SEMESTER - V

ELECTRONIC INSTRUMENTATION

UNIT – III

Transducers and Bridges

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UNIT-3

Transducers and Bridges

a) Linear Variable Differential Transformer (LVDT), Resistive, Capacitive & Inductive transducers, Piezoelectric transducer.

DC Bridge -Wheatstone's bridge, AC Bridges - Measurement of Inductance and Capacitance Maxwell's bridge, Schering Bridge, Measurement of frequency – Wien's bridge.

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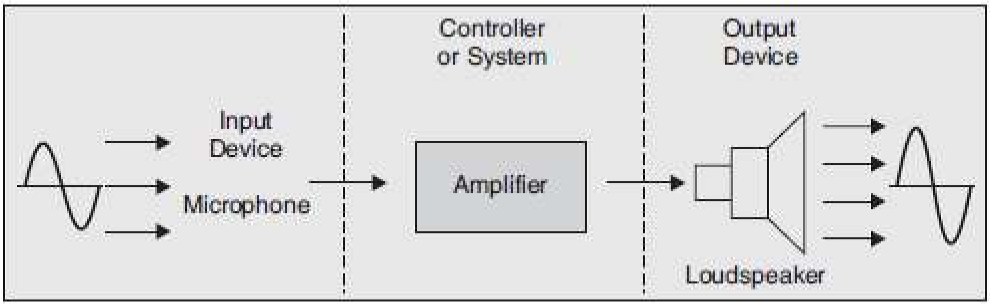
Introduction:

Transducer is a device that converts one type of energy into one type of energy into other type for the purpose of measurement or transfer of information. For example, a microphone as an input device converts sound waves into electrical signals for the amplifier to amplify, and a loudspeaker as an output device converts the electrical signals back into sound waves.



Classification of Transducer

The classification of transducers may be explained as follows:

1. Based on the physical phenomenon

(*a*) Primary transducer

(*b*) Secondary transducer

On the basis of application transducer may be classified as primary and secondary transducer. When the input signal is directly sense by the transducer, the non-electrical energy is converted into electrical energy directly then, this type of transducer is known as primary transducer. For example thermistor, senses the temperature directly and causes the change in resistance with the change in temperature. When the input signal is first sensed by some sensor or detector, then its output signal is feed to the other instrument as an input. The output of this instrument is given as the input of transducer for converting into electrical energy. This type of transducer is in secondary transducer classification. For example in the case of pressure measurement, we use bourdon tube to convert pressure into

1. Explain Resistive Transducers?

In such material the resistances of the transducer get varied according to the measured. The resistance of any metal conductor is expressed by a simple equation,

$$R = \rho L \frac{\rho L}{A}$$

where, L = length of the conductor

A = Cross Section area of the conductor

ρ = resitivity of conductor

From the above equation we see that the resistance of the material depends on L, A and r. Any method of varying one of the quantities involved in the above relationship can be the design

basic of electrical resistive transducer.

2. Explain about Inductive Transducers

The inductive transducers work on the principle of the magnetic induction of magnetic material. The induction of the magnetic material depends on a number of variables like the number of turns of the coil on the material, the size of the magnetic material, and the permeability of the flux path.

In the inductive transducers the magnetic materials are used in the flux path and there are one or more air gaps. The change in the air gap also results in change in the inductance of the circuit and in most of the inductive transducers it is used for the working of the instrument. There are two type of inductive transducers,

1. Linear Variable Differential Transformer
2. Rotary Variable Differential Transformer

3.Explain about Linear Variable Differential Transformer

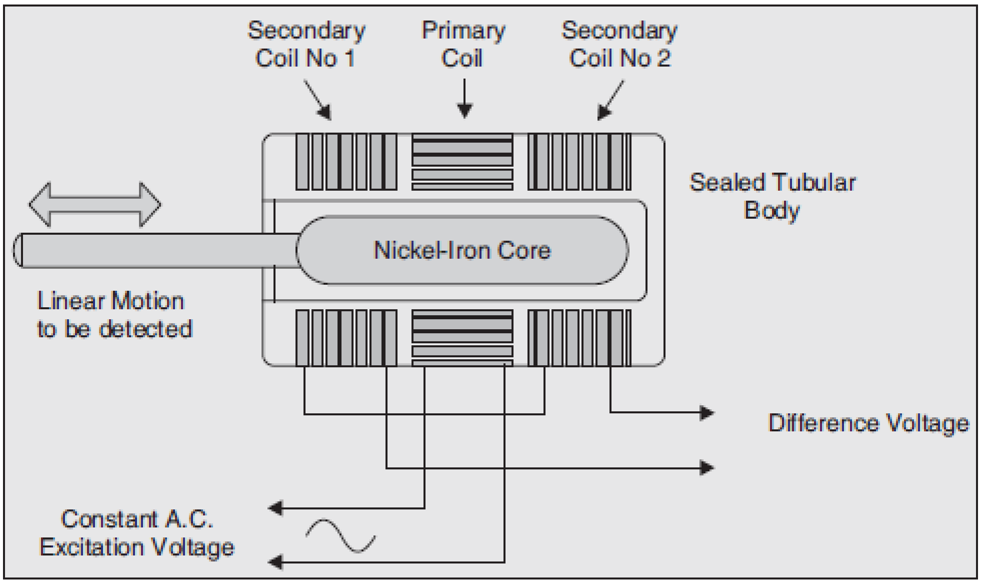
Linear Variable Differential Transformer (LVDT) is an inductive type position sensor which works on the same principle as the AC transformer that is used to measure movement. It is a very accurate device for measuring linear displacement and whose output is proportional to the position of its moveable core.

It consists of three coils on a hollow tube: one primary and two identical secondaries connected in series but 180° out of phase. A movable soft iron core linked to the measured object slides inside the tube. An AC excitation signal is applied to the primary, inducing EMF in the secondaries. This setup helps measure displacement based on induced voltage differences.

When the soft iron core is at the center (null position), the EMFs in the two secondary windings cancel out, giving zero output. If the core moves from this position, one secondary generates a stronger EMF than the other, producing an output signal. The polarity of this output depends on the direction of the core's displacement. The further the core moves from the center, the greater the output voltage. Thus, the output is a differential voltage that varies linearly with both the magnitude and direction of core movement.

The differential output voltage is given by,

$$E_0 = E_{S1} - E_{S2}$$



4 Explain about capacitive transducer

The capacitive transducer is a capacitor with variable capacitance, consisting of two parallel conductive plates separated by a dielectric like air.

In variable capacitance transducers, the distance between the plates changes, unlike fixed plate capacitors.

Capacitance is given by $C = \varepsilon \cdot A/d$

where A is plate area,

d is plate separation, and

ε is the dielectric permittivity.

Capacitance changes with variation in input quantities like displacement or pressure.

It also depends on the area of the plates, distance between them, and the dielectric constant of the material used. Thus, capacitance can vary due to changes in dielectric, plate area, or plate spacing. Based on the parameter that varies, there are three types of capacitive transducers.

Advantages:

1. They are very sensitive.

2. Good frequency response.

3. The force requirement of capacitive transducer is very small and therefore it require small power to operate.

Disadvantages

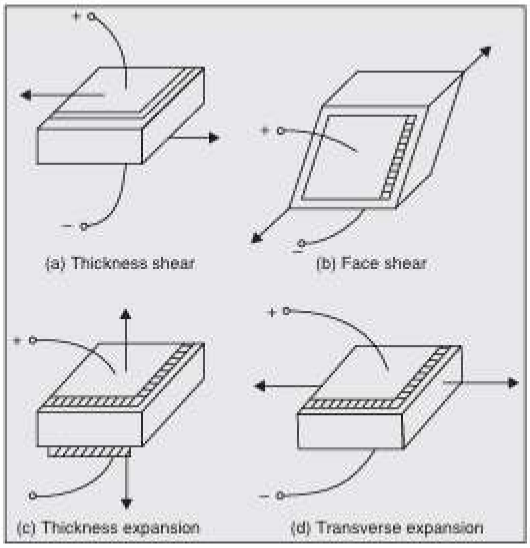
1. The capacitive transducer are temperature sensitive.

5. Explain about Piezo electric transducer

A piezoelectric transducer is a device that converts mechanical energy into electrical energy (and vice versa) using the piezoelectric effect. This effect is observed in certain crystalline materials—like quartz, Rochelle salt, and lead zirconate titanate (PZT)—that generate an electric charge when mechanically

Working Principle

When a piezoelectric material is subjected to mechanical stress it undergoes deformation, leading to a realignment of internal dipoles and the generation of an electric potential across its surfaces. This effect is reversible, meaning that applying an electric field can also induce mechanical deformation.



construction and Design

A typical piezoelectric transducer consists of:

1. A piezoelectric crystal bonded between two metal electrodes
2. A mechanical interface to apply force or vibration
3. A signal conditioning circuit (amplifier, charge amplifier, filter, etc.)

Characteristics

1. High-frequency response → suitable for dynamic measurements
2. No external power supply needed for sensor operation (in direct mode)
3. High output impedance → usually requires impedance matching circuitry
4. Linearity and sensitivity depend on the material and geometry

Applications

1. Used in combustion engines)
2. Vibration and acceleration measurement.
3. Used in Ultrasound generation and detection
4. Force and torque sensing in precision instruments

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DC BRIDGES

We have already discussed in the last chapter about the DC Bridge. In this chapter we shall discuss the AC Bridge in detail. The AC Bridge is the outgrowth of the DC Bridge. AC bridge are the best and most usual methods for the precise measurement of self and mutual inductance and capacitance. These bridges are used to determine the value of inductance, capacitance and frequency.

Measurement of Inductance

The inductance is measured with the following bridge circuit:

1. Maxwell Bridge

2. Hay Bridge

3. Anderson Bridge

4. Owen Bridge

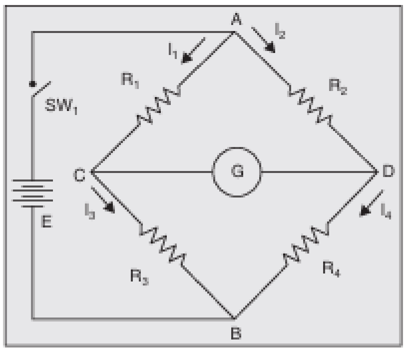
Measurement of Capacitance The capacitance is measured with the following bridge circuit:

1. De Sauty Bridge

2. Schering Bridge

6.**Explain about Wheatstone Bridge**

The Wheatstone bridge is widely used in control circuits and is the most accurate method for measuring resistance. It consists of four resistive arms, a power source, and a galvanometer connected between two midpoints. The bridge is balanced when the voltage across the galvanometer is zero, resulting in no current flow through it. At balance, equal voltage ratios across opposite arms ensure accurate resistance measurement.



The bridge is said to be balanced when the potential difference across the galvanometer is '0V' so that there is no current through the galvanometer. This condition occurs when the voltage from point '*C*' to point '*A*' is equal to the voltage from point '*D*' to point '*A*'. By referring the other battery terminal, the bridge is balanced when the voltage from point '*C*' to point '*B*' equals the voltage from point '*D*' to point '*B*'. Thus when the bridge is balanced,

$$I_1 R_1 = I_2 R_2 \qquad \ldots(i)$$

Applying Kirchhoff's Voltage Law in loop *ABC* when the galvanometer current is zero, we get,

$$I_1 R_1 + I_3 R_3 - E = 0$$

But since current $I_1 = I_3$, we get,

$$I_1 = I_3 = \frac{E}{R_1 + R_3} \qquad \ldots(ii)$$

Similarly, in loop *ADB* we get,

$$I_2 = I_4 = \frac{E}{R_2 + R_4} \qquad \ldots(iii)$$

Using equation (*i*) (*ii*) and (*iii*), we get

$$\frac{R_1}{R_1 + R_3} = \frac{R_2}{R_2 + R_4}$$

or

$$R_1 R_4 = R_2 R_3 \qquad \ldots(iv)$$

In balanced condition if three of the resistances have known values, then the value of fourth resistance is calculated from the equation (*iv*). If R_4 is unknown resistor R_x, then the value of R_x,

$$R_x = R_3 \frac{R_2}{R_1}$$

Resistor R_3 is called the standard arm of the bridge, and resistors R_2 and R_1 are called the ratio arms. The laboratory version of Wheatstone bridge instrument is shown in Fig. 4.15.

Measurement Errors in Wheatstone Bridge:

1. The main source of measurement error is found in the limiting errors of three known resistors

2. Insufficient sensitivity of the null detector

3.Heating from current can change the resistance of bridge arms.

4. Thermal EMFs may affect accuracy when measuring low-value resistors.

7.Explain about Maxwell bridge?

This bridge accurately measures medium inductance by comparing it with a variable standard inductance. The circuit includes an unknown inductance L_X a variable inductance

L_3, and resistors R_1, R_2, R_3 and r_3. A detector is used, and the bridge is balanced by adjusting L_3 and either R_1 or R_2. Alternatively, balance can be achieved by adding resistance in one of the other arms while keeping R_1 and R_2 constant.

The general equation of the bridge,

$$Z_1 Z_x = Z_2 Z_3 \quad \ldots(i)$$

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

The values of Y_1, Z_2, Z_3 and Z_X are

$$Z_1 = R_1$$
$$Z_2 = R_2$$
$$Z_3 = R_3 + j\omega L_3 + r_3$$
$$Z_X = R_X + j\omega L_X$$

Substituting all the above values in equation (*i*) we get,

$$R_1 (R_X + j\omega L_X) = R_2 (R_3 + j\omega L_3 + r_3)$$
$$R_X R_1 + j\omega L_X R_1 = R_3 R_2 + j\omega L_3 R_2 + r_3 R_2 \quad \ldots(ii)$$

Comparing the real terms on both sides of the above equation, we get,

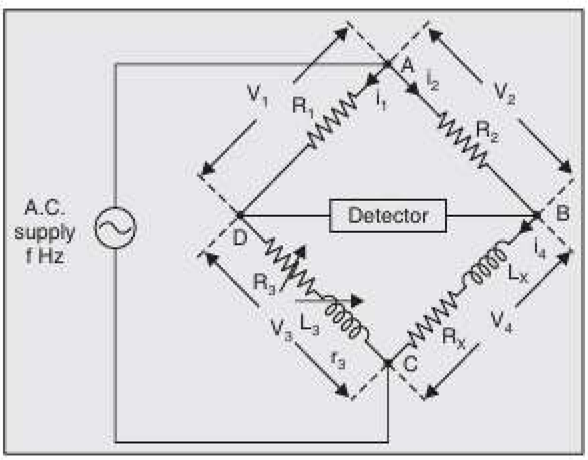
$$R_X = \frac{R_2}{R_1}(R_3 + r_3) \quad \ldots(iii)$$

Comparing the imaginary term on both sides of the equation (*ii*), we get,

$$\omega L_X R_1 = \omega L_3 R_2$$
$$L_X = \frac{L_3 R_2}{R_1} \quad \ldots(iv)$$

The value of unknown resistance R_X and inductance L_X is given by equation (*iii*) and (*iv*) :spectively. The quality factor (Q-factor) of coil is given by,

$$Q = \frac{\omega L_X}{R_Y}$$



Advantages

1. The measurement is independent of the excitation frequency.

2. The balance equation is independent of losses associated with inductance.

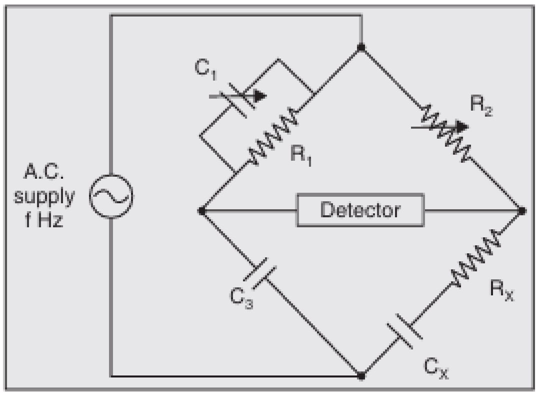
3. The Maxwell bridge is very useful for measurement of a wide range of inductance at power and audio frequency.

Disadvantages

1. The bridge cannot be used to measure very low Q or High Q values.

8. Explain about Schering bridge

The Schering bridge is widely used for measuring capacitance, dielectric loss, and power factor, both at low and high voltages. It is suitable for precision capacitor testing and insulation analysis, with flexible arrangements for various applications. In its circuit, a known capacitor C_1 with resistance R_1 is balanced against an unknown capacitor C_X in series with R_X.



In this bridge, arm 1 contains a parallel combination of a resistor and a capacitor. The capacitor C_3 is a high quality mica capacitor (low-loss) for general measurements, or an air capacitor for insulation measurement.

The general equations of the bridge are,

$$Z_1 Z_x = Z_2 Z_3$$

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

Admittance in branch 1 is given by,

$$Y_1 = \frac{1}{Z_1}$$

then,

$$Z_X = Z_2 Z_3 Y_1 \qquad \ldots(i)$$

The values of Y_1, Z_2, Z_3 and Z_X are

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

$$Z_2 = R_2$$

$$Z_3 = -\frac{j}{\omega C_3}$$

$$Z_X = R_X - j\frac{1}{\omega C_X}$$

Substituting all the above values in equation (i),

$$R_X - j\frac{1}{\omega C_X} = R_2\left(-\frac{j}{\omega C_3}\right)\left(\frac{1}{R_1} + j\omega C_1\right)$$

Rearranging the above equation, we get,

$$R_X - j\frac{1}{\omega C_X} = \frac{R_2 C_1}{C_3} - \frac{j R_2}{\omega C_3 R_1}$$

Comparing the real and imaginary terms we get

$$R_X = \frac{R_2 C_1}{C_3}$$

and

$$C_X = \frac{R_1 C_3}{R_2}$$

9. **Explain about Wien Bridge**

The Wien bridge is a frequency-sensitive circuit primarily used for frequency determination and control. It has a series R_C arm and a parallel R_C arm, and was once widely used for measuring capacitance and losses. Though now largely replaced by the Schering bridge, it remains useful for precise frequency applications.

bridge circuit is frequency sensitive, and now a days it is employed for determination and control of frequency.

The general equation of the bridge,

$$Z_1 Z_4 = Z_2 Z_3 \quad \ldots(i)$$

Admittance in branch 3 is given by

$$Y_3 = \frac{1}{Z_3}$$

then,

$$Z_1 Z_4 Y_3 = Z_2$$

The values of Z_1, Z_2, Z_4 and Y_3 are

$$Z_1 = -\frac{j}{\omega C_1}$$

$$Z_2 = R_2$$

$$Y_3 = \frac{1}{R_3} + j\omega C_3$$

$$Z_4 = R_4$$

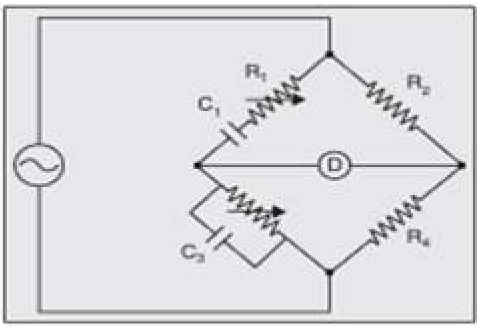


Fig. 5.15. Wien Bridge.

Substituting all the above values in equation (*i*) we get,

$$\left(R_1 - \frac{j}{\omega C_1}\right) R_4 \left(\frac{1}{R_3} + j\omega C_3\right) = R_2$$

$$\frac{R_1 R_4}{R_3} + j\omega C_3 R_1 R_4 - \frac{j R_4}{\omega C_1 R_3} + \frac{R_4 C_3}{C_1} = R_2$$

Comparing the real terms on both sides of the above equation, we get,

$$R_2 = \frac{R_1 R_4}{R_3} + \frac{R_4 C_3}{C_1}$$

$$\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1} \quad \ldots(ii)$$

Comparing the imaginary term we get,

$$\omega C_3 R_1 R_4 - \frac{R_4}{\omega C_1 R_3} = 0$$

or

$$\omega C_3 R_1 R_4 = \frac{R_4}{\omega C_1 R_3}$$

where $\omega = 2\pi f$ and solving for f, we get

$$f = \frac{1}{2\pi\sqrt{C_1 C_3 R_1 R_3}} \quad \ldots(iii)$$

The equation (*ii*) determines the resistance ratio, R_2/R_4 and equation (*iii*) determining the frequency of the applied voltage. When the circuit components $R_1 = R_3$ and $C_1 = C_2$, the equation (*ii*) is

$$\frac{R_2}{R_4} = 2$$

and equation (*iii*),

$$f = \frac{1}{2\pi RC}$$

Applications:

1. This bridge is used for measuring the frequency in audio range.

2. The Wien bridge is used in audio and HF oscillators as the frequency determining device.

3. The bridge is used in a harmonic distortion analyser, as a notch filter, and in audio frequency and radio frequency oscillators as a frequency determining element.