unit - 4

Electronic & Digital instruments

"voltmeters uses rectifiers, diodes, amplifiers and other supporting electronic circuits to produce a current which is proportion-al to quantity to be measured are called electronic voltmeters.

Ex:- FETVM, VTVM, TVM

Advantages of Electronic voltmeters

i) low level signal detection

In PMMC instruments (Analog instruments) cannot measure less than 50 μA. As amplifiers are absent in this they can't measure very (small) low level signals. But electronic voltmeters have amplifiers so it can measure very low level signals.

ii) Low power consumption

In PMMC instruments $P = I^2R$ ie $I = 50\mu A$ & $R = 50\Omega$ ∴ $P = 0.125\ \mu w$ which is very low but in electronic voltmeter even this much of power will disturb the signal to be measured. In Electronic voltmeter power required is provided by external circuit using amplifiers. it doesnot take from signal to be measured.

iii) less loading effect:

PMMC instruments 50μA of minimum current is taken from signal thus it produces loading effect.

But in electronic voltmeter as external circuit supplies power so it is not producing loading effect.

iv) High sensitivity and high input impedance

PMMC instruments have only impedance of 10kΩ & its range is 0.5V. They have low sensitivity & low input impedance

In electronic voltmeter have impedances from 10MΩ to 100MΩ ie have high input impedance & high sensitivity.

v) High frequency range:

* Electronic voltmeters practically can measure independent of frequency & also it can measure frequencies of order hundred to MHZ.
* It can also measure R, C, L etc

vi) Improved dynamic range:

"Dynamic range: meter which can detect input under various measurement conditions".

Electronic voltmeter have dynamic range compared to analog conventional meter. ie it can measure very low & very high input signal.

vii) High accuracy:

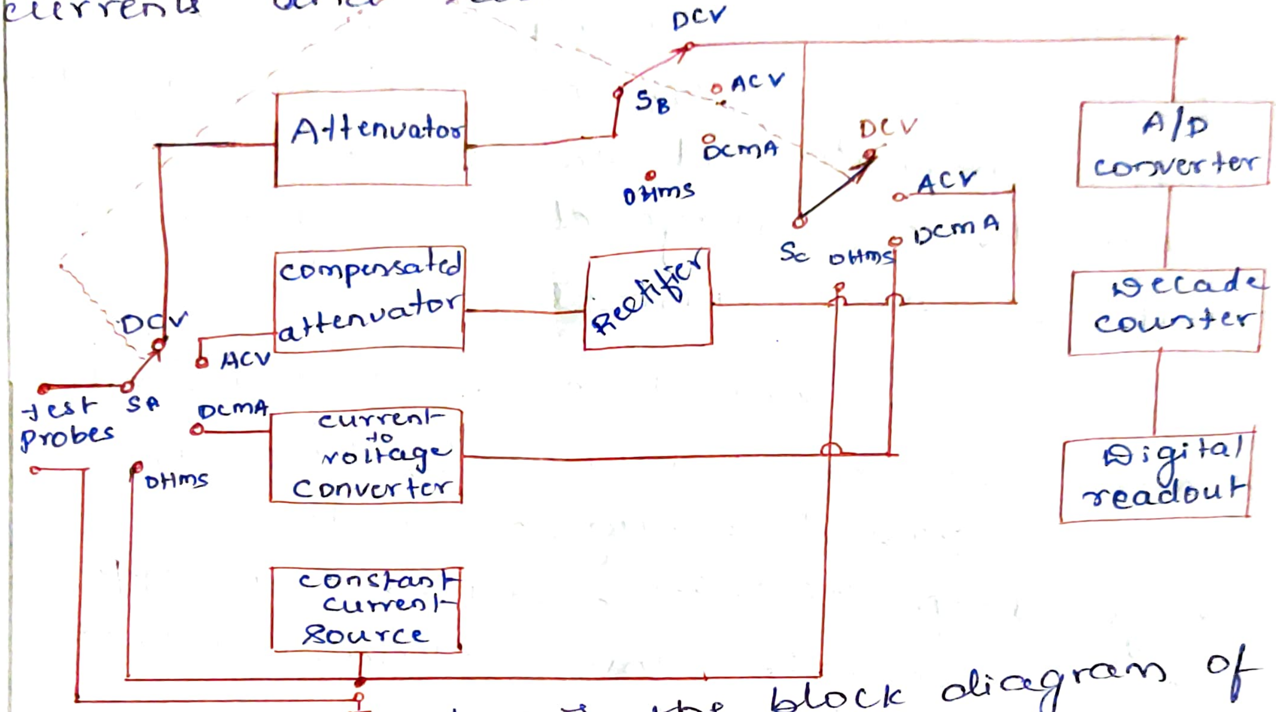
Electronic voltmeters are highly accurate as compared to analog voltmeters

viii) compactness & portability:

Electronic instruments are ~~___~~ small in size as compared to analog voltmeters hence they are compact & can be portable.

Electronic Multimeter (or) Voltage Ohm-meter (or) multimeter.

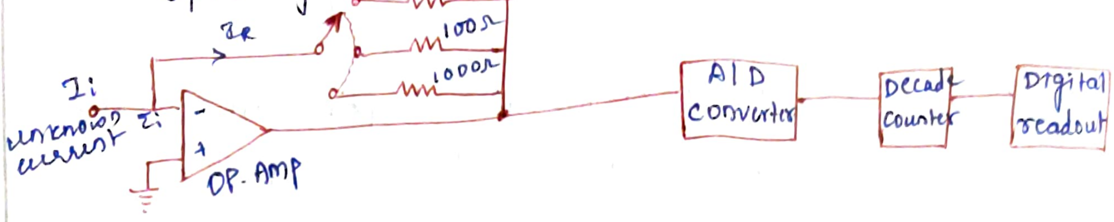
It is a instrument used for the measurement of a.c & d.c voltages & a.c & d.c currents and resistances over several ranges



Above fig shows the block diagram of digital multimeter.

* It mainly consists of 3 blocks
  1. A/D converters
  2. counting circuitry
  3. attenuation circuit.
* generally dual slope integration type ADC is used in multimeters
* single attenuator circuit is used for both a.c & d.c measurement
* A.C quantities are converted to D.C by various rectifiers & filtering circuit.
* To measure unknown currents, current to voltage converter circuit is implemented
* To measure current unknown current is applied at junction Σi as input

to OPAmp as shown below.



* As input current to OPAmp is zero ∴ $I_R = I_i$. Thus I_R causes voltage drop which is proportional to current to be measured. The voltage drop is given as input to A to D converter.

* To measure resistance a constant current source is used. i.e known current is passed through unknown resistance voltage drop across resistance is applied to A to D converter thus unknown resistance is read out.

Advantages

1) Input impedance is high
2) Frequency range is high
3) circuit is simple
4) cost is less
5) construction is simple
6) less electric noise.

Disadvantages

1) Accuracy is less
2) Resolution is poor.
3) Difficult to interface output with external devices
4) Not compact in size.
5) Reliability & repeatability are poor.

Q METER :-

Q factor is called quality factor or storage factor.

"It is ratio of power stored in element to power dissipated in element."

"It is the ratio of reactance to resistance of reactive element."

"Q meter is an instrument used to measure some of the electrical properties of coils and capacitors."

Storage factor $Q = \frac{\omega_0 L}{R}$

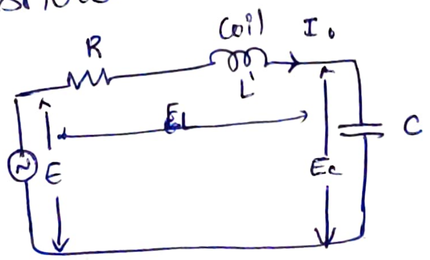
ω_0 = resonant angular frequency

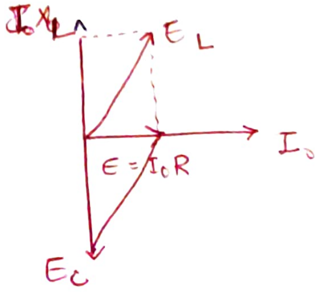
L = inductance

R = effective resistance of coil

Principle of working.

* It working is based on charateristics of series resonant circuit.
* i.e. voltage across the coil or capacitor is equal to applied voltage times the Q factor of circuit.
* If fixed voltage is applied to circuit, voltmeter across capacitor will read Q value directly.
* fig shows a series resonant circuit.





- At resonant frequency f_0

$$X_C = X_L$$

we know capacitive reactance $X_C = \frac{1}{2\pi f_0 C} = \frac{1}{\omega_0 C}$

Inductive reactance & $X_L = 2\pi f_0 L = \omega_0 L$

resonant freq. & $f_0 = \frac{1}{2\pi\sqrt{LC}}$

current at resonance $I_0 = \frac{E}{R}$ or $E = I_0 R$

from phasor diagram

voltage across capacitor $E_C = I_0 X_C = I_0 X_L$
$= I_0 \omega_0 L$

& input voltage $E = I_0 R$

$$\therefore \frac{E_C}{E} = \frac{I_0 \omega_0 L}{I_0 R} = \frac{\omega_0 L}{R} = Q$$

i.e. $\boxed{Q = \frac{\omega_0 L}{R}}$ or $\boxed{E_C = QE}$

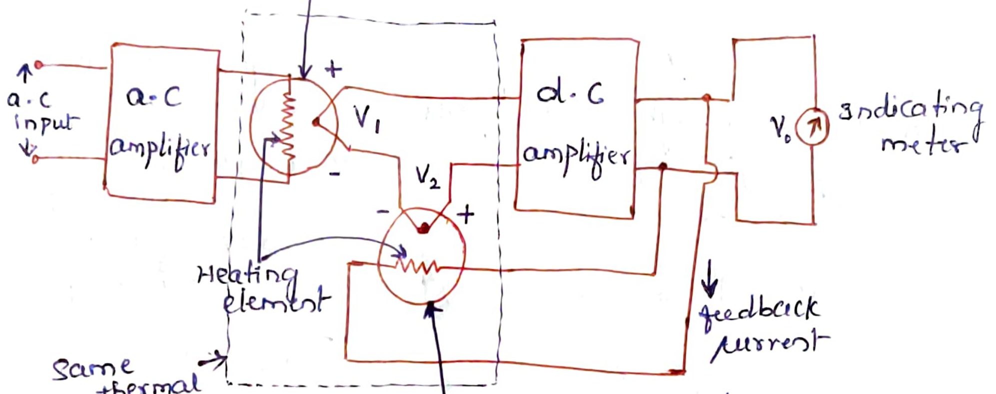
Application

1. Measurement of Q.
2. Measurement of inductance
3. Measurement of self-capacitance
4. Measurement of effective resistance
5. Measurement of bandwidth
6. Measurement of capacitance.

True R.m.s (or effective value) Responding voltmeter.

R.m.s means Root mean square value.

" It is obtained by squaring the input signal and taking square root of its average value."



* Above fig shows the true R.m.s responding voltmeter using two thermocouples.
* Two thermocouples are balancing & measuring the thermocouples forming balanced bridge in the input circuit of d.c amplifier.
* Thermocouples are used for the measurement of heating power
* when a.c input is applied, the thermocouple produces the voltage V_1. This applied to the heater. a.c voltage is amplified & its heating effect is sensed by thermocouple attached to it. Thus thermocouple generates the corresponding voltage.
* This voltage is amplified by d.c amplifier & this ~~voltage~~ amplified voltage again given as feedback to balancing thermocouple. which produces voltage V_2 thus it brings back the balance of the bridge.
* The d.c feedback current is the r.m.s value of input current.
* power in thermocouple $= \frac{E_{rms}^2}{R_{heater}}$

$V = IR$
$\frac{V}{R} = I$

$E_o \propto$ heat $\propto$ power

$$E_o = \frac{K E_{rms}^2}{R_{heater}}$$

E_{rms} = r.m.s value of a.c input

E_o = output voltage of thermocouple

K = constant of proportionality.

W.K.T $V_o = A(V_1 - V_2)$

(or) $V_1 - V_2 = \frac{V_o}{A} = 0$

A = gain of d.c amplifier

As A is very high at balanced condition

$\therefore$ $V_1 = V_2$ → (1)

V_1 = output of measuring thermocouple

V_2 = output of Balancing thermocouple.

$V_1 = K E_{rms}^2$ & $V_2 = K V_o^2$

$\therefore$ $K E_{rms}^2 = K V_o^2$

E_{rms} = rms value of input

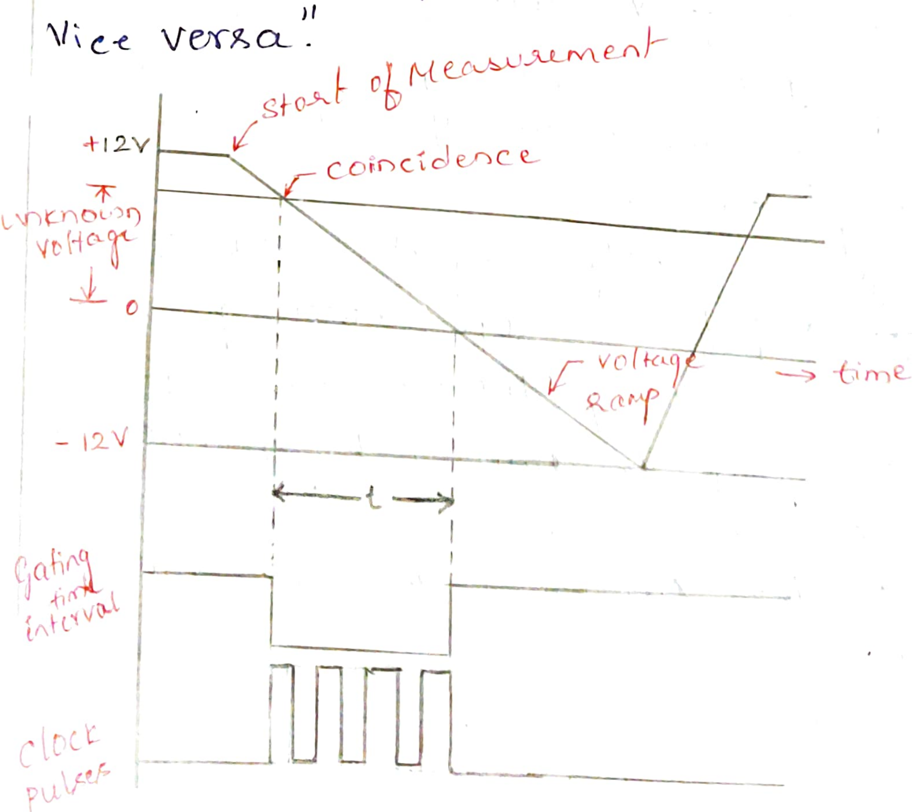
$$E_{rms} = V_o$$

V_o = output of dc voltage

Ramp Type Digital voltmeter.

Principle:-

"It Measures the time taken by Ramp voltage i.e time interval between the input voltage level to zero voltage or vice versa."



Above fig shows the timing diagram (5)

* In the fig ramp voltage is initiated & at that point measurement is started. Here we are using negative ramp even positive ramp is also used.

* From that point the ramp voltage & unknown voltages are continously compared at the instant when both these voltages are equal input comparator generates a pulse which opens a gate.

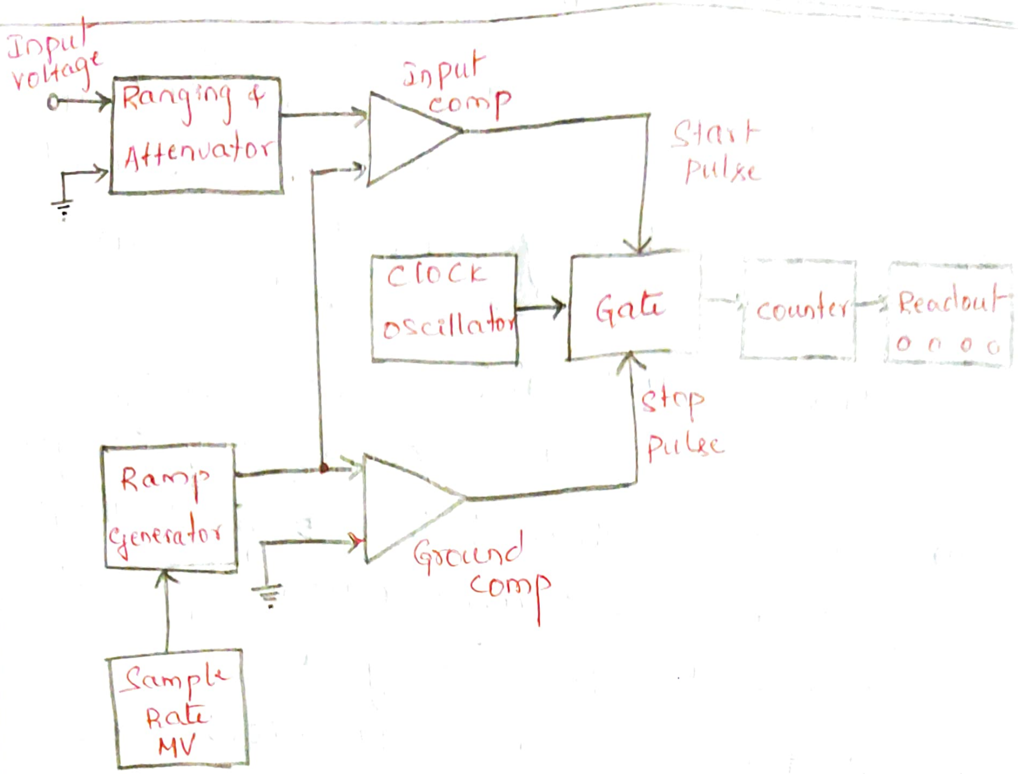
* Ramp voltage continues to decrease till it reaches ground level (or) zero voltage

* when it reaches zero voltage another comparator called ground comparator generates a pulse which closes the gate.

* Time Elapsed between opening & closing of the gate is t. This pulses from clock pulse generator pass through the gate and are counted & displayed. the decimal readout is the measure of value of input voltage.

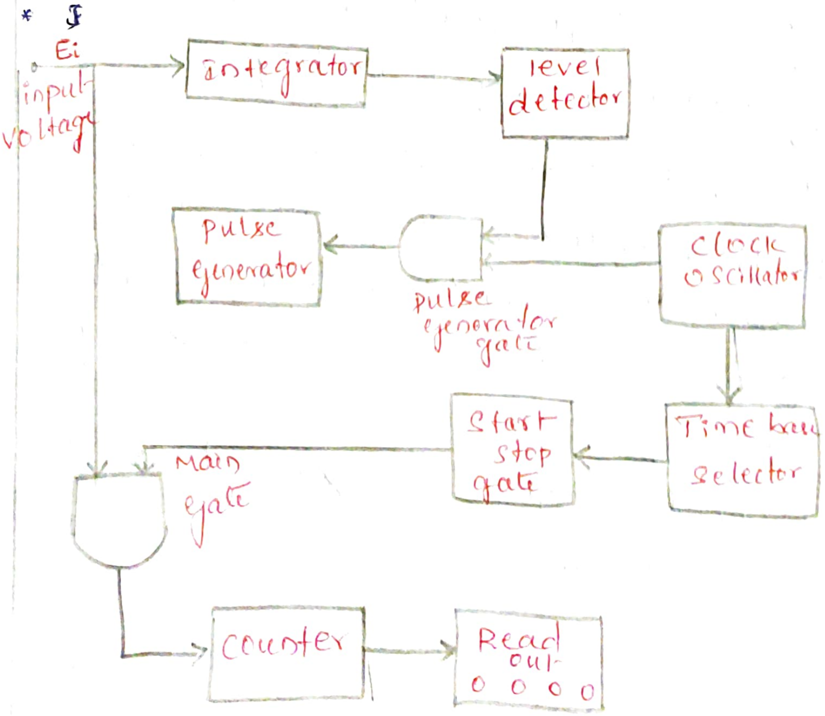
* Sample rate multivibrator determines the rate at which measurement cycles are initiated. Thus it provides initiating pulse for Ramp generator to start next ramp voltage.

* It also sends signal to counters such that to set them to 0.



Integrating type Digital voltmeter

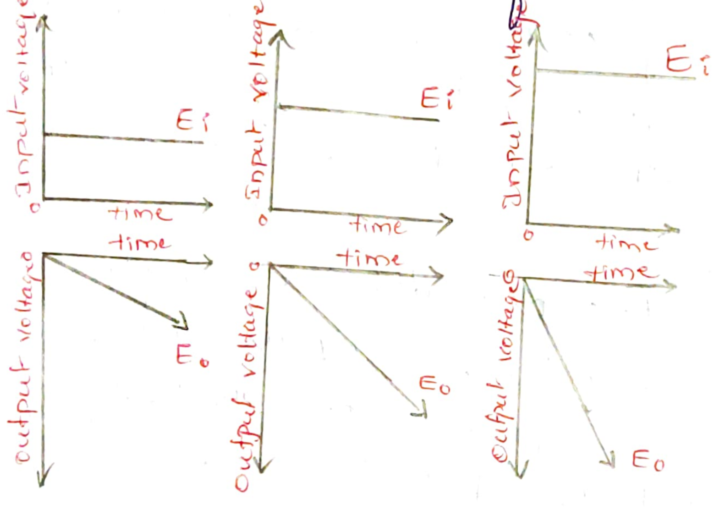
- This voltmeter measures true average value of input voltage over a fixed measuring period.
- Below fig shows the block diagram of a integrating type DVM



* In this E_i (unknown voltage) is applied to the input of integrator the E_o (output voltage) starts to rise.

* E_o - output voltage is feed to level detector. level detector compares the E_o with fixed voltage (reference) & when E_o reaches level it produces output pulse & sends to pulse generator gate.

* From below graphs it is evident that greater the value of input voltage E_i sharper will be slope of output voltage E_o thus quicker E_o reaches reference level



* when level detector opens pulse generation gate thus pulse from clock oscillator is allowed to pass through pulse generator.
* pulse generator produces output pulse of fixed amplitude & width for each pulse.
* The output produced will be having opposite polarity than E_i & greater amplitude which is feedback to integrator.
* As a result of reversed input to E_i as no output to detector. E_o drops back thus no output thus gate gets closed

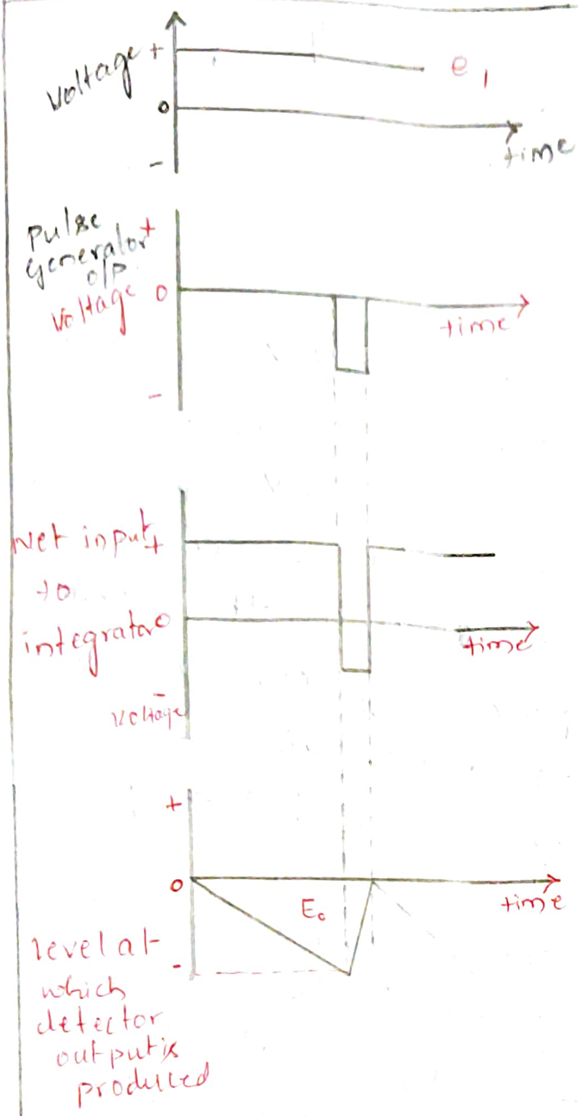
* thus no pulses from clock oscillator can pass through trigger the pulse generator.

* when output pulse from pulse generator has passed then E_i restores to original value. thus entire cycle is restored. thus obtained waveform of E_o is a sawtooth wave whose rise time dependent upon value of E_i & fall time is determined by the width of output pulse from pulse generator.

* Frequency of sawtooth wave may be measured by counting the number of pulses in a given interval of time. This frequency will indicate the voltage being measured.

* Pulses from clock oscillator are applied to time base selector. First pulse from Time base selector is passed to start-stop gate whose output is applied to main gate thus gate will be opened.

* Next pulse from Time base generator will closes the start-stop gate & main gate thus counter & read out will indicate the number of pulses that have passed during the interval. this count is indicating the voltage being measured.



Successive Approximation Type DVM

Principle of working:

In this method comparator compares the output of digital to analog converter with unknown voltage accordingly comparator provides high & low signal. D to A converter ~~continue~~ successively produces set of pattern of signals & this process continues untill output becomes equal to unknown voltage.

Below block diagram shows successive approximation type DVM.

* In this a capacitor is connected at the input of comparator. The output of comparator is given to logic control and ~~Analog~~ sequencer this generates sequence of codes & applied

to digital to Analog converter.

* Position 2 switch S_1 receives the output from D to A converter.

* Clock is used to alternate switch S_1 from position 1 to 2.

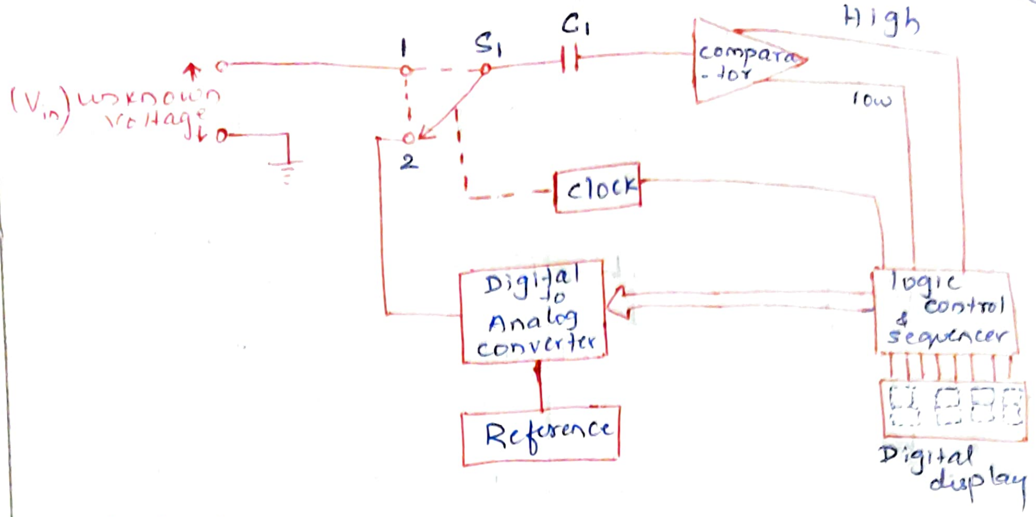
working

* let reference voltage be 3.79 V & set D to A converter as 8 V. thus converter generates 8 V & thus capacitor C_1 charges to 8 V. & switch is at S_1 position. Here clock is used to change position from S_1 to S_2. thus the voltages are compared by comparator ie (8 & 3.79) as 8 > 3.79 comparator sends high signal to logic control & sequence circuit.

* Thus later D to A converter resets to 4 & above process repeats later D to A converter resets to 2 & again it is compared as (2 < 3.79) comparator sends low signal & this 2V is stored in previously. next D to A is reset to 1V converter sends low signal & thus & thus comparator stores 2V & present 1V which is less than 3.79 thus low signal is generated Totally it becomes 3V

* Thus process of successive approximation continues till converter generates 3.79 V thus voltage is displayed on digital display.

* Block diagram is shown below.



Advantages

1. very high speed of order 100 readings/sec
2. ADC method is inexpensive
3. high resolution - upto 5 digits
4. Accuracy is high.

disadvantages

1. circuit is complex
2. DAC is required
3. input impedance is variable
4. noise causes error in comparator.

Difference between Electronic meters & conventional analog meters

Electronic meter	Analog meters.
1. Electronic components like rectifiers, diodes transistors are used	1. Electronic components are not used.
2. Amplifiers are present	2. Amplifiers are absent
3. low level signal detection is possible	3. low level signal detection is not possible
4. Pow consumption is low	4. power consumption is high.
5. loading effect are less	5. severe loading effects
6. sensitivity is high	6. sensitivity is less

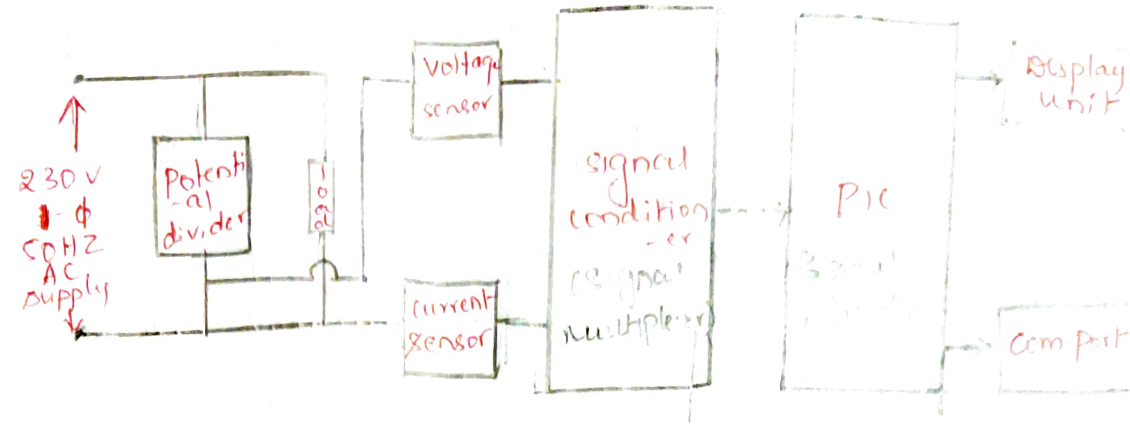
⑦ input impedance is very high	⑦ Input impedance is low
⑧ Frequency range is high	⑧ Frequency range is limited
⑨ Accuracy is high	⑨ Accuracy is low
⑩ meters are compact & portable	⑩ meters are not compact & portable
⑪ meters are not rugged	⑪ meters are rugged

Electronic Energy Meters

Advantages of Electronic Energy meter over conventional Energy meter

1) There are no friction losses
2) various adjustments for low load, full load, p.f, creeping etc are not necessary
3) common errors in conventional E.m are absent in Electronic E.m
4) Accuracy is more about ±1%.
5) EEM reduces the cost of theft
6) EEm also gives prepayment interfaces
7) mechanical defects and breakdown are absent
8) EEm measures current in both phase & neutral lines & calculate power consumption based on the larger of two currents.
9) EEm improves cost & quality of Electricity distribution.
10) Orientation problem is absent in EEm hence installation is easier.

Block diagram of Electronic Energy meter



* Measurement of Energy is basically measurement of power & time duration of its consumption.
* EEM in first stage it acts as wattmeter & measures electrical energy consumed by load in watts.
* In second stage it will measure power consumed for particular interval of time.
* It has basically two sensors i) voltage sensor ii) current sensor.

i) Voltage sensors is built around a step down element & potential divider.

ii) current sensors; senses current drawn by load at any point in time & it is built around CT & active devices which convert sensed current to voltage

iii) Potential divider network senses both the phase voltage & load voltage.

* The output from both sensors are fed into a signal conditioner which sends signal to control circuit (PIC).
* signal conditioner even contain ~~voltage~~ ~~current~~ ~~multiplier~~ or signal multiplexer which helps in sequential switching of both signals.

* PIC contain ADC which converts analog signal to digital equivalent.
- PIC even contain ~~contain~~ multiplier which multiplies both voltage & current output from signal conditioner.
* PIC is programmed in c language & it even receives data & calculate power consumption per hour. & even expected charges.
* The calculated value is displayed on liquid crystal display attached to PIC.