Q.2 a. Define the terms:

Ans.

(i) Accuracy: It is the closeness with which an instrument reading approaches the true value of the quantity being measured.

Accuracy (in percent) =100 - $\%\varepsilon_r$

(ii) Precision: This means when a quantity is measured repeatedly ; the instrument should give the same value i.e. precision is the measure of reproducibility of the- measurements.

(iii) Sensitivity: The ratio of change in the output to the change in the input, which causes after the steady state has reached, is known as sensitivity of an instrument.

(iv) Resolution: The least interval between two adjacent discrete details, which can be distinguished one from other is called "Resolution" of the instrument.

(v) Linearity: The amount of error change throughout an instrument's measurement range. Linearity is also the amount of deviation from an instrument's ideal straight-line performance.

b. A 0-25A ammeter has a guaranteed accuracy of 1 percent of full scale reading. The current measured by this instrument is 10A. Determine the limiting error in percentage.

Ans. The magnitude of limiting error of the instrument,

$\delta A = \varepsilon_r \times f.s.d = 0.01 \times 25 = 0.25$ amperes

$\varepsilon_{r(\text{of measured value})} = \delta A/A_m = 0.25/10 = 0.025$

Therefore, the current being measured is between the limits of

$A = A_m(1 \pm \varepsilon_r) = 10(1 \pm 0.025) = 10 \pm 0.25$ amperes

% Limiting error =$(0.25/10)\times 100 = 2.5\%$

Q.3 a. List the applications of Wheatstone bridge and explain its limitations?

Ans. <u>Applications of Wheatstone bridge</u>

1. The basic application of a Wheatstone bridge is measurement of resistance. It is used to measure medium resistance values.

2. It can also be used to measure inductance and capacitance values.

3. Various industrial applications involve measurement of physical quantities (such as temperature, pressure, displacement etc) in terms of electrical resistance. The various industrial applications in which a Wheatstone bridge is used are.

I. Temperature measurement systems involving electrical resistance thermometers as temperature sensors.
II. Pressure measurement systems involving strain gauge as secondary transducer.
III. Measurement of static and dynamic strains.
IV. It is used with explosive meter to measure the amount of combustible gases in a sample.
V. Temperature measurement systems involving electrical resistance thermometers as temperature sensors.
VI. Pressure measurement systems involving strain gauge as secondary transducer.

4. Measurement of static and dynamic strains.

5. It is used with explosive meter to measure the amount of combustible gases in a sample.

<u>Limitations of Wheatstone bridge</u>

1. Wheatstone bridge is not suitable for measuring low resistances because the resistance of leads and contacts of the bridge cause errors in the value measured by the Wheatstone bridge and thus affects the measurement of low resistances.

2. Wheatstone bridge cannot be used for measurement of high resistance also, because a galvanometer is not sensitive to the imbalance of the bridge caused by the high resistance of the bridge. This problem can be overcome by replacing the galvanometer with a Vacuum Type Volt Meter (VTVM) and by replacing the battery with a power supply.

3. A Wheatstone bridge cannot be used in high temperature or temperature-varying environment because the resistance of the arms of the bridge changes due to change in temperature.

4. The resistance of the bridge arms also changes due to heating effect of the current passing through the resistance. Flow of very large current through the resistors leads to a permanent change of resistance value.

b. Draw the useful modification of the Maxwell’s inductance capacitance bridge circuit and derive the expression for the unknown element at balance?

Ans. Maxwell's bridge, shown in Fig. 1.1, measures an unknown inductance in of standard arm offers the advantage of compactness and easy shielding. The capacitor is almost a loss-less component. One arm has a resistance *Rx* in parallel with *Cu* and hence

it is easier to write the balance equation using the admittance of arm 1 instead of the impedance.
The general equation for bridge balance is

$$Z_x = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 Y_1$$

$$Z_1 = R_1 \text{ in parallel with } C_1 \text{ i.e. } Y_1 = \frac{1}{Z}$$

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

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_x = R_x \text{ in series with } L_x = R_x + j\omega L_x$$

From equation of *Zx* we get,

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

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

Equating real terms and imaginary terms we have,

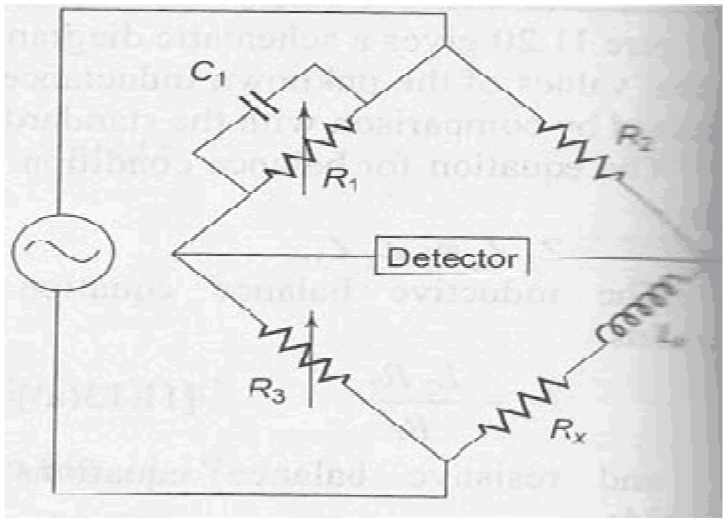
$$R_x = \frac{R_2 R_3}{R_1} \text{ and } L_x = C_1 R_2 R_3$$

Also,

$$Q = \frac{\omega L_x}{R_x} = \frac{\omega C_1 R_2 R_3 \times R_1}{R_2 R_3} = \omega C_1 R_1$$

Maxwell's bridge is limited to the measurement of low *Q* values (1 -10).The measurement is independent of the excitation frequency. The scale of the resistance can be calibrated to read inductance directly.
The Maxwell Bridge using a fixed capacitor has the disadvantage that there an interaction between the resistance and reactance balances. This can be avoids: by varying the capacitances, instead of *R2* and ft, to obtain a reactance balance. However, the bridge can be made to read directly in *Q*.

The bridge is particularly suited for inductances measurements, since comparison on with a capacitor is more ideal than with another inductance. Commercial bridges measure from 1 – 1000H. With ± 2% error (If the *Q* is very becomes excessively large and it is impractical to obtain a satisfactory variable standard resistance in the range of values required).



Maxwell's Bridge

Q.4 a. Explain the principle of operation of a dc - voltmeter and a multi range voltmeter.

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

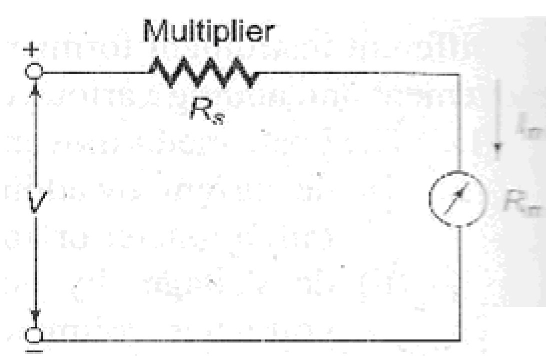


fig 4.a.(i) Basic Voltmeter

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

$V= Im * (Rm+ Rs)$

$Rs = (V-I_m R_m)/I_m$

Therefore Rs =V/Im –Rm

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

Multi range Voltmeter

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

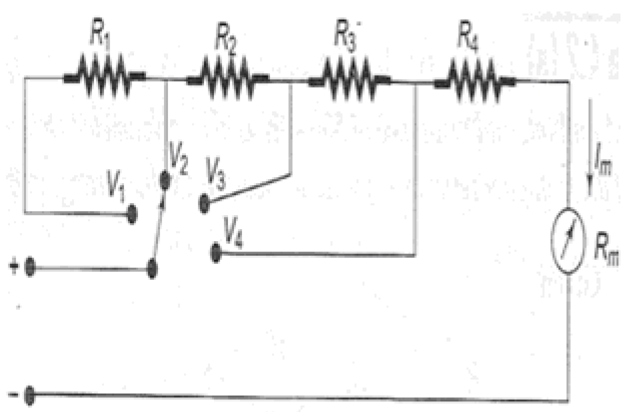


fig 4.a.(ii) Multiplier Connected in Series String

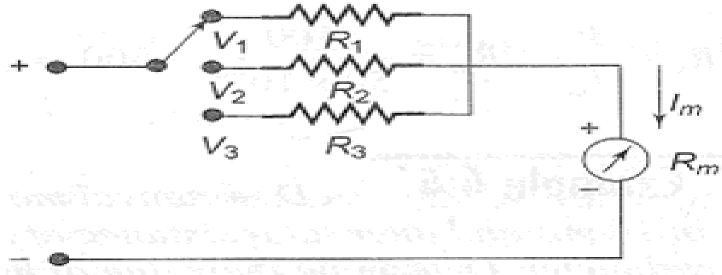


fig.4.a.(iii) Multirange Voltmeter

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.

Q4 b. Explain how the range of a dc-ammeter and a dc voltmeter can be extended?

Ans. Page No. 63, 75 of Textbook 'Electronic Instrumentation' by H.S. Kalsi.

Q.5 a. Explain the working of a dual slope integrating type digital voltmeter with the help of a neat block diagram.

Ans. Basic Principle:

Initially, the dual slope integrating type DVM integrates the input voltage Vi. The slope of the integrated signal is proportional to the input voltage under measurements .after certain period of time say *t1* the supply of input voltage Vi is stopped, and a negative voltage -Vr 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:

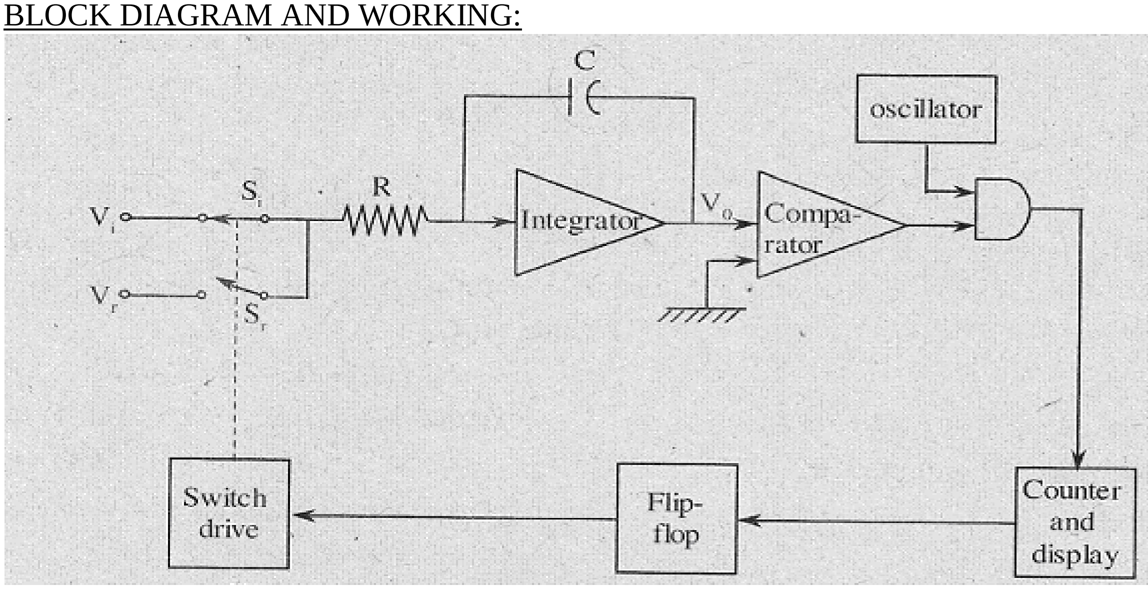


fig.5.a. Block Diagram of Dual Slope integrating Type DVM

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.

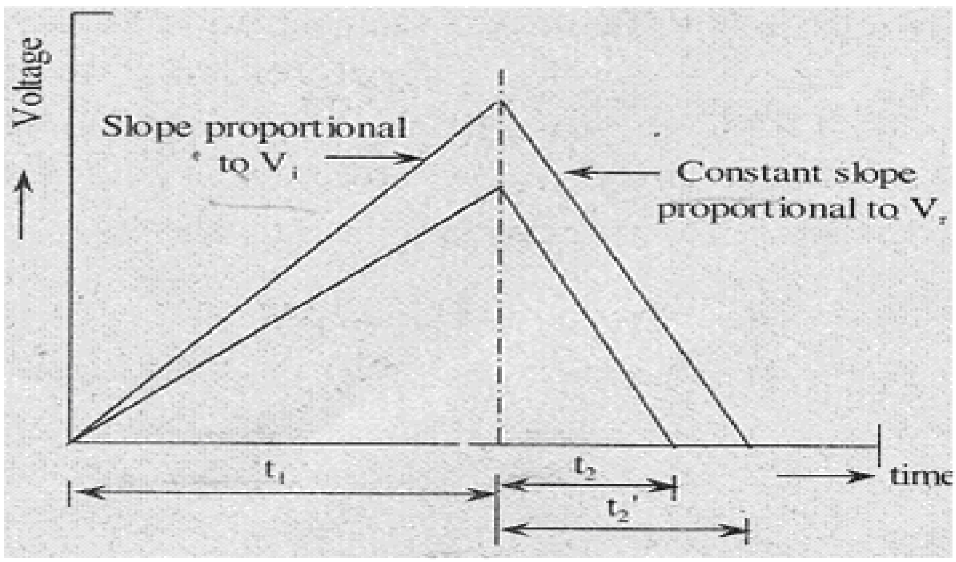


fig. 5. a. (ii) Basic Principle

Q.6 a. Describe the working of a standard signal generator. How can a sine wave and a square wave be generated using the signal generator?

Ans. A standard signal generator produces known and controllable voltages. It is used as power source for the measurement of gain, signal to noise ratio (SN), bandwidth standing wave ratio and other properties. It is extensively used in the measuring of radio receivers and transmitter instrument is provided with a means of modulating the carrier frequency, which is indicated by the dial setting on the front panel. The modulation is indicated by a meter. The output signal can be Amplitude Modulated (AM) or Frequency Modulated (FM). Modulation may be done by a sine wave, Square, rectangular, or a pulse wave. The elements of a conventional signal generator

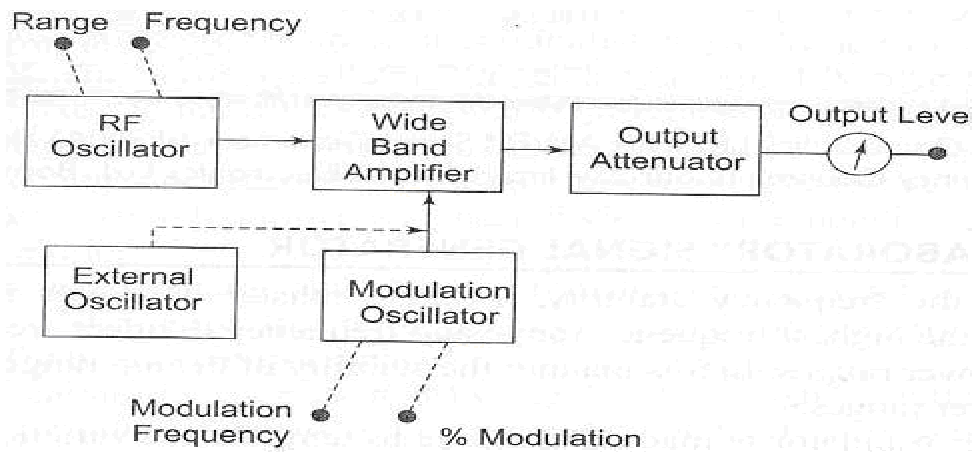


fig.6.a. conventional Signal generator

The carrier frequency is generated by a very stable RF oscillator using an LC tank circuit, having a constant output over any frequency range. The frequency of oscillations is indicated by the frequency range control and the venire dial setting. AM is provided by an internal sine wave generator or from an external source.

The signal generator is called an oscillator. A Wien bridge oscillator is used in this generator. The Wien bridge oscillator is the best of the audio frequency range. The frequency of oscillations can be changed by varying the capacitance in the oscillator. The frequency can also be changed in steps by switching the resistors of different values. The output of the Wien bridge oscillator goes to the function switch. The function switch directs the oscillator output either to the sine wave amplifier or to the square wave shaper. At the output, we get either a square or sine wave. The output is varied by means of an attenuator.

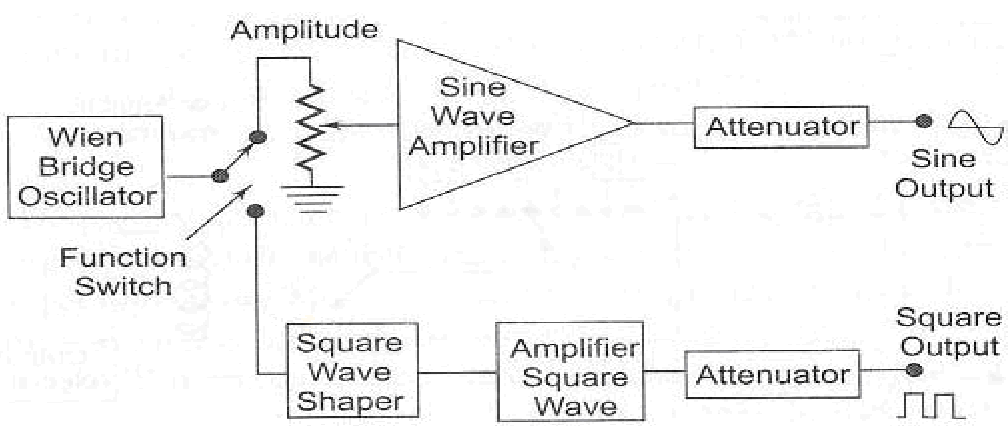


fig.6.a.(ii) AF sine & Square wave generator

The instrument generates a frequency ranging from 10 Hz to 1 MHz continuously variable in 5 decades with overlapping ranges. The output sine wave amplitude can be varied from 5 mV to 5 V (rms).The output is taker through a push-pull amplifier. For low output, the impedance is 6000. The square wave amplitudes can be varied from 0 - 20 v (peak). It is possible to adjust the symmetry of the square wave from 30 - 70%. The instrument requires only 7W of power at 220V, 50Hz.

b. Explain about storage oscilloscope with the help of a block diagram

Ans. Storage targets can be distinguished from standard phosphor targets by their ability to retain a waveform pattern for a long time, independent of phosphor persistence. Two storage techniques are used in oscilloscope CRTs, mesh storage and phosphor storage.

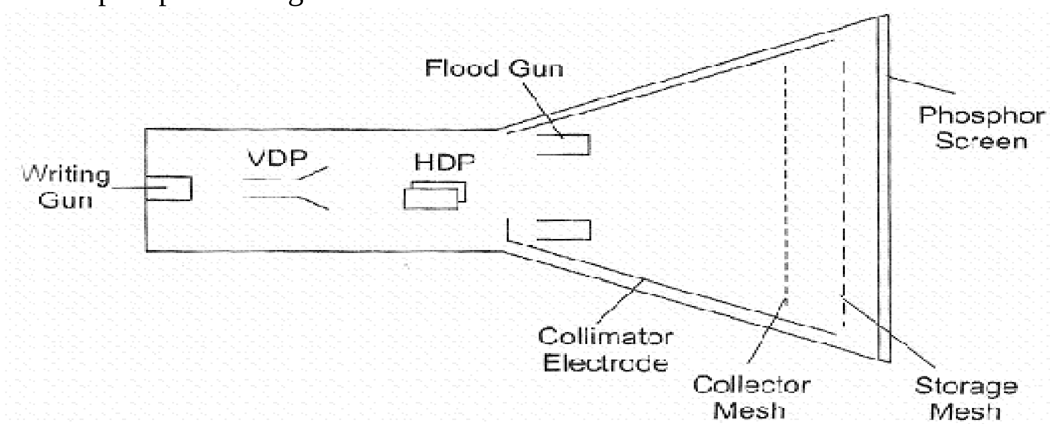


fig 6.b Basic Elements of storage mesh CRT

A mesh storage CRT, shown in Fig. contains a dielectric material deposed on a storage mesh, a collector mesh, flood guns and a collimator, in addition BO all the elements of a standard CRT. The storage target, a thin deposition of a dielectric material such as Magnesium Fluoride on the storage mesh, makes use of a property known as secondary emission. The writing gun etches a positively charged pattern on the storage mesh or target by knocking off secondary emission electrons. Because of the excellent insulating property of the Magnesium fluoride coating, this positively charged pattern remains exactly in the position where it is deposited. In order to make a pattern visible, a special electron gun, called the flood gun, is switched on (even after many hours). The electron paths ire adjusted by the collimator electrode, which constitutes a low voltage electrostatic lens system (to focus the electron beam), as shown in Fig. 1.2. Most of the electrons are stopped and collected by the collector mesh. Only electrons near the stored positive charge are pulled to the storage target with sufficient force to hit the phosphor screen. The CRT will now display the signal and it will remain visible as long as the flood guns operate. To erase the pattern on the storage mesh, a negative voltage is applied to neutralize the stored positive charge.

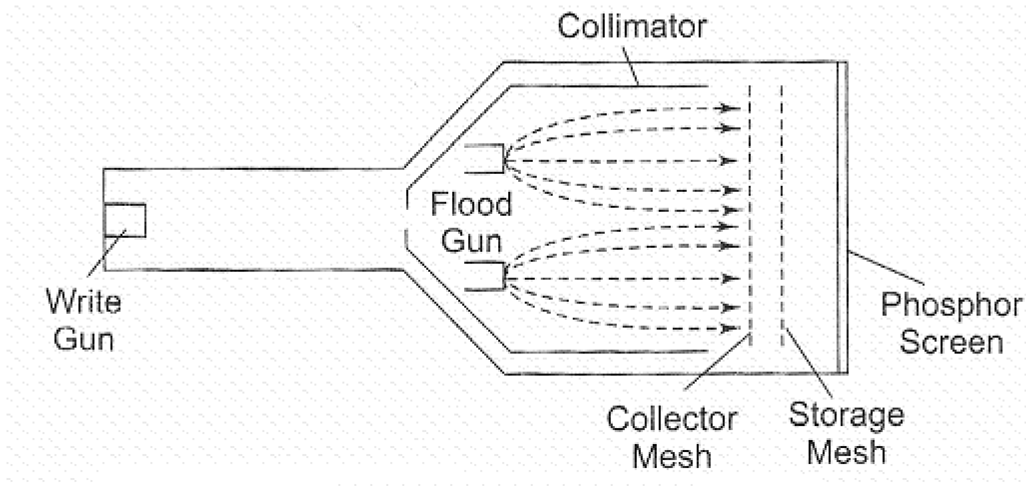


fig6.b.(ii) Storage mesh CRT

Since the storage mesh makes use of secondary emission, between the first and second crossover more electrons are emitted than are absorbed by the material, and hence a net positive charge results.

Below the first crossover a net negative charge results, since the impinging electrons do not have sufficient energy to force an equal number to be emitted. In order to store a trace, assume that the storage surface is uniformly charge; and write gun (beam emission gun) will hit the storage target. Those areas of the storage surface hit by the deflecting beam lose electrons, which are collects by the collector mesh. Hence, the write beam deflection pattern is traced on the storage surface as a positive charge pattern. Since the insulation of the dielectric material is high enough to prevent any loss of charge for a considerable length of time, the pattern is stored. To view, the stored trace, a flood gun is used when the write gun is turned off. The flood gun, biased very near the storage mesh potential, emits a flood of electrons which move towards the collector mesh, since it is biased slightly more positive than the deflection region. The collimator ,a conductive coating on the CRT envelope with an applied potential, helps to align the flood electrons so that they approach the storage target perpendicularly When the electrons penetrate beyond the collector mesh, they encounter either a positively charged region on the storage surface or a negatively charged region where no trace has been stored. The positively charged areas allow the electrons to pass through to the post accelerator region and the display target phosphor. The negatively charged region repels the flood electrons back to the collector mesh. Thus the charge pattern on the storage surface appears reproduced on the CRT display phosphor just as though it were being traced with a deflected bea

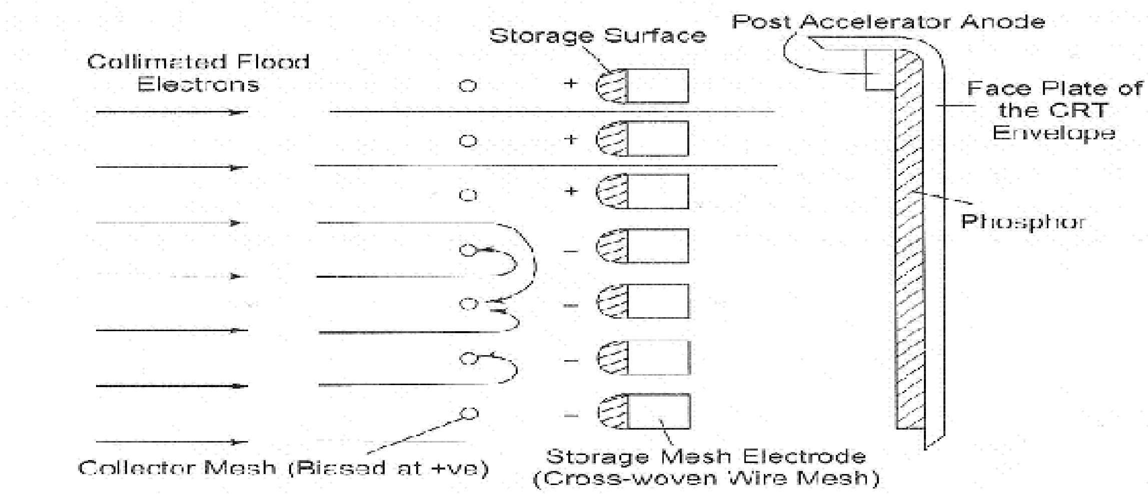


fig6.b.(iii) Display of stored charge pattern on mesh

Q.7 a. Draw the Block Schematic of AF Wave analyzer. Explain its principle of operation and working?

Ans. The wave analyzer consists of a very narrow pass-band filter section which can be tuned to a particular frequency within the audible frequency range (20Hz to 20 KHz).

The block diagram of a wave analyzer is as shown in fig.

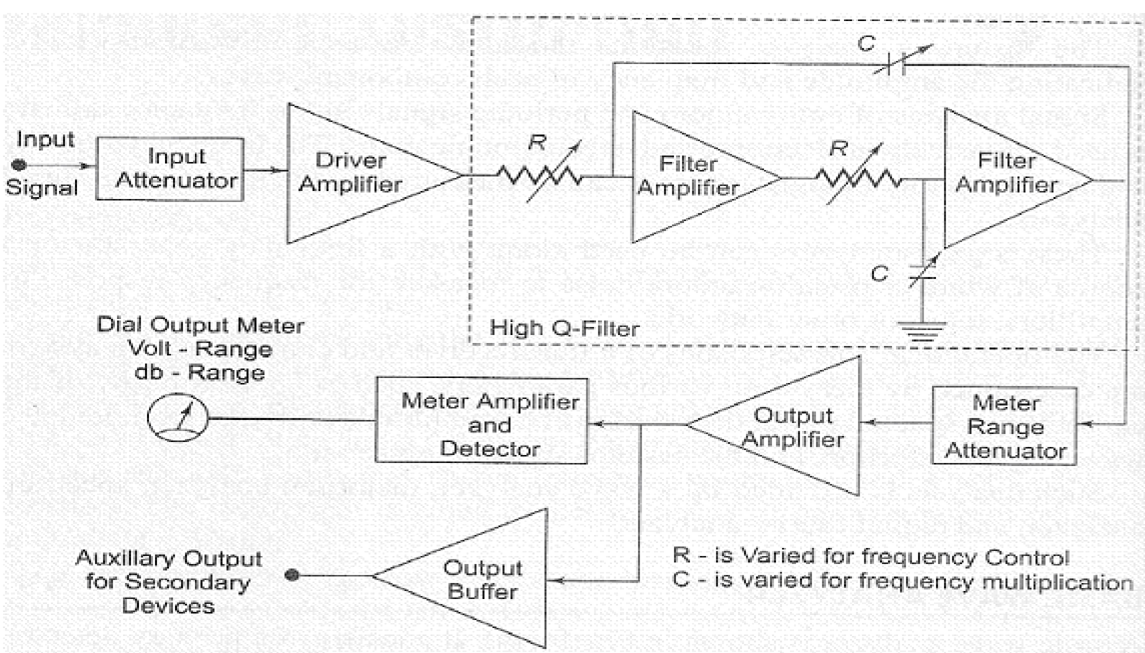


fig.7.a. frequency wave analyser

The complex wave to be analyzed is passed through an adjustable attenuator, which serves as a range multiplier and permits a large range of signal amplitudes to be analyzed without loading the amplifier

The output of the attenuator is then fed to a selective amplifier, which amplifies the selected frequency. The driver amplifier applies the attenuated input signal to a high-Q active filter. This high-Q filter is a low pass filter, which allows the frequency, which is selected to pass and reject all others. The magnitude of this selected frequency is indicated by the meter and the filter section identifies the frequency of the component. The filter circuit consists of a cascaded RC resonant circuit and amplifiers. For selecting the frequency range, the capacitors generally used are of the closed tolerance polystyrene type and the resistances used are precision potentiometers. The capacitors are used for range changing and the potentiometer is used to change the frequency within the selected pass-band, hence this wave analyzer is also called a Frequency selective voltmeter. The entire AF range is covered in decade steps by switching capacitors in the RC section.

The selected signal output from the final amplifier stage is applied to the meter circuit and to an unturned buffer amplifier. The main function of the buffer amplifier is to drive output devices, such as recorders or electronics counters. The meter has several voltage ranges as well as decibel scales marked on it. It is driven by an average reading rectifier type detector. The wave analyzer must have extremely low input distortion, undetectable by the analyzer itself. The band width of the instrument is very narrow typically about 1% of the selective band given by the following response characteristics shows in fig.

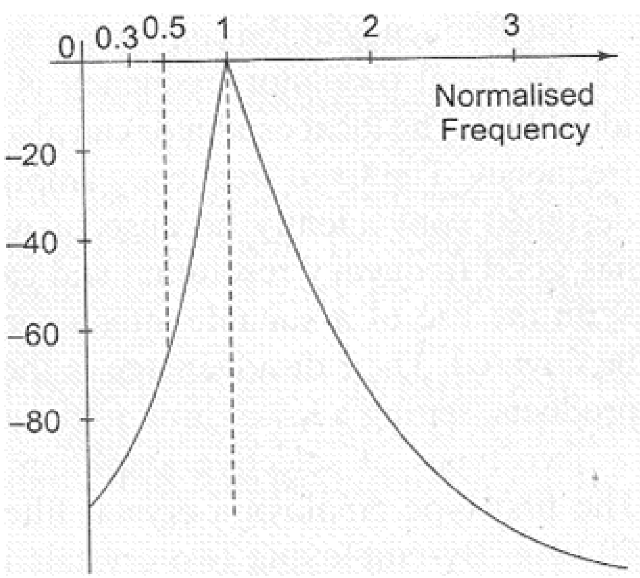


fig7.a.(ii) Relative response in db

b. Differentiate between a wave analyzer and a harmonic distortion analyzer.

Ans.

Wave analyzer	Harmonic distortion analyzer
1. These are designed to measure the relative amplitude of each harmonic or fundamental component separately.	1. These are designed to measure the total harmonic content present in a distorted or complex wave form.
2.They indicate the amplitude of single frequency component	2. They do not indicate the amplitude of single frequency component
3.These are tuned to measure amplitude of one frequency component with in a range of 10Hz to 40MHz	3.These can be operated with in a band of 5Hz to 1 MHz frequency
4.These are also known as frequency selective voltmeters, selective level voltmeters, carrier frequency voltmeters	4.It is general know as distortion analyzer
5. These are used with a set of tuned filters and a voltmeter.	5. These can be used along with a frequency generator.
6. Wave analyzers provide very high frequency resolution.	6. They measure quantitative harmonic distortions very accurately.7.
7.These can be used for electrical measurements, sound, vibration, noise measurement in industries	7. These can be used to measure frequency stability and spectral purity of signal sources

Q.8 a. Describe the working of potentiometric type recorder.

Ans. Potentiometric recorders have much better specifications than galvanometric recorders, with a typical inaccuracy of š0.1% of full scale and measurement resolution of 0.2% f.s. being achievable. Such instruments employ a servo system, as shown in Figure, in which the pen is driven by a servomotor, and a potentiometer on the pen feeds back a signal proportional to pen position. This position signal is compared with the measured signal, and the difference is applied as an error signal that drives the motor. However, a consequence of this electromechanical balancing mechanism is to give the instrument a slow response time in the range 0.2–2.0 seconds. This means that potentiometric recorders are only suitable for measuring dc and slowly time-varying signals. In addition, this type of recorder is susceptible to commutator problems when a standard dc motor is used in the servo system. However, the use of brushless servomotors in many recent models overcomes this problem. Newer models also often use a non-contacting ultrasonic sensor to provide feedback on pen position in place of a potentiometer.

b. Explain the capacitive transducer arrangement to measure angular velocity. What are its limitations?

Ans. The arrangement of capacitive transducer in the arrangement of angular velocity is shown in figure

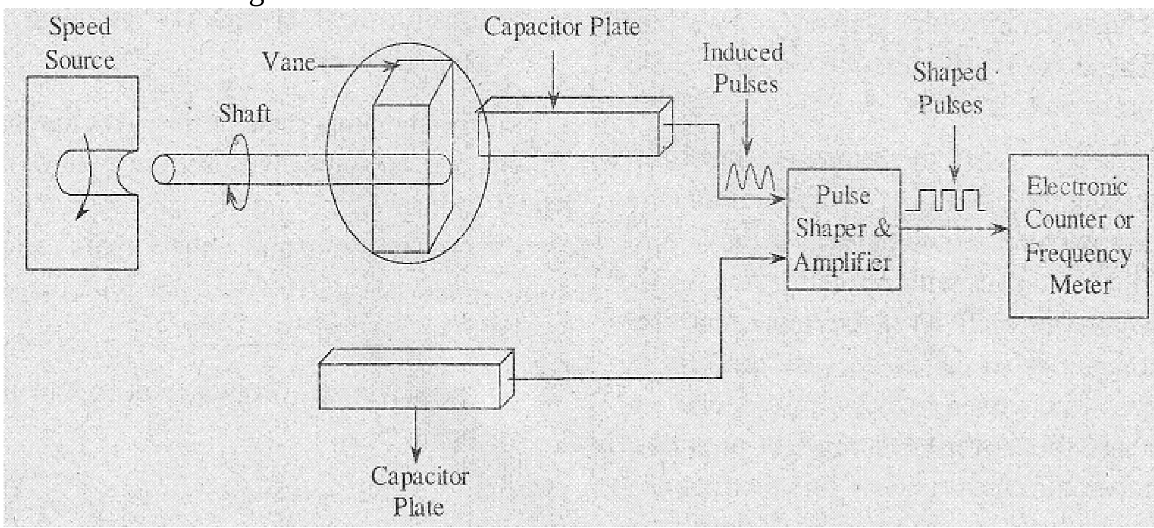


fig.8.b. Capacitive Transducer

The main components of a capacitive tachometer arrangement are given as follows:

1. Fixed capacitor plates
2. A vane attached to one of the two ends of a shaft
3. A pulse shaper and amplifier circuit
4. An electronic counter or frequency meter.

The vane is placed between the two fixed plates of capacitor and the free end of the shaft is connected to the source whose angular velocity is to be determined. Therefore the shaft rotates along with the source, which in turn rotates the vane between the plates. Due to this the capacitance of the capacitor changes. For every rotation of the vane a change in capacitance takes place and for every changed capacitance value, a voltage pulse is induced. The number of times the capacitance value changes per unit time gives the angular velocity of the rotating shaft.

The induced pulses are applied to pulse shaper and amplifier circuit which shapes the pulses into accurate pulses and then amplifies the pulses. These shaped and amplified pulses are then applied to electronic counter which counts the number of pulses. The counted number of pulses directly gives the value of angular velocity.

Limitations:

1. Capacitive transducers are highly sensitive to temperature. Therefore any variation in temperature affects the performance of the instrument.
2. High output impedance of capacitive transducers lead to loading effects.

Q.9 a. Explain the working of a semiconductor strain gauge. What are its specific advantages?

Ans. A typical semiconductor strain gauge is formed by the semiconductor technology i.e., the semi conducting wafers or filaments of length varying from 2 mm to 10 mm and thickness of 0.05 mm are bonded on suitable insulating substrates (for example Teflon). The gold leads are usually employed for making electrical contacts. The electrodes are formed by vapour deposition. The assembly is placed in a protective box as shown in the figure below.

The strain sensitive elements used by the semiconductor strain gauge are the semiconductor materials such as silicon and germanium. When the strain is applied to the semiconductor element a large of change in resistance occur which can be measured with the help of a wheatstone bridge. The strain can be measured with high degree of accuracy due to relatively high change in resistance. A temperature compensated semiconductor strain gauge can be used to measure small strains of the order of 10-6 i.e., micro-strain. This type of gauge will have a gauge factor of 130 ± 10% for a semiconductor material of dimension 1 x 0.5 x 0.005 inch having the resistance of 350 Ω.

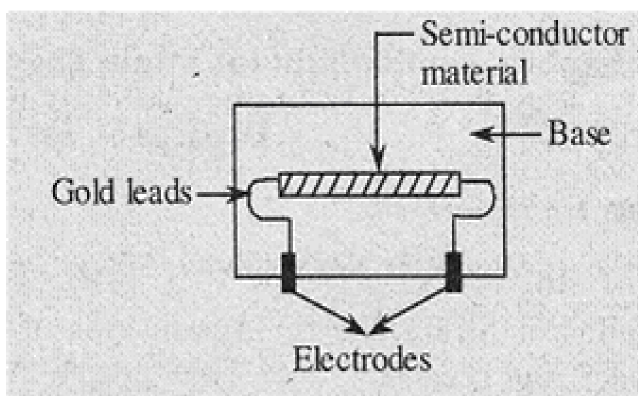


fig.9.a. Semiconductor Strain guage

Advantages of Semiconductor Strain Gauge:

1. The gauge factor of semiconductor strain gauge is very high, about ±130.
2. They are useful in measurement of very small strains of the order of 0.01 micro-strains due to their high gauge factor.
3. Semiconductor strain gauge exhibits very low hysteresis i.e., less than 0.05%.
4. The semiconductor strain gauge has much higher output, but it is as stable as a metallic strain gauge.
5. It possesses a high frequency response of 1012 Hz.
6. It has a large fatigue life i.e., 10 x 106 operations can be performed.
7. They can be manufactured in very small sizes, their lengths ranging from 0.7 to 7.0 mm.

b. Explain the general data acquisition system (DAS) with the help of a neat block diagram?

Ans. The block diagram of a general Data Acquisition System (DAS) is shown in the figure below:

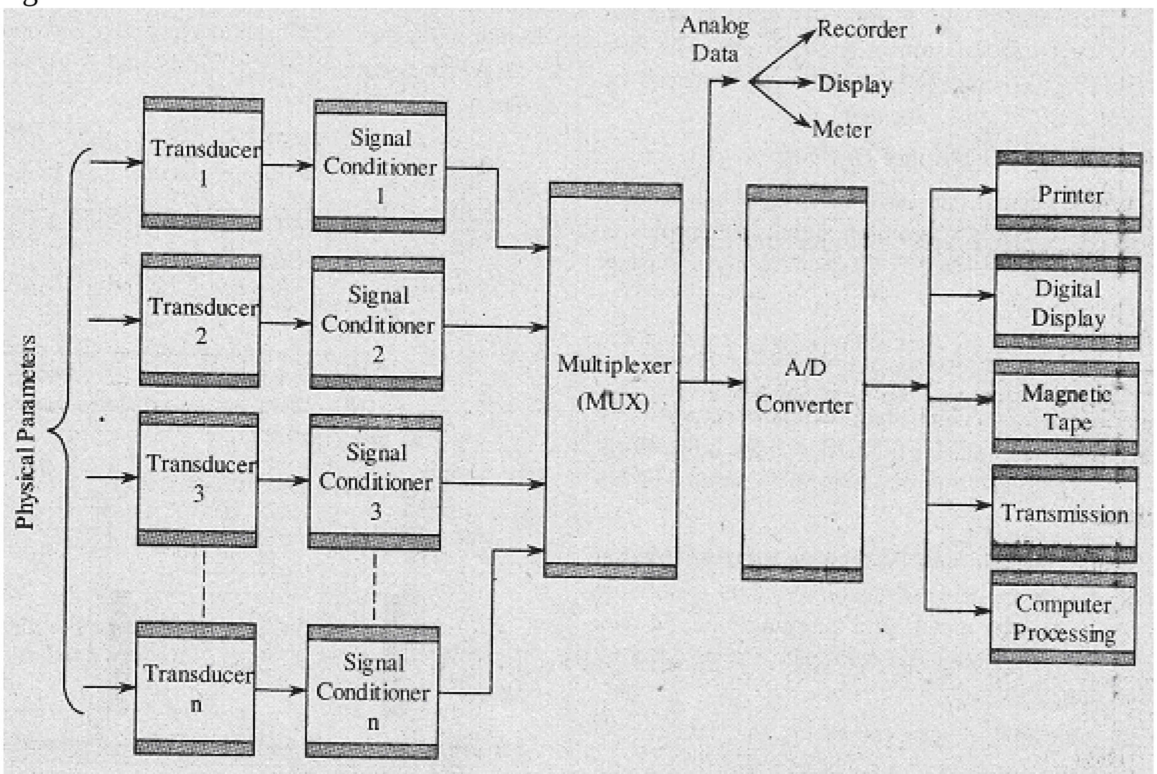


fig.9.b. Generalised Data Acquistion System

It consists of the following elements:
1. Transducer
2. Signal conditioner
3. Multiplexer
4. Analog to Digital Converter
5. Recorders and Display devices

1. Transducer
A transducer is used to convert the physical parameters corning from the field into electrical signals or it is used to measure directly the electrical quantities such as resistance, voltage, frequency, etc.

2. Signal Conditioner
Usually the output signals of the transducer will be of very low level (weak) signals, which cannot be used for further processing. In order to make the signals strong enough to drive the other elements signal conditioners such as amplifiers, modifiers, filters etc., are used.

3. Multiplexer
The function of the multiplexer is to accept multiple analog inputs (after signal conditioning) and provide a single output sequentially according to the requirements.

4. A/D Converter
The analog-to-digital (A/D) converter is generally used to convert the analog data into digital form. The digital data is used for the purpose of easy processing, transmission, digital display and storage.

Processing involves various operations on data such as comparison, mathematical manipulations, data is collected, converted into useful form and utilized for various purposes like for control operation and display etc. The transmission of data in digital form is possible over short distances as well as long distances of and has advantages over transmission in analog form. The data can be stored permanently or temporarily and can be displayed on a CRT or digital panel.

5. Recorders and Display Devices
In display devices the data is displayed in a suitable form in order to monitor the input signals. Examples of display devices are oscilloscopes, numerical displays, panel meters, etc.

In order to have either a temporary or permanent record of the useful data recorders are used. The analog data can be recorded either graphically or on a magnetic tape. Optical recorders, ultraviolet recorders, styles-and-ink recorders are some of its examples. The digital data can be recorded through digital recorders. The digital data is first converted into a suitable form for recording by means of a coupling unit and then recorded on a magnetic tape, punched cards or a perforated paper tape.

Text Books

1. **A Course in Electrical and Electronics Measurements and Instrumentation, A.K. Sawhney, Dhanpat Rai & Co., New Delhi, 18th Edition 2007**

2. **Electronic Instrumentation, H.S. Kalsi, Tata McGraw Hill, Second Edition 2004**