MODULE 3

AF Wave analyzer

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 1.

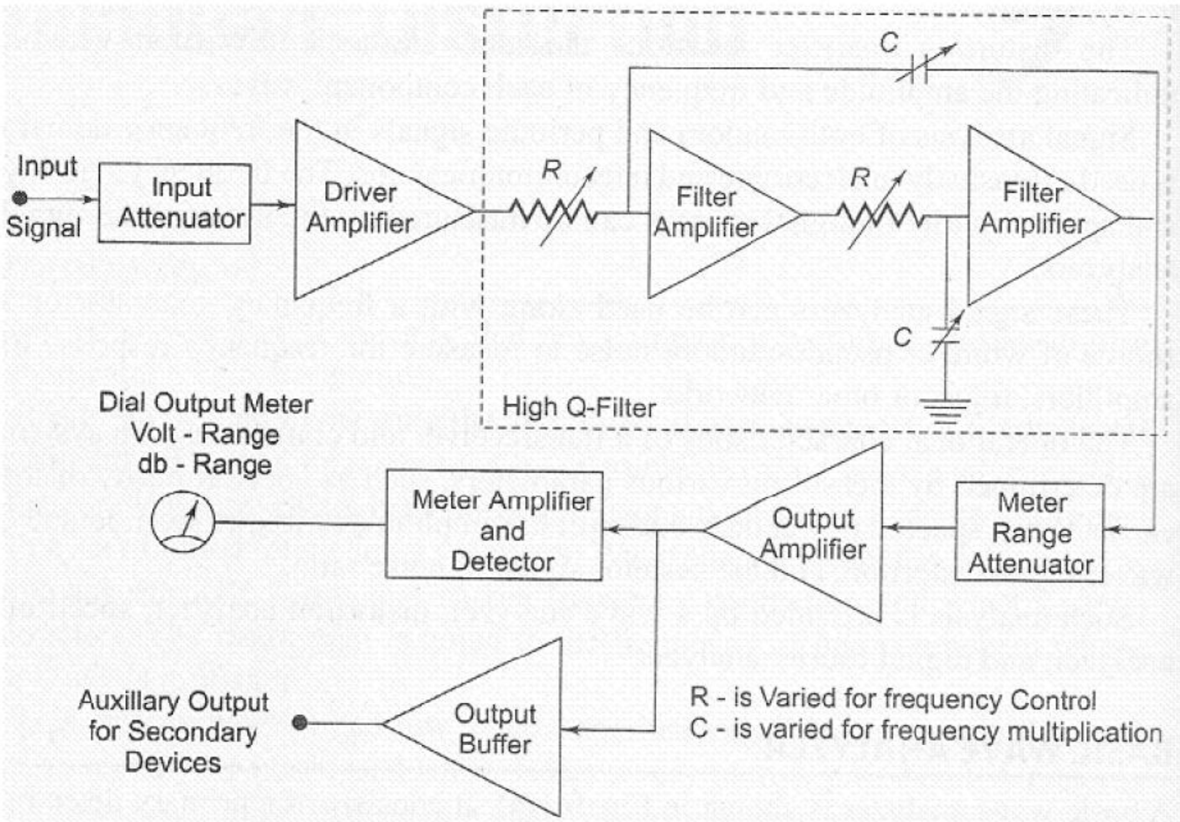

Fig 1: Frequency wave analyzer

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 requency. 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

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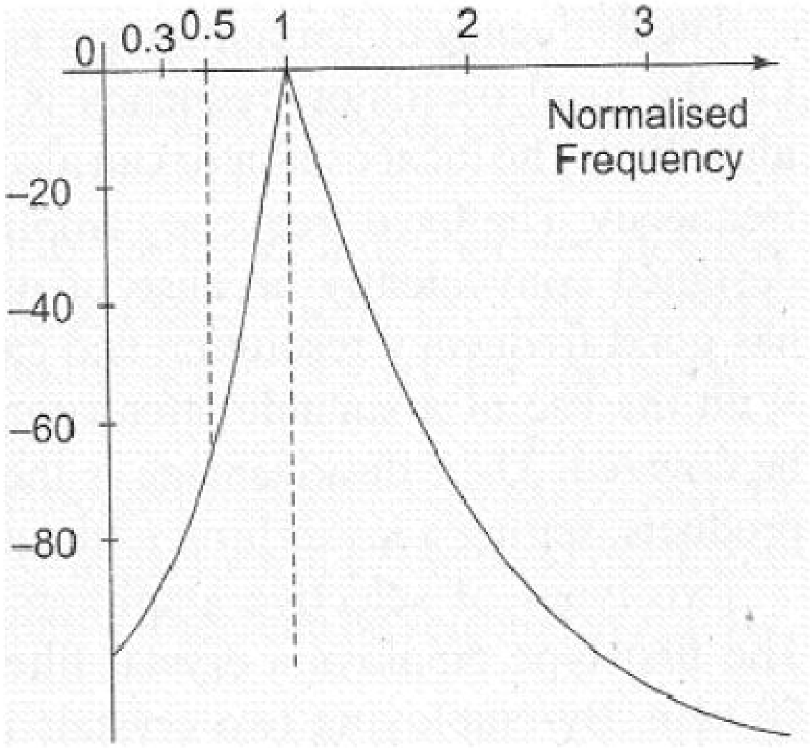
The selected signal output from the final amplifier stage is applied to the meter circuit and to an unturned buffer amplifier. The main function of the buffer amplifier is to drive output devices, such as recorders or electronics counters.

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.1.2



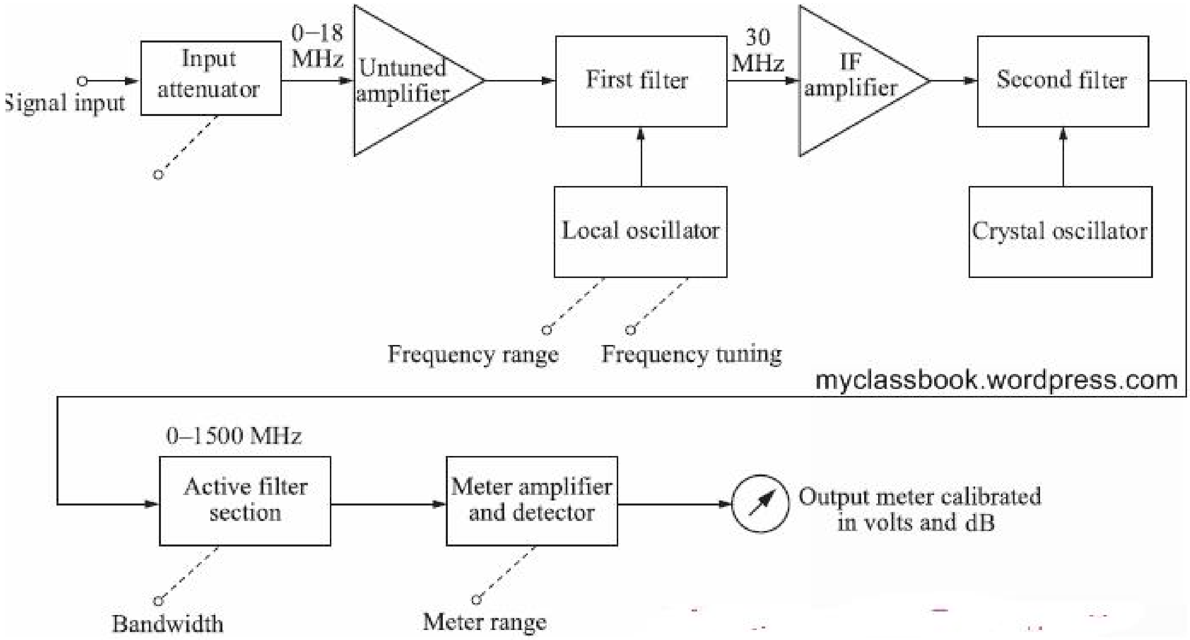
Application of wave analyzer

1. Electrical measurements
2. Sound measurements
3. Vibration measurements.

In industries there are heavy machineries which produce a lot of sound and vibrations, it is very important to determine the amount of sound and vibrations because if it exceeds the permissible level it would create a number of problems. The source of noise and vibrations is first identified by wave analyzer and then it is reduced by further circuitry.

Heterodyne wave analyzer

A wave analyzer, in fact, is an instrument designed to measure relative amplitudes of single frequency components in a complex waveform. Basically, the instrument acts as a frequency selective voltmeter which is used to the frequency of one signal while rejecting all other signal components. The desired frequency is selected by a frequency calibrated dial to the point of maximum amplitude. The amplitude is indicated either by a suitable voltmeter or CRO.This instrument is used in the MHz range. The input signal to be analysed is heterodyned to a higher IF by an internal local oscillator. Tuning the local oscillator shifts various signal frequency components into the pass band of the IF amplifier. The output of the IF amplifier is rectified and is applied to the metering circuit. The instrument using the heterodyning principle is called a *heterodyning tuned voltmeter.*



The block schematic of the wave analyser using the heterodyning principle is shown in fig. above. The operating frequency range of this instrument is from 10 kHz to 18 MHz in 18 overlapping bands selected by the frequency range control of the local oscillator. The bandwidth is controlled by an active filter and can be selected at 200, 1000, and 3000 Hz.

Wave analyzers have very important applications in the following fields:
1) Electrical measurements
2) Sound measurements and
3) Vibration measurements.
The wave analyzers are applied industrially in the field of reduction of sound and vibrations generated by rotating electrical machines and apparatus. The source of noise and vibrations is first identified by wave analyzers before it can be reduced or eliminated. A fine spectrum analysis with the wave analyzer shows various discrete frequencies and resonances that can be related to the motion of machines. Once, these sources of sound and vibrations are detected with the help of wave analyzers, ways and means can be found to eliminate them.

Spectrum Analyzer

The modern spectrum analyzers use a narrow band super heterodyne receiver. Supereterodyne is nothing but mixing of frequencies in the super above audio range. The functional block diagram of super heterodyne spectrum analyzer or RF spectrum nalyzer as shown in the Figure

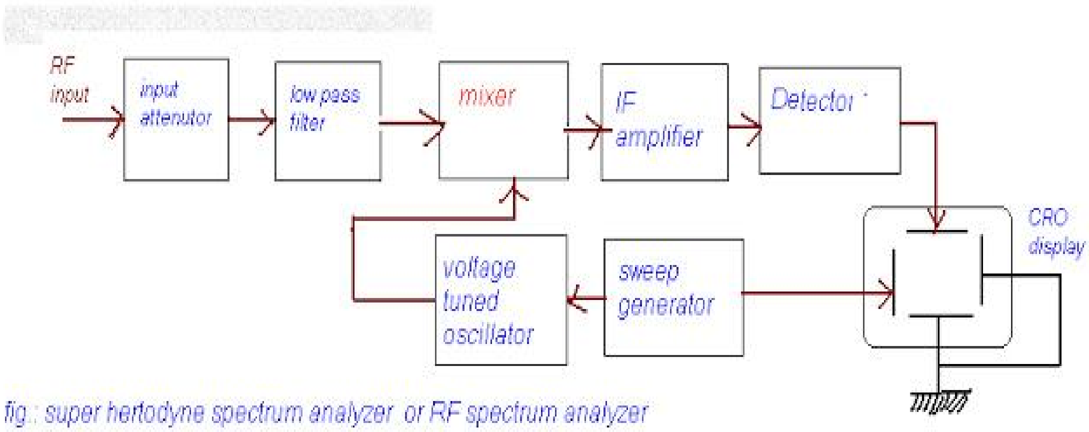


fig.: super hertodyne spectrum analyzer or RF spectrum analyzer

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The RF input to be analyzed is applied to the input attenuator. After attenuating, the signal is fed to low pass filter. The low pass filter suppresses high frequency components and allows low frequency components to pass through it. The output of the low pass filter is given to the mixer, where this signal is fixed with the signal coming from voltage controlled or voltage tuned oscillator.

This oscillator is tuned over 2 to 3 GHz range. The output of the mixer includes two signals whose amplitudes are proportional to the input signal but their frequencies are the sum and difference of the input signal and the frequency of the local oscillator.

Since the frequency range of the oscillator is tuned over 2 to 3 GHz, the IF amplifier is tuned to a narrow band of frequencies of about 2 GHz. Therefore only those signals which are separated from the oscillator frequency by 2 GHz are converted to Intermediate Frequency (IF) band. This IF signal is amplified by IF amplifier and then rectified by the detector. After completing amplification and rectification the signal is applied to vertical plates of CRO to produce a vertical deflection on the CRT screen. Thus, when the saw tooth signal sweeps, the oscillator also sweeps linearly from minimum to maximum frequency range i.e., from 2 to 3 GHz.

Here the saw tooth signal is applied not only to the oscillator (to tune the oscillator) but also to the horizontal plates of the CRO to get the frequency axis or horizontal deflection on the CRT screen. On the CRT screen the vertical axis is calibrated in amplitude and the horizontal axis is calibrated in frequency.

FFT spectrum analyzer

A spectrum analyzer, which uses computer algorithm and an analog to digital conversion phenomenon and produces spectrum of a signal applied at its input is known as digital Fourier or digital FFT or digital spectrum analyzer

Principle

When the analog signal to be analyzed is applied, the A/D converter digitizes the analog signal (i.e., converts the analog signal into digital signal). The digitized signal, which is nothing but the set of digital numbers indicating the amplitude of the analog signal as a function of time is stored in the memory of the digital computer. From the stored digitized data, the spectrum of the signal is computed by means of computer algorithm.

Description:

The block arrangement of a digital Fourier analyzer is illustrated in the figure above .The analog signal to be ana1ysed is applied to the low pass filter, which passes only low frequency signals and rejects high pass spurious signals. This filter section is used mainly, to prevent aliasing. The output of low pass filter is given to the attenuator. The attenuator is a voltage dividing network whose function is to set the input signal to the level of the A/D converter. The use of attenuator prevents the converter from overloading. The function of A/D converter is to convert the samples of analog data into digital i.e. ., to digitize the analog signal. When the output of A/D converter is applied to the digital computer, the computer analyzes the digitized data and adjusts the attenuator setting accordingly in order to obtain the maximum output from the inverter without any overloading. As soon as the entire analog signal is sampled and digitized by the A/D converter) computer performs calculations on the data according to the programmed algorithm and the calculated spectral components are stored in the memory of the computer

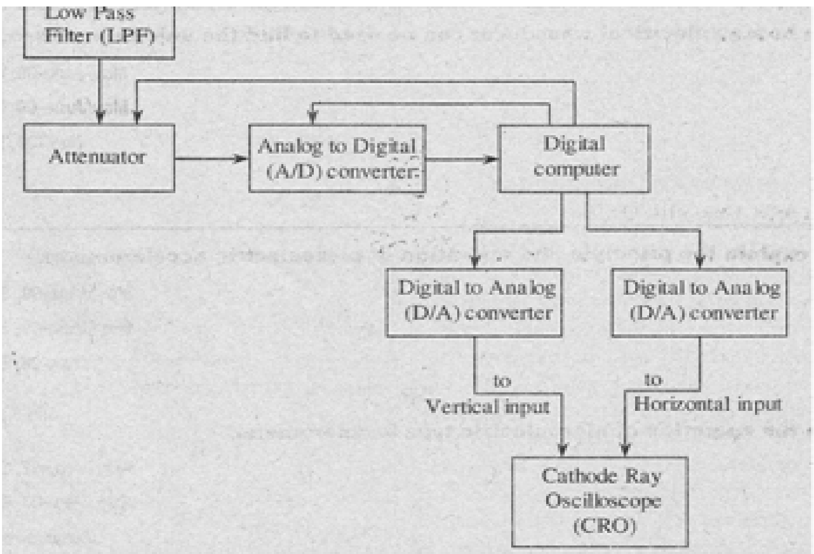


Fig Digital Fourier Analyzer

If the spectral display is to be viewed on the oscilloscope, the digital values of spectral components stored in the computer memory are converted into analog by using D/A converters and then applied to the CRO. Thus the spectral display of the input waveform is obtained on the CRT screen.

Advantages

1. The use of computer avoids most of the hardware circuitry such as electronic switches, Filters and PLLs. The use of less hardware reduces the cost of the analyzer.
2. More mathematical calculations can be carried-out on the spectral display.
3. The rate of sampling analog signal can be modified in order to obtain better spectral display.

Time base of a frequency counter

The logic diagram of a time base for a frequency counter is shown in figure, the expected output from the time base are,

(i) Reset pulse

(ii) Gating pulse
(iii) Store pulse.

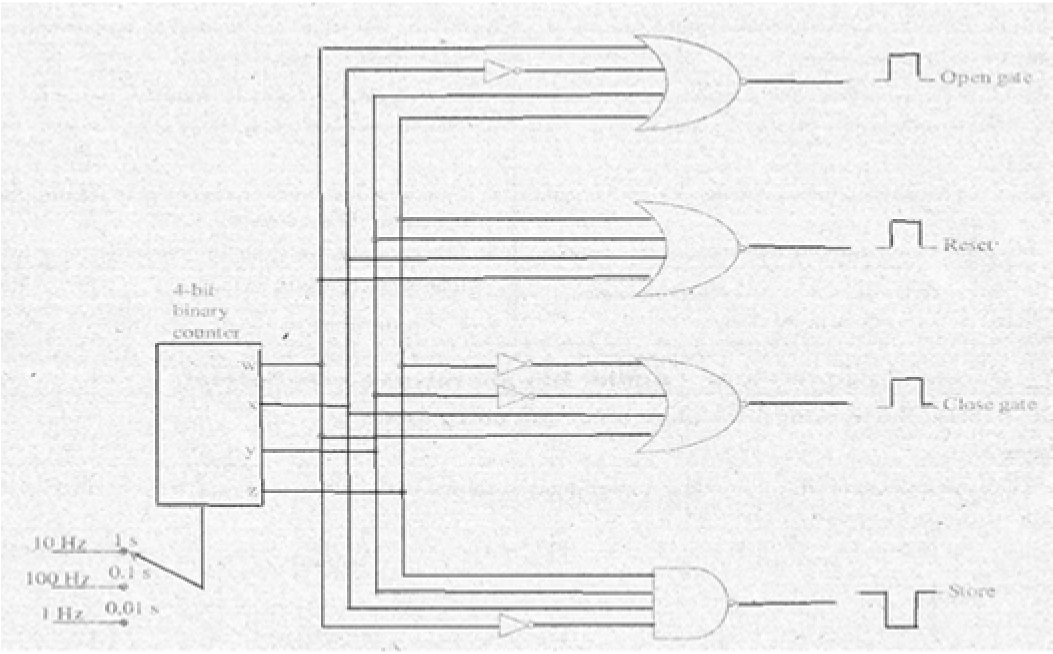


fig Time Base of Frequency Conuter

The above pulses must be produced without overlap. If the wanted gate pulse duration is larger than the frequency period of the crystal then the frequency of crystal oscillator is divided by powers of ten. The binary counter consist of 1 6 states since it is a 4 bit counter The reset pulse is provided by the decoded zero state of the binary counter. To produce open gate pulse the 2nd state of the binary counter is decoded. To produce a delay period after the reset pulse the 1st state of the binary counter was not .used. The gate remains, open In between 2n state and 12l ' state of the binary counter. Therefore, the close gate pulse is produced by the decoded 12 state of the binary counter. To produce a delay before storing the counter is latch during 14th state of the binary counter; the 13 ' state is not decoded The non overlap between the reset and store pulses can provided-by the non decoded 15th state of the binary counter. A switch is used in this arrangement, to select the, gate time intervals of the frequency counter. In the above figure 1 sec, 0.1 sec, 0.01 sec are the available gate time intervals and 1 Hz, 10 Hz, 100 Hz are the available input frequencies

Transducer

A measuring device which measures and converts nonelectrical variable into electrical variable is known as transducer.

Transducers are classified into several types. However, these can be categorized into five types. They are,

1. Classification on the basis of transduction principle used.
2. Active and passive transducers
3. Analog and digital transducers
4. Primary and secondary transducers
5. Transducers and inverse transducers.

Active and Passive Transducers

Active Transducer

The transducer which does not requires any external excitation to provide their outputs are referred as active transducer.

Examples of Active Transducer

1. Photo voltaic cell.
2. Thermocouple.

Applications

1 (i) Used in light meters
(ii) Used in solar cells.

2. Used to measure,
(i) Temperature
(ii) Radiation and
(iii) Heat flow.

Passive Transducer

The transducer which requires an external excitation to provide their output is referred as passive transducer.

Examples of Passive Transducer

1. Capacitive transducers.
2. Resistive transducers.
3. Inductive transducers.

Applications

1. Used to measure liquid level, noise, thickness etc.
2. Used to measure temperature, pressure, displacement etc.
3.Used to measure pressure, vibration, position, displacement etc.

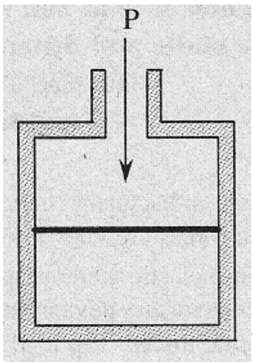
Principle of force summing devices

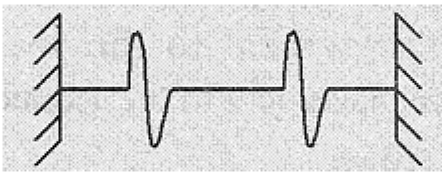
Force summing devices serve as primary transducers and convert the pressure applied at the input into displacement, which then can be measured by means of secondary transducer. The lists of most widely used force summing devices are

1. Diaphragms
2. Bellows
3. Bourdon tubes

1. Diaphragms

Any thin metal whose ends are fixed between two parallel plates is referred to as diaphragm. It is one of the pressure measuring elements. The operating principle is the applied pressure is converted into proportional displacement. The materials used to make diaphragms are phosphor bronze, nickel, beryllium copper, stainless steel, etc. These can be available in flat or corrugated shapes.

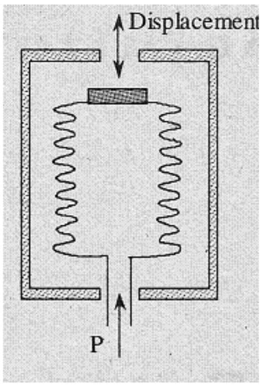




Flat corrugated

Bellows

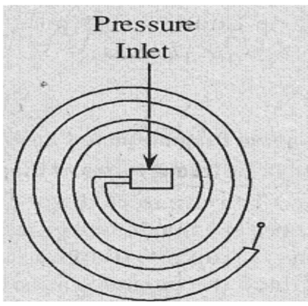
Bellows, the pressure measuring elements are formed by the series combination of capsules. The working principle of bellows is same as that of diaphragms i.e., the applied displacement is converted into proportionate mechanical displacement. The materials used to construct bellows are beryllium copper, brass, monel, stainless steel and nickel.

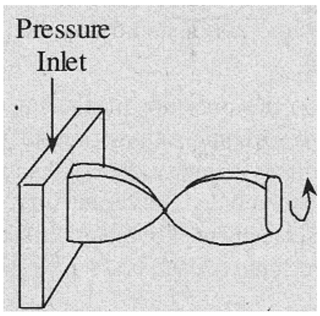


Whenever the pressure to be measured is applied the sealed end of bellow suffers displacement. The generated displacement can be known by attaching a pointer scale arrangement to the sealed end or by transmitting the displacement to the secondary transducer.

Bourdon Tubes

The bourdon tubes are available in different shapes such as spiral, helical, twisted and C shaped. However all the tubes have non-circular cross-section. Also the materials used and working of all these types are same. The materials used in the construction of bourdon tubes are brass, steel and rubber.





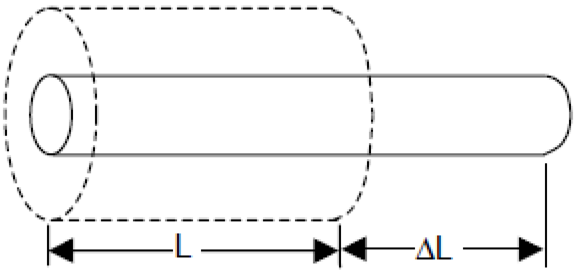
Spiral Twisted

Strain gauge

The fundamental formula for the resistance of a wire with uniform cross section, A, and resistivity, ρ, can be expressed as:

$$R = \rho \frac{L}{A} \quad \text{............(1)}$$

where L is the wire length. This relation is generally accurate for common metals and many



non metals at room temperature when subjected to direct or low frequency currents*. We consider the gage to be formed from a length of uniform wire and subjected to an longation as shown:

The change in resistance can be expressed from Eq. 1 as

$$\Delta R = \rho \frac{L}{A} - (\rho + \Delta\rho)\frac{L + \Delta L}{A + \Delta A}$$

where Δ signifies a change in the quantity. This is a complicated expression in its present form, however, it should be clear that for metallic wires subjected to engineering strain levels that ΔL << L and Δ A << A. If Δ ρ<< ρ as well, then we can simplify the expression by approximating Δ with the infinitesimal differential change, d():

$$\Delta R \cong dR = d\left(\rho \frac{L}{A}\right)$$

The differential expression on the right side is tedious to compute directly but can be easily determined using "log derivatives" as follows. First take the natural log (ln) of the equation yielding:

$$\ln(R) - \ln(\rho) + \ln(L) - \ln(A)$$

and now take the differential of this recalling that d(ln(x))=dx/x to get the simpler result:

$$\frac{dR}{R} - \frac{d\rho}{\rho} + \frac{dL}{L} - \frac{dA}{A}$$

In general we may write $A=C\,D^2$ where D is a cross section dimension and C is some constant (e.g., D=R and C=Π for a circle). Using the "log derivative" method, it follows that:

$$\frac{dA}{A} = 2\frac{dD}{D}$$

At this point we note that the longitudinal strain can be written in differential form as:

$$\varepsilon = \frac{dL}{L}$$

and the transverse or lateral strain as:

$$\varepsilon_D = \frac{dD}{D}$$

Also for linearly elastic and isotropic behavior of the wire:

$$\varepsilon_D = -\upsilon\varepsilon$$

Then using these results:

$$\frac{dA}{A} = 2\varepsilon_D = -2\upsilon\varepsilon = -2\upsilon\frac{dL}{L}$$

Finally, the resistance change per unit resistance (Δ R/R) can then be written:

$$\frac{dR}{R} = \frac{d\rho}{\rho} + (1 + 2\upsilon)\varepsilon \qquad \text{.................(2)}$$

This expresses the basic proportionality between resistance and strain in the gage element material. A measure of the sensitivity of the material (or its resistance change per unit applied strain) is defined as the Gage Factor:

$$GAGE\ FACTOR = GF = \frac{dR/R}{\varepsilon} \qquad \text{................(3)}$$

From the above resistance calculations (Eq. 2) the Gage Factor can then be determined as The Gage Factor as expressed above includes effects from two sources. The first term on the right represents directly the Poisson effect, i.e., the tendency in an elastic material to contract laterally in response to axial stretching. The second term represents the contribution due to changes in resistivity of the material in response to applied strain. In the absence of a direct resistivity change, then, the maximum and minimum values expected for the Gage Factor would be $1 \le GF \le 2$ corresponding to the theoretically allowable range $0 \le \nu \le ½$ for Poisson's Ratio.

Metal Foil Strain Gauges

In this type of strain gauges a metal foil is used to sense the applied strain. The materials used for its construction are nickel, nichrome, platinum, isoelastic (nickel + chromium + molybdenum), constantan (nickel + copper). The gauge factor and characteristics of foil strain gauges are similar to the wire strain gauges.

The metal foil gauges can be easily etched on a flexible insulating carrier film. In the construction of etched foil strain gauge first a layer of strain sensitive material is bonded to a thin sheet of backelite or paper. The part of some masking material and then to this unit an etching solution is applied. Therefore, the unmasked part of the metal will be removed thereby leaving the required grid structure. By this method of construction, the etched foil strain gauges are made in thinner sizes.

When a force or pressure is applied to the sensing element of metal foil strain gauge the physical dimensions of it will change. Since, the strain gauge element is pasted on its surface, the dimensions of the strain gauge changes due to which the resistance of the gauge changes. The measure of change in resistance will become the measure of applied pressure or force (this change in resistance of the gauge can be measured by connecting the gauge in any one of the four arms of balanced Wheatstone bridge).

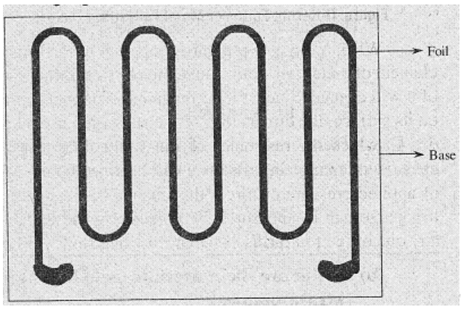


Fig. Metal foil strain gauge

Velocity transducer

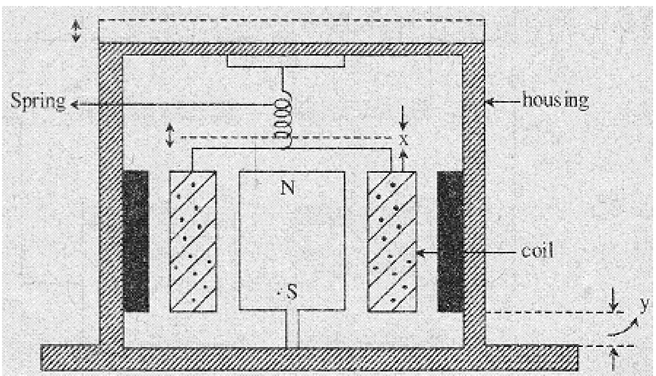
The main elements of a velocity transducer are coil and a permanent magnet. In such type of transducers velocity is measured based upon electromagnetic induction principle. These two elements can be arranged in two different configurations (i.e., electrodynamic and electromagnetic) to measure the velocity.

In electrodynamics velocity transducer, moving coil scheme is employed. In this configuration the coil and the magnet are arranged in housing such that the magnet is attached to the base of the housing and the coil is attached to the other side (top) of the housing with the help of a spring so that the coil is suspended in the magnetic field as shown in the figure below. The body whose velocity is too measured is connected to the base of the housing. Due to the displacement of the body, the housing also gets displaced which in turn caused a displacement of the coil in the magnetic field. This movement of the coil causes a change in the flux linkages between the Magnet and the coil, and thus according to the electromagnetic induction principle an electrical voltage gets induced in the coil. This induced voltage is proportional to the relative velocity of the spring and is given by the equation.

$$e = BLVr \times 10^{-8}$$

Where,

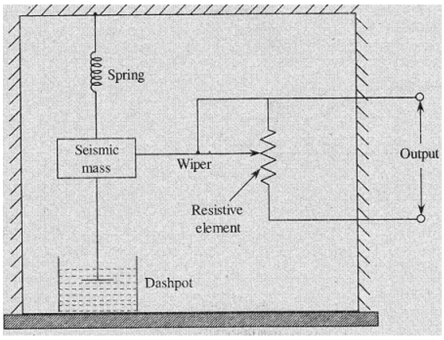
e-Induced voltage, B-Flux density, L-Length of coil, Vr=dx/dt=relative velocity of coil with respect to magnet (cm/s)



Potentiometric accelerometer

A potentiometric accelerometer employs a seismic mass, spring arrangement, dashpot, and a resistive element. The seismic mass (potentiometer) is connected between spring and dashpot. The wiper of the potentiometer is connected to the mass.

In the presence of vibration or acceleration, vibrational displacement of seismic mass takes place with respect to the housing of the device. The displacement of mass is transferred to the potentiometers through the wiper. Therefore the resistance of the potentiometer changes. This change in resistance gives the value of displacement and hence the acceleration.



Advantages

1. Construction and operation are very simple.
2. Low cost.

Disadvantages

1. Resolution is low.
2. They cannot be suitable for high frequency vibrations.

Piezoelectric transducer

Piezoelectric pressure transducers depend on the principle of 'piezoelectric effect' i.e., when some pressure or stress is applied to the surface of the piezoelectric crystal, an electric charge voltage will be developed by the crystal. The materials used in the construction of piezoelectric crystals are quartz, Rochelle salt, dipotassium titrate, lithium sulphate, barium titanate etc.

A piezoelectric pressure transducer is formed by connecting a diaphragm to the piezoelectric crystals and this assembly is shown below. The pressure which is to be measured is applied to corrugated metal diaphragm. The diaphragm deflects depending on the applied pressure, and this deflection signal is transmitted to the crystal through the mechanical link. In other words, the pressure is applied to the crystal through the diaphragm and the link.

When the crystal senses the pressure it will generate some voltage corresponding to the applied pressure, and is measured in the output voltage measuring device which is calibrated in terms of applied pressure.

Applications

(a) These can be used in the process which requires measurement of high pressure.

(b) Can be applied in those systems which requires measured variable in electrical form.

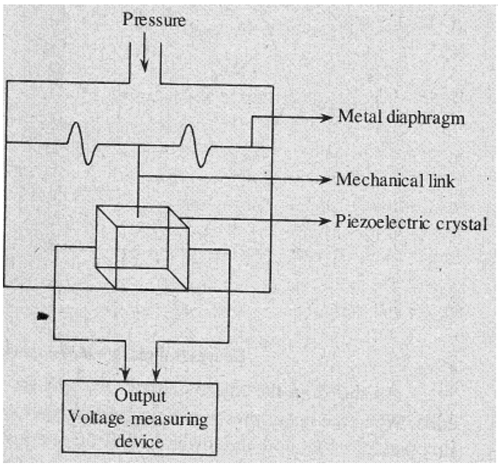
Merits

1. Provides electrical output.
2. This transducer does not require any external power supply.
3. Size in small.
4. Rugged construction.

Demerits

1. It cannot be used for static pressure measurements.
2. The response will get affected by the variations in temperature.

3. In some cases it requires signal conditioning circuitry which is complex.
4. Cost is high



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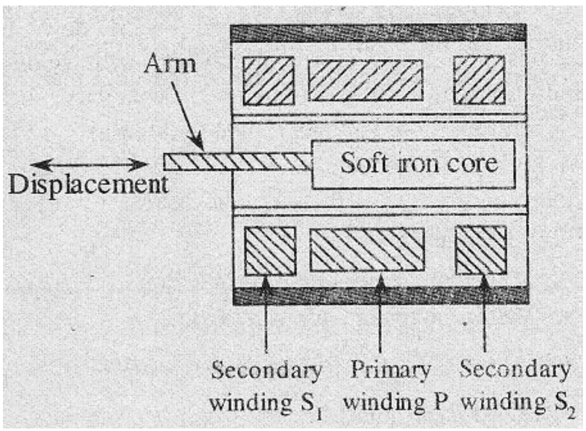
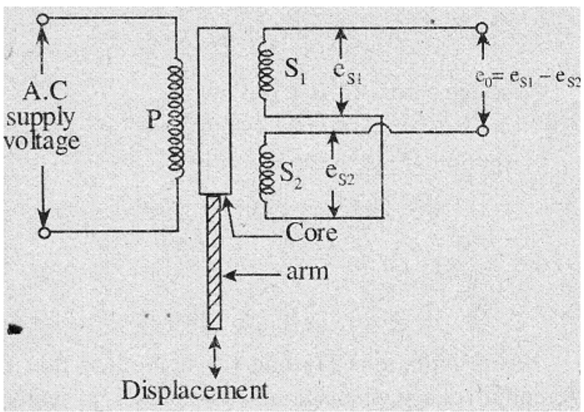
Linear Variable Differential Transformer (LVDT)

LVDT consists of one primary winding *(P)* and two secondary windings (S1 and S2).with equal number of turns wound on a cylindrical former. The two secondary windings are connected in series opposition and are placed identically on either side of primary winding to which an AC excitation voltage is connected. A movable soft iron core is placed within the cylindrical former. When the displacement to be measured is applied to the arm of the core, the LVDT converts this displacement into an electrical signal.
The construction of LVDT is illustrated in figure





The operating principle of LVDT depends on mutual inductance. When the primary winding is supplied with A.C. supply voltage, it generates alternating magnetic field. Due to this magnetic field an alternating voltage will be induced in the two secondary windings. In the figure (5.2) *es1* is the output voltage of secondary winding *S1* and *es2* is the output voltage of secondary winding S*2* In order to get single differential output voltage two secondary windings are connected in series opposition. Thus the differential output voltage is given by,

e0=es1-es2

When the core is placed symmetrically with respect to two secondary windings an equal amount of voltage will be induced in both windings. Therefore *esl* - *es2* and the output voltage is '0'.

Hence, this position is known as null position. Now if the core is moved towards up from null position, more magnetic field links with secondary winding S_1, and small field links with secondary winding S_2. Therefore more voltage will be induced in S_1 and less in S2 i .e . , $e s_1$ will be larger than es_2 . Hence the differential output voltage is e0=es1-es2 and is in phase with primary voltage.
But when the core is moved towards down from null position more magnetic field links with secondary winding S_2 and small field links with secondary winding S1. Therefore more voltage will be induced in *S2* and less in S1, i.e.,*es2* will be larger than *es1*. Hence, the differential output voltage is *e0 = es2 – es1* and is 180° out of phase with primary voltage. Thus the output voltage *e0* position of the core and hence the displacement applied to the arm of the core.

Merits

1. LVDT has good linearity i.e.. it produces linear output voltages.
2. It can measure displacements of very high range usually from 1.25mm to 250mm.
3. It has high sensitivity.
4. Since it produces high output, it does not require amplifier devices.
5. It has low hysteresis.
6. It consume less power (about < 1w)

Demerits

1. It is sensitive to stray magnetic fields.
2. Performance of LVDT is affected by variations in temperature.
3. It has limited dynamic response.
4. To provide high differential output, it requires large displacements.