**E-CONTENT(DOCUMENT TYPE)**

**NAME:- ARUN A. BHOYAR**

**SEM- IV**

**UNIT-II (PAPER-II)**

**TOPIC:- INTRODUCTION TO TRANSDUCER, TYPE OF TRANSDUCER, CLASSIFICATION , ADVANTAGES & DISADVANTAGES ETC.**

**NOTE:- PAGE 1 TO 5 Already taught to student. Also the soft/hard copy are already made available to the students.**

TRANSDUCER:-

An Electronic Instrumentation system consists of many components to perform a measurement and record the results. We come across many types of measurands like temperature , pressure, force , velocity etc. which are physical quantities, but reliable data sampling, conditioning and processing are possible on electrical signals only. Hence it is very important to convert the measurands into a proportional electrical signal , which is the input to the measurement system. After processing , the electrical signal has to be converted back into a physical form like a deflection of a pointer in a voltmeter.

Sensors:-

A sensor is a device that can sense the physical signal and its variations

E.g. Our skin is the best example of a sensor that can sense the temperature wheather it is very hot or cold . But it cannot tells us the exact temperature.

Actuators:- An actuator is a device that converts the electrical signals such as voltage or current into a signal from the physical domain such as opening or closing a valve.

E.g. Relay is an example of an actuators.

TRANSDUCERS:-

A transducer is a device which converts one form of energy into another form . It means that , the transducer is actuated or energized by the energy from one transmission system and supplied to the other system in same or another form.E.g. Strain guage, thermistor.photo- tubes etc. A transducer provides a usable output in response to a specified input measurand which may be a physical or mechanical quantity. The energy transmitted by these system may be electrical , mechanical or acoustics.

The nature of the electrical output of the transducer depends upon the basic principle involved in the energy transmission. The output may be digital , analogue or frequency modulated.

(1)

Type of Transducer:-

Basically there are two types of Transducer as:- 1) Active transducer

2) Passive Transducer

Acive Transducer:-

Active Transducer are those transducer which generates an electrical signal directly in response to the physical parameter and does not require an external power supply for its operation. They are self generating type and operate under energy conversion principal and generate an equivalent output signal.

E.g. piezoelectric sensors ( generation charge in response to pressure) and photovoltaic cell ( generation of voltage in response to illumination).

The active transducer or self generating type transducer are usually of electrical type

These transducer are further classified as:-

1. Photovoltaic
2. Thermoelectric
3. Piezoelectric
4. Electromagnetic
5. Chemical

Passive Transducer:-

Passive Transducer are those transducer which requires an external power supply for its operation. These transducer operates under energy controlling principals. Their operation depends upon a change in an electrical parameters like R,L or C. E.g. strain gauges ( resistance change in response to pressure variations) and thermistors ( resistance change in response to temperature variations). The passive transducer require external energy source i.e. DC Power supply for conversion. The output of passive transducer is in the form of resistance, capacitance or some other electrical parameter in response to the input .

The passive transducer are basically divided into following types:-

1. Variable resistance
2. Hall effect
3. Optoelectronic
4. Variable resistance

Further subdivision of passive transducer are as follows:-

Variable Resistance transducer:-

1. Variable Resistor, Photo conductor
2. Strain gauge
3. Thermistor, Magneto resistance,PN junction point wire

(2)

Opto Electronic transducer:-

1. Photo junction b) photo emissive

Variable Reactance transducer:-

1. Inductive:- i) LVDT

ii) Variable reluctance

Iii)Eddy current

iv) Variable permiability

1. Capacitive:-
2. Variable area
3. Variable seperation
4. Variable permittivity

The transducer are further classified as :-

1. Analogue transducer

And ii) Digital Transducer

Analogue transducer:- Analogue transducer are those transducer where the information obtained by these transducer is analog in nature i.e. it produces a continuous function at the output.

The analog transducer are usually voltage or current generating devices and they are also variable parameter and variable frequency devices.

Digital Transducer:- Digital Transducer are those transducer , where the output is in discrete from and some coding system is utilised in it. The output of digital Transducer is suitable for long distance transmission and it is free from noise.

Difference between Active and Passive Transducer:-

Active transducer. Passive transducer

1)It do not require. 1)It requires external

External power. Power source for

Source. Convertion

2)They are self 2) it basically consists

generating and of two elements one

produces their own for sensing other for

voltages/ currents. Converting.

e.g. Thermistors,. E.g. Resistive, capaci-

Tive and inductive Thermocouple

(3)

Characteristics of Transducer:-

Since the transducer is used to sense a specific measurand and hence it is very essential to know all its detailed electrical and mechanical characteristics so that the proper Instrumentation system may be designed .

The basic required characteristics are as follows:-

1)Ruggedness :- The transducer must be able to withstand overloads and mechanical stress.

2) Linearity:- Their must be a linear relationship between the input and output signals.

3) Repeatability:- It must reproduce the output signal exactly when the same input is applied under similar environmental conditions.

4) Large sensitivity:- It is the electrical output per unit change in the non-electrical parameter ( voltage/%c) High sensitivity is desirable for transducer.

5) Stability and Reliability:- The output must not be affected by environmental factors like temperature , vibration, humidity etc.

6) Good dynamic Response:- The output must be faithful to the input as a function of time.

7) Excellent mechanical characteristics:-

The effects of mechanical hysteresis, elastic deformation etc. must be small. It should have minimal weight and size so that its presence in the system does not disturbed the existing conditions.

8) Integration:- It must be amenable to integrate into the system.

Other characteristics:-

Some of the other characteristics of the transducer are as follows:-

1)Measurand characteristics

2) Electrical characteristics

3) Static performance characteristics

4) Dynamic performance characteristics

5) Reliability characteristics

6) Mechanical characteristics

7) Environmental characteristics

(4)

(1)Measurand characteristics:-

The important measurand characteristics are the nature and range of measurand.

A ) Nature:- The nature of measurand like temperature, pressure etc. are specified.

B) Range:- The range of transducer is specified in terms of the upper and lower limits of the measurand.

(2)Electrical Characteristics:-

The Electrical characteristics of Transducer specifies the information about the following:-

1. Type of excitation ii) output iii) End points
2. Impedance v) Grounding and Insulation

Excitation:- The external excitation is required by passive transducer. The excitation may be AV or DC

Output:- The output of transducer may be electrical signal that may be analog or digital type.

End points:- The end points are the output values at the upper and lower limits of range of transducer.

Impedance:- The impedance of the transducer should be properly matched with the input impedance of signal conditioning circuit. The output of the transducer which may be voltage or current is very small which needs to be amplified with proper gain and bandwidth.

Grounding and Insulation:-

The ground of the excitation sensor should be separated from the ground of the supply. In some cases this may be common.

3) Static performance characteristics:-

The static performance characteristics are as follows:-

1. Static sensitivity:- The slope of the static calibration curve is known as the static sensitivity of the transducer.
2. Linearity:- The measure of the maximum deviation for any calibration point from a straight line response is known as the linearity response of the transducer.
3. Threshold:- The threshold of the transducer is the maximum value of measurand below which the output response from the transducer is not available.
4. Resolution:- The minimum increment in measurand which produces noticeable change in the output is known as resolution.
5. Hysteresis and span:- While applying the Input to the transducer, the response of the transducer may not be same in possitive or negative direction. This is because of the hysteresis effect of that transducer.

(5)

4)Dynamic performance characteristics:-

The dynamic performance characteristics are essential in following two conditions as,

* 1. Occurance of rappid changes in measurand values

And b) Monitoring of step changes in measurand level.

The dynamic performance characteristics provides the following information.

1. Frequency response
2. Response time
3. Damping

Frequency response:- Frequency response of a transducer is nothing but the graph between output of the transducer and frequency.

Response time:- In most of the transducer , the output does not changes immediately with the change in input but it takes some time to respond. “ The response time is the time taken by the output of the transducer having step input to reach some specified percentage of it final output value.

Damping:- Damping corresponds to the energy dissipating properties of the transducer.

Three types of damping are observed in the transducer response.

1. Underdamped
2. Overdamped
3. Critically damped

(5) Reliability characteristics:-

“ The rated performance of transducer without failure for a specific time period is known as reliability”

The following are the reliability characteristics:-

1. Overload. Ii) Span

Overload:- Input value above the normal range of transducer input is called as overload.

Span:- The time period over which a transducer performs as per the specifications is known as the life span of the transducer.

**(6) Mechanical characteristics:-** This characteristics is related to the mounting,diamentions, shape, size, internal and external connection arrangements.

(7)Environmental characteristics:-

Changes in environmental conditions like temperature, vibration, pressure, acceleration etc. may be responsible for change in the transducer output. These conditions are usually temporary. A care must be taken for these environmental changes for reliable operation

(6)

Advantages of active/ Electrical transducees:-

The main advantages of Electrical transducer are:-

1. Convenient Electrical amplification and attenuation.
2. Maximum mass-inrtia effects.
3. No frictional effects.
4. The output can be measured or recorded remotely at a distance.
5. The signal can be conditioned or mixed with other outputs.
6. It can be controlled with a very small power level.
7. The electrical output can be easily used, transmitted and processed for the purpose of measurement.
8. It can be designed in such a way that it does not disturb the measurand phenomenon.
9. The size and shape can be suitably designed to achieve optimum weight and volume.

Disadvantages of Electrical Transducer:-

1. They are less reliable than mechanical type.
2. More expensive than mechanical type.
3. Less accuracy than mechanical type.
4. The components show ageing and drift.

Thermistor ( NTC,PTC):-

We know that the resistance of most of the materials changes with temperature so this property can be used in temperature control and measurement circuits.

Thermistors (THERMally Sensitive ResISTOR) are non metallic resistor(semiconductor materials) made by sintering mixture of metallic oxides such as manganese, nickel, cobalt, copper and generally Thermistor have a negative Temperature coefficient (NTC) i.e. its temperature decreases exponentially as the temperature increases and it is given by the relation

RT= R0e-Ea/ KT

Where Ea is the activation energy of Thermistor and T is the temperature in absolute temperature.for a typical Thermistor, the resistance at room temperature ranges from 100u to 10Mu. They are suitable for use upto 800 degree centigrade.

A PTC thermistor has a positive temperature coefficient of resistance i.e. its temperature increases exponentially as the temperature increases.

Fig.(1) characteristics of the thermistor and it is graph of resistance verses temperature of the thermistor.(PTC & NTC).

The Thermistor are made in variety of shapes like beads,discs,washers and rods. Typical shape of the thermistors are shown in fig . (2).

Parameters of the thermistors:-

(7)

* 1. Temperature coefficient of resistance (TCR):- It is defined as the rate of change of Rt with temperature to the resistance Rt, where Rt is the resistance of the thermistor at T0 Kelvin

TCR is denoted by alpha

Alpha=1/Rt dR/dT%/degree centigrade.

* 1. Dissipation constant:- Dissipation constant is is defined as the power in milliwatts required to raise the temperature of the thermistor by 1 degree centigrade above the surrounding temperature.
  2. Time constant:- The time constant is defined as the time required for a thermistor to indicate 63.2% of the difference between its initial temperature value and that of a new surrounding temperature value supported by its leads in still air. Typically time constant is 30sec.
  3. Self Heating:- Self heating is the power dissipated in the thermistor that will heat it above the ambient (sufficient).

Self Heating can be avoided by reducing the excitation current.

* 1. Stability:- It is defined as the ability of a thermistor to retain its characteristics.
  2. Maximum operating Temperature:-

It is the maximum body temperature due to external or internal heating at which a thermistor is operated with acceptable stability of its characteristics.

Advantages of Thermistor:-

1. Small size and low cost
2. Fast response over a narrow temperature range.
3. Good sensitivity in NTC region.
4. There is no need of a reference temperature as the resistance depends on absolute temperature.
5. It has a large resistance and so ther is no effect of connecting wires.
6. They are chemically stable and can be used in extreme conditions like nuclear reactors.
7. They have high power handling capability.
8. They can be used in limiting and regulating circuits, time delays and memory units.

Disadvantages of a Thermistors:-

1. They have non-linear characteristics.
2. They are suitable only in a narrow range of temperatures.
3. Due to high resistance, we have to use very low excitation currents to avoid self heating.
4. They have to be calibrated before use.

Characteristics of a Thermistor:-The graph between the resistance of thermistor versus temperature is called the characteristics of themistor.The fig. Shows the circuit used to determine the thermistor characteristics. The Thermistor is dipped in oil and is energized by the power supply. The Thermistor is heated and the voltage and current accros thermistor are noted at various temperature. Similarly the reading ate noted while cooling also and the resistance is calculated at each temperature as the average of two.

(8)

But it should be remembered that all the temperature are in degree Kelvin. A graph is plotted by taking log(R) on Y-axis and 1/T degree Kelvin along X-axis . It is found that the graph is straight line with possitive slope for PTC and negative slope for NTC Thermistor. The activation energy of the thermistor can be calculated by calculating the slope of the graph as.

Ea= -2.303\*k\*slope

Where k is Boltzmann constant.

Application of Thermistor:-

The following are the application of the thermistor,

1 ) As a temperature sensor.

2 ) In d.c. or high frequency power measurement.

3) In biomedical instrumentation.

4) In temperature compensation circuits.

5) Time delay circuits.

6) Power level control.

7) Thermal conductivity measurement.

Difference Between PTC and NTC:-

PTC. NTC

I ) Its resistance i) Its resistance decrea

Increases with the. With the increase in

Increase in temperature

Temperature. 2 ) Semiconductor oxides

2 ) This type of of cobalt, manganese

Thermistor are. And nickel are used

Formed using nickel. To form these

, Copper, platinum. Thermistors

And aluminium. 3 ) The R VS T slope is

3 ) The slope of R. Negative.

VS T curve is. 4) The stability of

Possitive. NTC type Thermistor

(9)

4 ) stability of these. Moderate

Sensor is excellent. 5) sensitivity is very

5 ) sensitivity is fair. Good.

6 ) Hysteresis is less. 6) Hysteresis is more

7 ) PTC Thermistors are 7) NTC Thermistors are

Used in resistance. Used in biomedical

Temperature ther. Process instrumenta-

Mometer. Tion

Temperature sensor LM35:-

The LM35 series are precision integrated circuit temperature sensors , with an output voltage linearily proportional to the centigrade temperature. Thus the LM35 has an advantage over linear temperature sensors calibrated in degree Kelvin temperature because the user is not required to subtract large constant voltage from the output to obtain convenient centigrade scaling. The LM35 does not any external calibration or trimming to provide typical accuracies of +1/4 degree centigrade at room temperature and + ¾ degree centigrade over full -55 to +150 degree centigrade temperature range. Low cost is assured by trimming and calibration at the wafer level. The low output impedance,linear output and prcise inherent calibration make it to use and interface.

The main features of LM35 IC are:-

I ) Calibrated directly in degree centigrade.

Ii ) Linear +10mV/degree centigrade scale factor.

Iii ) 0.5 degree cen Ensured accuracy at 25 degree centigrade.

Iv ) Rated for full -55 to +150 degree centigrade range.

V ) Suitable for remote applications.

Vi ) Low cost due to wafer level trimming.

Vii ) oprates from 4to 30V.

Viii ) Less than 60uA current drain.

Ix ) Low self Heating , 0.08 in still air.

X ) Nonlinearity only +1/4 degree centigrade .

(10)

Xi ) Low output impedance , 0.1 ohm for 1mA load

.

Figures:- The fig. shows the block diagram of LM35 IC.

It is three pin IC and the pin configuration is shown in fig. Here the transistor Q1 and Q2 are used as band gap type reference elements and their resistance varies linearly with temperature.

The other amplifiers are used to amplify and linearized the output.

Advantages of LM35 over Thermistor:-

1. The Thermistor is a nonlinear device while LM35 is a linear device.
2. The Thermistor has to be calibrated before use but LM35 is inherently calibrated by the manufacturer.
3. The resistance of thermistor depends upon the absolute temperature while the output voltage of LM35 depends vupon the temperature in degree centigrade.
4. LM35 is easy to use and interface with the computers while Thermistor requires more hardware and software .
5. The effect of self Heating is very small in LM35.
6. LM35 is a low impedance device but Thermistor has high impedance.
7. Thermistor is cheaper than the LM35 and so preferred when temperature has to be measured at multiple points.

Light Dependent Resistance (LDR):- LDR or photo cell is a device whose Resistance depends upon the amount of light falling on it. That’s why it can used as a light sensor for the measurement or to activate devices through light.

Construction:- LDR uses a semiconductor material such as Cds,Cdse(cadmium selenium), InSb(indium antimony) etc.

Based on the materials used, The LDRs can be classified into two types :-

* 1. Intrinsic LDR :-Intrinsic

LDR are pure semiconductor materials such as germanium and silicon.

* 1. Extrinsic LDR:- In extrinsic LDRs semiconductor materials are doped with impurities which are called as dopants . This reduces the energy gap and therefore requires less energy to excite electrons to conduction band.

Fig.a) shows the construction of a typical LDR . The semiconductor material is coated as a thin film on a ceramic base . The leads are attached to it and the whole things is encapsulated with a transparent window to allow the light to be incident on it. The materials of LDR decides the frequency of the light to which it will respond. Cds and CdSe are used in the visible region . Where as InSb and PbS are used in mid-IR while Cu-Ge is used in far-IR

(11)

Working and characteristics:-When the light of suitable frequency falls on it , the valence band electrons absorbes the photon energy and jumped into the conduction band , one electron-hole pair for each photon.So the carrier concentration increases and consequently, the resistance of the LDR decreases hence as the intensity of light increases , more and more photons falls on the LDR so more and more e-h pairs are formed and the resistance further decreases.

The dependanc of the resistance of LDR on frequency and intensity of incidents light is called its characteristics. Figure (b) the characteristics of LDR. It is observed that as the frequency of the incidents radiation is increased keeping the intensity of the light constant, the LDR shows maximum sensitivity at a particular frequency for which the photon matches the band gap of the material. Similarly at a particular frequency, ad the light intensity increases, the resistance decreases.

Application of LDR:-

LDR are used in variety of applications where the intensity of light is to be measured, the presence or absence of light is to be detected or to activate/deactivated a circuit of appliance.E.g. camera light meters, street light, clock radios, alarm devices, night lights, outdoor clocks,solar street lamps, solar road studs, far-infrared detectors that are used in infrared astronomy and infra-red spectroscopy.

Photo-Transistor:-

A transitor whose collector current is a function of external illumination is called a Photo-Transistor. Hence Photo-Transistor are mounted in transparent packages. The construction , symbol and output characteristics of a typical Photo-Transistor are shown in figure (a)

Working:-

When light falls on the base region of the Photo-Transistor,e-h pairs are released. This lowers the potential barrier across both the BE and CB junctions. So there is an increase in the number of carriers flowing from emmiter to base and on to the collector . For a given illumination over unit area, the Photo-Transistor produces much larger current than LDR,i.e. it has more sensitivity. Arrays of Photo-Transistors are used as photo-detectors.

Photo-Transistor operation:-

The Photo-Transistor are operated in their active region , where the base connection is left open that is there is no need to connect base terminal in the circuit. But in case the transistor is to be biased properly then the base terminal may be utilised. In NPN type of Photo-Transistor collector is to be made possitive with respect to emmiter.

The light enters the base region of the Photo-Transistor where it causes e-h pairs to be generated. This mainly occurs in the reverse bias base-collector junction. The e-h pairs move under the influence of the electric field and provides the base current, causing electron to be injected into the emmiter.

(12)

In other words , the illumination in central region causes the release of e-h pairs. This reduces the barrir potential across both B-E & B-C junctions causing an increase in the flow of electrons from the left region into the central region and on to the right region.

For a given amount of illumination on a very small area , the Photo-Transistors provides a much larger output. Thus Photo-Transistors is much more sensitive as that of photo-diode.

Application:-

Typical application of Photo-Transistor are ,

* 1. In TV remotes
  2. Burglar detectors
  3. Automatic counters at the gates of cinema
  4. In relay circuit

Application of Photo-Transistor as a relay circuit:-

Figure shows a Photo-Transistor relay circuit. When light falls on the Photo-Transistor,its current increases. So more current flows in the 50Ku Resistor and its potential drop increases. Thus the base potential of the transistor increases, which in turn drives the relay and activates the circuit of interest.

Figure:-

Piezoelectric Transducer:-

Asymmetrical crystalline materials such as Rochelle salt, Tormaline,Quartz and Barium titanate are piezoelectric materials i.e. They produces an e.m.f. when placed under stress. This property is exploited to measure the applied stress as the emf is proportional to the nmagnitude of the applied stress. Alternatively when an AC voltage is applied to the piezoelectric crystal , it vibrates. The piezoelectric transducer is active or self generating type and does not require external power source. Figure shows piezoelectric transducer and its equivalent circuit. The crystal is placed between the force summing member and a base. The externally applied force, entering the transducer through its pressure port which applies the pressure onto the top of the crystal. It produces an emf proportional to the magnitude of the applied force . The main disadvantage is that it cannot measure the static conditions. It is inherently dynamic responding type and requires the pressure to be changing continuously. When the pressure is decreased, emf of possitive polarity is generated. The piezoelectric transducer are used in HF accelerometers because of their good HF response.

The basic expression for output voltage is given by,. E= Q/Cp

Where Q= generated charge

Cp= shunt capacitances

(13)

Advantages and disadvantages of crystal:-

Advantages:-

* 1. Crystals are small in size.
  2. In case of synthetic crystal, output is high.
  3. Crystals have rugged construction.
  4. Frequency response is high.

Disadvantages:-

* 1. Temperature sensitivity is high.
  2. Static conditions cannot be measured.

Applications of piezoelectric Transducer:-

1. Piezoelectric Transducer can be used for the dynamic measurement of force in the range of 1N to 200KN with an accuracy of1%.
2. Transient measurement of fluid pressure can be carried out using piezoelectric transducer.
3. Piezoelectric transducers are used in accelerometers for measurement of acceleration.
4. These transducers were used in record- player pickups.
5. Piezoelectric transducers are used in Electronic watches.

Digital pressure sensors:-(MPXV 4006 DP)

The MPXV 4006 series piezo-restive Transducers are state of the art monolithic silicon pressure sensors having onchip signal conditioning, temperature compensation and calibration. Which is designed for applience, consumer health care and industrial market. The analog output can be read directly into the A/D input of microcontrollers. This Transducer combines advanced micromachining techniques, thin-film metallization and bipolar processing to provide an accurate high level Analogue output signal that is proportional to the applied pressure.

The axil port has been modified to accommodate industrial grade tubing. It is inherently temperature compensated and so the output does not vary with the temperature.

The figures shows the schematic and pin diagram of MPXV 4006

The figure (b) shows the cross sectional diagram of MPXV 4006 A gel die coat isolates the die surface and the wire bonds from the environment, while allowing the pressure signal to be transmitted to the silicon diaphragm. The range of measurement is from 0 to 6KPa and the corresponding output ranges from 0.2 to 4.8V

Features of MPXV 4006 pressure sensor:-

1. 2.5% maximum error over +10 degree centigrade to +60 degree centigrade with auto zero.
2. 5% maximum error over +10 degree centigrade to +60 degree centigrade without zero.
3. Durable thermoplastic package (PPS).
4. Available in surface mount (SMT) or Through- Hole(DIP) configuration.

(14)

1. Available with standard Fluorosilicon gel or Media resistant gel.

Applications of MPXV 4006 pressure sensor:-

1. Washing Machine water level measurement.
2. Suited for microprocessor and microcontroller based systems.
3. Used in appliences for liquid level and water level measurement.
4. Respiratory equipment.

(15)

.