UNIT-IV: ELECTRONIC MEASUREMENTS: Signal generators: Function Generator, RF Signal Generator, Random Noise Generator, Sweep generators, Wave Analyzer- Harmonic, Distortion Analyzer - Spectrum Analyzer - DC & AC Voltmeters, Digital Voltmeters, Electronic Multi meters, VOM meters. Measurement of physical parameters force, pressure, velocity, humidity and Data acquisition systems.

FUNCTION GENERATOR

A function generator produces different waveforms of adjustable frequency. The common output waveforms are the sine, square, triangular and sawtooth waves. The frequency may be adjusted, from a fraction of a Hertz to several hundred kHz.

The various outputs of the generator can be made available at the same time. For example, the generator can provide a square wave to test the linearity of an amplifier and simultaneously provide a sawtooth to drive the horizontal deflection amplifier of the CRO to provide a visual display.

Capability of Phase Lock The function generator can be phase locked to an external source. One function generator can be used to lock a second function generator, and the two output signals can be displaced in phase by adjustable amount. In addition, the fundamental frequency of one generator can be phase locked to a harmonic of another generator, by adjusting the amplitude and phase of the harmonic, almost any waveform can be generated by addition. The function generator can also be phase locked to a frequency standard and all its output waveforms will then have the same accuracy and stability as the standard source.

The block diagram of a function generator is illustrated in Fig. 8.5. Usually the frequency is controlled by varying the capacitor in the LC or RC circuit. In this instrument the frequency is controlled by varying the magnitude of current which drives the integrator. The instrument produces sine, triangular and square waves with a frequency range of 0.01 Hz to 100 kHz.

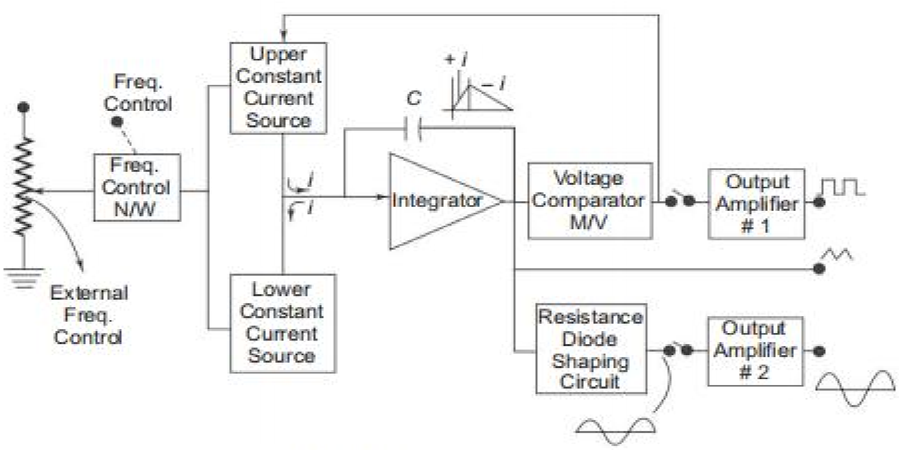


Fig. 8.5 Function generator

The frequency controlled voltage regulates two current sources. The upper current source supplies constant current to the integrator whose output voltage increases linearly with time, according to the equation of the output signal voltage.

$$e_{out} = -\frac{1}{C}\int_0^t i\,dt$$

An increase or decrease in the current increases or decreases the slope of the output voltage and hence controls the frequency. The voltage comparator multivibrator changes states at a pre-determined maximum level of the integrator output voltage. This change cuts off the upper current supply and switches on the lower current supply. The lower current source supplies a reverse current to the integrator, so that its output decreases linearly with time. When the output reaches a pre-determined minimum level, the voltage comparator again changes state and switches on the upper current source.

The output of the integrator is a triangular waveform whose frequency is determined by the magnitude of the current supplied by the constant current sources. The comparator output delivers a square wave voltage of the same frequency. The resistance diode network alters the slope of the triangular wave as its amplitude changes and produces a sine wave with less than 1% distortion

RF SIGNAL GENERATOR

A standard signal generator produces known and controllable voltages. It is used as power source for the measurement of gain, signal to noise ratio (S/N), bandwidth, standing wave ratio and other properties. It is extensively used in the testing of radio receivers and transmitters.

The 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 wave, triangular wave or a pulse. The elements of a conventional signal generator are shown in Fig. 8.2 (a).

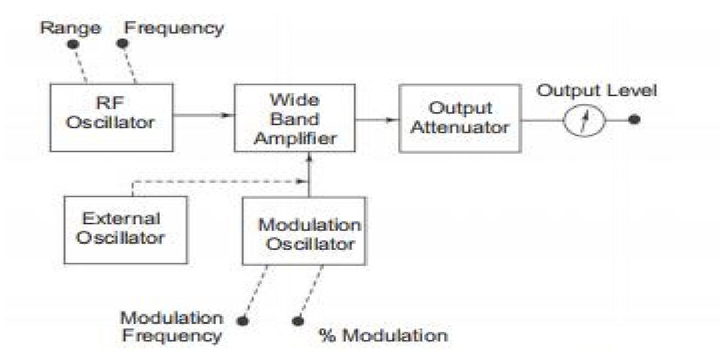


Fig. 8.2 (a) Conventional standard signal generator

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 vernier dial setting. AM is provided by an internal sine wave generator or from an external source.

Frequency stability is limited by the LC tank circuit design of the master oscillator. Since range switching is usually accomplished by selecting appropriate capacitors, any change in frequency range upsets the circuit design to some extent and the instrument must be given time to stabilise at the new resonant frequency.

In high frequency oscillators, it is essential to isolate the oscillator circuit from the output circuit. This isolation is necessary, so that changes occurring in the output circuit do not affect the oscillator frequency, amplitude and distortion characteristics. Buffer amplifiers are used for this purpose.

RANDOM NOISE GENERATOR

A simplified block diagram used in the audio frequency range is shown in Fig. 8.8. The instrument offers the possibility of using a single measurement to indicate performance over a wide frequency band, instead of many measurements at one frequency at a time.

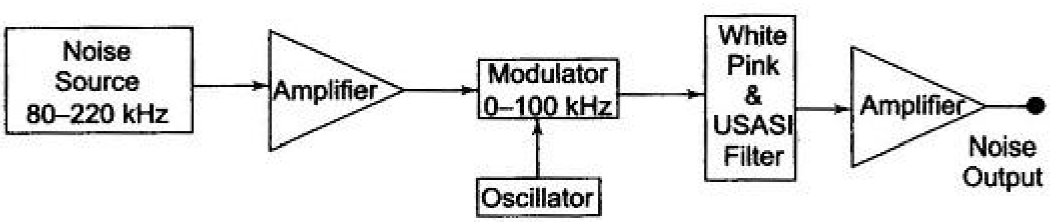


Fig. 8.8 Random Noise Generator

The spectrum of random noise covers all frequencies and is referred to as White noise, i.e. noise having equal power density at all frequencies (an analogy is white light). The power density spectrum tells us how the energy of a signal is distributed in frequency, but it does not specify the signal uniquely, nor does it tell us very much about how the amplitude of the signal varies with.

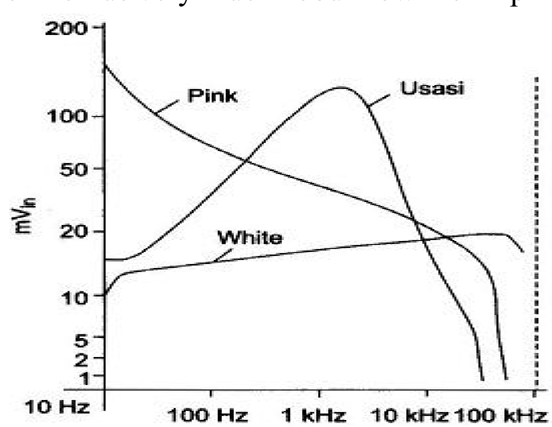


Fig. 8.9 Frequency Response

The instrument offers the possibility of using a single measurement to indicate performance over a wide frequency band, instead of many measurements at one frequency at a time. The spectrum of random noise covers all frequencies and is referred to as White noise, i.e. noise having equal power density at all frequencies (an analogy is white light). The power density spectrum tells us how the energy of a signal is distributed in frequency, but it does not specify the signal uniquely, nor does it tell us very much about how the amplitude of the signal varies with.

SWEEP GENERATOR

It provides a sinusoidal output voltage whose frequency varies smoothly and continuously over an entire frequency band, usually at an audio rate. The process of frequency modulation may be accomplished electronically or mechanically. It is done electronically by using the modulating voltage to vary the reactance of the oscillator tank circuit component, and mechanically by means of a motor driven capacitor, as provided for in a modern laboratory type signal generator. Figure 8.10 shows a basic block diagram of a sweep generator.

The frequency sweeper provides a variable modulating voltage which causes the capacitance of the master oscillator to vary. A representative sweep rate could be of the order of 20 sweeps/second. A manual control allows independent adjustment of the oscillator resonant frequency.

The frequency sweeper provides a varying sweep voltage for synchronisation to drive the horizontal deflection plates of the CRO. Thus the amplitude of the response of a test device will be locked and displayed on the screen.

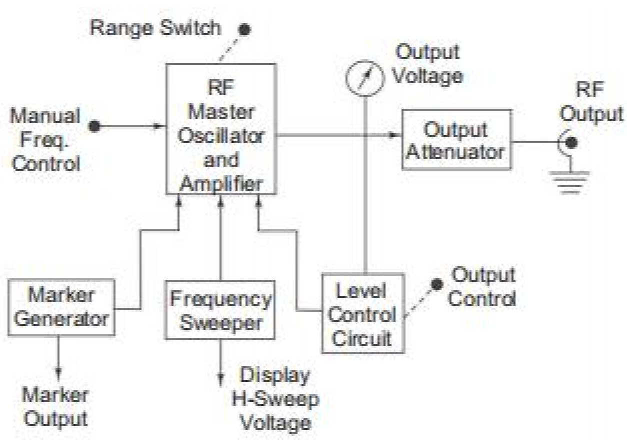


Fig. 8.10 Sweep generator

To identify a frequency interval, a marker generator provides half sinusoidal wave forms at any frequency within the sweep range. The marker voltage can be added to the sweep voltage of the CRO during alternate cycles of the sweep voltage, and appears superimposed on the response curve.

The automatic level control circuit is a closed loop feedback system which monitors the RF level at some point in the measurement system. This circuit holds the power delivered to the load or test circuit constant and independent of frequency and impedance changes. A constant power level prevents any source mismatch and also provides a constant readout calibration with frequency.

BASIC WAVE ANALYZER

A basic wave analyzer is shown in Fig. 9.1(a). It consists of a primary detector, which is a simple LC circuit. This LC circuit is adjusted for resonance at the frequency of the particular harmonic component to be measured. The intermediate stage is a full wave rectifier, to obtain the average value of the input signal.

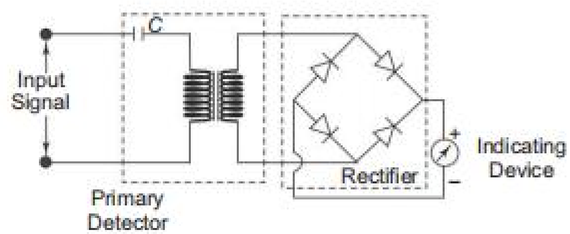


Fig. 9.1 (a) Basic wave analyzer

The indicating device is a simple dc voltmeter that is calibrated to read the peak value of the sinusoidal input voltage. Since the LC circuit is tuned to a single frequency, it passes only the frequency to which it is tuned and rejects all other frequencies. A number of tuned filters, connected to the indicating device through a selector switch, would be required for a useful Wave analyzer.

HARMONIC DISTORTION ANALYZER

A distortion analyzer measures the total harmonic power present in the test wave rather than the distortion caused by each component. The simplest method is to suppress the fundamental frequency by means of a high pass filter whose cut off frequency is a little above the fundamental frequency. This high pass allows only the harmonics to pass and the total harmonic distortion can then be measured. Other types of harmonic distortion analyzers based on fundamental suppression are as follows.

1. Employing a Resonance Bridge

The bridge shown in Fig. 9.5 is balanced for the fundamental frequency, i.e. L and C are tuned to the fundamental frequency. The bridge is unbalanced for the harmonics, i.e. only harmonic power will be available at the output terminal and can be measured. If the fundamental frequency is changed, the bridge must be balanced again. If L and C are fixed components, then this method is suitable only when the test wave has a fixed frequency. Indicators can be thermo-couples or square law VTVMs. This indicates the rms value of all harmonics. When a continuous adjustment of the fundamental frequency is desired, a Wien bridge arrangement is used as shown in Fig. 9.6.

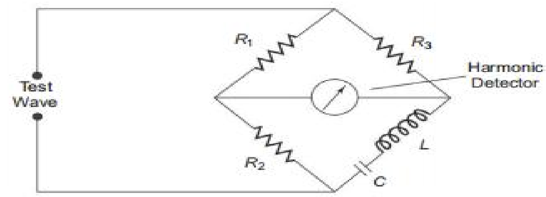


Fig. 9.5 Resonance bridge

2. **Wien's Bridge Method**

The bridge is balanced for the fundamental frequency. The fundamental energy is dissipated in the bridge circuit elements. Only the harmonic components reach the output terminals. The harmonic distortion output can then be measured with a meter. For balance at the fundamental frequency, $C_1 = C_2 = C$, $R_1 = R_2 = R$, $R_3 = 2R_4$.

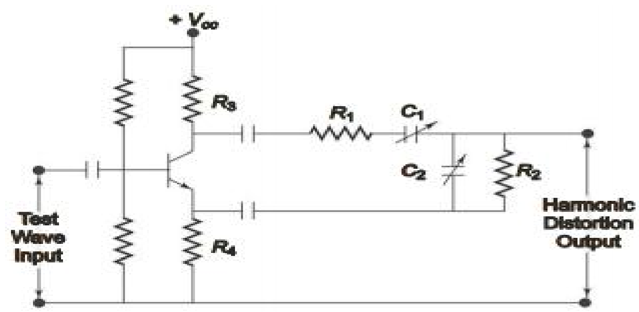


Fig. 9.6 Wien's bridge method

3. **Bridged T-Network Method**

Referring to Fig. 9.7 the, L and C's are tuned to the fundamental frequency, and R is adjusted to bypass fundamental frequency. The tank circuit being tuned to the fundamental frequency, the fundamental energy will circulate in the tank and is bypassed by the resistance. Only harmonic components will reach the output terminals and the distorted output can be measured by the meter. The Q of the resonant circuit must be at least 3–5.

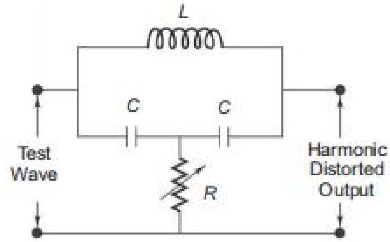


Fig. 9.7 Bridged T-network method

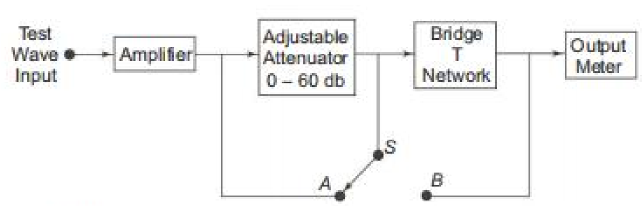


Fig. 9.8 Harmonic distortion analyzer using bridged T-network

One way of using a bridge T-network is given in Fig. 9.8. The switch S is first connected to point A so that the attenuator is excluded and the bridge T-network is adjusted for full suppression of the fundamental frequency, i.e. minimum output. Minimum output indicates that the bridged T-network is tuned to the fundamental frequency and that the fundamental frequency is fully suppressed.

The switch is next connected to terminal B, i.e. the bridged T-network is excluded. Attenuation is adjusted until the same reading is obtained on the meter. The attenuator reading indicates the total rms distortion. Distortion measurement can also be obtained by means of a wave analyzer, knowing the amplitude and the frequency of each component, the harmonic distortion can be calculated. However, distortion meters based on fundamental suppression are simpler to design and less expensive than wave analyzers. The disadvantage is that they give only the total distortion and not the amplitude of individual distortion components.

SPECTRUM ANALYZER

Referring to the block diagram of Fig. 9.9(b), the sawtooth voltage which drives the horizontal axis element of the scope and this sawtooth voltage is the frequency controlled element of the voltage tuned oscillator. As the oscillator sweeps from f_{min} to f_{max} of its frequency band at a linear recurring rate, it beats with the frequency component of the input signal and produce an IF, whenever a frequency component is met during its sweep.

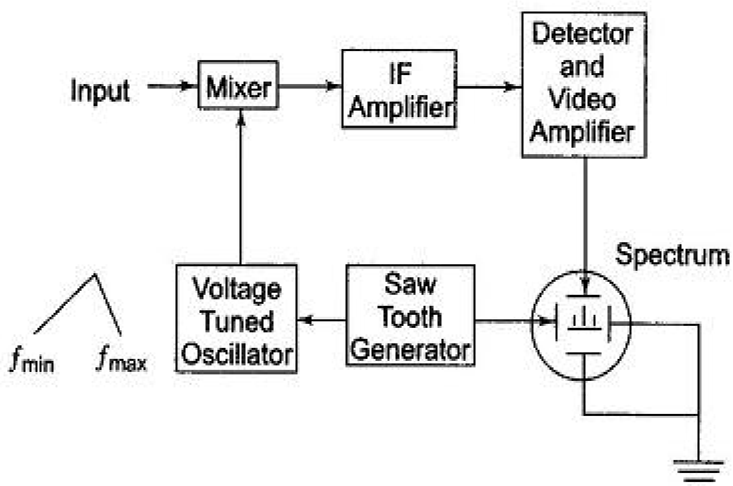


Fig. 9.9 (b) Spectrum Analyzer

The frequency component and voltage tuned oscillator frequency beats together to produce a difference frequency, i.e. IF. The IF corresponding to the component is amplified and detected if necessary, and then applied to the vertical plates of the CRO, producing a display of amplitude versus frequency The spectrum produced if the input wave is a single toned A.M. is given in Figs 9.10, 9.11, and 9.12.

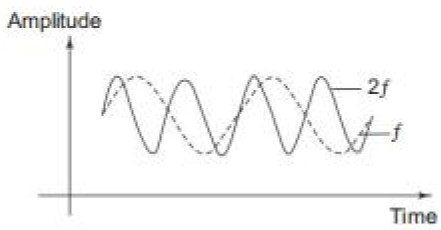


Fig. 9.10 Test wave seen on ordinary CRO

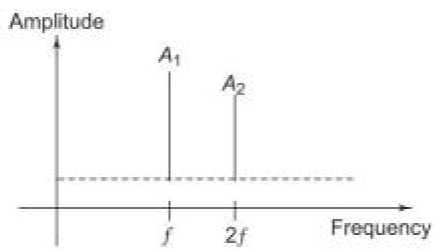


Fig. 9.11 Display on the spectrum CRO

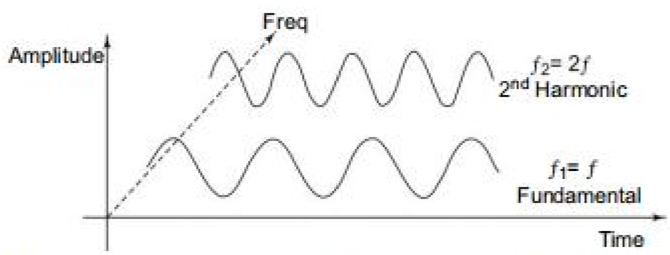


Fig. 9.12 Test waveform as seen on X-axis (Time) and Z-axis (Frequency)

One of the principal applications of spectrum analyzers has been in the study of the RF spectrum produced in microwave instruments. In a microwave instrument, the horizontal axis can display as a wide a range as 2 – 3 GHz for a broad survey and as narrow as 30 kHz, for a highly magnified view of any small portion of the spectrum. Signals at microwave frequency separated by only a few kHz can be seen individually. The frequency range covered by this instrument is from 1 MHz to 40 GHz. The basic block diagram (Fig. 9.13) is of a spectrum analyzer covering the range 500 kHz to 1 GHz, which is representative of a super-heterodyne type.

The input signal is fed into a mixer which is driven by a local oscillator. This oscillator is linearly tunable electrically over the range 2 – 3 GHz. The mixer provides two signals at its output that are proportional in amplitude to the input signal but of frequencies which are the sum and difference of the input signal and local oscillator frequency. The IF amplifier is tuned to a narrow band around 2 GHz, since the local oscillator is tuned over the range of 2 – 3 GHz, only inputs that are separated from the local oscillator frequency by 2 GHz will be converted to IF frequency band, pass through the IF frequency amplifier, get rectified and produce a vertical deflection on the CRT.

From this, it is observed that as the sawtooth signal sweeps, the local oscillator also sweeps linearly from 2 – 3 GHz. The tuning of the spectrum analyzer is a swept receiver, which sweeps linearly from 0 to 1 GHz. The sawtooth scanning signal is also applied to the horizontal plates of the CRT to form the frequency axis. (The spectrum analyzer is also sensitive to signals from 4 – 5 GHz referred to as the image frequency of the super-heterodyne. A low pass filter with a cutoff frequency above 1 GHz at the input suppresses these spurious signals.) Spectrum analyzers are widely used in radars, oceanography, and bio-medical fields.

RAMP TYPE DVM (Digital Volt Meter)

The operating principle is to measure the time that a linear ramp takes to change the input level to the ground level, or vice-versa. This time period is measured with an electronic time-interval counter and the count is displayed as a number of digits on an indicating tube or display. The operating principle and block diagram of a ramp type DVM are shown in Figs 5.1 and 5.2. The ramp may be positive or negative; in this case a negative ramp has been selected.

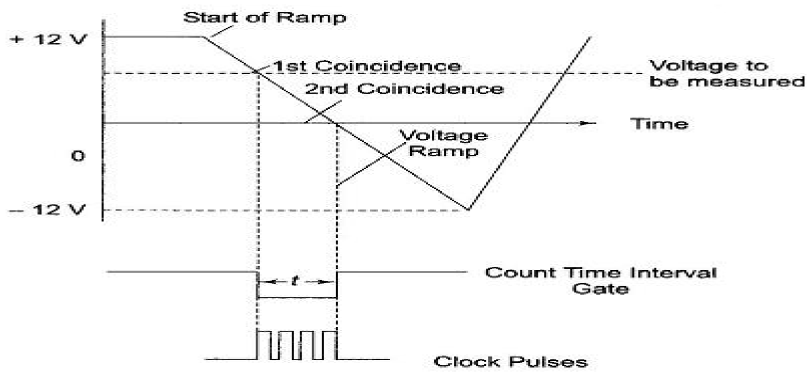


Fig. 5.1 Voltage to Time Conversion

At the start of the measurement a ramp voltage is initiated (counter is reset to 0 and sampled rate multivibrator gives a pulse which initiates the ramp generator). The ramp voltage is continuously compared with the voltage that is being measured. At the instant these two voltage become equal, a coincidence circuit generates a pulse which opens a gate, i.e. the input comparator generates a start pulse. The ramp continues until the second comparator circuit senses that the ramp has reached zero value. The ground comparator compares the ramp with ground. When the ramp voltage equals zero or reaches ground potential, the ground comparator generates a stop pulse. The output pulse from this comparator closes the gate. The time duration of the gate opening is proportional to the input voltage value.

In the time interval between the start and stop pulses, the gate opens and the oscillator circuit drives the counter. The magnitude of the count indicates the magnitude of the input voltage, which is displayed by the readout. Therefore, the voltage is converted into time and the time count represents the magnitude of the voltage. The sample rate multivibrator determines the rate of cycle of measurement. A typical value is 5 measuring cycles per second, with an accuracy of ± 0.005% of the reading.

The sample rate circuit provides an initiating pulse for the ramp generator to start its next ramp voltage. At the same time a reset pulse is generated, which resets the counter to the zero state. Any DVM has a fundamental cycle sequence which involves sampling, displaying and reset sequences.

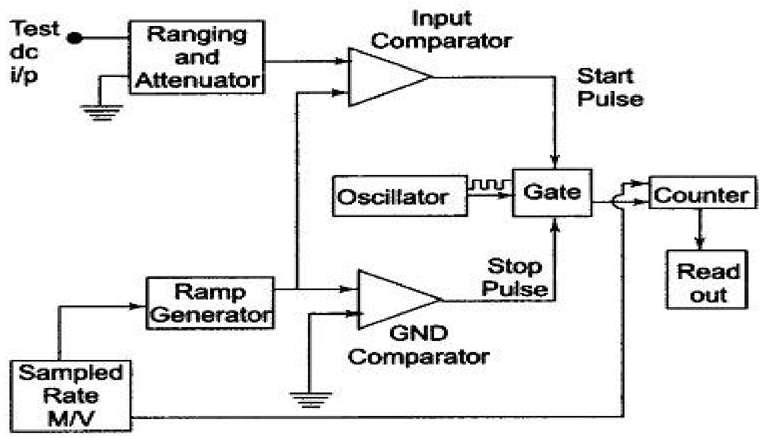


Fig. 5.2 Block Diagram of Ramp Type DVM

Advantages and Disadvantages The ramp technique circuit is easy to design and its cost is low. Also, the output pulse can be transmitted over long feeder lines. However, the single ramp requires excellent characteristics regarding linearity of the ramp and time measurement. Large errors are possible when noise is superimposed on the input signal. Input filters are usually required with this type of converter.

DUAL SLOPE INTEGRATING TYPE DVM (Digital Volt Meter)

As illustrated in Fig. 5.3, the input voltage 'e_i ' is integrated, with the slope of the integrator output proportional to the test input voltage. After a fixed time, equal to t_1, the input voltage is disconnected and the integrator input is connected to a negative voltage $-e_r$. The integrator output will have a negative slope which is constant and proportional to the magnitude of the input voltage.

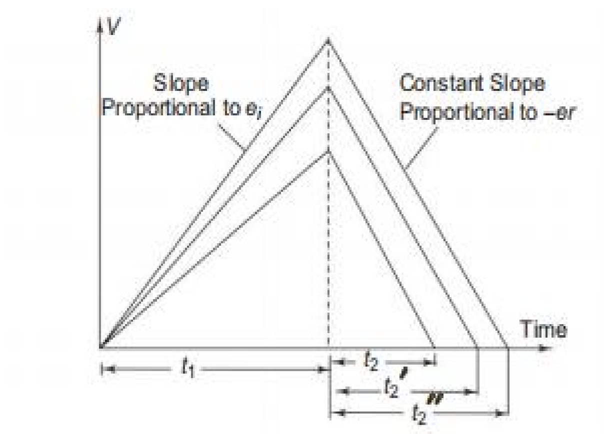


Fig. 5.3 Basic principle of dual slope type DVM

The block diagram is given in Fig. 5.4. At the start a pulse resets the counter and the F/F output to logic level '0'. S_i is closed and S_r is open. The capacitor begins to charge. As soon as the integrator output exceeds zero, the comparator output voltage changes state, which opens the gate so that the oscillator clock pulses are fed to the counter. (When the ramp voltage starts, the comparator goes to state 1, the gate opens and clock pulse drives the counter.)

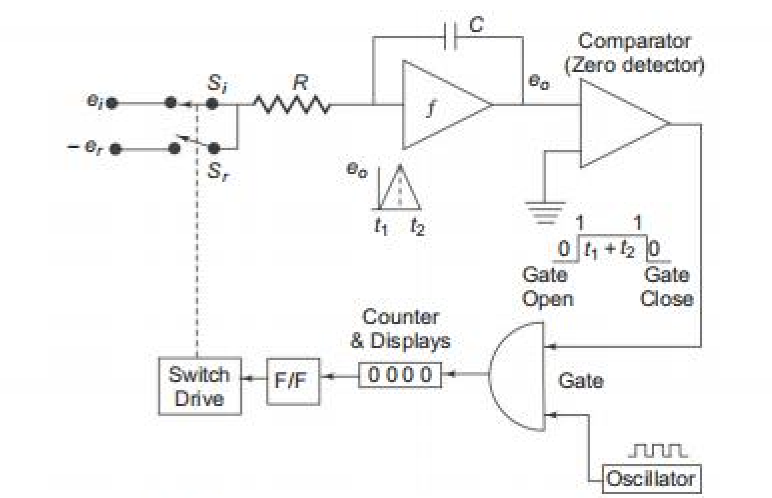


Fig. 5.4 Block diagram of a dual slope type DVM

When the counter reaches maximum count, i.e. the counter is made to run for a time 't1' in this case 9999, on the next clock pulse all digits go to 0000 and the counter activates the F/F to logic level '1'. This activates the switch drive, e_i is disconnected and $-e_r$ is connected to the integrator. The integrator output will have a negative slope which is constant, i.e. integrator output now decreases linearly to 0 volts. Comparator output state changes again and locks the gate. The discharge time t_2 is now proportional to the input voltage.

The counter indicates the count during time t_2. When the negative slope of the integrator reaches zero, the comparator switches to state 0 and the gate closes, i.e. the capacitor C is now discharged with a constant slope.

As soon as the comparator input (zero detector) finds that e_o is zero, the counter is stopped. The pulses counted by the counter thus have a direct relation with the input voltage.

During charging

$$e_o = -\frac{1}{RC}\int_0^t e_i\,dt = -\frac{e_i\,t_1}{RC} \qquad (5.1)$$

During discharging

$$e_o = \frac{1}{RC}\int_0^{t_2} -e_r\,dt = -\frac{e_r\,t_2}{RC} \qquad (5.2)$$

Subtracting Eqs 5.2 from 5.1 we have

$$e_o - e_o = \frac{-e_r\,t_2}{RC} - \left(\frac{-e_i\,t_1}{RC}\right)$$

$$0 = \frac{-e_r\,t_2}{RC} - \left(\frac{-e_i\,t_1}{RC}\right)$$

$$\Rightarrow \qquad \frac{e_r\,t_2}{RC} = \frac{e_i\,t_1}{RC}$$

$$\therefore \qquad e_i = e_r\,\frac{t_2}{t_1} \qquad (5.3)$$

If the oscillator period equals T and the digital counter indicates n_1 and n_2 counts respectively,

$$\therefore \qquad e_i = \frac{n_2\,T}{n_1\,T}e_r \quad \text{i.e.} \quad e_i = \frac{n_2}{n_1}e_r$$

Now, n_1 and e_r are constants. Let $K_1 = \frac{e_r}{n_1}$. Then $e_i = K_1\,n_2$ (5.4)

From Eq. 5.3 it is evident that the accuracy of the measured voltage is independent of the integrator time constant. The times t_1 and t_2 are measured by the count of the clock given by the numbers n_1 and n_2 respectively. The clock oscillator period equals T and if n_1 and e_r are constants, then Eq. 5.4 indicates that the accuracy of the method is also independent of the oscillator frequency. The dual slope technique has excellent noise rejection because noise and superimposed ac are averaged out in the process of integration. The speed and accuracy are readily varied according to specific requirements; also an accuracy of ± 0.05% in 100 ms is available.

<u>ELECTRONIC MULTI METER</u> or <u>VOM meter (Volt Ohm Milliammeter)</u>

A multimeter is basically a PMMC meter. To measure dc current the meter acts as an ammeter with a low series resistance. Range changing is accomplished by shunts in such a way that the current passing through the meter does not exceed the maximum rated value.

A multimeter consists of an ammeter, voltmeter and ohmmeter combined, with a function switch to connect the appropriate circuit to the D'Arsonval movement. Figure 4.35 shows a meter consisting of a dc milliammeter, a dc voltmeter, an ac voltmeter, a microammeter, and an ohmmeter.

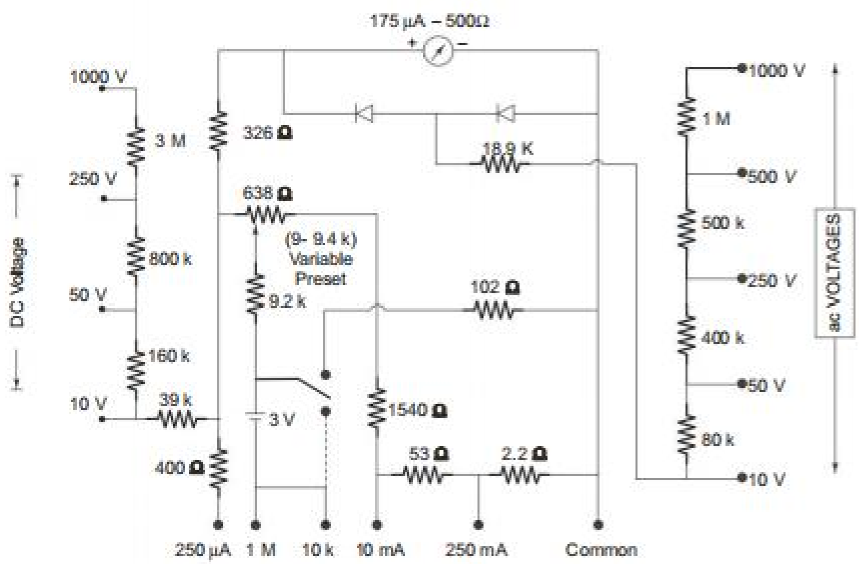


Fig. 4.35 Diagram of a multimeter

Microammeter Figure 4.36 shows a circuit of a multimeter used as a microammeter.

DC Ammeter Figure 4.37 shows a multimeter used as a dc ammeter.

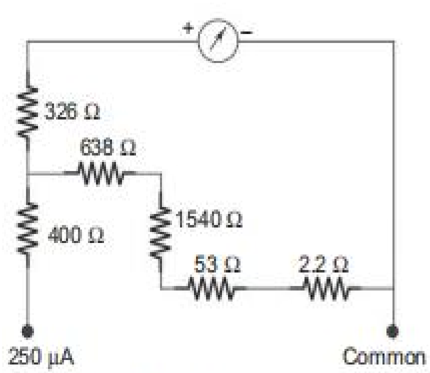


Fig. 4.36 Microammeter section of a multimeter

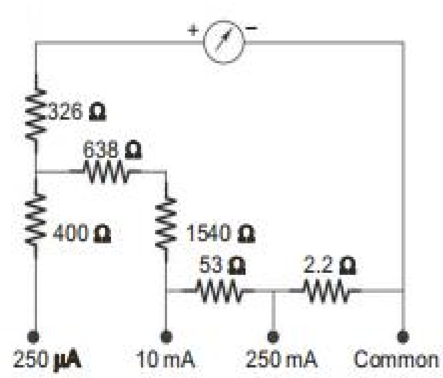


Fig. 4.37 dc ammeter section of a multimeter

DC Voltmeter Figure 4.38 shows the dc voltmeter section of a multimeter

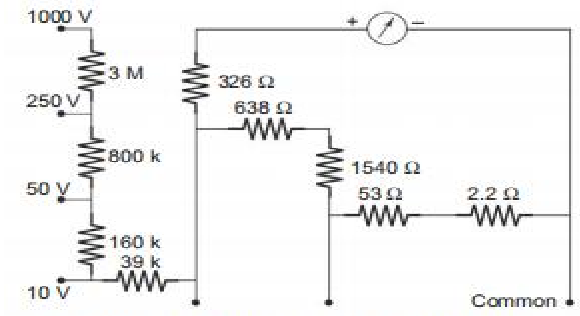


Fig. 4.38 DC voltmeter section of a multimeter

AC Voltmeter Figure 4.39 shows the ac voltmeter section of a multimeter. To measure ac voltage, the output ac voltage is rectified by a half wave rectifier before the current passes through the meter. Across the meter, the other diode serves as protection. The diode conducts when a reverse voltage appears across the diodes, so that current bypasses the meter in the reverse direction.

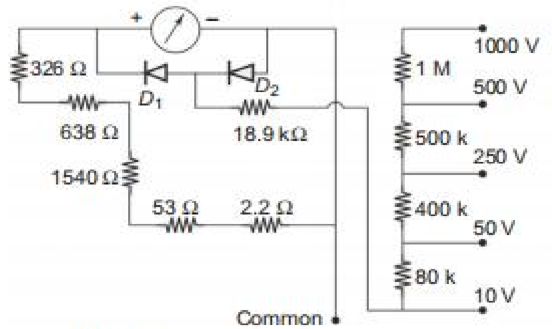


Fig. 4.39 AC voltmeter section of a multimeter

Ohmmeter Referring to Fig. 4.40 which shows the ohmmeter section of a multimeter, in the 10 k range the 102 W resistance is connected in parallel with the total circuit resistance and in the 1 MW range the 102 W resistance is totally disconnected from the circuit. Therefore, on the 1 M range the half scale deflection is 10 k. Since on the 10 k range, the 102 W resistance is connected across the total resistance, therefore, in this range, the half scale deflection is 100 W.

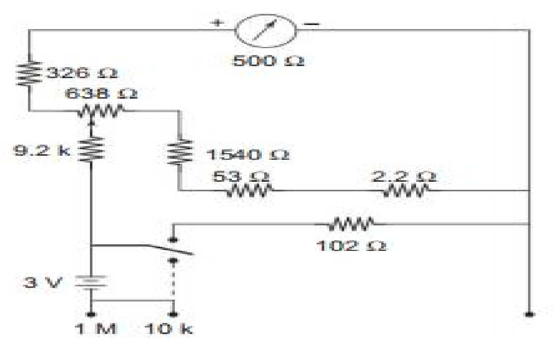


Fig. 4.40 Ohmmeter section of a multimeter

PRESSURE MEASUREMENT

1. Piston gauges: Because of their complicated structure and operation these gauges are only used for calibration purposes. According to Eq. (1) the force F acting on the area A of a moveable piston placed in a cylinder can be used for the determination of the pressure. Figure 1 represents the principle. A piston P with a mass m and a cross section of area A limits a well defined gas volume V. If the pressure in V is increased with the help of a gas inlet the volume can be restored by an additional weight of mass Δm. For equilib rium we find :

$$p = \frac{(m + \Delta m)g}{A}$$

where g is the gravitational acceleration.

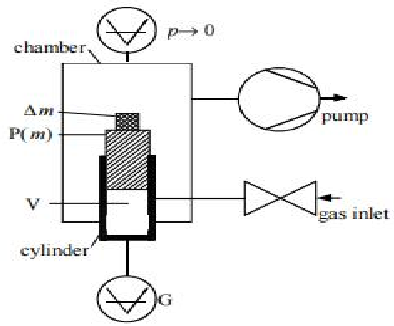


Fig. 1 Principle of a Piston gauge

To avoid the influence of the surrounding atmosphere the cylinder and piston are placed in an additional chamber, which is evacuated. To reduce the influence of friction between the cylinder and pis ton the piston is made to rotate. With the help of such an apparatus as that represented in Fig. 1 it is possible to calibrate any gauge indicated in the sketch by G.

2. Bourdon tube The Bourdon tube (see Fig. 2a) consists of a bent tube with an elliptic cross section closed at one end and connected at the other open end to the chamber in which the pressure is to be measured. Pressure differences between the environment of the gauge and the interior cause forces to act on the two walls of the tube (Fig. 2b) so that it is bent by an amount that depends on the pressure difference between the environment and the interior.

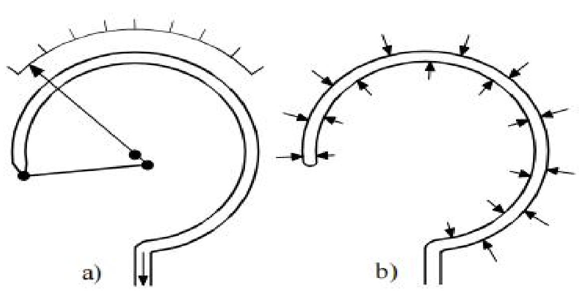


Fig. 2 Bourdon gauge, a) principle, b) distribution of forces

The bending is transformed by a lever to a pointer whose position can be calibrated. The importance of this type of gauge is that it is very robust and that it covers a range of pressure measurement from pressures higher than atmospheric pressure down to rough vacuum (about 10 mbar). The accuracy and reproducibility are relatively poor, so that it is not suitable for precision measurements, and its usefulness for vacuum measurements is limited.

3. U-tube Manometer These gauges use the hydrostatic pressure of a liquid column for pressure reading. Mostly mercury is used as the liquid because of its low vapor pressure and its cohesion characteristics. In the simplest case a gauge of this type consists of a U-shaped glass tube closed at the one end and connected at the other to the chamber whose pressure is to be measured (Fig. 5). The tube is filled with mercury so that in the volume between the closed end and the level of the mercury column there is only the vapor pressure of the mercury and is called Torricelli´s vacuum.

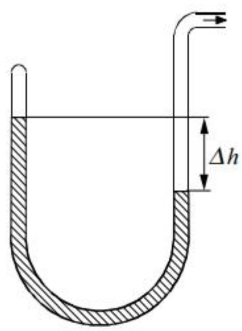


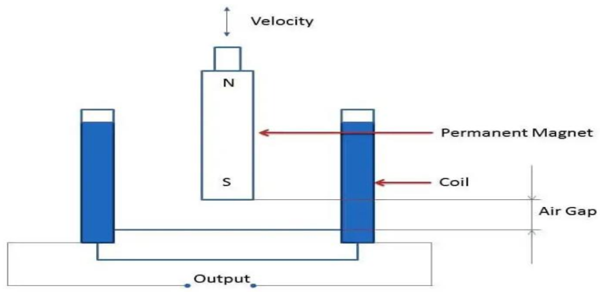
Fig. 5 U-tube gauge with one closed glass tube

The difference in heights of the mercury levels in the two legs of the U-shaped tube is proportional to the pressure where ρ is the density of the used liquid, usually mercury, g gravitational acceleration, and Δh the difference in heights of the levels of the two columns. Because the lowest measurable difference of heights of the mercury levels is about 1 mm the lowest pressure detectable with this gauge is in the order of 100 Pa . Because of its uncertainty, its limited range of pressure reading, and the absence of possibilities for electronic recording, this simple type of gauge has nearly no importance for practical application today

VELOCITY MEASUREMENTS

1. MEASUREMENT OF LINEAR VELOCITY

a. *MOVING MAGNET TYPE TRANSDUCER***:** The sensing element is a rod type permanent magnet that is rigidly coupled to the device whose velocity is being measured .There is a coil surrounding the permanent magnet.The motion of the magnet induces a voltage in the coil and the amplitude of the voltage is directly proportional to the velocity.The polarity of the output voltage determines the direction of motion.



Moving Magnet type Velocity Transducer

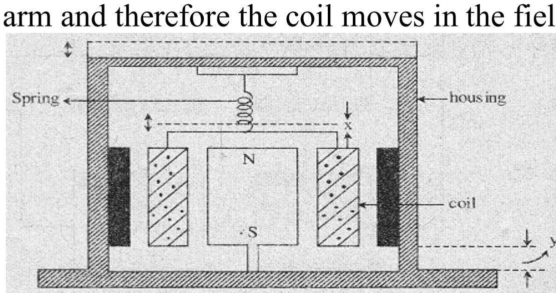
For a coil placed in magnetic field the voltage generated is

$$e_0 = B.A.N.v$$

B=flux density ; Wb/m2 ,
A= area of coil;
N= Number of turns of coil,
v=relative velocity of magnet with respect to coil

b. MOVING COIL TYPE VELOCITY TRANSDUCER:

It operates essentially through the action of a coil moving in a magnetic field. A voltage is generated in the coil which is proportional to the velocity of the coil. The velocity to be measured is applied to the arm and therefore the coil moves in the field of permanent magnet.



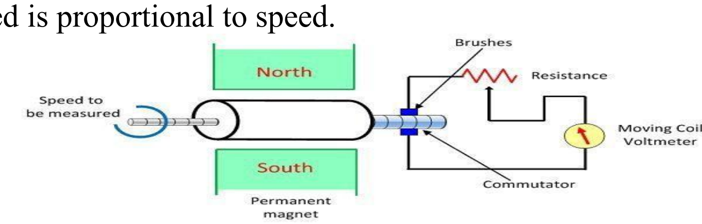
Moving coil type velocuity Transducers

A voltage is generated on account of motion of the coil in the magnetic field. The output voltage is proportional to the velocity.

2. MEASUREMENT OF ANGULAR VELOCITY

a. D.C. Tachometer Generators

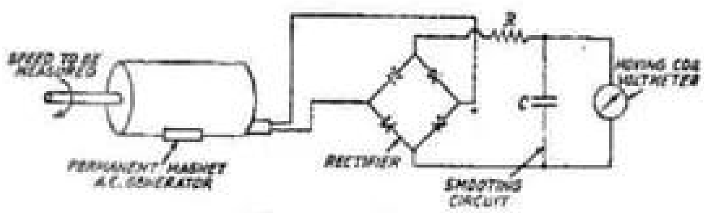
They consist of a small armature which is coupled to the machine whose speed is to be measured. This armature revolves in a field of permanent magnet. The emf generated is proportional to the product of flux and speed. Since the flux of the permanent magnet is constant, the voltage generated is proportional to speed.



The polarity of output voltage indicates the direction of rotation. This emf is measured with the help of a moving coil voltmeter having a uniform scale and calibrated directly in terms of speed. A series resistance is used in the circuit for the purpose of limiting the current from the generator in the event of a short circuit on the output side.

b. A.C. Tachometer Generator

It consists of, like an alternator, a stationary armature (stator) and a rotating field system (rotor). Owing to the generation of e.m.f in a stationary coil on a stator, commutation problems no longer exist.The alternating e.m.f. induced in the stationary coil is rectified, and the output D.C. voltage is measured with the help of a moving coil voltmeter (V).



A.C. Tachometer Generator.

The ripple content of the rectified voltage is smoothened by the capacitor filter (C).As the speed depends on both the amplitude of the voltage and frequency, anyone of themcan be used as a measure of the speed. In an A.C. tachometer, it is the induced voltage that is considered as the required parameter

HUMIDITY MEASUREMENT

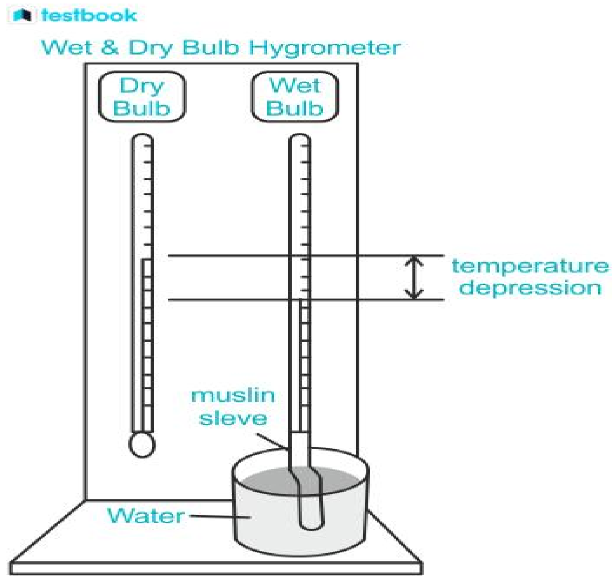
The presence of moisture (water vapor, an invisible gas) in the atmosphere is measured by the humidity of the air. Humidity and condensation are closely related as condensation inevitably occurs when the air is saturated with moisture (100% humidity).

Absolute humidity measures the amount of water vapor in air. Grams H2O/m3 of air. This water is a gas, water vapor.

Relative humidity measures the amount of water vapor in air relative to the maximum amount of water vapor the air could hold at that temperature. Relative humidity increases with increasing water vapor or decreasing temperature. Cold air can't "carry" as much water vapor as warm air.

1. Hygrometer

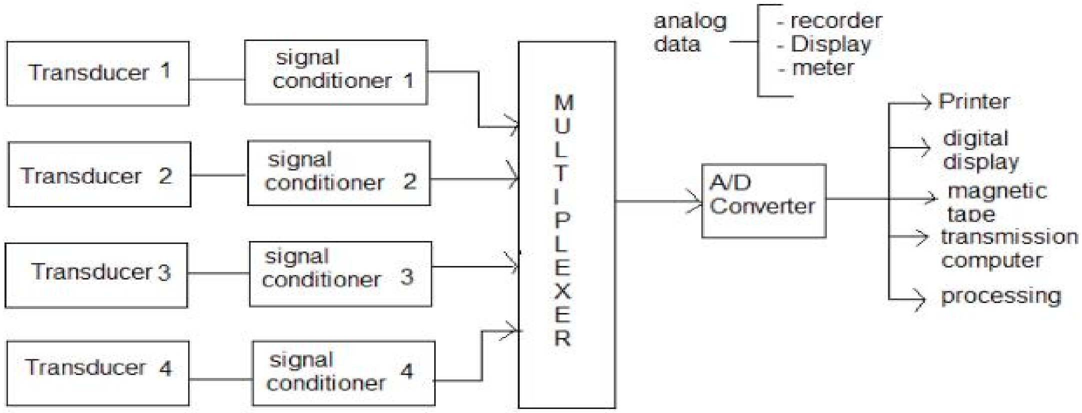
A hygrometer is a device used to measure the amount of water vapour in the air, soil, and enclosed places. Instruments for measuring humidity typically rely on measurements of other values, such as temperature, pressure, mass, or a mechanical or electrical change in a substance caused by the absorption of moisture. By calibrating and calculating these measured quantities, humidity can be determined.



There are two bulbs in a hygrometer: one moist and one dry. One of the bulbs is covered with a wet or dry towel to simulate a thermometer. After a length of time, the water on the bulb evaporates, and the temperature of each bulb is then measured. The difference in temperatures is recorded. The temperatures are then plotted on a chart to determine the relative humidity for each temperature and location. Relative humidity is a ratio, therefore ratios do not have units. A tiny temperature difference between the bulbs indicates a high relative humidity resulting from a low evaporation rate. In dry air, evaporation occurs more rapidly, resulting in a large temperature differential and a low relative humidity.

DATA AQUSITION SYSTEM

In order to optimize the characteristics of the system in terms of performance of the system, data handling capacity and cost, different relevant sub-system are combined together. The system used for data processing, data conversion, data transmission, data storage is called data acquisition system.



The digital data acquisition system includes all the block shown in fig may use some additional functions block. The essential functions of digital data acquisitions are as follows,

1. It handles the analog signals
2. it performs measurement
3. it converts analog signal into digital data and handles it.
4. it performs internal programming and control.

1. TRANSDUCERS: -
They convert the physical quantity into a proportional electrical signal which is given as an input to the digital data acquisition system.

2. SIGNAL CONDITIONERS: -
They include supporting circuits for amplifying, modifying or selecting certain positions of these signals.

3. MULTIPLEXERS: -
The multiplexer accepts multiple analog inputs and connect them sequentially to one measuring instruments.

4. SIGNALCONVERTERS: -
The signal converters are used to translate analog signal to a form which is suitable for the next stage that is analog to digital converter. This block is optional one.

5. ANALOG TO DIGITAL CONVERTER(A/DCONVERTER): -
It converts the analog voltage to its equivalent digital form. The output of the analog to digital converter may be fed to the digital display device for display or to the digital recorders for recording. The same signal may be fed to the digital computer for data reduction or further processing.

6. AUXILIARYEQUIPMENTS: -
The devices which are used for system programming functions are digital data processing are included in the auxiliary equipment's. The typical functions of the auxiliary equipment's include linearization and limit comparison of the signal. These functions are performed by the individual instruments or the digital computer.

7. DIGITAL RECORDER: -
They record the information in digital form. The digital information is stored on punched cards, magnetic tape recorders, type written pages, floppies or combination of these systems. The digital printer used provides a high quality, hard copy for recorders minimizing the operators work.

The data acquisition system is used, now days in increasing, wide fields. These are becoming very much popular because of simplicity, accuracy and the most important reliability of the system. These are widely used in industrial areas, scientific areas, including aerospace, biomedical and telemetry industries.

7.6 Force Transducer

According to Newton's law, when a force 'F' is applied to a body of mass 'm', it accelerates at a rate 'a' Mathematically we can write,

$$F = m \cdot a \quad \text{.... (i)}$$

From above equation it is clear that, unknown force applied to body of mass m can be measured by measuring acceleration of that body. Another technique is to measure the change in resonant frequency of a vibrating wire under tension due to applied force. The unknown force can be measured by using force measuring sensors i.e. load cells.

7.6.1 Force Measurement Using Accelerometer

By using accelerometer of any type, the acceleration of a body of known mass due to the applied force can be measured. Then by using Newton's law of mass acceleration, the applied unknown force can be calculated. But practically use of accelerometers for force measurement is limited because the forces are not free but they are the part of system. It is very difficult to decouple these forces from the system. Also many systems, the body on which force acting is not free to accelerate. Still this technique is useful in measuring some transient forces. The advanced application of this technique is in calibration of forces produced by thrust motors in the space vehicles.

7.6.2 Force Measurement using Vibrating Wire Sensor

The basic arrangement of vibrating wire sensor is as shown in the Fig. 7.21.

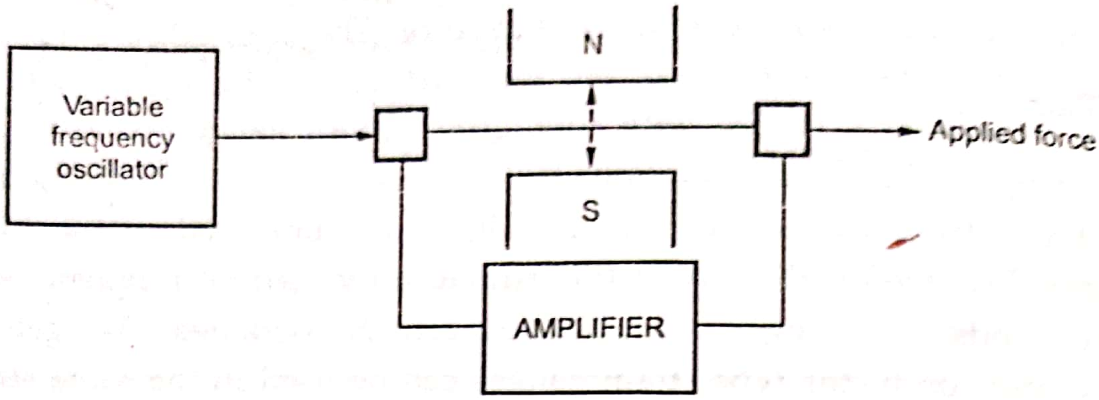


Fig. 7.21 Vibrating wire sensor arrangement

A wire is kept vibrating at its resonant frequency by using variable frequency oscillator. The resonant frequency is given by

$$f = \frac{0.5}{L}\sqrt{\frac{M}{T}} \quad \text{..... (i)}$$

where f = resonant frequency,

L = length of a wire,

M = mass per unit length of wire, and

T = tension due to applied force.

Thus from equation (i) stated above it is clear that when applied force changes, tension changes and hence the output frequency changes. Thus by measuring the output frequency of the local oscillator, the force applied to the wire can be calculated.

7.6.3 Force Measurement Using Load Cell

Basically the load cell is a electromechanical sensor used to measure static and dynamic forces. It is the most widely used transducer used in many industrial applications, which can handle wide range of forces. The material used for load cell should posses linear stress strain relationship upto a fairly large elastic strain limit, low strain hysteresis and very low creep-over during loading period. The various elastic materials suitable for the purpose are medium to high carbon steels of chromium molybdenum and precipitate hardened stainless steel.

Let us study some typical forms of force measuring devices using load cell.

7.6.3.1 Cantilever Beam Type Load Cell

It is the simplest configuration as shown in the Fig. 7.22.

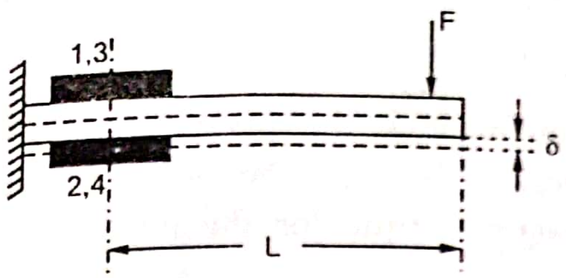


Fig. 7.22 Cantilever beam type load cell

On the top and bottom surfaces of the beam four strain gauges are bonded. On the application of force F, at free end of the cantilever beam, a bending moment developes in the beam which is proportional to the applied force. With reference to the direction of force shown, strain gauges 1 and 3 measures tensile strains developed on top surface while strain gauges 2 and 4 measures compressive strains developed at the bottom surface. The maximum deflection (δ) occurs at the free end of the beam while the maximum strain (ε) develops at the fixed end of the beam. Thus, in cantilever beam type load cell, applied force ε can be measured as a function of deflection δ or strain ε.

7.6.3.2 Column Type Load Cell

The simplest method for measuring unidirectional forces is to use column or rod in tension or compression. By using the electrical strain gauges attached to the body, the stress developed due to force on loading can be measured. The column type load cell structure is as shown in the Fig. 7.23.

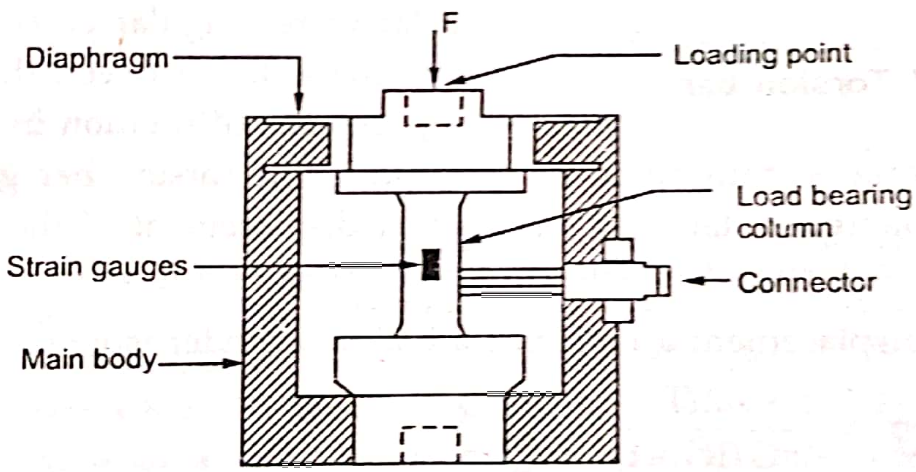


Fig. 7.23 Column type load cell structure

The strain gauges are mounted on exactly opposite faces of each other. Strain gauges 1 and 3 are aligned to measure axial strains while the strain gauges 2 and 4 are alligned to measure circumferential strains only. It is very essential to arrange gauges and the rod symmetrically. Also the column must be loaded as centrally as possible to avoid bending forces in the columns.