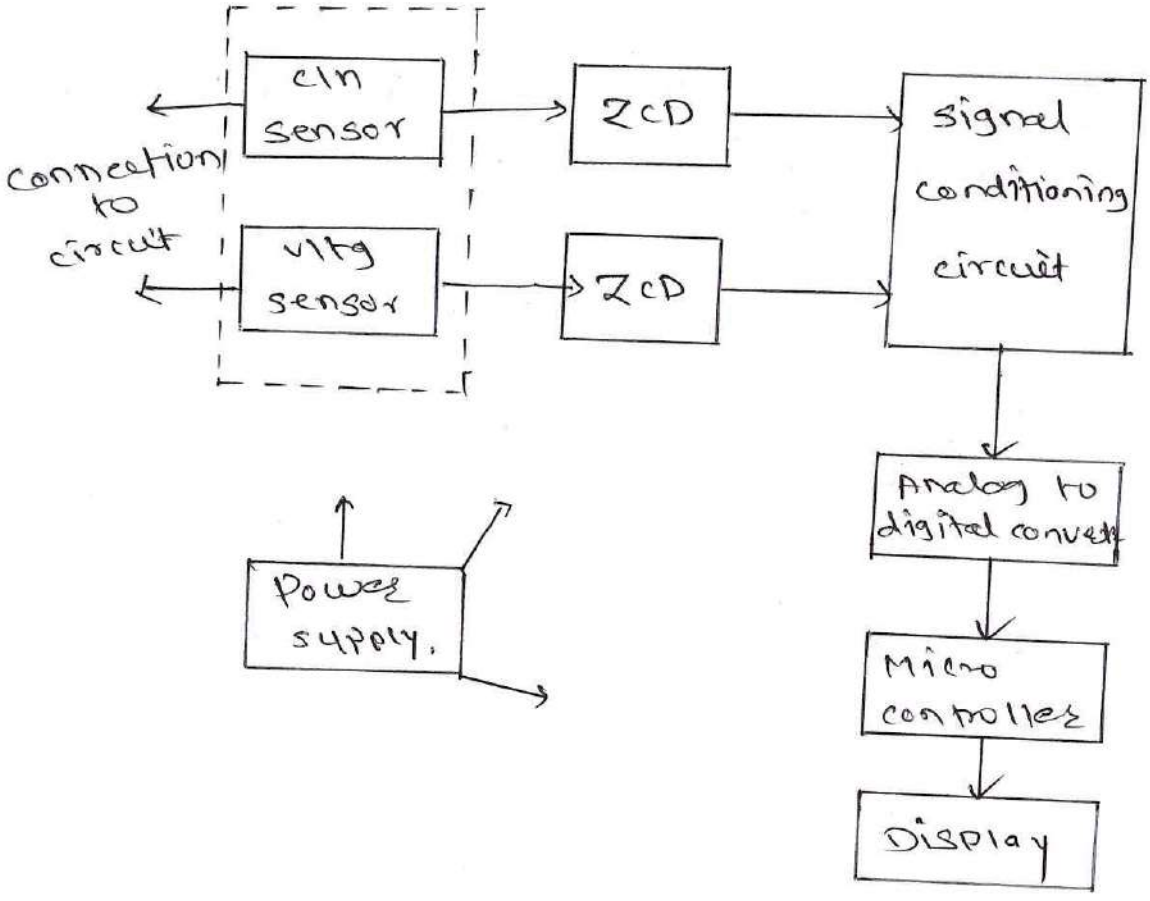
14) The control slw routed the greater of E_1 & E_2 to Avg vltg detector [AVD] & the lesser to phase sensitive detector [PSD]

15) The vltg signal fed to AVD is also routed as reference signal to phase lock loop & vltg control oscillator [PLL & VCO]

16) The olp of AVD & PSD are DC vltg are given to the digital integrator which in turn the display.

* Power factor meter:

1) A digital power factor meter uses vltg & cln sensor, zero crossing detector, signal conditioner circuit, ADC, microcontroller, display & power supply.



2) The vltg & cln sensor provide necessary signal which are conditioning & converted to digital form. The microcontroller processes this signal to calculate the p.f.

Vltg sensor - It measure vltg across the load

cln sensor - measure the cln flowing thro load

Zero crossing detector - To detect the zero crossing time of vltg & cln waveform.

signal conditioning ckt - conditioning the cln & vltg sensor i/p & send to ADC

ADC - convert analog vltg & cln signal into digital form.

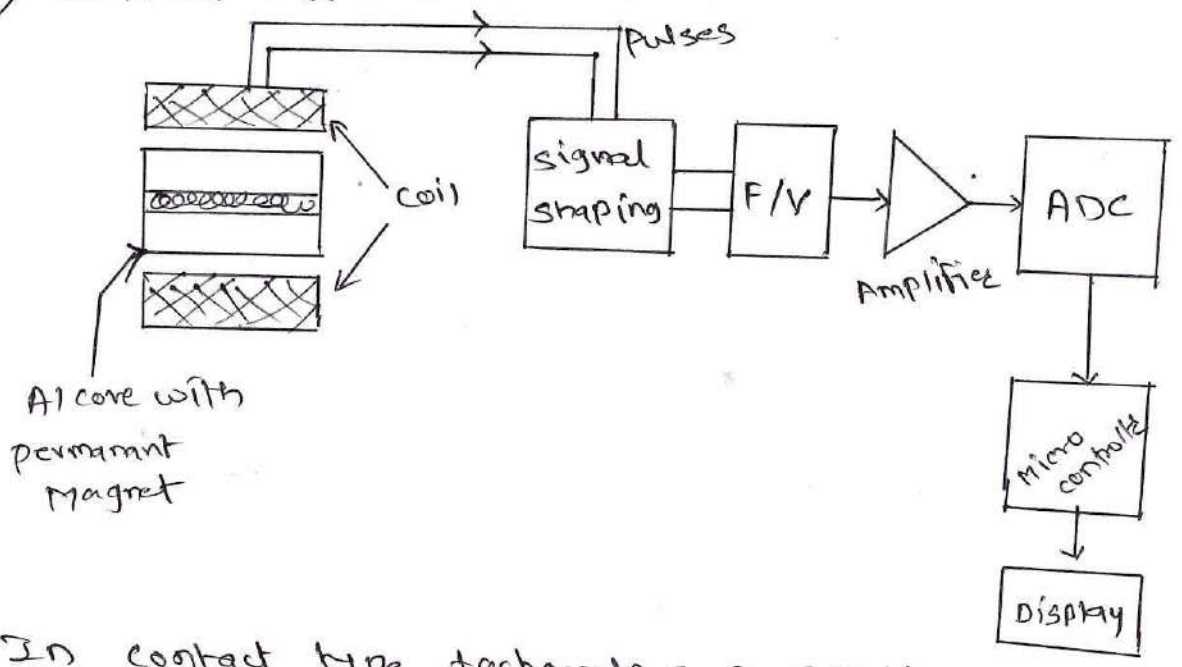
Micro controller - It process digital signal & calculate the time difference of an o/p voltg waveform.

Display - It shows the calculated P.F.

Supply - It provide necessary power for the internal circuit of meter.

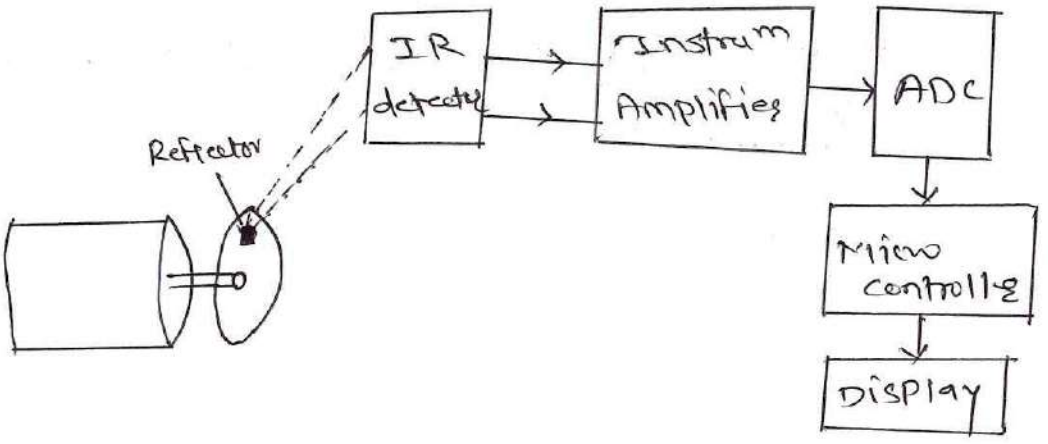
* Tachometer:

1) Contact type tachometer:



- In contact type tachometer, a small magnet is connected on aluminium core.
- The rotation of this core generate electrical pulses in winding. Number of pulses per second depends on rpm of rotor.
- Pulses generated are processed in signal shaping block. F|V converter convert the pulses into vltg. It amplified & fed to ADC to get digital signal.
- Micro controller based system output the result to display unit.

2) Non-contact type Tachometer:

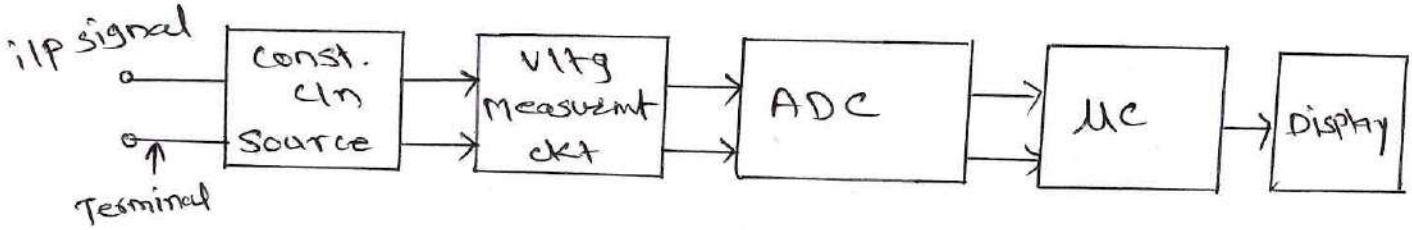


- In non-contact type method, a light source & photo detector is used (IR source & detector). light get reflected from reflector, which is placed on rotating wheel.
  - The number of light rays are counted per second then it directly measures the rotation or speed of rotor.
  - The speed is measure in terms of freq.

* ohm Meter:

1) The digital ohm meter measure electrical resi. & display digital value.

2) The following fig. shows block diag of digital ohm meter.



i/p terminal - It uses to connect across component or circuit, whose resi is to be measured.

Constant cln source - it provide or supply small, stable & known cln thro the resistor.

Vltg measurment ckt - It can measure the vltg drop across the resistor.

ADC - It convert analog signal to digital signal

Micro controller - It can process the signal & calculate the resi using ohm's law.

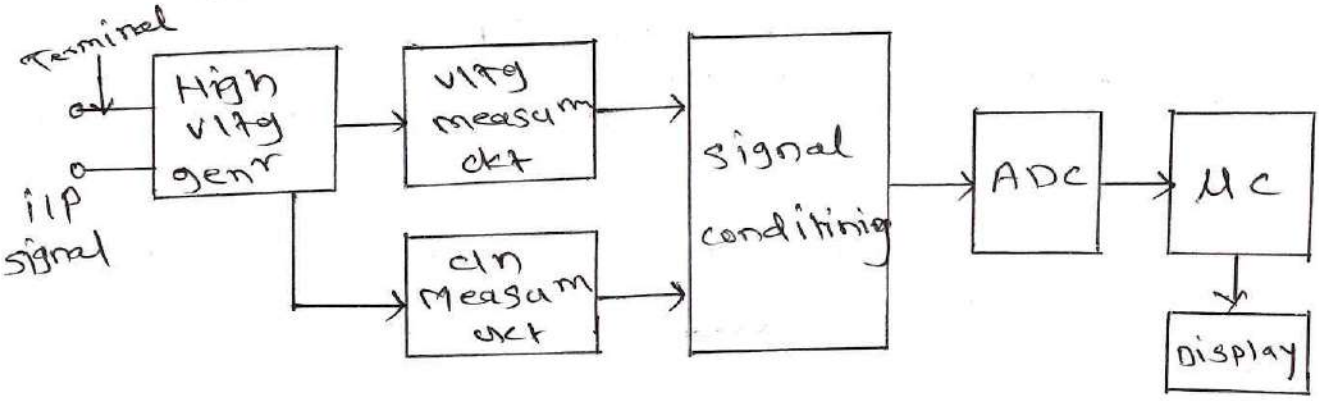
Display - It shows the measured resistance value in ohm.

Power supply - It provide necessary power to internal circuit of meter.

* Digital Megger:

1) The digital megger is an electronic device use to measure the insulation resistance of electrical component such as cable, motor etc.

2) The following fig. shows block diag of digital megger.



3) A digital megger uses high vltg generator, cln & vltg measuring ckt, ADC, µc & display

High vltg generator - It can generate high vltg [500, 1000, 2500V etc]

vltg measuring ckt - It can measure vltg drop across the insulation.

cln measuring ckt - It can measure leakage cln thro the insulation.

signal conditioning - conditioning the cln & vltg input & send to ADC.

ADC - It convert analog signal into digital signal

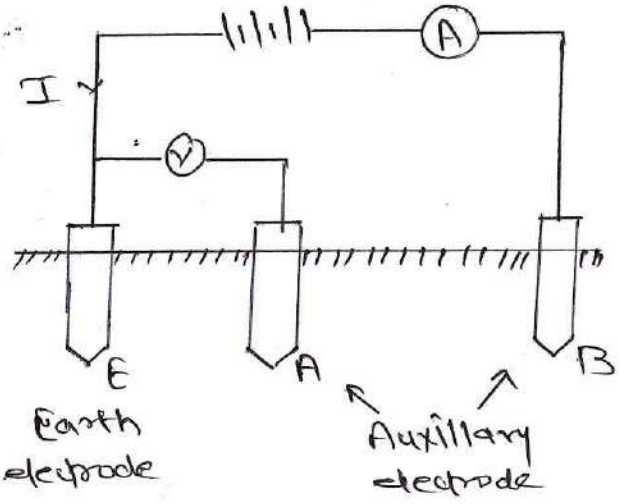
µc - It can process the digital signal & calculate the insulation resi.

Display - It can shows the insulation resi digitally.

* Digital Earth Tester:

1) The method which is use for measurement of resi. of earthing electrode is known as Fall of Potential method.

2) The earth electrode is incerted in the ground, it should have low resi & carry large c/n.



3) Earth tester consist of two auxillary electrode in addition with earth electrode.

4) The V/tg drop [V & I] are simultaneously measure The ratio of V & I gives resistance.

5) Electrode E & B placed at a fixed distance and c/n is pass through them.

6) Auxillary electrode A & E, the potential difference measure betn them.

7) The earth resistance is calculated using ohm's law

8) The distn betn E & B are fixed & position of A is change at regular interval from E.

g) earth tester consist of

vltg injection ckt - it generate a known vltg signal and injected into the earth.

clm injection ckt - generate a known clm signal inject into the earth

vltg measurment ckt - measure the vltg drop across electrode E & A. and provide necessary vltg signal.

ADC - It convert analog signal to the digital signal.

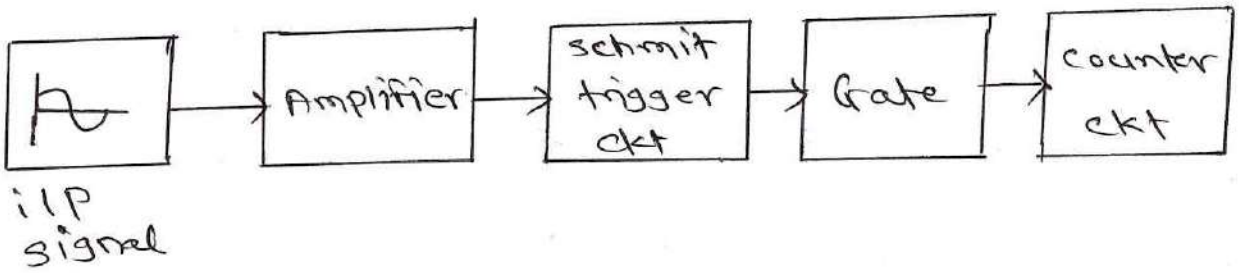
Mc - It can process the signal & calculate the earth resistance.

Display - It shows the earth resi digitally

Power supply - It provide necessary power for internal circuit.

* Frequency Meter:

1) Following fig. shows block diag of digital freq meter.



2) The i/p signal is amplified by amplifier ckt.

3) The schmit trigger convert it to square wave. with high rate of rise & fall time.

4) Due to this, the o/p signal from schmit trigger is in the form of train of pulses.

5) The o/p of schmit trigger is given to gate ckt. The gate is start-stop device.

6) when gate is start, pulse are pass to the counter ckt.

7) when gate is stop, the square wave pulse are stop.

8) The counter ckt count the number of square wave pulser for a given period of time.

9) The freq range is upto 10^9 Hz.

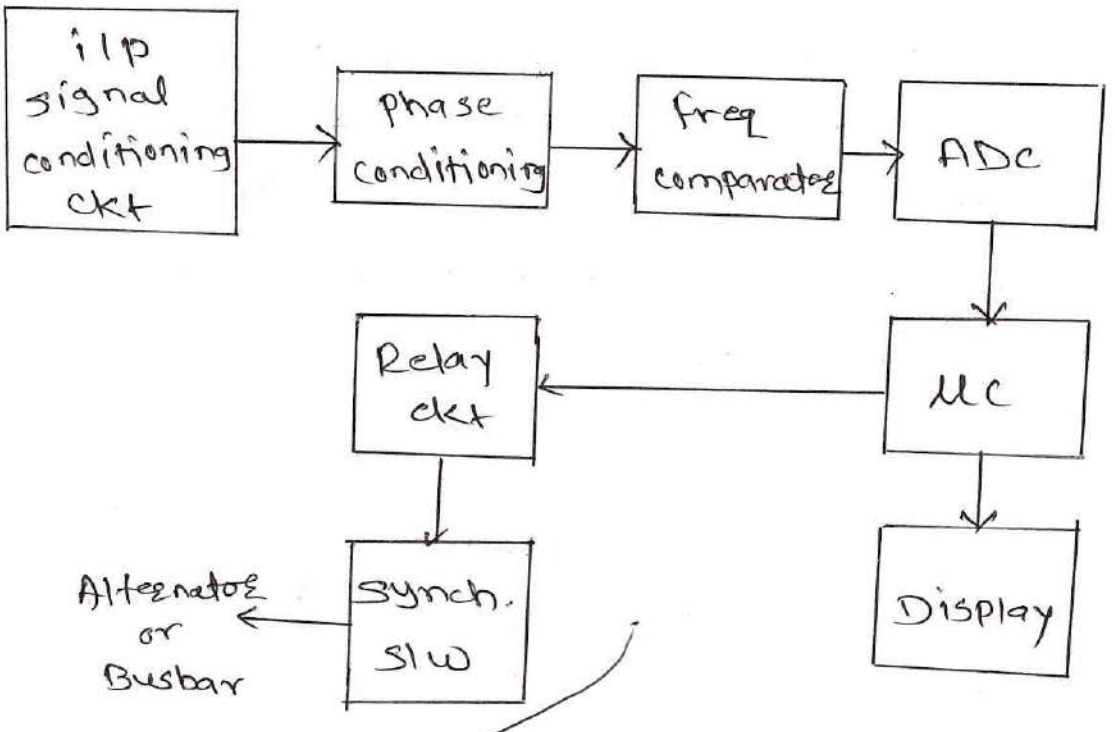
*Synchronization:

1) It is a process of connecting alternator to the bus bar with specific terms & condition this process is called synchronization.

2) Synchronization matching speed, freq, vltg and phase.

3) When all this parameters of generator match with busbar, the synchronoscope gives a signal.

* Digital synchronoscope:



1) A synchronoscope is a static device, use for synchronizing genr with bus-bar.

2) It provide a visible indication of phase difference betn incoming genr & busbar.

3) Synchronizing include vltg matching, freq phase angle matching, phase sequence.

4) A synchro. is used to determine correct instant of closing the switch.

5) The i/p signal from gen & busbar are fed to i/p signal conditioning ckt.

6) After conditioning signal send to phase & freq comparator. These ckt determine phase angle difference & freq diff^n bet^n gen^r & busbar.

7) The analog signal then fed to analog to digital converter.

8) The µc process the digital signal. It calculate the exact phase angle diff^n & freq diff^n.

9) The process signal is send to display, which shows phase angle diff^n or synchronization status.

10) When the phase sequence & freq are same the operator can close the synchronizing s/w to connect gen^r to busbar.

11) This indicate the correct instant of synchronization & synchronizing s/w is put off.

* Phase Sequence indicator:

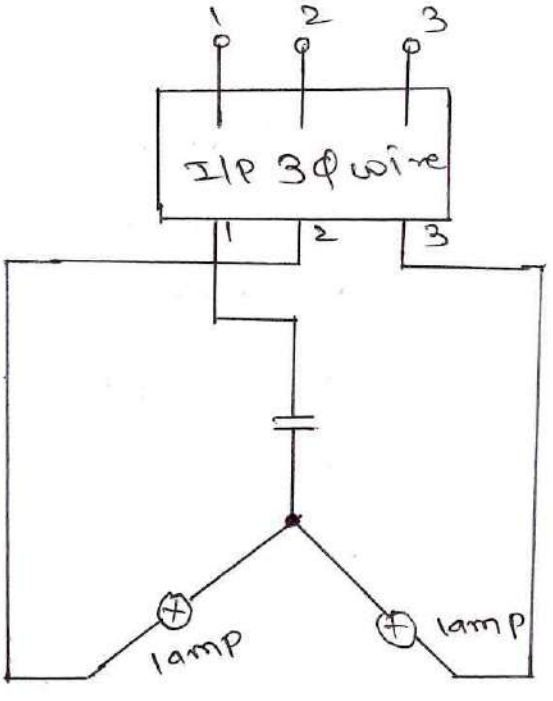
1) Three phase system should be connected to supply terminals R, Y, B correctly.

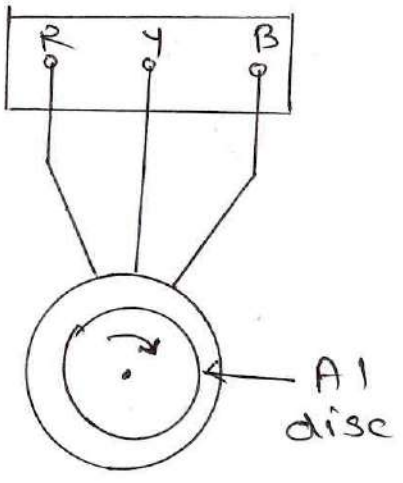
2) So, the instrument rotate in correct direction, if any two terminals are interchange then direction is reverse, so correct phase sequence of supply terminal must be known.

3) Phase sequence indicator is use for checking phase sequence of 3-ϕ AC supply.

4) It consist of 3-ϕ star connected winding. above the winding Aluminum disc is placed.

5) This Al disc is seen thro transperant glass on the meter dial. Arrow is mark on dial.





6) When incoming 3-ϕ supply connected to rotary type phase sequence indicator

7) If phase sequence is match, the aluminum disc rotate in direction of arrow shown.

8) In static type, Phase sequence indicator consist identical lamp with one capacitor.

9) If supply R terminal connected to capacitor, the lamp with more brightness belongs to Y phase and second lamp belongs to B phase. Thus phase sequence can be determine.

* Function Generator :-

- Function generator is an instrument which produces different functions (waveform) at the output. This functions are available simultaneously or selectively at the output.

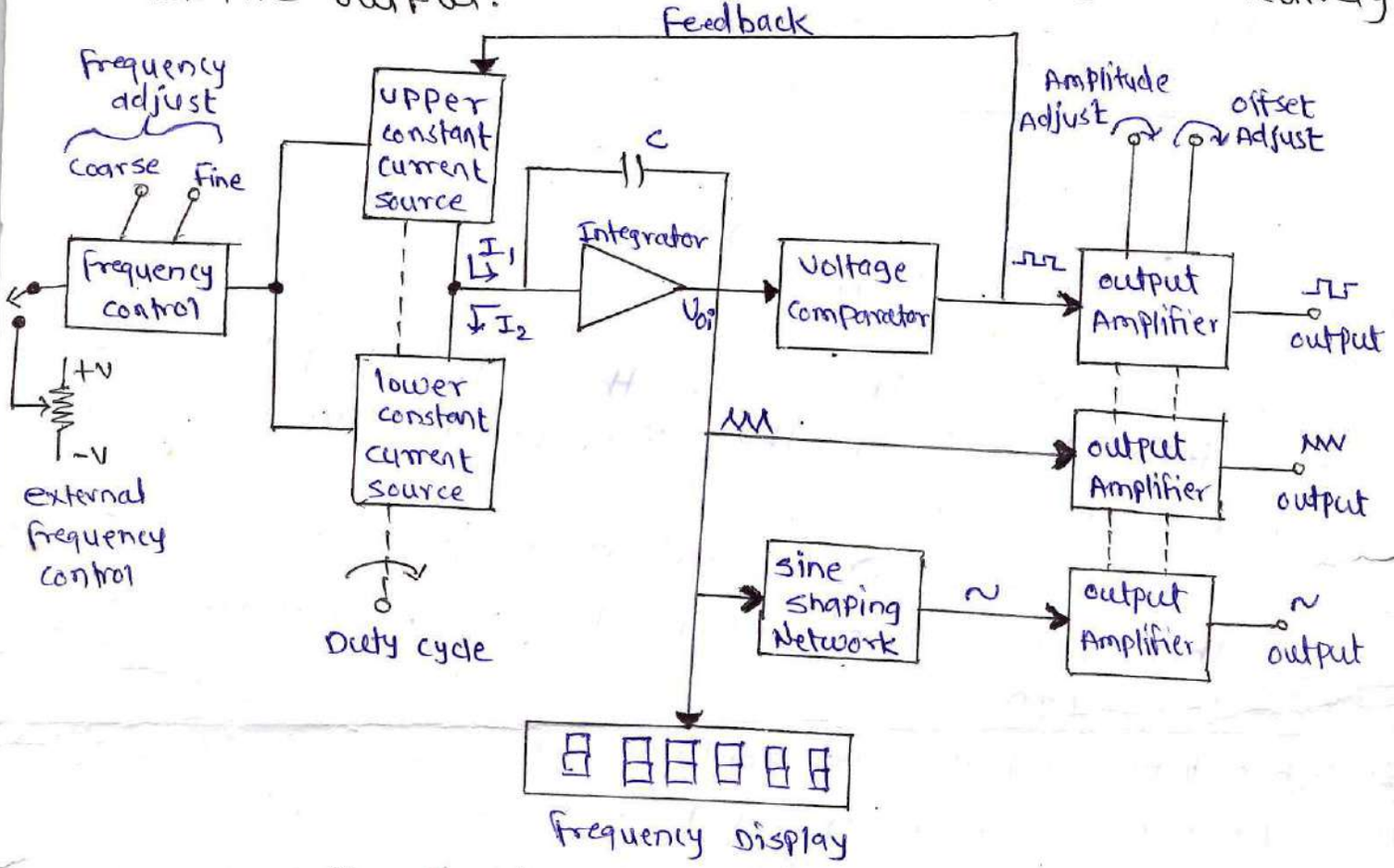
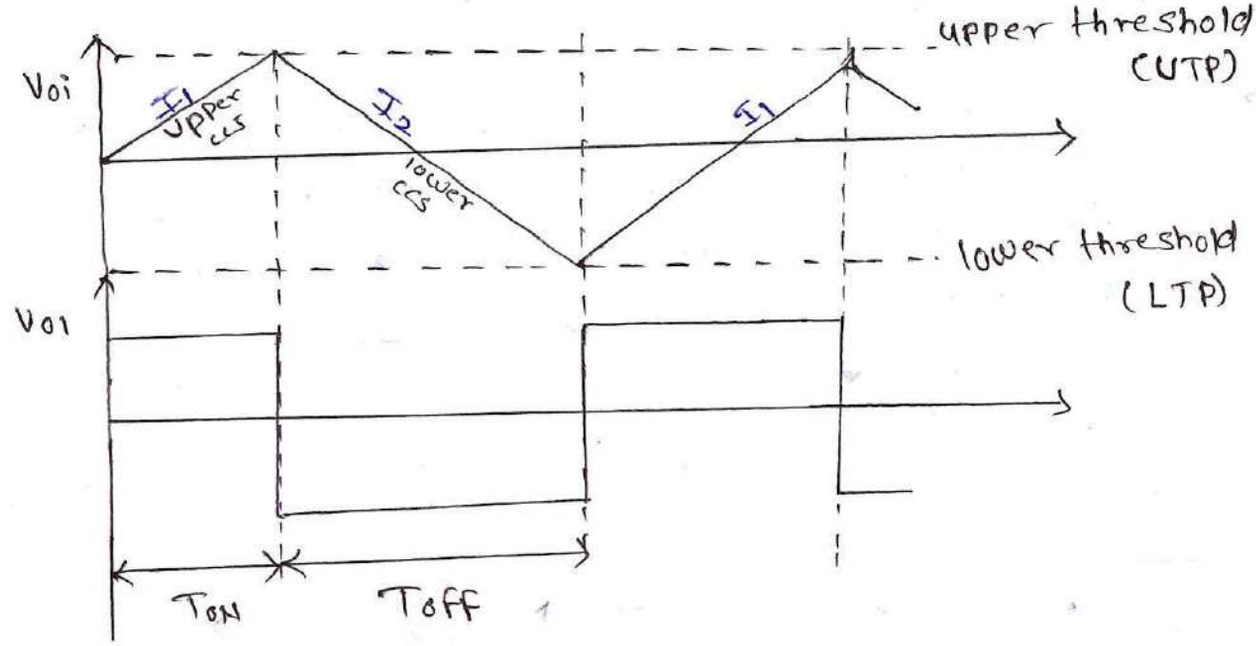


fig: Function generator Block diagram.

- Range of frequency is from few Hz to MHz. Amplitude range is from mV to few tens of volt rms.
- Frequency control can be internal or external. If external control is selected, the external dc vltg is applied. Upper & lower constant current sources (ccs) supply dc cln I_1 & I_2 in opposite direction.
- let upper ccs is ON & supplying dc constand current I_1 to an integrator. Now the output of an integrator is

$$V_{oi} = \frac{1}{C} \int I_1 \, dt.$$

since I_1 is constant, V_{oi} is the linear ramp wave increasing towards positive upper triggering point (UTP). The o/p V_{oi} is remain positive upto UTP.



- as Voi is greater than UTP, the output Vo1 becomes -ve. It is linked back by feedback line. It turns upper ccs off. and lower ccs ON.
- Now reverse c/n I_2 flows. This discharges capacitor C to zero and then recharges towards negative as shown in above fig. upto lower LTP.
- This action repeats and continuous triangular wave is obtained
- Square wave obtain if I_1 & I_2 are not equal in amplitude in opposite in phase, the waveform becomes asymmetric, duty cycle is not 50%.
- Sine wave obtain by using sine shaping network, it is resistor-diode network.

Thus three functions that are sine, square & triangular are available simultaneously at the outputs.

* Applications :-
  1) used as troubleshooting tool to diff^n analog & digital ckt.
  2) used as a source.
  3) waveforms like burst, sweep, cardiac, sawtooth, AM FM, fsk, noise etc are available on fu^n generator.

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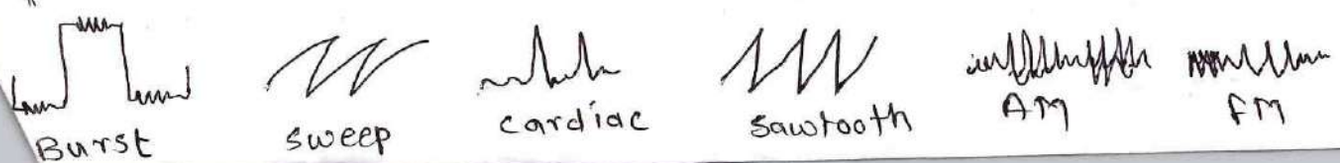

* Cathode Ray Oscilloscope:-

- The most versatile tool which can be used for the development of electronic circuits and system is the CRO.
  It allows the amplitude of electrical signals, whether they are voltage, current or power, to be displayed as a fun of time.
- There is a graphical scale present on the screen which is used to calculate the voltage or frequency value.
- A important specification of CRO is it's bandwidth which gives the maxm frequency of signal which a CRO can measure.
- A simple oscilloscope consist of cathode ray tube, a vertical amplifier, Delay ~~time~~ line, Horizontal deflection system, Time base Trigger circuit and power supply.

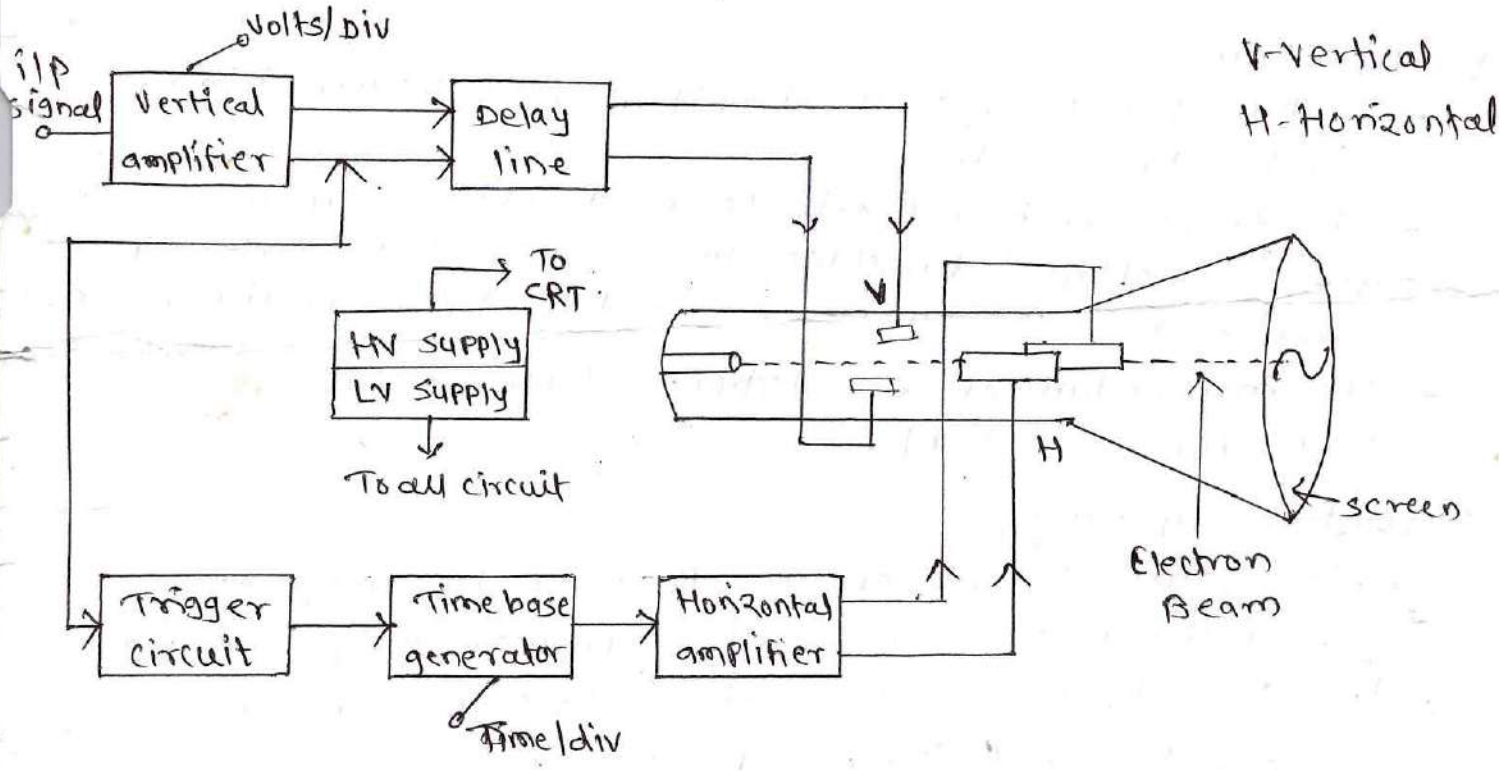

Fig: Block diagram of CRO.

- It consist of an elektron gun. The electron gun produces an electron beam. This beam is narrow & is allowed to pass down the tube, & fall on the screen.
- The electron beam passes through two pair of electrostatic deflection plates. i.e the Horizontal & vertical deflecting plates.
- Horizontal deflecting plates move the spot in horizontal dirn & vertical deflecting plates move the spot in vertical direction.

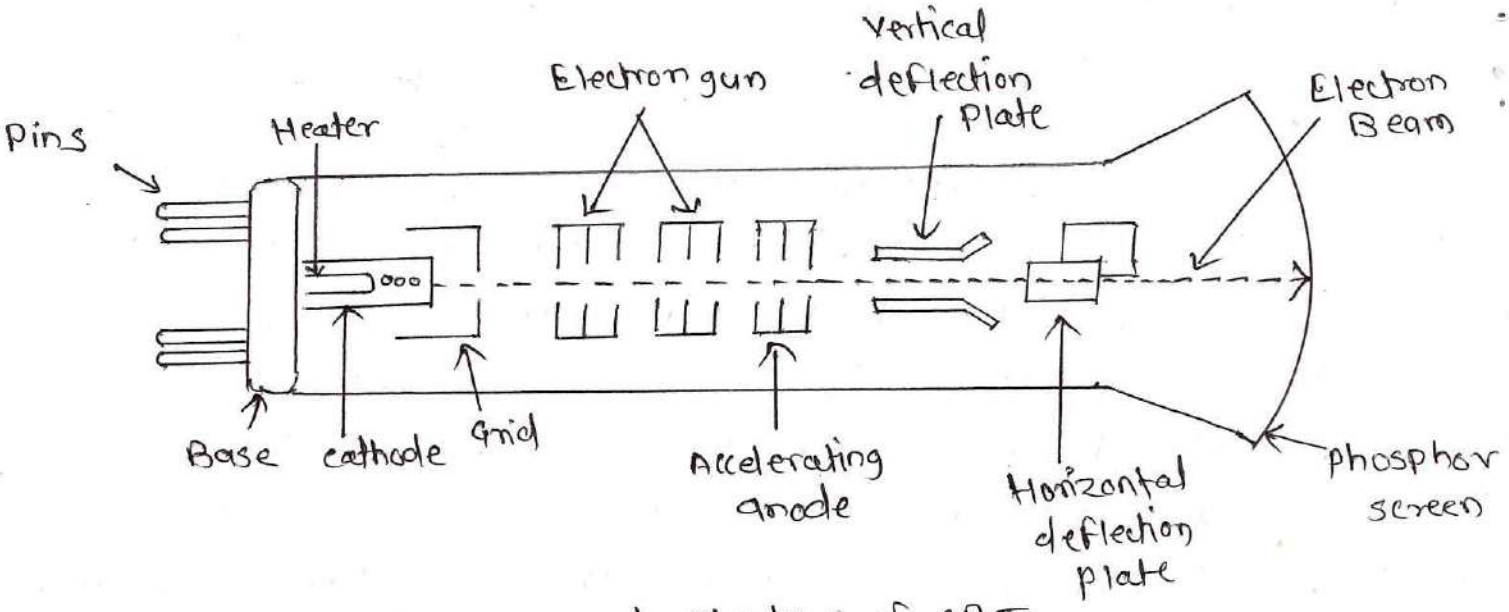

Fig: Internal structure of CRT.

- The CRT is composed of two main parts. 1) Electron Gun 2) Deflection system.

1) Electron Gun:-
   - Electron gun provides a sharply focused electron beam directed towards the screen.
   - The thermally heated cathode emits electrons in many dirn the control grid provides an axial dirn to electron beam and controls the number & speed of electron in the beam.
   - The momentum of the electrons determines the intensity or brightness of light.

2) Deflection system:-
   - This system consist of two pairs of parallel plates,
   - one of the plates in each set is permanently connected to the ground, whereas the other plate of each set is connected to input signals of CRO.

* uses of CRO.
1) Display waveforms of alternating potential difference
2) measure A.C. as well as D.C Quantity.
3) Measurment of frequency.
4) Measurment of phase.

* Digital storage oscilloscope :-

The signal is to be stored is digitized & then it is stored into the digital memory. Additional circuitry is required to digitize and store the signal into the memory. The stored signal can be displayed by using the conventional oscilloscope tube.

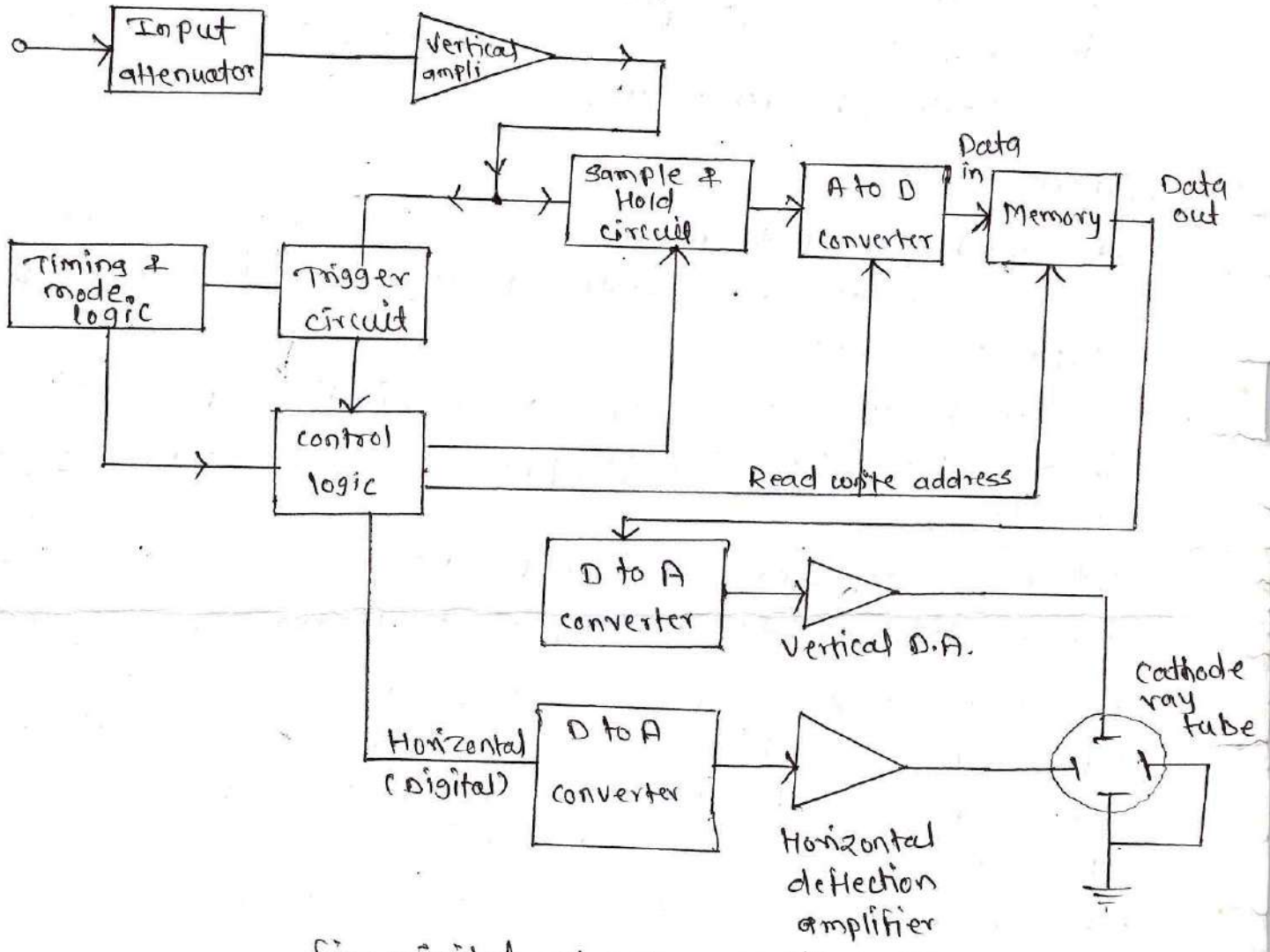

fig: Digital storage oscilloscope.

Operation :-

- The i/p signal is applied to the input amplifier & attenuator section. This i/p is then amplified & attenuated as that in conventional oscilloscope. This signal is applied to the vertical amplifier.
- The o/p of vertical amplifier is connected to A to D converter.
- generally successive approximation type of ADC is used.
- Digitizing the analog signal means to take samples of input at period intervals of time. The sampling rate should be greater than twise the highest freq present in input signal

- The sampling rate may be as high as 1,00,000 samples per second. for such high sampling rates, a fast conversion ADC is reqr.

* Advantages :-
  1) The storage time is infinite.
  2) It is easy to operate.
  3) It is capable of display X-Y, B-H & P-V diagram.
  4) Give complete information of analog input like, rms value, peak value, frequency etc.

* Applications :-
  1) It can be used to measure ac aswell as DC vltg & cln.
  2) It can calculate rms value, peak value, peak to peak value duty cycle etc.
  3) It can be used to measure frequency, time period, time interval betn two signals, phase for periodic & non periodic signals.
  4) It is used in aeroplane, ship etc.
  5) In medical fields, to display cardiograms.
  6) It can be used to observe V-I chara of diodes, transistors.
  7) It can be used to observe B-H curve, P-V diagrams.
  8) It can be used to determine modulation chara & detect the standing waves in transmission lines.
  9) It is used to observe the radiation pattern generated by the transmission antenna.
  10) In modern DSO it is possible to Add, subtract the waveforms.
  11) The signals can also be integrated & differentiated.
  12) It can be used to measure the inductance, capacitance.

Question Bank

Unit - 3

1) Enlist any two differences in digital & analog instrument.

W-23/S-24/W-25/S-25/W-24

2) Identify advantages of non contact type tachometer. Explain it with block diagram W-25

3) Identify the instrument used for synchronization and explain the working in brief.

W-25

4) Describe the working of digital earth tester.

W-23/W-25/S-25/W-24

5) With neat labelled sketch explain the function of each block of CRO.

W-23/W-25/S-25/W-24

6) Explain clamp-on meter with neat sketch. list the application of it

W-25/W-23/S-23

7) Draw a labelled block diagram of sine wave generator & write fun of each block

S-25/S-24/W-23

8) write two applications of fun generator & CRO

W-24

9) Explain with neat diagram function generator

W-24/S-24/W-23/S-23

10) Explain function with neat diagram

a) Freq meter

b) phase sequence indicator

c) Synchronoscope

W-24

11) Explain working of phase sequence indicator

S-24 / S-23

12) What is the necessity of synchroscope. Explain with neat sketch, the working of synchroscope

S-24 / W-23

13) Explain with neat sketch the construction & working of megger. Its need

S-24 / W-23 / S-23

14) Explain with block diagram of freyency meter

W-23

15) State the advantages of digital measuring instrument.

W-24 / S-25