TRANDUCERS

Major elements of an instrumentation system:

An instrumentation system generally consists of following major elements.

(i) An input device
(ii) processing device
(iii) an output device

The input device receives the quantity under measurement and delivers a proportional electrical signal to the processing device. Transducers are used as input devices. The processing device is used to amplify, filter or otherwise modify the signal to a format acceptable to the output device. The output device may be a simple indicating meter, a digital computer or a CRO etc.

Transducer is defined as a device which converts one form of energy into another form.

Mostly in industry, transducers are used to convert non-electrical quantities like temperature, pressure, light etc into an electrical signal that may be amplified, recorded and otherwise processed in the instrumentation system.

CLASSIFICATION OF TRANSDUCERS:-

Electrical transducers can be classified as active and passive.

Active transducer: These transducers are of the 'self generating' type. They do not require external power. An analog voltage or current is produced when stimulated by some physical form of energy.

e.g. thermocouple, piezoelectric crystal, photovoltaic cell.

Passive transducer: These transducers require external power. They produce a variation in some electrical parameter such as resistance, capacitance etc which can be measured as a voltage or current variation e.g. thermistor, photoconductive cell, LVDT.

TRANSDUCER SELECTION

Before selecting a transducer, one must study the following parameters.

1) Transducer Type

This point is very fundamental. One must know the nonelectrical physical quantity which is to be received by the system. According to this knowledge, one must decide the group to which the required transducer belongs e.g. when a luxmeter is to be designed, then it is clear that a photosensitive transducer is to be selected for this. After selecting the main group of transducer type, the proper and specific transducer can be easily selected by knowing operating range and the processing technique.

2) Transducer Specifications

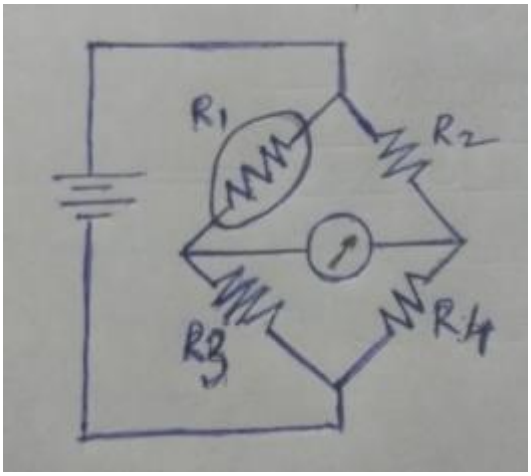
After selecting the group one must think about physical specifications like size, diameter, height, and so on. Transducer selection also includes technical specifications like operating range, sensitivity, graphical analysis, minimum and maximum limitations etc.

3) Transducer Compatibility

Environmental conditions like temperature, acceleration, shock and vibration should not affect the accuracy of the instrument and if they affect beyond certain limit, then what technique is to be used to reduce their effects, must be considered. Compatibility also includes impedance matching, insulation resistance and tolerance in sensitivity so that the transducers performance becomes compatible with associated equipment system. These parameters help us while designing a system with maximum accuracy.

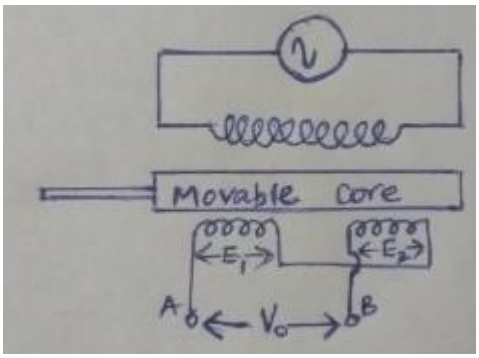
TEMPERATURE TRANSDUCER

Thermistors are semiconductors with a high usually negative temperature coefficient of resistance. They are used as temperature transducers.



R1 is a thermistor placed in the above bridge circuit. Its resistance decreases with increase in temperature. When this thermistor is placed on a patients body, due to temperature of the body, resistance of thermistor changes. The bridge which was balanced when the thermistor was not in use, now gets unbalanced. The unbalanced bridge will cause current through the meter. The deflection produced by galvanometer is calibrated in terms of degree celsius.

LVDT: Linear Variable Differential Transformer



LVDT is a transformer having a single primary winding and two secondary windings as shown. These secondary windings have equal number of turns, connected in series but in opposite direction so that the voltage induced in them oppose each other. In other words, output voltage of LVDT is $V_o=E_1-E_2$ where E_1 is voltage induced in coil 1 and E_2 is voltage induced in coil 2. There is a movable core, which can change its position due to force applied on it. It determines the flux linkage between common primary coil and the two secondary coils.

The output of LVDT is always $|E_1-E_2|$ because the applied force produces displacement of core causing difference in flux linkage of coil 1 and coil 2.

(i) When the core is at the centre or when there is no force, an equal and opposite voltage is induced in both the coils which will cancel each other. Hence $V_0=E_1-E_2=0$

(ii) When the core is displayed towards the left, more flux is linked between the primary and coil-1 than primary and coil2. Therefore $E_1>E_2$. The differential output voltage is in phase with E_1.

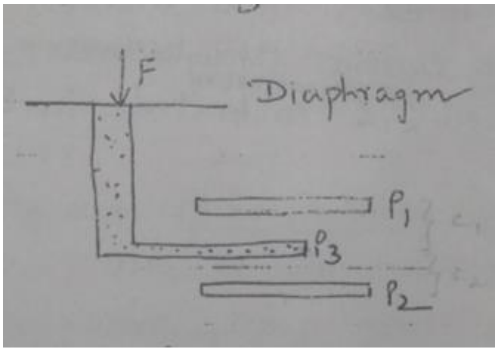
(iii) When the external applied force moves the core on to the right hand side, then the induced voltage in coil2 is greater than that of coil1. The output of LVDT is in phase with E_2 since $E_2>E_1$.

Use - It is used as a displacement or pressure transducer.

CAPACITIVE TRANSDUCER (Variable capacitance)

This is a passive transducer. In this pressure transducer, capacitance is varied with the stimulus. In almost all varieties, the capacitive transducer uses a stationery plate and a movable plate that changes position under the influence of the stimulus. Capacitance is inversely proportional to the distance between plates. Any change in the distance, causes a corresponding change in the capacitance. This is the principle of a capacitive transducer.

The figure below shows the construction. Movable plate P_3 is placed between two stationery plates P_1 and P_2. This forms a differential capacitor consisting of two sections.



C_1 – capacitance between P_1 & P_3

C_2 – capacitance between P_3 & P_2

If force applied to the diaphragm is downwards, P_3 moves closer to P_2. Therefore $C_2 > C_1$.

If force is in upward direction, P_3 moves closer to P_1.

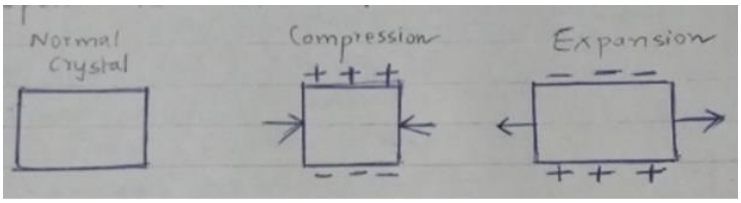
Therefore $C_1 > C_2$.

The resulting change in capacitance is measured with an oscillator circuit. This change in capacitance can cause the oscillator frequency to change, which is measure of the magnitude of the applied force.

PIEZO ELECTRIC TRANSDUCER

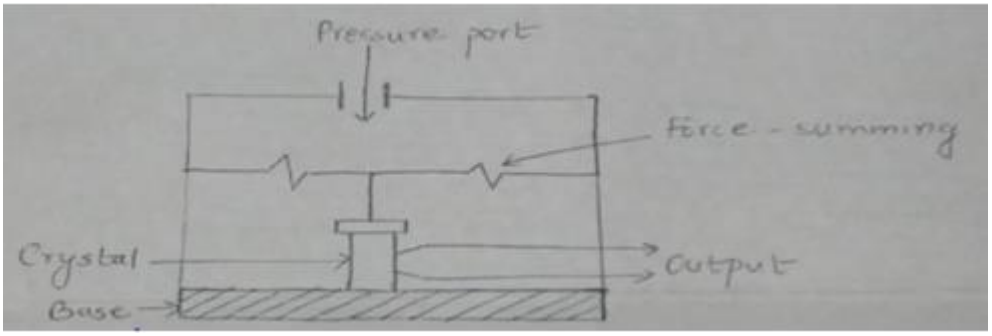
This is an active type of pressure transducer. It uses piezoelectric effect exhibited by certain crystals like quartz.

Piezoelectric effect



When a piezoelectric crystal is subjected to mechanical pressure, it develops a potential difference across its opposite faces e.g. If the crystal is compressed, it may develop a potential difference of the polarity shown above. When expanded, the polarity of potential differential reverses. This is the basic principle of a piezoelectric transducer.

In the piezoelectric transducer shown below the crystal is placed between a solid fixed base and a movable part known as summing element F.



An externally applied force entering through the pressure port applies pressure to the top of the crystal and an emf is produced across the crystal proportional to the magnitude of applied pressure.

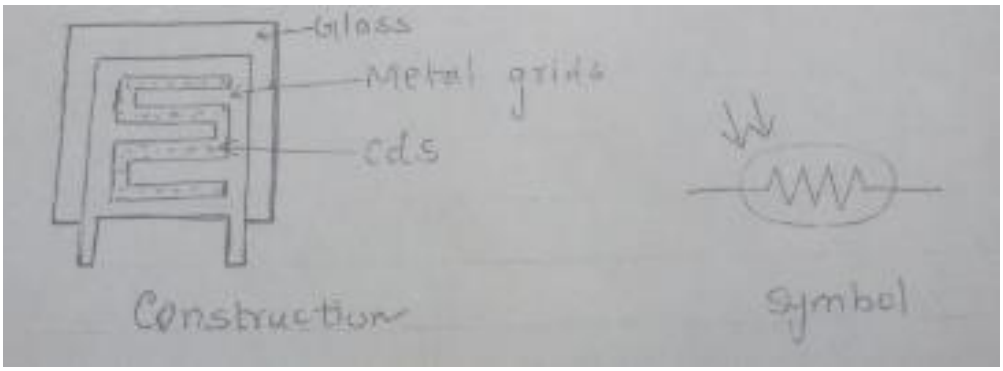
LIGHT DEPENDENT RESISTOR (LDR)

It is a light transducer and works on the principle of photoconductive effect.

In light, conductivity increases causing resistance to decrease.

In dark, with no incident light, conductivity decreases i.e. resistance increases.

Construction:

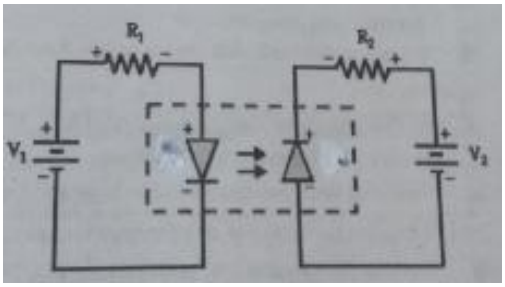


Two metal grids which are to serve as the LDR terminals are cemented to a sheet of glass or some non-conductive transparent plastic. A thin layer of photoconductive substance (mostly CdS) is deposited between the grids. This assembly is covered by another sheet of glass or plastic.

Working: When LDR is exposed to light, it receives energy of photon due to which photosensitive material increases its conductivity causing decrease in resistance. In dark, with no incident photon, conductivity decreases i.e. resistance increases.

Applications: Used in burglar alarm, photo relay circuits etc.

OPTOCOUPLER



Optocoupler: This is a type of light transducer. It is also called an optoisolator or optically coupled isolator.

It combines a LED and a photodiode in a single package. It has a LED on the input side and a photodiode or a phototransistor on the output side.

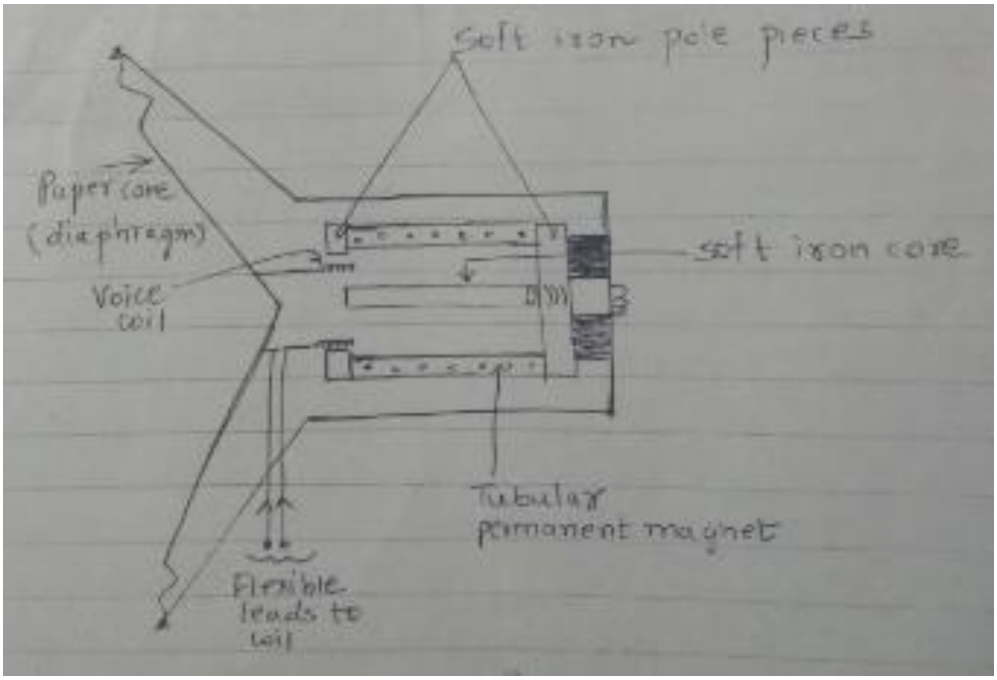
When LED is forward biased, the light from LED falls on the photodiode and produces a reverse current. The output voltage depends on the reverse current. If input voltage is changing, amount of light changes and the output voltage accordingly changes.

Optocoupler hence couples an input signal to the output circuit.

Application – Optocoupler provides electrical isolation between the input and output. Such isolation is useful in high voltage circuits, where the potentials of two circuits may differ by several thousand volts.

LOUDSPEAKER

Loudspeakers change the electrical impulses from the amplifier into a mechanical movement of the speaker cone to produce a sound output. The construction of moving coil type (dynamic) loudspeaker is shown in the figure below.



The voice coil is placed where the magnetic field is concentrated. Two connections are made to the voice coil. When there is current through the coil, a magnetic field is setup inside the coil. This magnetic field either helps or opposes the permanent magnet field, causing the voice coil and the speaker cone to move either in or out. If we apply an ac to the coil, the cone reproduces sound as it moves the surrounding air back and forth. The spider allows motion in forward and backward direction only.

Loud speaker does not require external source of power other than the signal power to make it operate. Magnet is the powerhouse of the loud speaker.