**Automation in Manufacturing**
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**Week - 04**
**Sensors**
**Lecture – 10**
**Measurement system and potentiometer sensors**

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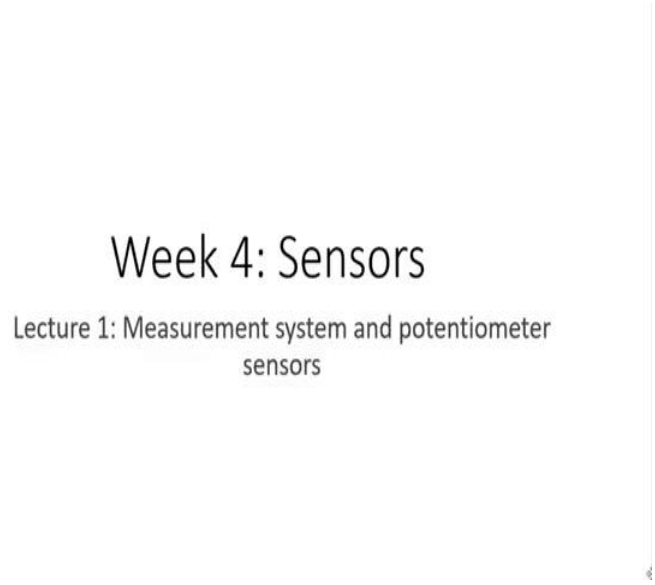


This is Lecture 1 of Week 4, and in this lecture we will be studying the meaning of Measurement system and the potentiometer sensors.

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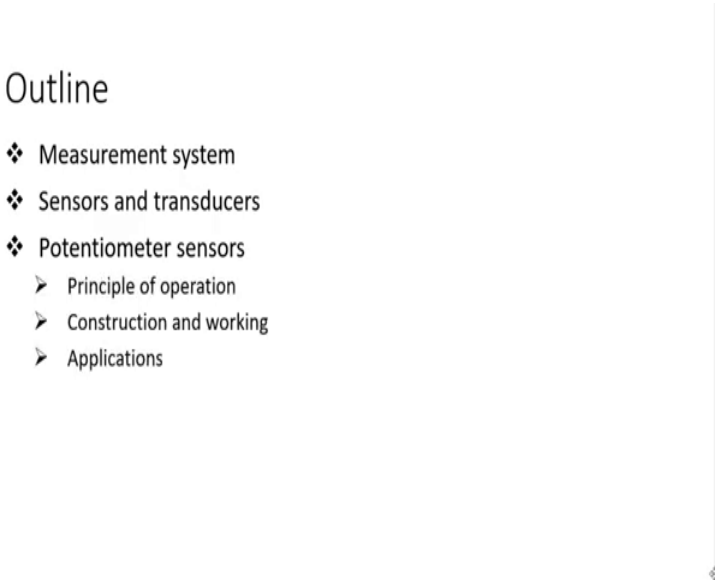


The outline of this lecture is as follows. At the start of the lecture, we will study the meaning of measurement system, its elements. Then, we will learn the definition of sensors and transducers.

We will see, what is the difference between the concept of a sensor and a transducer. After that, we will see the classification of sensors or the types of sensors and we will start learning the constructional details of a typical potentiometer sensor, its principle of operation and its applications in the industry.

The fundamental element of a measurement system is sensor. Lot of sensors are being used in automation. We will try to see some of the important sensors which are used in automation applications in manufacturing. Let us begin our discussion on the measurement system.

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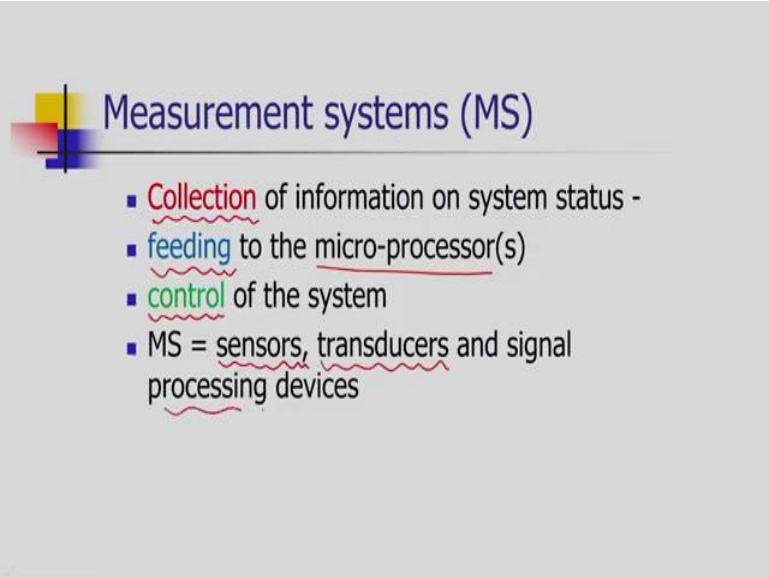


Measurement system is primarily developed to collect the information on the system status. There are various building blocks of an automated system.

Measurement system collects the information from the ground, from the application and it sends that information to the microprocessor, the microprocessor processes that information and it gives the decision to control the process. The information is to be collected from the ground and from the environment of the processing.

Ultimately, we have to collect the information and we need to feed this information to microprocessors. Collection of the information, feeding the information to microprocessor are the basic functions of the measurement system. Based on this information itself, the controlling operation would be done.

The accuracy of the information and efficient feeding to the microprocessor system, are the two at most important requirements of the efficient measurement system. The measurement system has various elements sensors, transducers and signal processing devices.

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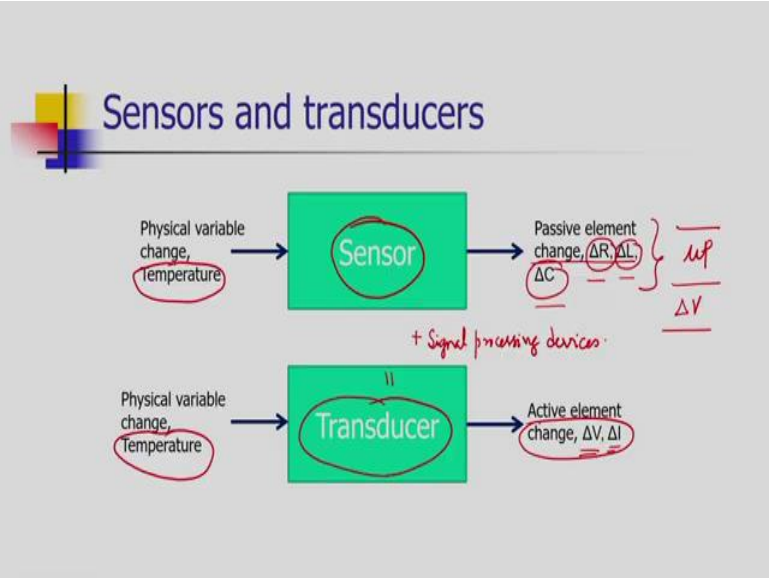


What is the meaning of a sensor? The definition of a sensor is a physical element which produces a signal relating to the quantity being measured. Sensor is a physical element which senses the measurement, and it generates a signal, and produces a signal. This is called a sensor.

What may be the physical variables? A temperature can be called a physical variable or displacement or we may also call the noise or the vibrations. These are the input variables, or the physical variables which needs to be measured.

Sensor is a physical element which senses these variables, and it generates certain signals. These signals may be change in resistance, change in inductance or change in capacitance. But change in resistance or inductance and capacitance may not be useful for microprocessor application.

The microprocessor understand the language of 0's and 1 and these 0's and 1's are nothing, but the voltages. We need to have a signal in terms of change in voltage or a sequence of pulses and these pulses are nothing, but change in voltage.

When a sensor produces the change in voltage or change in current which can be understood by the microprocessor, then that system is called as the transducer. Transducer by definition is a device which converts one form of energy into the other form of energy.

Again, the physical variable is temperature, but it is generating the signal into delta V and delta I. So, delta V is voltage and delta I is the current. To have a transducer, we need to attach or integrate sensors plus the signal processing devices. Thus, all the sensors are transducers, but all transducers are not sensors.

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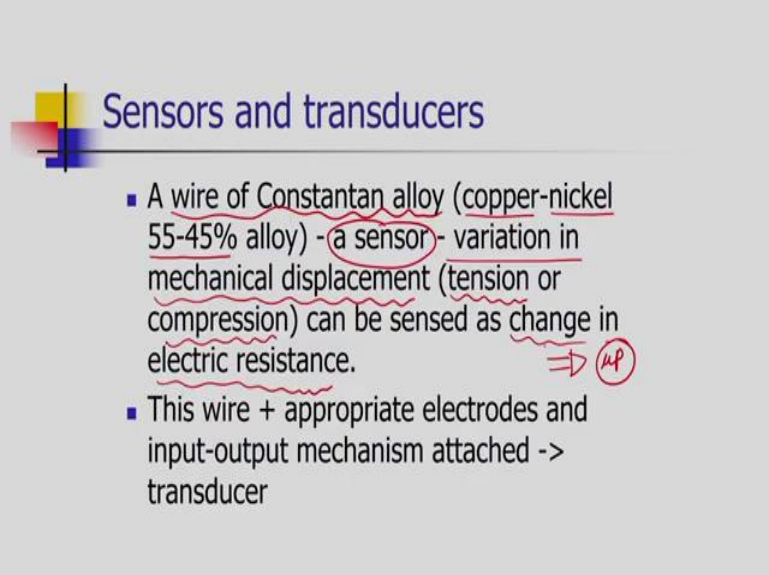


A simple example is a wire of constantan alloy, a metal alloy and it has two elements; copper and nickel. The proportion is 55 percentage of copper and 45 percentage of the nickel. This alloy can be called a sensor as it is generating a signal when there is a change in physical variable.

Let us consider the change in physical variable to be measured is mechanical displacement. Mechanical displacement is provided in terms of tension or compression.

When this element, mechanical element is applied with tension or the compression, then there is a change in electrical resistance of this constantan alloy. As a wire or element made up of the constantan alloy is pulled, there is a change in resistance or compressed, then there is a change in resistance.

But this change in resistance will not be useful to take the appropriate decision by the microprocessor. For that purpose, we need to add few electrodes, we need to have input-output mechanism, and when we add this to the sensor, then we are having a transducer. In automation or in applications of the sensors, additional elements are used, these

additional processing devices are the signal processing devices. Nowadays, there is a concept of smart sensors which are also coming into the industry. The concept of smart sensor is nothing, but it is a plug and play kind of device. Sensor is a simple physical element, transducer is having a physical element and a signal processing device. The smart sensors are one step ahead. The smart sensors are having physical element, signal processing device and microprocessor as well. So, we can consider a smart sensor as a plug and play device.

We just plug it and we can simply sense the variable. These devices are having self-calibration capability. They can adjust with changes in the environment and are very intelligent with the capability to communicate with variety of other devices, which are not in the transducers. Such type of sensors are being used as independent devices in the manufacturing domain nowadays.

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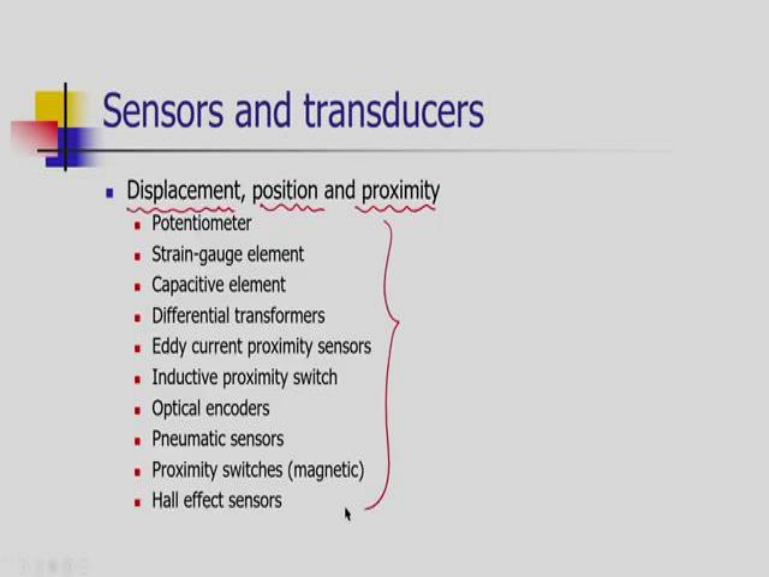


Now, let us look at various sensors and transducers which are used in manufacturing automation. The first type of sensors are displacement, position and proximity sensors. The automated systems have various mechanisms, and these mechanisms have various linkagesand elements. During the process of operation, these linkages and elements displace, there is a movementand motion of these elements or linkages. We need to monitor the displacement of these linkages or the elements.

Second is the position. The automated systems are moving inside a shop floor and the position of these systems inside the shop floor need to be tracked. We need to track the position and locate the devices in the specified space. For that purpose, we need to position sensors. Proximity is the closeness with the object. When the objects are coming closer to the equipment or the instrument, we need to generate certain signals to know the proximity of that elements or the objects.

For that purpose the proximity sensors are required. There are various sensors. Potentiometer, strain-gauge element, capacitive element, differential transformers, eddy current proximity sensors, inductive proximity switch, optical encoders, pneumatic sensors, proximity switches, hall effect sensors and many more. These sensors are in general used in the manufacturing automation.

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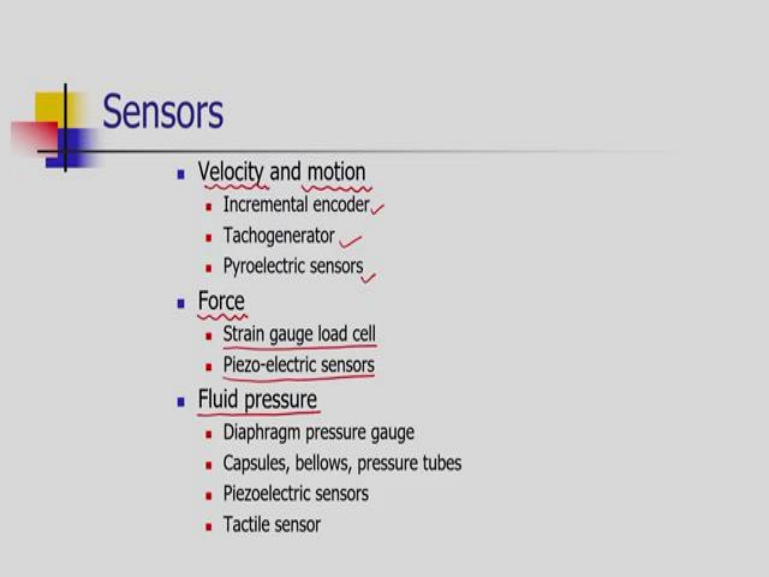


In addition to the displacement, position and the proximity sensors, we also need to measure the variable such as velocity and motion of either the physical elements of the equipment or the objects for which we are carrying out the automated processing operations. For velocity and motion, incremental encoders, tachogenerators and pyroelectric sensors are used.

We also need to measure the force; so, for that purpose, strain gauge-based load cells and piezoelectric based sensors are used. In automation, there are a lot of fluids being used. It maybe gas or it may be a liquid. In gas, air or some other gases are to be used for the

applications, or in fluid, it may be water or some chemicals or it may be a serum. For that purpose, various sensors are used like diaphragm pressure gauge, capsules, bellows and pressure tubes, piezoelectric sensors and tactile sensors.

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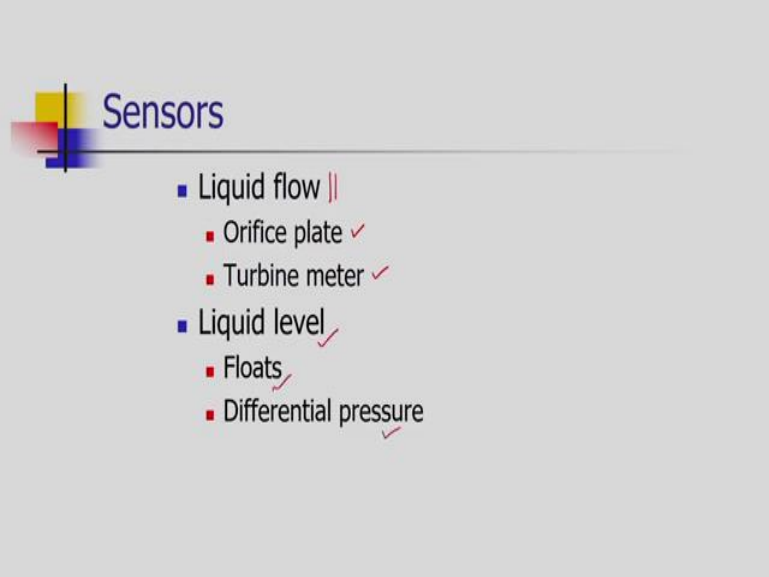


Then, the flow of the liquid. To measure the flow of liquid, orifice plate and turbine meter are used. To sense the level of the liquid, floats and differential pressure gauges are used.

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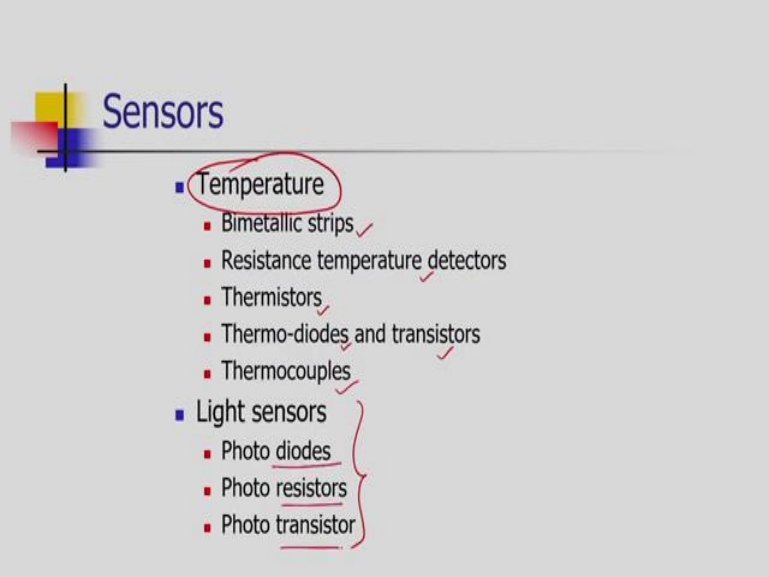

Temperature is a very important parameter as far as the process monitoring and control is concerned. Temperature suggest or temperature indicates the health of the equipment as well. For that purpose, bimetallic strips, RTD's that is Resistant Temperature Detectors, thermistors, thermo-diodes and transistors and thermocouples are used. Lights are used to carry out the office automation or the home automation. For that purpose, various diodes, resistors and transistors are used.

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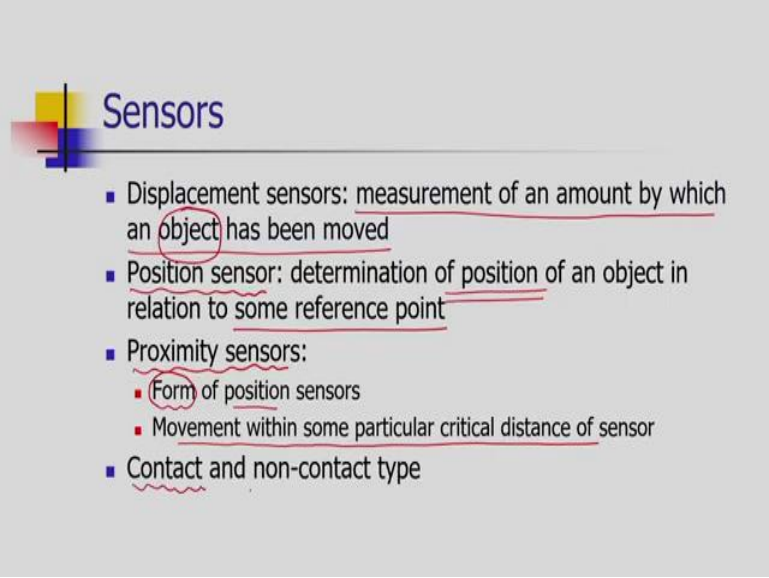


Now, let us come to our first group of sensor that is displacement, position and proximity sensor. We need to measure an amount by which an object has been moved. This object maybe the mechanism or the element of a particular mechanism or machine or an equipment or it may be the object. We need to measure and track the displacement and then record the displacement.

Then, the position sensor; these sensors are used to determine the position of an object in relation to some reference point. This reference point maybe a reference point of the equipment or it may be the reference point of the space in which the objects are moving.

Third is proximity sensor. The proximity sensors are the type of position sensors only and they are detecting the movement of the object with some particular critical distance of the sensor. If the object is coming closer to the sensor and if it is crossing the critical distance, then the sensor detects that object. These sensors are available in the industry in contact or non-contact mode.

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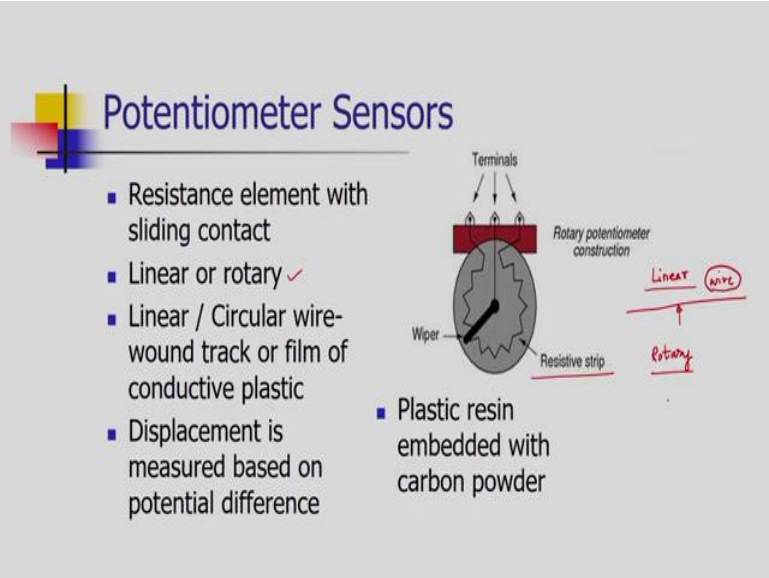


Now, let us come to the first sensor that is the potentiometer sensor. Potentiometer sensor has a resistance element and a sliding contact. These are available in linear or rotary format. As the length of the sliding contact changes, the resistance of the system changes and that resistance is producing further voltage output. The length of the sliding contact is affecting the resistance of the system and it is affecting the potential difference across the connections.

If the sliding contact is connected with the physical element of which the displacement is to be measured, the displacement can be easily computed by calibrating the change in potential difference inside the circuit. A typical linear potentiometer has a long wire and a slider. Such a long wire based linear potentiometer is difficult to handleand tedious, and we cannot use these as a sensor. For that purpose, the rotary modes or rotary type of potentiometers are used as sensors.

These rotary sensors has wire wound track or a film of conductive plastic. This wire wound track has number of turns over the core of the sensor. And, as the wiper or the slider is getting contacted with the turns, we are measuring the resistance according to the contact of the slider with a typical number or a specified number of turns on the circular wound track.

The resistance we can get, when the wiper is connecting to or is contacting to a wire. Nowadays, a film of conductive plastic is also used. This film is nothing, but a plastic resin which is embedded with carbon powder.

Instead of having a number of turn coils, the carbon powder is embedded with plastic resin and the wiper is moving over the plastic resin. The carbon powder is conducting so, wherever the wiper is connecting, we are getting the resistance accordingly.

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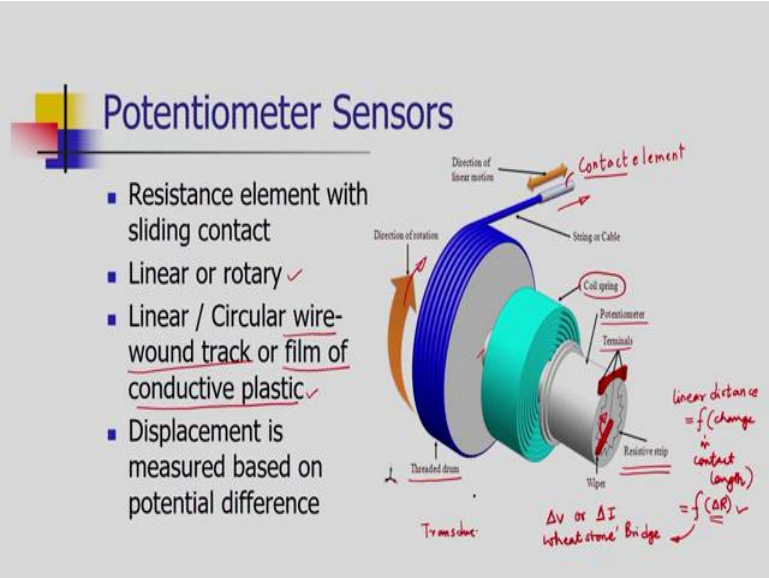


A typical application of potentiometer sensor is shown on the screen. Here, we need to measure the linear displacement by using a rotary type potentiometer sensor. For that purpose, we are getting a string or a cable, we are winding this string or the cable over a threaded drum. This drum is mounted on a shaft and on the shaft, we are having a coil spring. At the end of this shaft, we are having the potentiometer sensor.

The potentiometer sensor has a resistive strip and a wiper arrangement. There are three terminals; two terminals of the resistive strip are attached to two ends of the wire. This is pulling element or the contact element of this sensor. This element is in contact with the application of which we need to measure the displacement. We consider there is a pool in this conduct element.

As there is pulling moment, the drum is rotating in clockwise direction and as the drum rotates in clockwise direction, the wiper also rotates in the clockwise direction. As the

wiper is rotating along the clockwise direction, there is a change in length of contact with the resistive strip. The linear distance is the function of the change in contact length of the potentiometer sensor, and further it is a function of the resistance.

So, this delta R will further be used to generate the appropriate signals that is a delta V or delta I current signals by using a Wheatstone bridge device. Delta R signals cannot be used by the microprocessor to process the information. We need to convert these signals from one form of energy that is resistance to the voltage and then, the potentiometer sensors will be converted into a transducer.

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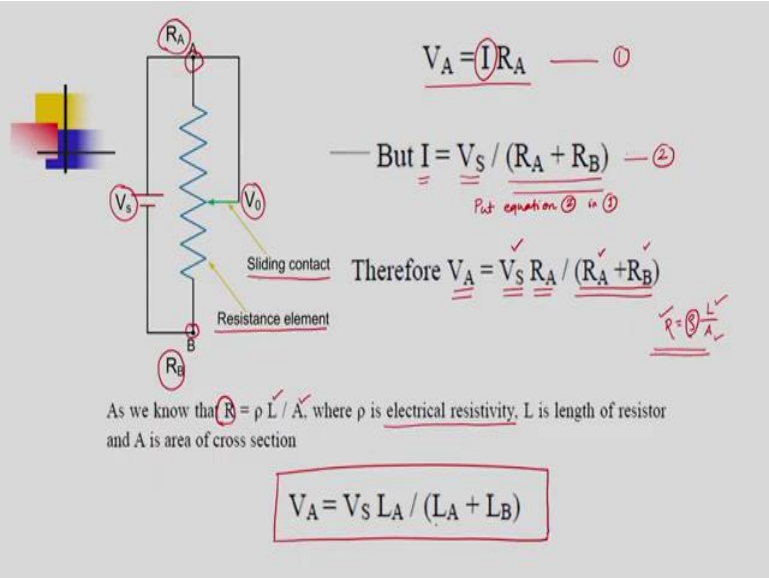


The correlation will be shown with a very simple circuit. There is a resistance element, sliding contact. This resistance element has two ends A and B. A has resistance $R_A$, and the node B has a resistance $R_B$. We are applying a supply voltage $V_S$ across these two terminals, two ends A and B. The voltage at the sliding contacts is $V_O$.

Now, let us try to find out the correlation.

$$V_A = I\,R_A \qquad (1)$$

$$But\ I = V_s / \left(R_A + R_B\right) \qquad (2)$$

Substituting equation 2 in equation 1, we get

$V_A = V_S \, R_A / (R_A + R_B)$

The voltage at point A is a function of the supply voltage, which is the constant supply voltage that we are applying, resistance at node A and resistance at node B. The resistance R is directly proportional to length of the contact and is inversely proportional to the area of the cross section of the wire.

Thus, $R = \rho L / A$

where $\rho$ is nothing, but the constant of proportionality and is called as electrical resistivity.

Thus, resistance is directly proportional to the length and inversely proportional to the area. Let us use this correlation and modify the equation of $V_A$.

Thus, $V_A = V_S \, L_A / (L_A + L_B)$

Thus, from point A, if the sliding contact length is varied, then there is a change in potential difference, which is nothing, but the potentiometer.

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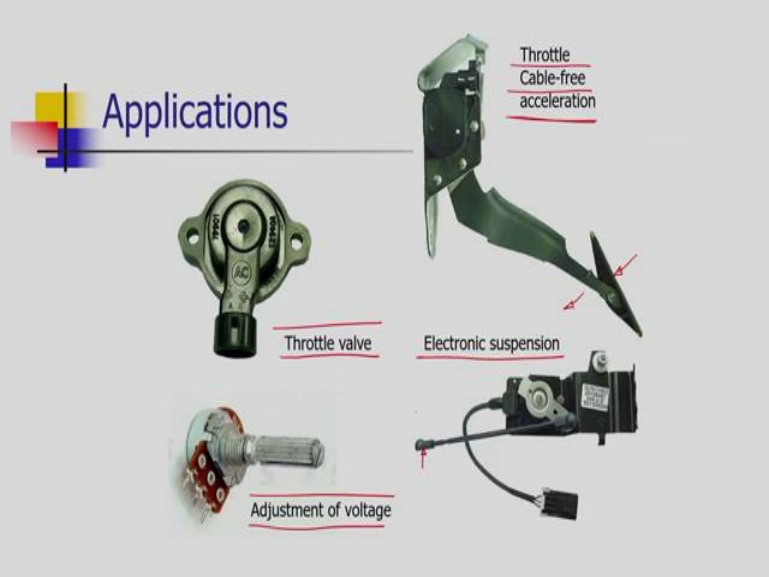


What are the various applications of the potentiometer? Potentiometers are used in throttle valve. Throttle valves are used to control the flow of the gas or the fluid inside the combustion chamber. To monitor the operation or to monitor the displacement of the

element of the throttle valve, these are either manually operated or automatically operated.

When the manual operation is carrying out or when the automatic operations are carrying out, it needs to be monitored whether the specified or desired amount of displacement is there or not. The next is adjustment of voltage. This is a very common application. We also do have a lot of electrical appliances at home. To control the speed of the ceiling fan we are using a knob; we are using a device and that device is having the potentiometer sensors.

We are just rotating the knob and accordingly there is a change in the speed. Then, for the acceleration as well. This is the pedal and when we apply pressure or a force on this pedal, this pedal is getting displaced.

We need to continuously monitor the displacement of the pedal, because this displacement of the pedal is accelerating the automobile, or it is accelerating certain process. If it is beyond the limit, then we have to give certain alarm or control the acceleration. For that purpose, the control movement of this pedal is required. Earlier, it was used with the cables.

The next type of application is electronic suspension. In this application, the lever which is attached to the axle of the automobile, the displacement of that lever will be sensed by using the potentiometer sensor. As the lever is moving, that movement can be sensed by the microprocessor.

The lever is moving due to the unevenness on the road, as it is getting bumps or the vibrations from the road unevenness through the axle, that will be sensed by this lever and the microprocessor is taking certain decisions or it is giving alarm to the rider either to control the speed of the automobile or it itself will take the decisions to control it.

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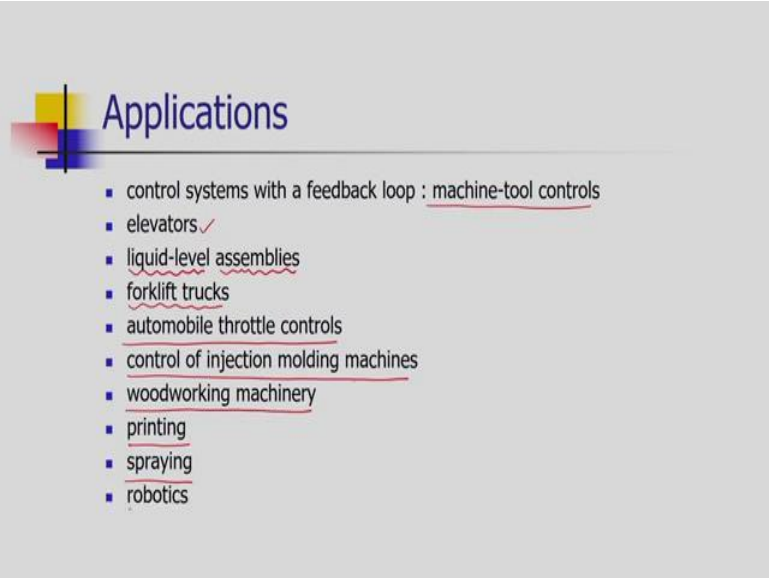


In addition to this, there are variety of other applications. In machine-tools, potentiometers are required. Machine-tools have many elements or mechanisms. There are displacement of these elements and mechanisms, which needs to be monitored. For that purpose, potentiometer sensors are required. Elevators are moving in upward direction or they are coming down in direction.

This liquid levels in assemblies are connected with a physical element or mechanical element and as there is a change in level of the liquid, the mechanical elements are moving. This displacement can be monitored and the liquid level can be controlled.

The forklift trucks are having forklifts which are lifting the commodities. The lift or the displacement of the forks can be monitored using the potentiometer sensor.

Control of injection molding machine; the injection molding machine has very critical parts the two dyes that to be closed regularly, and when we are carrying out the closing and opening operations of the dyes and the molds in the injection molding operation in a rapid way, we need to continuously monitor the opening and closing of these dyes and molds and shutters.

For that purpose, the potentiometer sensors are used. Then, for the woodworking machinery to measure or to monitor the displacement. Printing applications, printing machineries, spraying applications, robotics; the potentiometer sensors are used.

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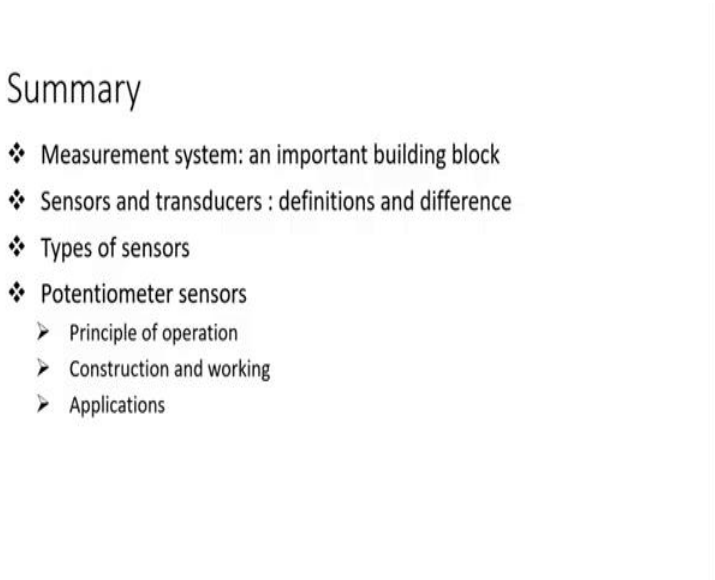


In this lecture, we studied the meaning of the measurement system. It is an important building block of the mechatronics base automated system. We learnt the definition of the term sensor and transducer. We understood the difference between a sensor and a transducer.

Then, we looked at various types of sensors which are used in automation in manufacturing. Basically, we have seen the classification and then, we started studying the potentiometer sensor. We have seen its principle of operation, constructional details and the important applications in the industry.

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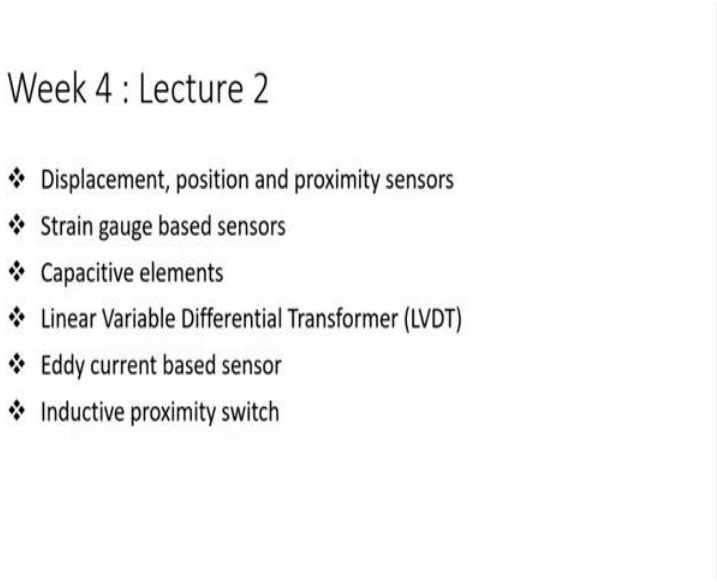


In the next lecture that is lecture 2 of week 4, we will study the strain gauge based sensors, capacitive elements, linear variable differential transformer, eddy current based sensor, strain gauge based sensors, capacitive elements, LVDT's are used to measure the displacement. Eddy current based sensors and inductive proximity switch are used as proximity sensors.

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