UNIT-1

1. What are the basic performance characteristics of a system?

Ans:

STATIC CHARACTE RISTICS

The static characteristics of an instrument are, in general, considered for instruments which are used to measure an unvarying process condition. All the static performance characteristics are obtained by one form or another of a process called calibration. There are a number of related definitions (or characteristics), which are described below, such as accuracy% precision, repeatability, resolution, errors, sensitivity, etc.

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

2. **Measurement:** The process of determining the amount, degree, or capacity by comparison (direct or indirect) with the accepted standards of the system units being used.

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

4. Resolution: The smallest change in a measured variable to which an instrument will respond.

5. Precision: A measure of the consistency or repeatability of measurements, i.e. successive readings does not differ. (Precision is the consistency of the instrument output for a given value of input).

6. Expected value: The design value, i.e. the most probable value that calculations indicate one should expect to measure.

7 Error**:** The deviation of the true value from the desired value.

8. Sensitivity: The ratio of the change in output (response) of the instrument to a change of input or measured variable.

DYNAMIC CHARACTERISTICS

Instruments rarely respond instantaneously to changes in the measured variables. Instead, they exhibit slowness or sluggishness due to such things as mass, thermal capacitance, fluid capacitance or electric capacitance. In addition to this, pure delay in time is often encountered where the instrument waits for some reaction to take place. Such industrial instruments are nearly always used for measuring quantities that fluctuate with time. Therefore, the dynamic and transient behavior of the instrument is as important as the static behavior.

The dynamic behavior of an instrument is determined by subjecting its primary element (sensing element) to some unknown and predetermined variations in the measured quantity. The three most common variations in the measured quantity are as follows:

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

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

3, Sinusoidal change, in which the primary element follows a measured variable, the magnitude of which changes in accordance with a sinusoidal function of constant amplitude
.
The dynamic characteristics of an instrument are (i) speed of response,
(ii) Fidelity, (iii) lag, and (iv) dynamic error.

(i) **Speed of Response:** It is the rapidity with which an instrument responds to changes in the measured quantity.
(ii) **Fidelity:** It is the degree to which an instrument indicates the changes in the measured variable without dynamic error (faithful reproduction).
(iii) **Lag:** It is the retardation or delay in the response of an instrument to changes in the measured variable.
(iv) **Dynamic Error:** It is the difference between the true values of a quantity changing with time and the value indicated by the instrument, if no static error is assumed.

When measurement problems are concerned with rapidly varying quantities, the dynamic relations between the instruments input and output are generally Defined by the use of differential equations

2. What are the different types of static errors in a system?

Ans:

The static error of a measuring instrument is the numerical difference between the true value of a quantity and its value as obtained by measurement, i.e. repeated measurement of the same quantity give different indications. Static errors are categorized as gross errors or human errors, systematic errors and Random errors.

1. Gross Errors

This error is mainly due to human mistakes in reading or in using instruments or errors in recording observations. Errors may also occur due to incorrect adjustments of instruments and computational mistakes. These errors cannot be treated mathematically. The complete elimination of gross errors is not possible, but one can minimize them .Some errors are easily detected while others may be elusive. One of the basic gross errors that occur frequently is the improper use of an Instrument the error can be minimized by taking proper care in reading and recording the measurement parameter. In general, indicating instruments change ambient conditions to some extent when connected into a complete circuit.

2. Systematic Errors

These errors occur due to shortcomings of, the instrument, such as defective or worn parts, or ageing or effects of the environment on the instrument.

These errors are sometimes referred to as bias, and they influence all measurements of a quantity alike. A constant uniform deviation of the operation of an instrument is known as a systematic error. There are basically three types of systematic errors
(i) Instrumental, (ii) Environmental, and (iii) Observational

(i) Instrumental Errors

Instrumental errors are inherent in measuring instruments, because of their mechanical structure. For example, in the D'Arsonval movement friction in the bearings of various moving components, irregular spring tensions, stretching of the spring or reduction in tension due to improper handling or over loading of the instrument. Instrumental errors can be avoided by
(a) Selecting a suitable instrument for the particular measurement applications.
(b) Applying correction factors after determining the amount of instrumental error.
(c) Calibrating the instrument against a standard.

(ii) Environmental Errors

Environmental errors are due to conditions external to the measuring device, including conditions in the area surrounding the instrument, such as the effects of change in temperature, humidity, barometric pressure or of magnetic or electrostatic fields.
These errors can also be avoided by (i) air conditioning, (ii) hermetically sealing certain components in the instruments, and (iii) using magnetic shields.

(iii) Observational Errors

Observational errors are errors introduced by the observer. The most common error is the parallax error introduced in reading a meter scale, and the error of estimation when obtaining a reading from a meter scale.

These errors are caused by the habits of individual observers. For example, an observer may always introduce an error by consistently holding his head too far to the left while reading a needle and scale reading.

In general, systematic errors can also be subdivided into static and dynamic Errors. Static errors are caused by limitations of the measuring device or the physical laws governing its behavior. Dynamic errors are caused by the instrument not responding fast enough to follow the changes in a measured variable.

3. What is the method used to calculate the errors in an instrument?

Ans:

ERROR IN MEASUREMENT

Measurement is the process of comparing an unknown quantity with an accepted standard quantity. It involves connecting a measuring instrument into the system under consideration and observing the resulting response on the instrument. The measurement thus obtained is a quantitative measure of the so-called "true value" (since it is very difficult to define the true value, the term "expected value" is used). Any measurement is affected by many variables; therefore the results rarely reflect the expected value. For example, connecting a measuring instrument into the circuit under consideration always disturbs (changes) the circuit, causing the measurement to differ from the expected value. Some factors that affect the measurements are related to the measuring instruments themselves. Other factors are related to the person using the instrument. The degree to which a measurement nears the expected value is expressed in terms of the error of measurement. Error may be expressed either as absolute or as percentage of error. Absolute error may be defined as the difference between the expected value of the variable and the measured value of the variable, or

$$e = Y_n - X_n$$

Where e=absolute errors;

Y_n=expected value;

X_n=measured value;

Therefore %error = (absolute value/expected value)*100=(e/Y_n)*100

Therefore %error= $\left(\frac{Y_n - X_n}{Y_n}\right) * 100$

It is more frequently expressed as an accuracy rather than error.

Therefore A=1-$mod\left(\frac{Y_n - X_n}{Y_n}\right)$

Where A is the relative accuracy

Accuracy is expressed as % accuracy

a=100%-%error

a=A*100% (where a=%accuracy)

4. Describe the function of the DC-Voltmeter and multi range voltmeter and explain their operation?

Ans: DC-Voltmeter

A basic D'Arsonval movement can be converted into a dc voltmeter by adding a series resistor known as multiplier, as shown in the figure. The function of the multiplier is to limit the current through the movement so that the current does not exceed the full scale deflection value. A dc voltmeter measures the potential difference between two points in a dc circuit or a circuit component. To measure the potential difference between two points in a dc circuit or a circuit component, a dc voltmeter is always connected across them with the proper polarity. The value of the multiplier required is calculated as follows.

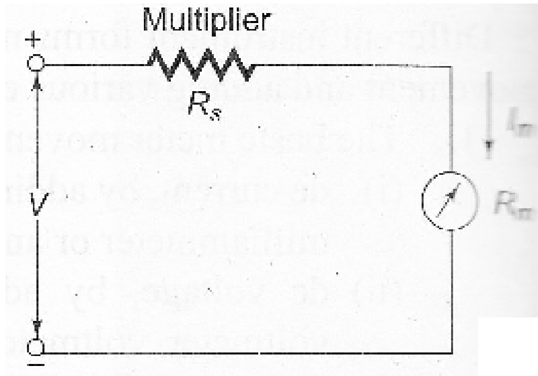

fig 4.1 Basic Voltmeter

I_m: full scale deflection current of the movement
Rm : internal resistance of movement
R_s : Multiplier resistance
V: full range voltage of the instrument
From the circuit of Fig. 4.1

$$V = I_m * (Rm + R_s)$$

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

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

The multiplier limits the current through the movement, so as to not exceed the value of the full scale deflection I_{fsd}.
The above equation is also used to further extend the range in DC voltmeter'.

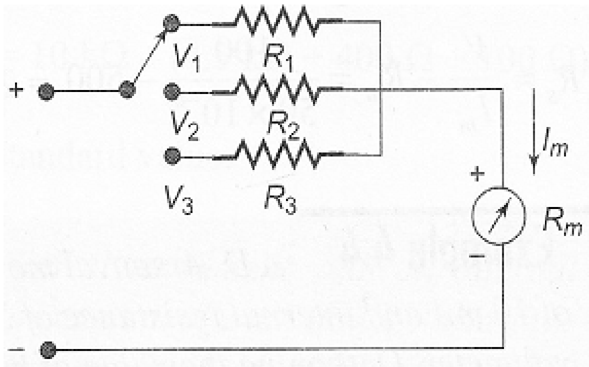

fig 4.2 Multirange Voltmeter

Multi range Voltmeter:

As in the case of an ammeter, to obtain a multi range ammeter, a number of shunts are connected

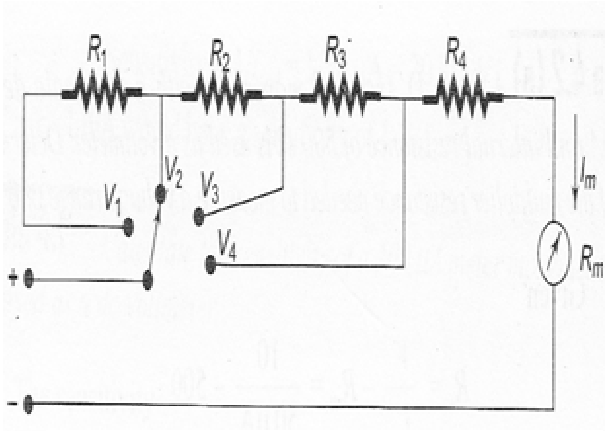

fig 4.3 Multiplier connected in series string

across the movement with a multi-position switch. Similarly, a dc voltmeter can be converted into a multi range voltmeter by connecting a number of resistors (multipliers) along with a range switch to provide a greater number of workable ranges. The below Figure shows a multi range voltmeter using a three position switch and three multipliers R1, R2, and R3, for voltage values V1, V2, and V3. Fig 4.2 can be further modified to multipliers connected in series string, which is a more practical arrangement of the multiplier resistors of a multi range voltmeter. In this arrangement, the multipliers are connected in a series string, and the range selector selects the appropriate amount of resistance required in series with the movement.

This arrangement is advantageous compared to the previous one, because all multi1llier resistances except the first have the standard resistance value and are also easily available in precision tolerances. The first resistor or low range multiplier, R4, is the only special resistor which has to be specially manufactured to meet the circuit requirements.

5. Explain the working of solid state voltmeter?

Ans:

The below figure shows the circuit of an electronic voltmeter using an IC Op Amp 741C.This is a directly coupled very high gain amplifier. The gain of

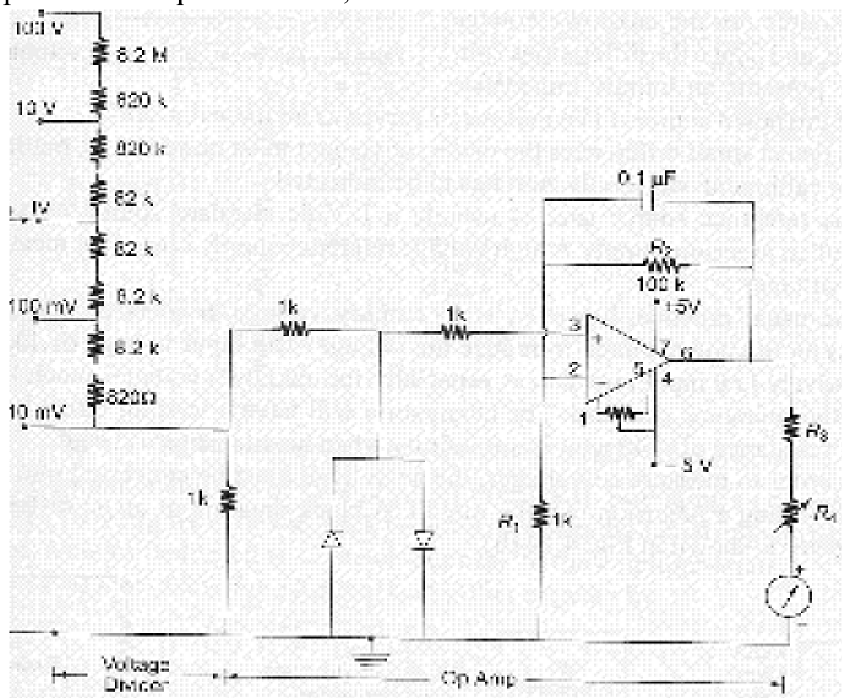

fig 5.1 Solid state mV voltmeter using OpAmp

the Op Amp can be adjusted to any suitable lower value by providing appropriate resistance between its output terminal, Pin No. 6, and inverting input, Pin No. 2, to provide a negative feedback. The ratio R_2 /R_1 determines the gain, i.e. 101 in this case, provided by the Op Amp. The 0.1 pF capacitor across the 100 k resistance R is for stability under stray pick-ups Terminals 1 and 5 are called offset null terminals.

A 10 kΩ potentiometer is connected between these two offset null terminals with its centre tap connected to a - 5V supply. This potentiometer is called zero set and is used for adjusting zero output for zero input conditions.

The two diodes used are for IC protection. Under normal conditions, they are non-conducting, as the maximum voltage across them is l0 mV. If an excessive voltage, say more than 100 mV appears across them, then depending upon the polarity of the voltage, one of the diodes conducts and protects the IC. A μA scale of 50 - 1000 μA full scale deflection can be used as an indicator. Ro is adjusted to get maximum full scale deflection.

6. Draw the block diagram of the measuring system and explain the function of each stage of this system?

Ans:

The generalized measuring system consists of three main functional elements. They are,

1. Primary sensing element, which senses the quantity under measurement.
2. Variable conversion element, which modifies suitably the output of the primary sensing element
3. Data presentation element that renders the indication on a calibrated scale.

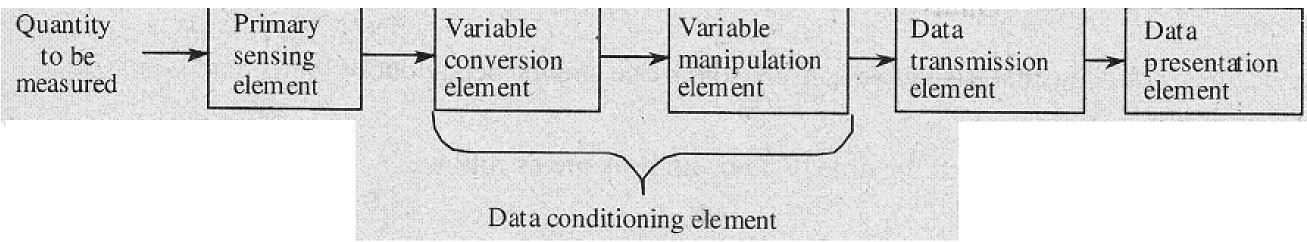

fig 6.1 Functiona Elements of measuring sysytem

1. Primary Sensing Element

The measurement first comes into contact with primary sensing element where the conversion takes place. This is done by a transducer which converts the measurement (or) measured quantity into a usable electrical output. The transduction may be from mechanical, electrical (or) optical to any related form.

2. Variable Conversion Element

The output of the primary sensing element is in the electrical form suitable for control, recording and display. For, the instrument to perform the desired function, it may be necessary to convert this output to some other suitable for preserving the original information. This function is performed by the variable conversion element. A system may require one (or) more variable conversion suitable to it.

(a) Variable Manipulation Element

The signal gets manipulated here preserving the original nature of it. For example, an amplifier accepts a small voltage signal as input and produces a voltage, of greater magnitude. The output is the same voltage but of higher value, acting as a voltage amplifier. Here the voltage amplifier acts as a variable manipulation element since it amplifies the voltage. The element that follows the primary sensing element in a measurement system is called signal conditioning element. Here the variable conversion element and variable manipulation element are collectively called as Data conditioning element (or) signal conditioning element.

(b) Data Transmission Element

The transmission of data from one another is done by the data transmission element. In case of spacecrafts, the control signals are sent from the control stations by using radio signals.
The stage that follows the signal conditioning element and data transmission element collectively is called the intermediate stage.

(c).Data Presentation Element

The display (or) readout devices which display the required information about the measurement, forms the data presentation element. Here the information of the measurand has to be conveyed for, monitoring, Control (or) analysis purposes.
(a). 1t case of data to be monitored, visual display devices are needed like ammeters; voltmeters and so on are used.
(b) In case of data to be recorded, recorders like magnetic tapes, T.V equipment, and storage type C.R T, printers and so on are used.

7. Explain the types of test signals used in determining dynamic characteristics of measurements applied to a system.

Ans:

The a dynamic characteristic (or) analysis is classified with respect to time and frequency as time domain analysis and frequency domain analysis
(a).In time domain analysis the i/p is applied to the system and the behavior of the system is studied as a function of time.
(b) In frequency, domain analysis the i/p is a sinusoidal one and the behavior of the system is studied as a function of frequency.

The standard test signals used for time domain analysis are as follows.

(i) Step input
(ii) Ramp input
(iii) Parabolic input
(iv) Impulse input.

(i) Step Input

The continuous time step input u (t) is defined as the discrete time step input a[n] is defined as,
U (t) = $\begin{cases} 1 \ for \ t \geq 0 \\ 0 \ for \ t < 0 \end{cases}$ and discrete time step input u[n] is defined as, u (n) = $\begin{cases} 1 \ for \ n \geq 0 \\ 0 \ for \ n < 0 \end{cases}$

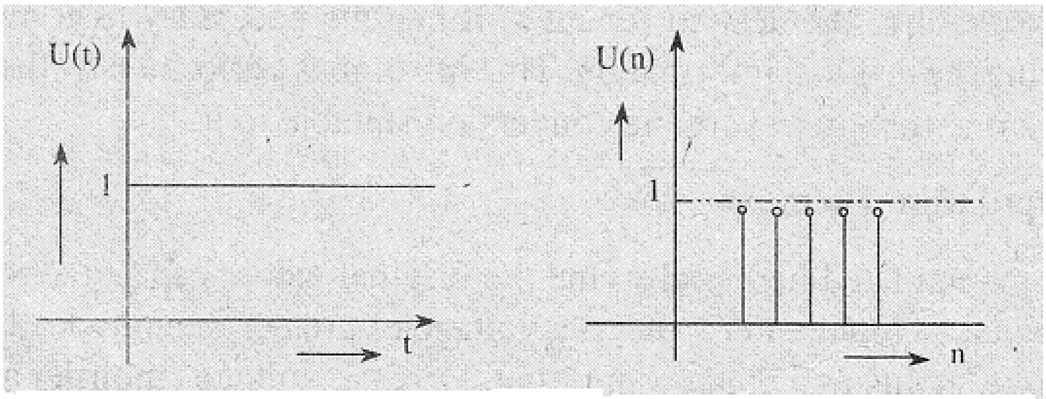

fig 7.1 (a) Continuous Time Step Input

fig 7.1 (b) Discrete Time Step Input

Therefore, a unit step input represents a signal which changes its level from 0 to I in zero time and. it reveals a great deal about how quick, the system responds to an abrupt change in the input signal

(ii) Ramp Input

The ramp input is defined in continuous time as

$$r(t) = \begin{cases} t & for\ t \geq 0 \\ 0 & for\ t < 0 \end{cases}$$

and $$r[n] = \begin{cases} n & for\ n \geq 0 \\ 0 & for\ n < 0 \end{cases}$$

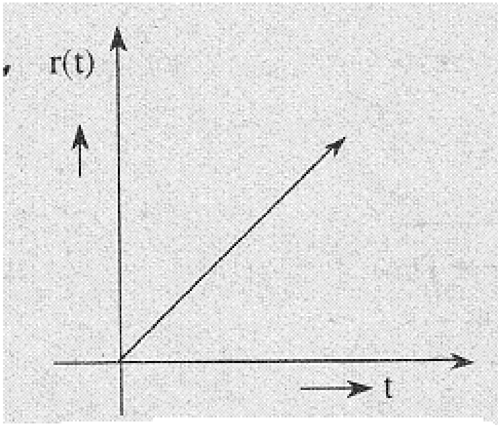

fig 7.2 (a) Unit Ramp Signal

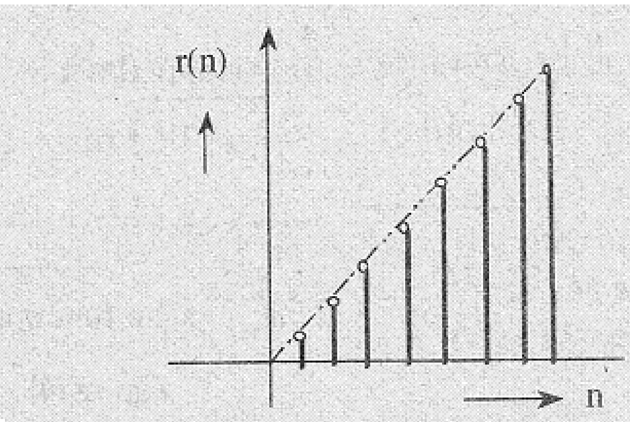

fig 7.2 (b) Discrete Ramp Signal

(iii) Parabolic Input

The parabolic input is defined as,

$$r(t) = \begin{cases} t^2 ; & t \geq 0 \\ 0 ; & t < 0 \end{cases}$$

and the discrete time is defined as,

$$r[n] = \begin{cases} n^2 ; & n \geq 0 \\ 0 ; & n < 0 \end{cases}$$

The signal are given below,

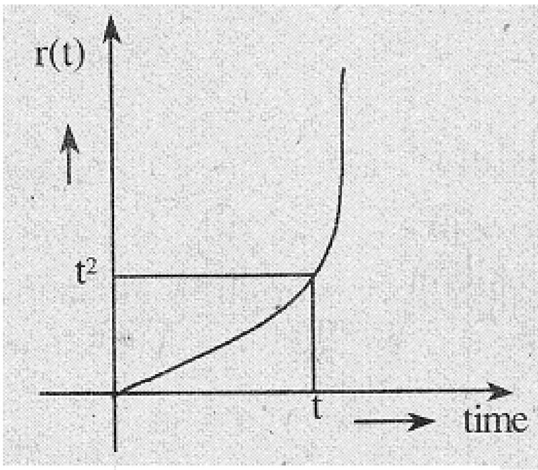

fig 7.3 (a) Unit Parabolic Signal

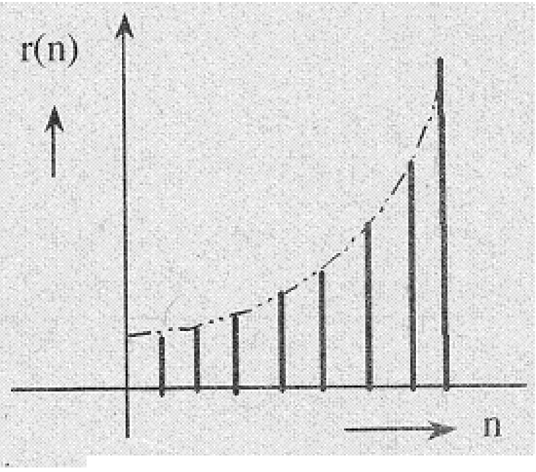

fig 7.3 (b) Discrete Parabolic Signal

This signal is also called as acceleration input since the input signal is proportional to represents a constant acceleration.

(iv) Impulse Input

It is also called as a δ (delta) function. The continuous time impulse input is given by, square of time and

$\delta(t) = 0$ for $t \neq 0$

And discrete time impulse input is given by,

$$\delta(n) = \begin{cases} 1, n = 0 \\ 0 \; n \neq 0 \end{cases}$$

The unit impulse is defined as the signal which has a zero value everywhere except at t=0.where the magnitude is finite.

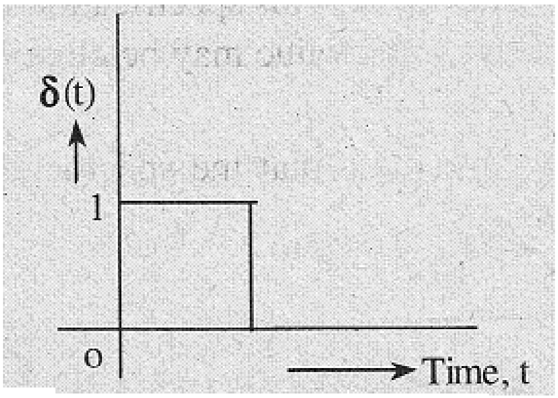

fig 7.4 Unit Impluse Function

In frequency domain analysis, the system behavior is studied through the sinusoidal signal because the time varying signals such as step, ramp, and parabolic inputs can be expressed in terms of sinusoidal signal of differential amplitudes and frequencies.

A continuous time sinusoidal signal is given as

$X(t)=A \sin(\omega t + \varphi)$

Where A= amplitude
ω = frequency in radians/sec.
φ = phase angle in radians.

A sinusoidal signal is an example of a periodic signal, the period of which is $T=\frac{2\pi}{\omega}$

The discrete time version of a sinusoidal signal is given by,

$X[n] = A \sin(\omega n + \varphi)$
Where, ω = angular frequency in radians/cycle.

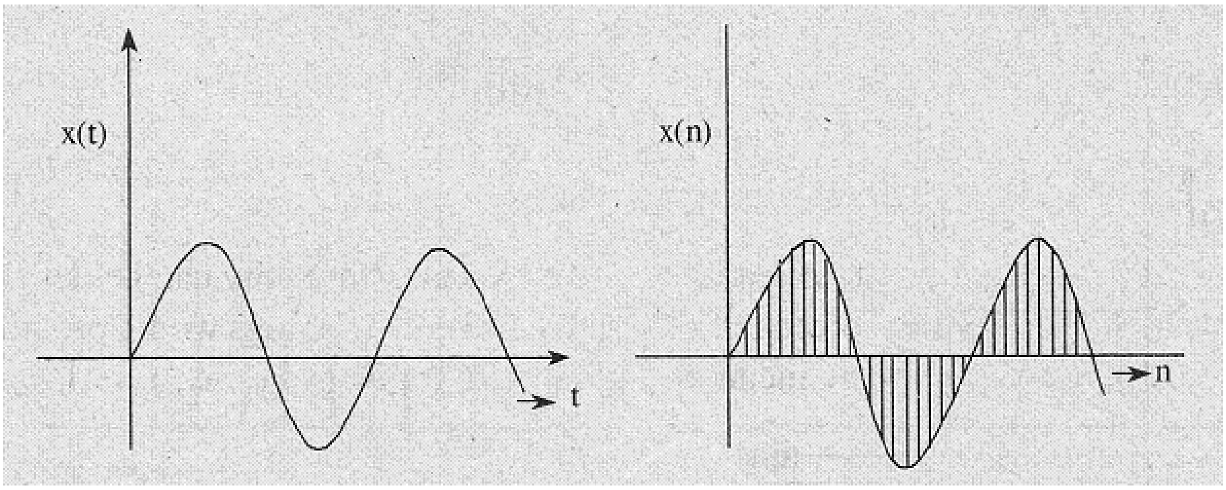

fig 7.5 (a) continuous Time Sinusoidal Signal fig 7.5 (b) Discrete Time Sinusoidal signal

8. Explain the terms
(i). significant figures
(ii). Conformity

Ans:

(i) Significant Figures

The number of meaningful digits used to express a numerical value (measured value of a quantity) are known as, significant figures. Significant figures indicate the precision of the measurement and the magnitude of the measurements. The measured value should be expressed in more number of significant figures because the more significant figures the higher will be the precision.

Consider an example in which the measured voltage across a resistor in a circuit is specified as 50 V. It indicates that the measured voltage may be close to 49 V or 51 V. This specification has two significant figures. If the measured voltage is specified as 50.0 V then it indicates that the value may be close to 49.9 V or 50. 1 V. This specification has three significant figures. From the above illustration, it can be observed that the specification with three significant figures is more precise than the one with two significant figures.

(ii) Conformity

Conformity is one of the characteristics which determine the precision. If a measuring instrument consistently and repeatedly provides a value as close to the true value (of the measured quantity) as an observer can estimate the true value from its scale reading then this characteristic refers to the conformity of the measurement. Let us consider an example of measuring resistance of a resistor which has a true resistance of 10,654,739 Ω). If the multi meter indicates the resistance value as 10.7 MO consistently and repeatedly, then the condition of conformity is satisfied. But, due to the limitation of scale reading, there exists an error in the measured value as the scale provides the reading up to one decimal place only.

Thus, conformity is a necessary condition, but not a sufficient condition for the measurement to be precise.

9. What is ayrton shunt? Describe it with a neat sketch .specify its application?
Ans:

Aryton shunt: It is also known as universal shunt. Figure shows the basic circuit of an aryton shunt.

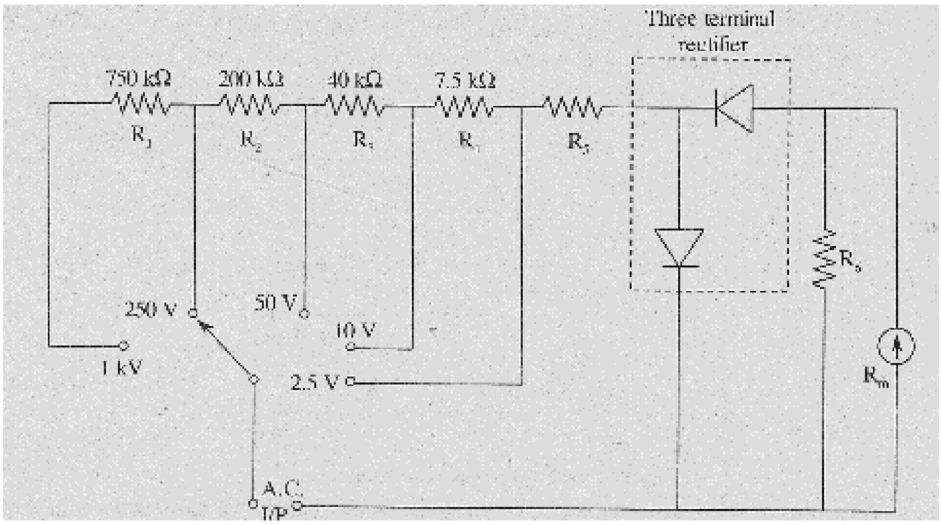

fig 9.1 Multi Range A.C Voltmeter

It avoids the possibility of using the meter in the circuit without a shunt. This is the most important merit of the aryton shunt.

From the above figure, it is noted that the series combination of resistors R_2, R3 and the meter movement is in parallel with R_1 when the switch (SW) is connected to position "1". Therefore, the current through the meter movement is less than the current through the shunt, thereby protecting the meter movement. This reduces the sensitivity of meter movement. The series combination of resistor R_6 and the meter movement is in parallel with resistor R_1, R_2, when the SW is connected to position "2". Therefore, the current through the shunt resistance is less than the current through the meter movement.

The resistors R_1, R_2, and R_3, are together in parallel with meter movement. When the switch is in position "3".Now the current flowing through the shunt is very little whereas the current flowing through the meter is very high. Hence the sensitivity of the meter movement is increases.

10. Explain with a neat block diagram of a dual slope digital voltmeter?
Ans:

Basic Principle:

Initially, the dual slope integrating type DVM integrates the input voltage V_i. The slope of the integrated signal is proportional to the input voltage under measurements .after certain period of time say t_1 the supply of input voltage V_i is stopped, and a negative voltage $-V_r$ of the integrator. Then the output signal of integrator will have negative slope, and is constant and also proportional to the magnitude of the input voltage.

BLOCK DIAGRAM AND WORKING:

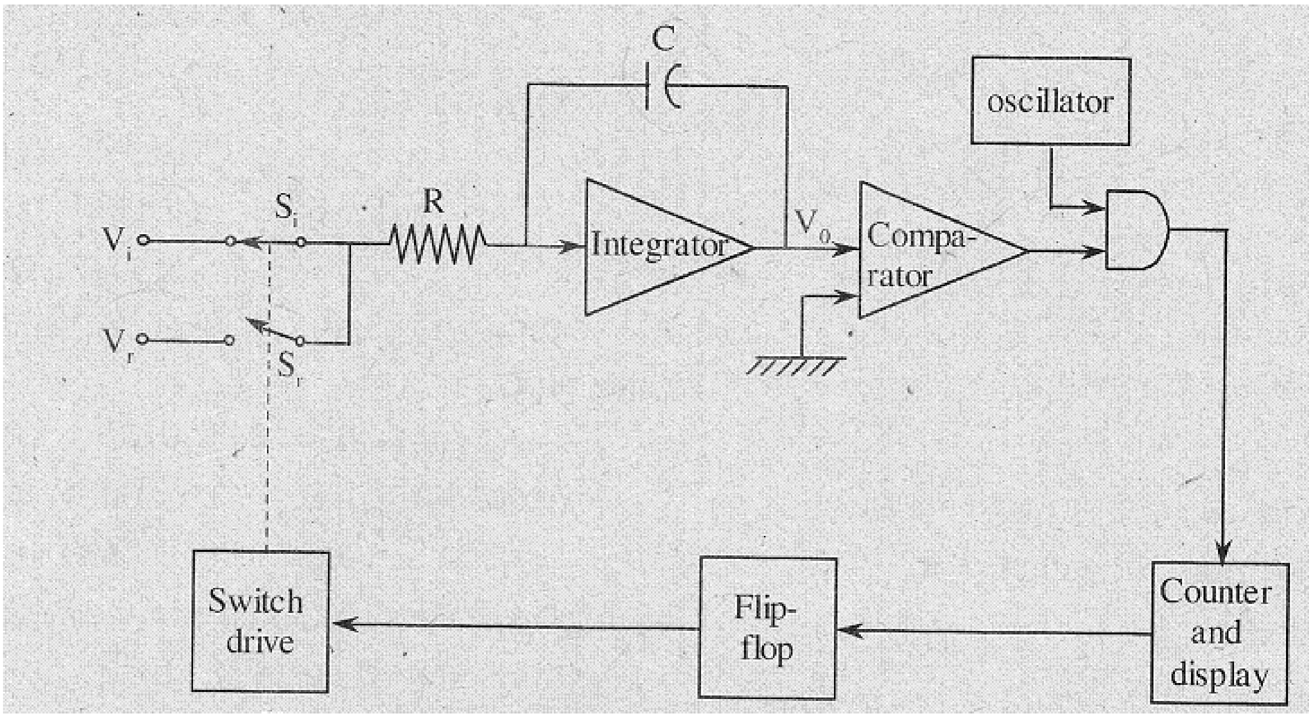

fig 10.1 Block Diagram of Dual slope integrating Type DVM

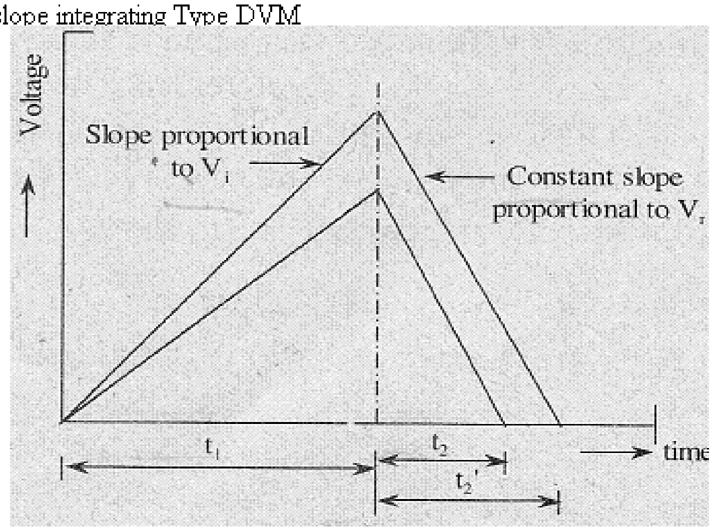

fig 10.2 Basic principle

The major blocks of a dual slope integrating type DVM (dual slope analog to digital converter) are,

1. An op-amp employed as an integrator
2. A level comparator
3. Oscillator for generating time pulses
4. Decimal counter
5. Block of logic circuitry.

Initially a pulse is applied to reset the counter and the output of flip-flop will be at logic '0'. The switch Sr is in open condition and the switch, Si is in closed condition. Now, the capacitor 'C' starts to charge. Once the output of the integrator becomes greater than zero, the output state of the comparator changes which in turn opens the AND gate .When the gate opens the output of the oscillator (clock pulses) are allowed to pass through it and applied to the counter. Now the counter counts the number of pulses fed to it. As soon as it reaches its maximum count that is the counter is preset to run for a time period r,, in this condition the maximum count will be'9999', and for the next immediate clock pulse the count changes or goes to '0000' and the flip-flop will be activated. Therefore, the output of flip flop becomes logic 'I' which in turn activates the switch drive circuitry. This makes the switch S_i, to open and Sr to close (i.e., the supply of Vi will be stopped. and the supply of V is applied to the integrator) with this applied signal the output of the integrator will be a constant negative slope i.e., its output signal linearly decreases to zero. This again makes the output of the comparator to change its state which in turn closes the gate. Here, the discharging time t_2 of the capacitor is proportional to the input voltage signal V_i .During this discharging period the counter indicates the count. As soon as, the negative slope reaches zero volts the comparator changes its output state to 'zero' which in turn locks the gate. Once, the output of integrator becomes zero (or the input of the comparator is zero) the counter will be stopped. And the counted pulses are displayed (which directly gives the input voltage).

From the above equation, it is clear that the measured voltage signal's accuracy does not depend on the time constant of the integrator.

Advantages

1. Depending on the requirement the accuracy and sped can be varied.
2. It can provide the output with an accuracy of +-0.005% in 100ms
3. This technique exhibits excel lent noise rejection since the integration process eliminates both noise and super imposed A.C.

11. Explain the constructional details and differentiate between Ohmmeter series type and shunt type. ?

Ans: ohmmeter (SERIES TYPE OHM METER)

A D'Arsonval movement is connected in series with a resistance R, and a battery which is connected to a pair of terminals A and B, across which the unknown resistance is connected. This forms the basic type of series ohm meter, as shown in the fig 11.

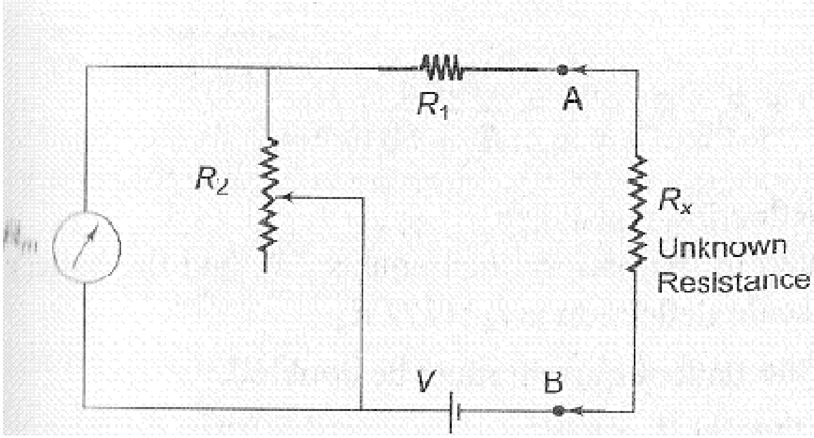

fig 11.1 Series type ohm meter

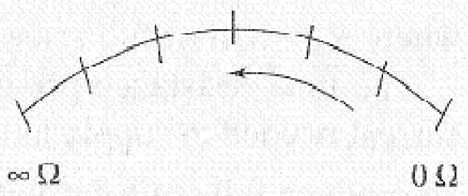

fig 11.2 Dial of series ohm meter

The current flowing through the movement then depends on the magnitude of the unknown resistance. Therefore, the meter deflection is directly proportional to the value of the unknown resistance referring to the figure 11.
R_1: current limiting resistance
R_2: zero adjust resistance
V= battery
R_m =meter resistance
R_x=un know resistance

Calibration of the Series Type Ohmmeter:

To mark the "0" reading on the scale, the terminals A and B are Shorted, i.e. the Unknown resistance Rx=0, maximum current flows in the circuit and the shunt Resistance R_2 is adjusted until the movement indicates full scale current (I_{fsd}). The Position of the pointer on the scale is then marked "0" ohms. Similarly, to mark the "∞" reading on the Scale, terminals *A* and B are open, i.e., the unknown resistance $R_x=\infty$, no current flow in the circuit and there is no deflection of the pointer. The position of the pointer on the scale is then marked as "∞" 0hms.

By connecting different known values of the unknown resistance to terminals *A* and B, intermediate markings can be done on the scale. The accuracy of the Instrument can be checked by measuring different values of standard resistance, i.e., the tolerance of the calibrated resistance, and noting the readings a major drawback in the series ohmmeter is the decrease in voltage of the internal battery with time and age. Due to this, the full scale deflection current Drops and the meter does not read "0" when A and B are shorted. The variable Shunt resistor R_2 across the movement is adjusted to counteract the drop in battery Voltage. There by bringing the pointer back to "0" ohms on the scale'

It is also possible to adjust the full scale deflection current without the shunt R_2 in the circuit, by varying the value of R_1, to compensate for the voltage drop. Since this value affects the calibration of the scale, varying by R_2 is much better solution. The internal resistance of the coil R_m is very low compared to R_1 When R_2 is varied, the current through the movement is increased and the current through R_2 is reduced, thereby bringing the pointer to the full scale deflection position. The series ohmmeter is a simple and popular design, and is used extensively For general services work, Therefore ,in a series ohmmeter the scale marking on the dial has “0” on the right side ,corresponding to full scale deflection current ,and "∞" on the left side corresponding to no current flow as given in the fig 11.1 Values of R_1 and R_2 can be determined from the value of R_x ,which gives half the full scale deflection.