Significance of Sensors and Transducers in Mechatronics System

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ABSTRACT:
The purpose of this paper is to give significance of various sensors and transducers in mechatronics system. In all the mechatronics system is the need to measure some physical quantities such as displacement, speed, position, velocity, motion, pressure, temperature etc. This paper includes terminology of performance parameter and different types of sensors and transducers with application.

Keywords: Mechatronics, Sensors, Transducers, Performance Parameters, Application

I. INTRODUCTION

A sensor is an element in a measurement system that acquires a physical parameter and changes it into a signal. The sensing element is in contact with the object or process and provides the output, which depends upon the variation in the process, or experiences a change, which is related to process variables being monitored. Most sensors work by converting some physical parameter in to an electrical signal.

Transducer is an element in measurement system that converts one form of energy into other. Hence a transducer provides the means of conversion between two physical variables in a process.

Mechatronics basically refers to mechanical electronic systems and normally described as a synergistic combination of mechanics, electrical, electronics, computer and control which, when combined, make possible the generation of simple, more economic and reliable systems. [1]

II. PERFORMANCE PARAMETERS

1) Range and span
The range of transducer defines the limits between which the input can vary. The span is the maximum value of input minus minimum value of input.

2) Error
Error is the difference between the results of measurement and the true value of the quantity being measured.

3) Accuracy
The accuracy defines the closeness of the agreement between the actual measurement result and a true value of the measurand. It is often expressed as a percentage of the full range output or full–scale deflection.

4) Sensitivity
Sensitivity of a sensor is defined as the ratio of change in output value of a sensor to the per unit change in input value that causes the output change.

5) Nonlinearity
The nonlinearity indicates the maximum deviation of the actual measured curve of a sensor from the ideal curve. Nonlinearity (%) = Maximum deviation in input / Maximum full scale input
6) **Hysteresis error**

The hysteresis is an error of a sensor, which is defined as the maximum difference in output at any measurement value within the sensor’s specified range when approaching the point first with increasing and then with decreasing the input parameter.

7) **Resolution**

Resolution is the smallest detectable incremental change of input parameter that can be detected in the output signal. Resolution can be expressed either as a proportion of the full-scale reading or in absolute terms.

8) **Stability**

Stability is the ability of a sensor device to give same output when used to measure a constant input over a period of time. The term ‘drift’ is used to indicate the change in output that occurs over a period of time. It is expressed as the percentage of full range output.

9) **Dead band/time**

The dead band or dead space of a transducer is the range of input values for which there is no output. The dead time of a sensor device is the time duration from the application of an input until the output begins to respond or change.

10) **Repeatability**

It specifies the ability of a sensor to give same output for repeated applications of same input value. It is usually expressed as a percentage of the full range output:

\[
\text{Repeatability} = \frac{\text{maximum} - \text{minimum values given}}{\text{full range}} \times 100
\]

11) **Response time**

Response time describes the speed of change in the output on a step-wise change of the measurand. It is always specified with an indication of input step and the output range for which the response time is defined.
III. CLASSIFICATION OF SENSORS AND TRANSUDER

Sensors and transducers can be classified into various groups according to the factors such as measurand, application fields, conversion principle, energy domain of the measured and thermodynamic considerations.

| A. Displacement, position and proximity sensors | B. Velocity and motion | C. Fluid pressure | D. Liquid flow | E. Liquid level | F. Temperature | G. Light Sensor |
|-----------------------------------------------|-----------------------|------------------|----------------|----------------|----------------|----------------|
| Potentiometer                                 | Optical encoders      | Incremental encoder | Diaphragm pressure gauge | Orifice plate | Floats | Resistance temperature detectors | Photo diodes |
| Strain gauged element                         | Pneumatic sensors     | Tacho generator   | Capsules, bellows, pressure tubes | Turbine meter | Differential pressure | Thermistors | Photo resistors |
| Capacitive element                            | Proximity switches (magnetic) | Pyroelectric sensors | Piezoelectric sensors |                |                | Thermocouples | Photo transistor |
| Differential transformers                     | Hall effect sensors   |                  | Tactile sensor |                |                | Thermo-diodes and transistors |                |
| Eddy current proximity sensors                | Inductive proximity switch |                  | Diaphragm pressure gauge |                |                |                |                |

Table no.1 classification of sensor and transducer

**Photo diodes:**

Photodiode is a solid-state device which converts incident light into an electric current. It is made of Silicon. It consists of a shallow diffused p-n junction, normally a p-on-n configuration. When photons of energy greater than 1.1eV (the band gap of silicon) fall on the device, they are absorbed and electron-hole pairs are created. The depth at which the photons are absorbed depends upon their energy. The lower the energy of the photons, the deeper they are absorbed. Then the electron-hole pairs drift apart. When the minority carriers reach the junction, they are swept across by the electric field and an electric current establishes.

Photodiodes are one of the types of photo detector, which convert light into either current or voltage. These are regular semiconductor diodes except that they may be either exposed to detect vacuum UV or X-rays or packaged with a opening or optical fibres connection to allow light to reach the sensitive part of the device.

![Fig.3 Construction of photo diode detector](image-url)

Figure 3 shows the construction of Photo diode detector. It is constructed from single crystal silicon wafers. It is a p-n junction device. The upper layer is p layer. It is very thin and formed by thermal diffusion or ion implantation of doping material such as boron. Depletion region is narrow and is sandwiched between p layer and bulk n type layer of silicon. Light irradiates at front surface, anode, while the back surface is cathode. The incidence of light on anode generates a flow of electron across the p-n junction which is the measure of light intensity.
Applications of photo diodes

**Camera:** Light Meters, Automatic Shutter Control, Auto-focus, Photographic Flash Control

**Medical:** CAT Scanners - X ray Detection, Pulse Oximeters, Blood Particle Analyzers

**Industry**
- Bar Code Scanners
- Light Pens
- Brightness Controls
- Encoders
- Position Sensors
- Surveying Instruments
- Copiers - Density of Toner

**Safety Equipment**
- Smoke Detectors
- Flame Monitors
- Security Inspection Equipment - Airport X ray
- Intruder Alert - Security System

Resistance temperature detectors (RTDs):

RTDs work on the principle that the electric resistance of a metal changes due to change in its temperature. On heating up metals, their resistance increases and follows a linear relationship as shown in Figure 4. The correlation is

\[ R_t = R_0 (1 + \alpha T) \]

where \( R_t \) is the resistance at temperature \( T \) (°C) and \( R_0 \) is the temperature at 0°C and \( \alpha \) is the constant for the metal termed as temperature coefficient of resistance. The sensor is usually made to have a resistance of 100 Ω at 0 °C.

![Figure 4: Behavior of RTD Materials](image1)

Figure 5 shows the construction of a RTD. It has a resistor element connected to a Wheatstone bridge. The element and the connection leads are insulated and protected by a sheath. A small amount of current is continuously passing through the coil. As the temperature changes the resistance of the coil changes which is detected at the Wheatstone bridge.
Differential Pressure Sensor (DPS):
Differential pressure flow meters have a primary and a secondary element. Generally speaking, the primary element is designed to produce a difference in pressure as the flow increases. There are many different types of primary element, the most common being the orifice plate, venturi, flow nozzle and Pitot tube.

The secondary element of the flow meter is the differential pressure transmitter. It is designed to measure the differential pressure produced by the primary element as accurately as possible. In particular it is important that the differential pressure measurement is not affected by changes in the fluid pressure, temperature or other properties such as ambient temperature. The output signal from an industrial DP transmitter is likely to be 4-20mA.

IV. APPLICATION

The AHU (Air Handling Unit) application is capable of controlling many different air handlers and control strategies. Figure 7 is air flow and instrumentation diagram of a mixed air single path application of Air Handling Unit in HVAC with various sensor for measurement purpose.
V. CONCLUSION

Sensor and transducer is an important element of a mechatronics system. Its main function is to collect the information on system status and to feed it to the micro-processor for controlling the whole system. Today a wide variety of these elements and devices are available in the market. For a mechatronics system designer it is quite difficult to choose suitable sensors/transducers for the desired application. It is therefore essential to learn the principle of working of commonly used sensors/transducers. A detailed consideration of performance parameter of sensors/transducers for design mechatronics system.

VI. REFERENCES

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