Introduction to Industry 4.0 and Industrial Internet of Things

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Lecture – 01
Introduction: Sensing & Actuation

In this course, you are going to learn about Industry 4.0 and Industrial IoT (IIoT). So, we will get into the depth of each of these in detail throughout the course. However, let us first try to understand, what is central to each of these technologies. So, IIoT is Industrial IoT, which is about the applications of IoT in the industries. There are some industry specific requirements, for which the existing IoT technology, which have applications in different domains, will have specific requirements of industries. We will have to be tailored to get to cater to those industrial requirements. So, that is where industrial IoT comes into picture, and is so much popular, particularly in the industry.

Nowadays, most of the industries are transforming globally. They have been mandated to transform to be Industry 4.0 compliant. And they are transforming towards the adoption of IIoT technologies. So, we will be learning about the different aspects of each of these Industry 4.0 and IIoT. But first, let us try to understand, what is IoT.

Precisely, IoT is about internet of things. IoT is a technology, which tries to build up an inter-network of different things, different physical objects that we use and see around us. These physical objects could be anything and everything that we can think of starting from things like, the toothbrushes which we use very early in the morning, to the air conditioner of the room, the heating system, and the projection system in front of us. And this also includes the traditional computational devices such as computers and PDAs.

The computational as well as the traditional computational devices, the present different physical objects, mentioned earlier like the toothbrush, projection system, heating system and this refrigeration system. All of these things would be inter-networked and interconnected. Then this inter-network is going to send huge amount of data, which will have to be processed, in order to make use of the data retrieved.

There are different uses of it. IoT finds applications in building smart homes for instance, smart cities and so on. So, there are even different components of smart cities like smart

transportation, smart parking, and smart healthcare. IoT finds applications in making cities and homes smart. In the industrial context, we are trying to think about an extension of all of these to serve making the industrial processes, much more efficient and autonomous. So, we will look into each of these.

Sensors and actuators are central to the IoT or IIoT. And there are few other associated peripheral technologies also, but sensing and actuation is the key to IoT and IIoT. So, let us try to understand, what is this sensor, and what is this actuator.

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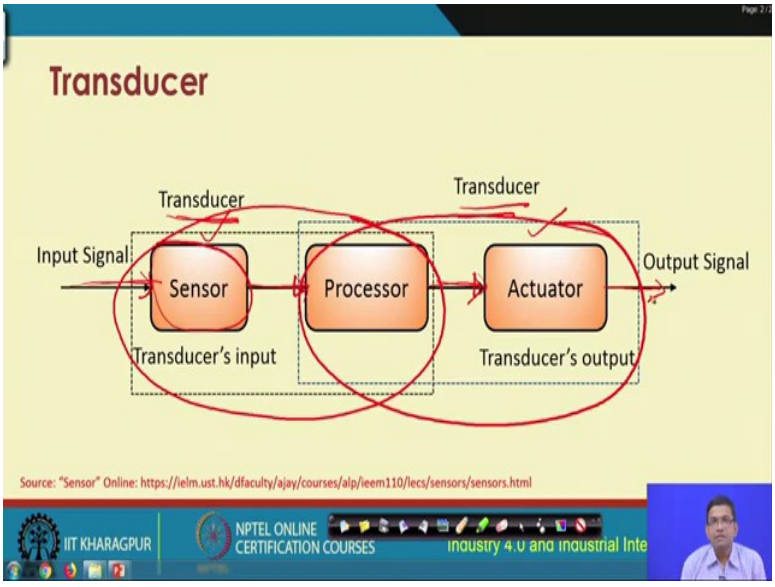

Both the sensors and actuators can be classified as transducers. Transducer converts the signal in one form into a signal in another form. The sensor plus the processor, which will process the input coming from these sensors, is a transducer. Similarly, actuator plus processor is also a transducer.

The transducer and the sensor takes some input signal and produce a certain output, send certain output, which will be processed further. And based on the processed data, the transducer will be actuated. Therefore, energy transformation is happening. The actuator then produces certain output. This is how transducers work.

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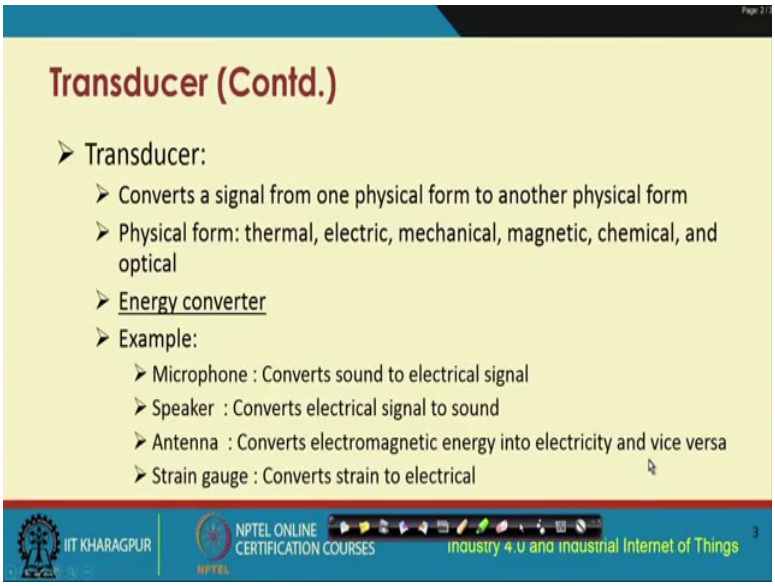

The transducer converts a signal from one physical form to another physical form. These physical forms could be like electrical form, mechanical form, magnetic form, thermal, chemical, and optical. Therefore, a transducer is nothing but an energy converter. It converts the energy from one form to the energy in another form.

For instance, things like traditional microphone, basically converts sound signals to electrical signals, which basically are amplified and the speakers basically through the speakers we are able to hear. This is the basic working concept of a microphone. A speaker is also likewise a converter of energy from electrical form to sound. So, a speaker is also another example of the transducer.

Similarly, we have antennas which converts electromagnetic energy into electrical energy and vice versa. Therefore, antenna is also a transducer. There are many other examples of transducer such as a strain gauge.

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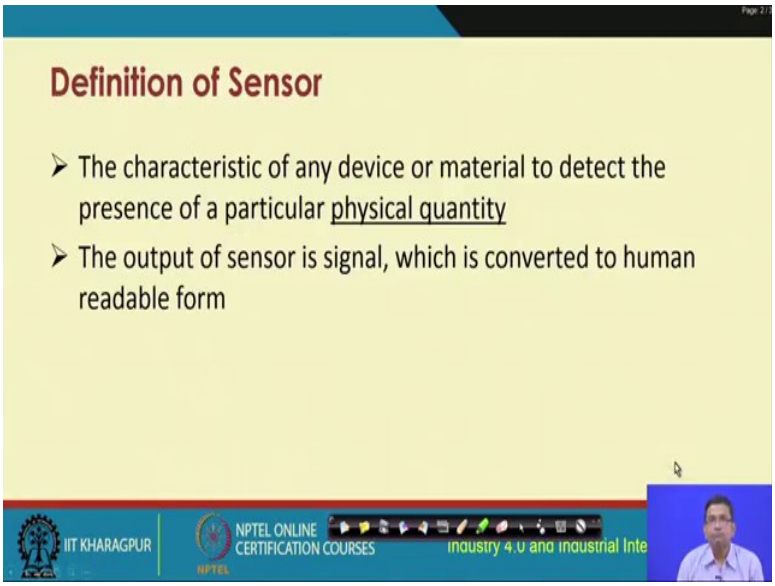

Sensor as this name suggests senses some physical quantity, which changes with the characteristic of the environment, in which it is operating. For example, a temperature sensor, will sense the changes in the temperature of the environment in which the sensor, has been deployed and operating.

The output of the sensor is a signal which is converted to some human readable form, which can be different forms. For example, changes in the current characteristics, changes in the voltage characteristics, changes in the resistance, changes in the capacitance, and changes in the impedance, are understandable by humans.

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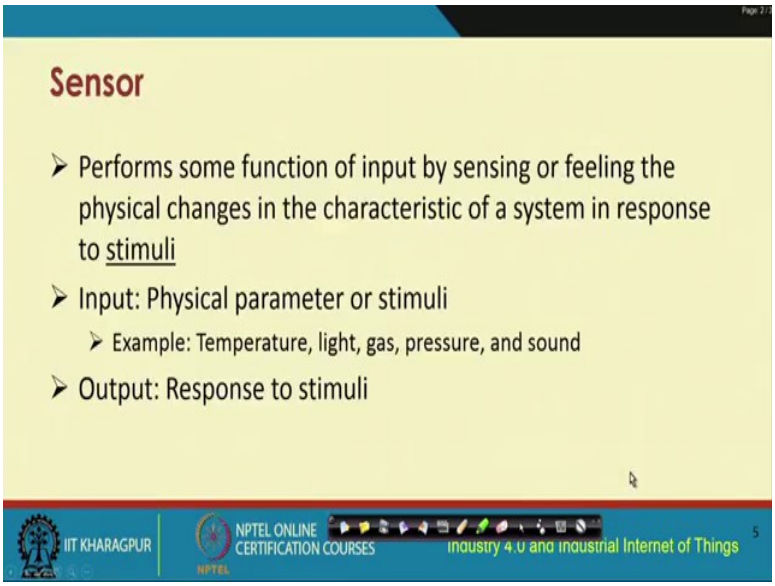

A sensor basically performs some function of input by sensing or feeling the physical changes in the characteristic of a system, in response to some stimulus. These stimuli are the physical parameters. This stimulus could be changes in the temperature, changes in the lighting condition, or changes in the gas. For example, a gas sensor senses the changes in different gases. Gas sensors such as methane gas sensor, a carbon dioxide sensor, carbon monoxide sensor, oxygen sensor have been devised to sense the changes in the amounts of these gases in the environment. So, gas sensors are incidentally useful to monitor presence of different gases particularly in context of environment. They are also very useful for mining environments. Methane sensors are used in the mines to detect the increase in methane gas in coal mines. As you know, these gases are very dangerous. The physical quantity sensed and the response is in the form of some changes in the resistive capacities, changes in the capacitive capacities or changes in current voltage characteristics in the form of the output.

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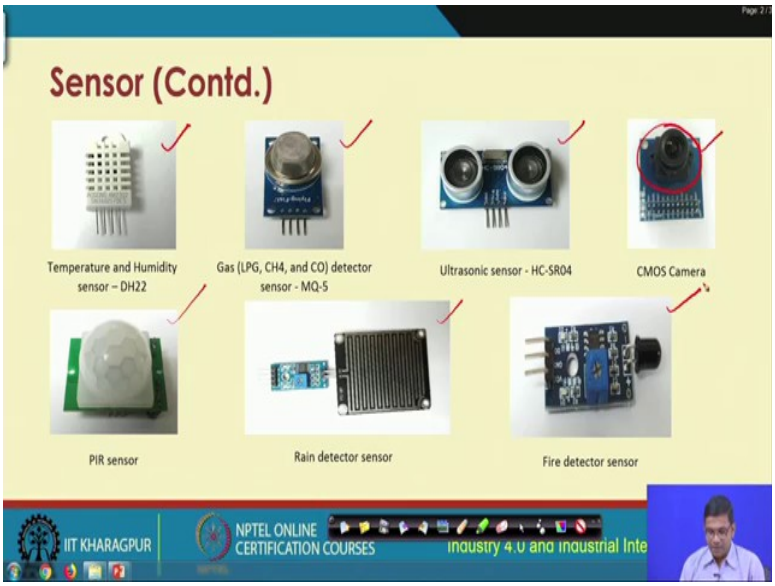

So, here are some pictures of certain sensors. These are the sensors that I have in my lab, and there are many other sensors also. I picked up these ones in order to show you how different sensors look like. Actually, the sensors basically they come in different shapes and sizes. Some of these are macro-sized sensors, but you could also have micro-sized sensors which are like MEMs based sensors. There could be nano-sensors also available for different purposes.

This is a temperature and humidity sensor. This is a type of gas sensor which detects LPG gas, methane, and carbon monoxide. This is an ultrasonic sensor. This is a camera sensor you can see the camera over here, Camera sensor. This is PIR sensor, this is rain detector sensor, and this is fire detector sensor. Now, let me see if I can show you some of these different sensors.

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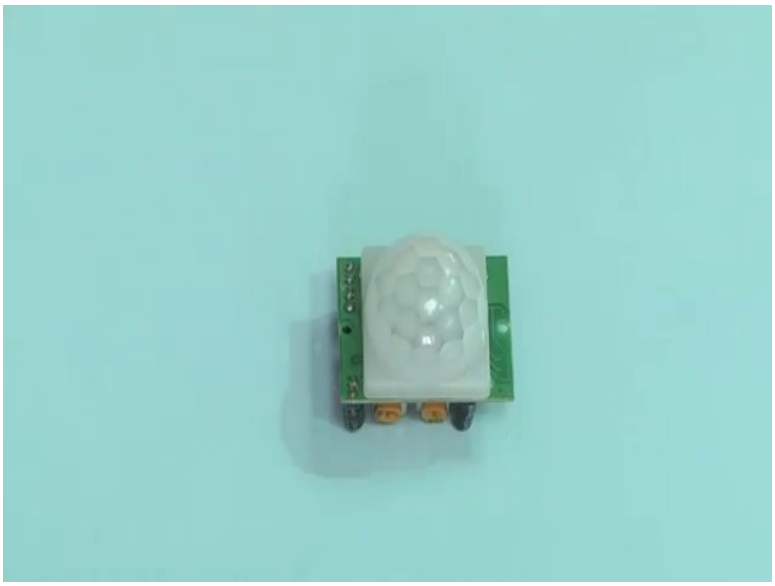

So, this is a PIR sensor.

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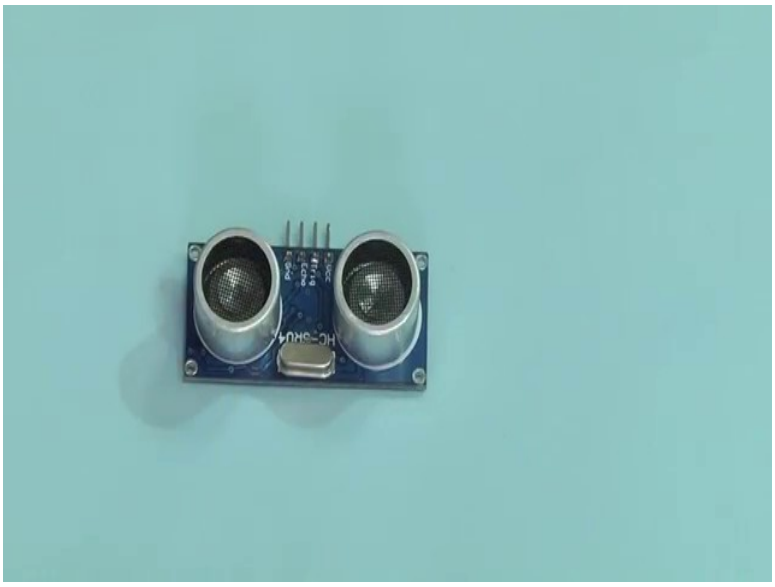

This is an ultrasonic sensor which helps you to detect how far a particular object is. Therefore, obstacles can be detected with the help of this sensor. When ultrasound, a sound wave that is sent from any one of these two cylinders, one cylinder sends sound signal, it gets reflected by that obstacle, and is detected by the other. Based on this how far a particular obstacle is, or whether there is an obstacle in its range.

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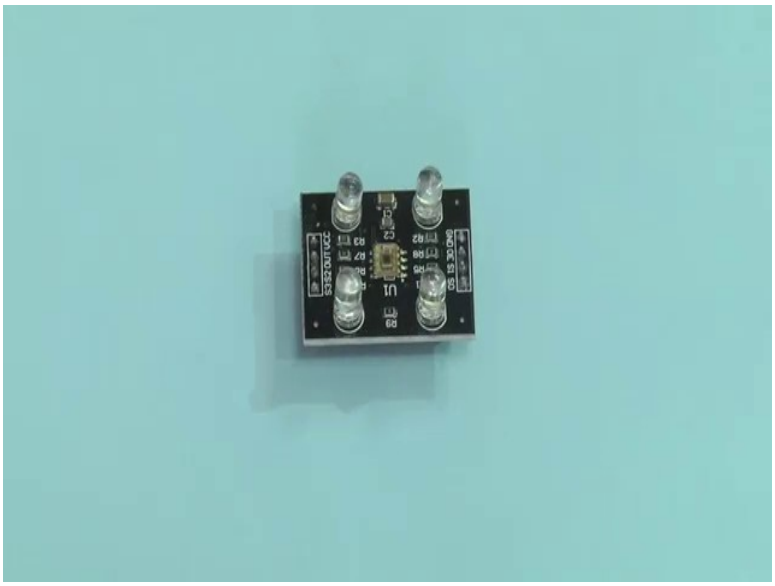

Let me show you another sensor of different type, the color sensor, which can detect different types of colors.

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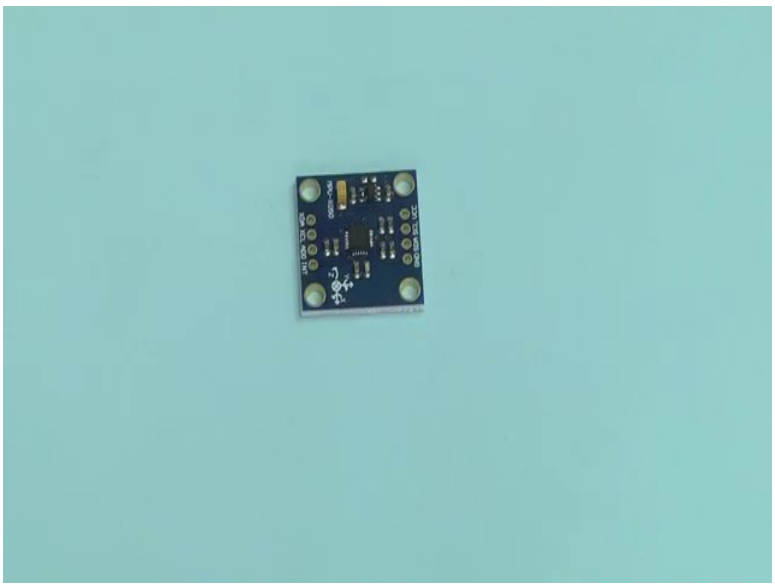

This is an accelerometer sensor.

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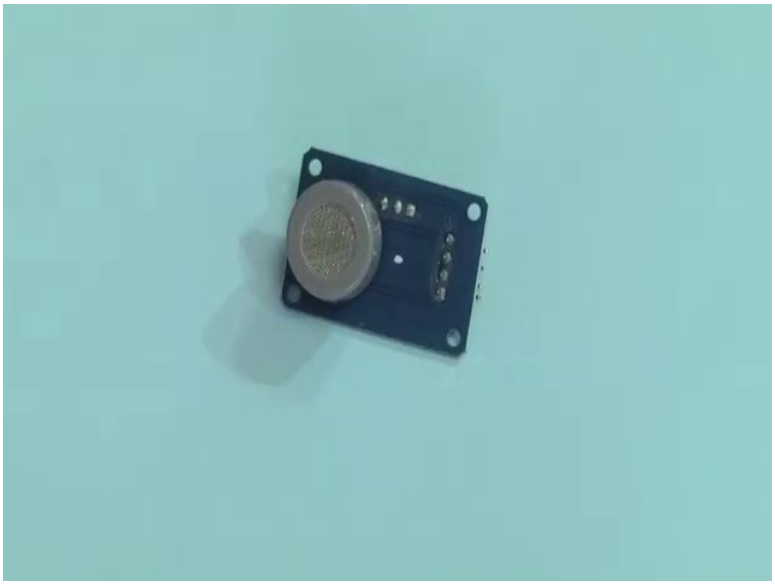

Then we have the gas sensor, carbon monoxide, which detect carbon monoxide gas. Then, we I have also brought for you another sensor which is the rain gauge. Rainfall sensors detects the rainfall.

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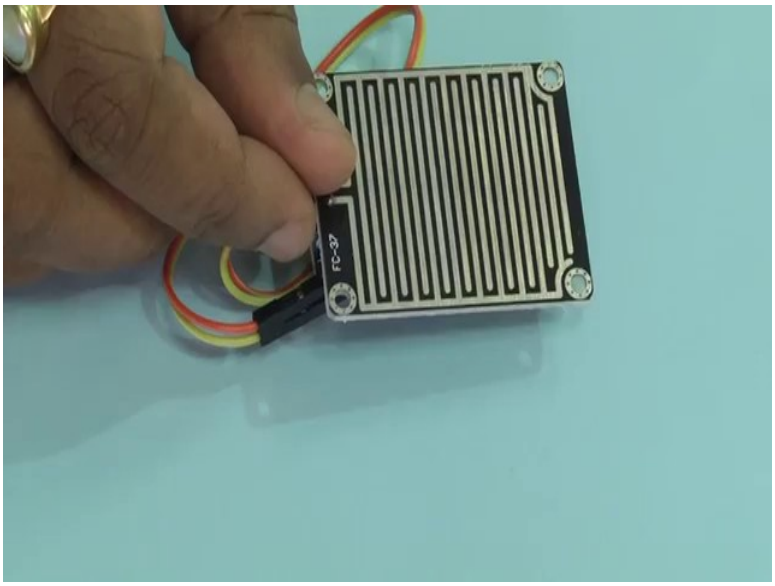

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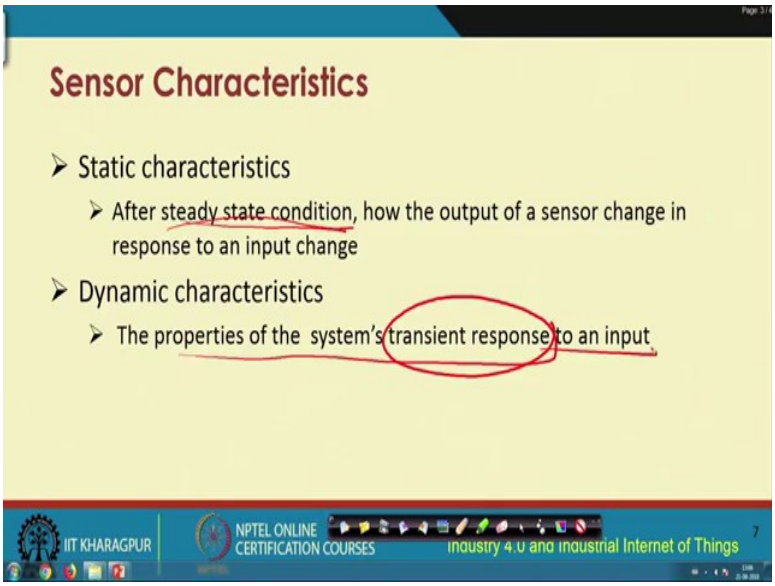

The characteristics of sensors can be classified into two types, the static characteristics and the dynamic characteristics. Different sensors have different operating mechanisms. In general, when a sensor starts its operation, it takes a while, in general, not necessarily in many cases, to come to the steady state. Static characteristics are the characteristics of a particular sensor in the steady state condition. Once the sensor has attained its steady state, the output of a sensor does not change significantly in response to the change in input. Dynamic characteristics are about the properties of the systems transient response to an input, before the sensor achieves the steady state.

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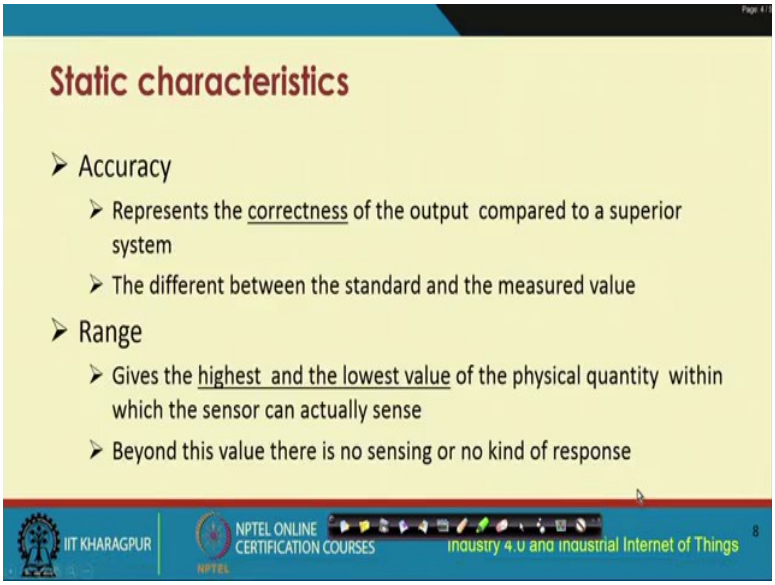

The static characteristics could be characteristics such as accuracy. As this name suggests, it is about the correctness of the output compared to a superior system. In other words, how accurately the sensor measures. Range means the range of operation lowest value to highest value. The range of operation of a particular sensor, lowest temperature to highest temperature of a particular temperature sensor is the range of that particular sensor.

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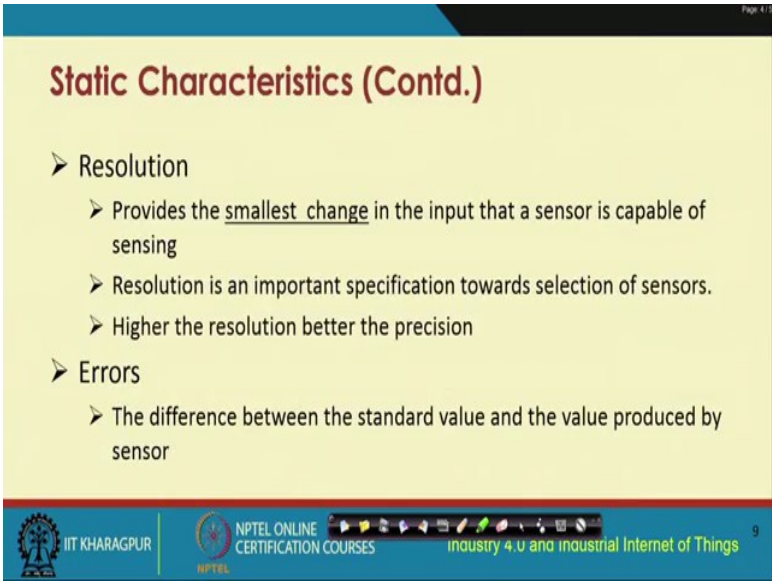

Resolution is the smallest change in the input that a sensor is capable of sensing. Similarly, you have the resolution of a sensor like a temperature sensor. The smallest change in temperature that a particular temperature sensor is able to sense or detect is basically the resolution of a particular sensor. Error is the difference between the standard value and the value produced by the sensor.

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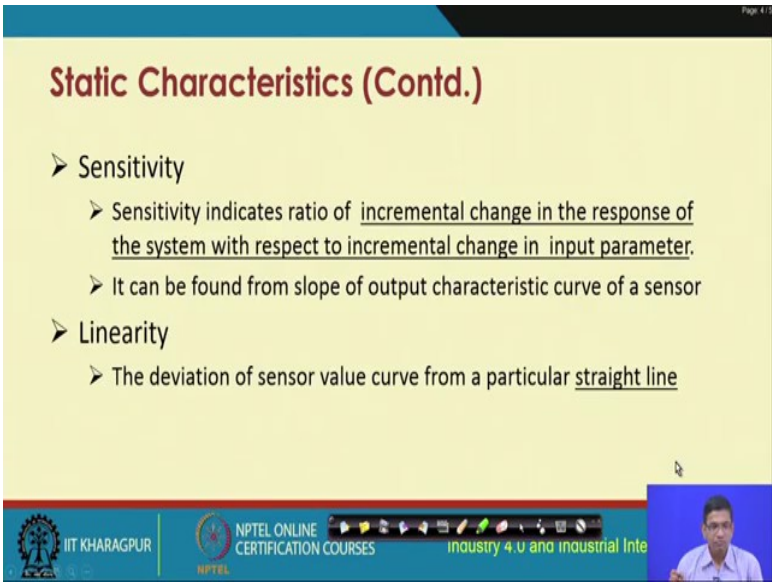

Sensitivity indicates the ratio of incremental change in the response of the system with respect to the incremental change in the input parameter. The linearity characteristic is the deviation of the value of a sensor from the straight line curve.

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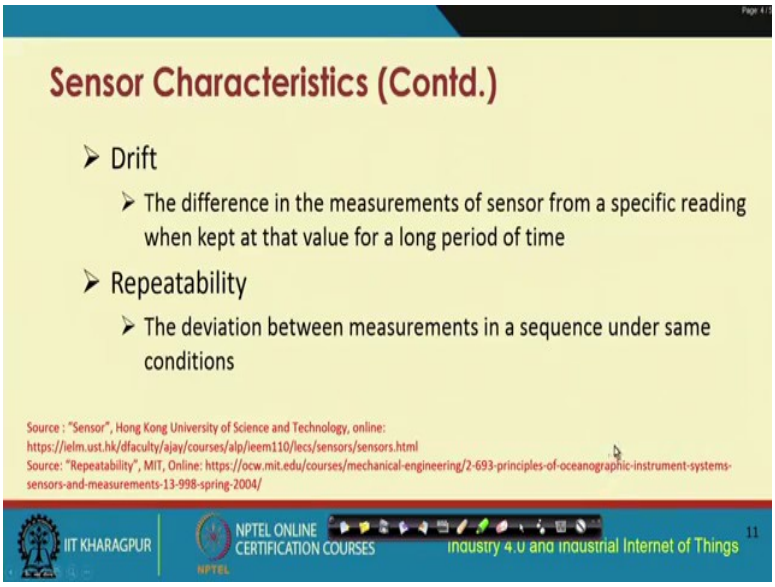

Drift is the fluctuation in the value of a sensor, if it is kept at the same conditions for long duration. For example, in case of temperature sensor or any other sensor for a particular reading condition, if you are keeping it for a sufficiently long duration of time, then the difference in measurements that it will show over the period of time is the drift. Then we

have the repeatability characteristic, which is the deviation from the measurements, in a sequence, under the same conditions.

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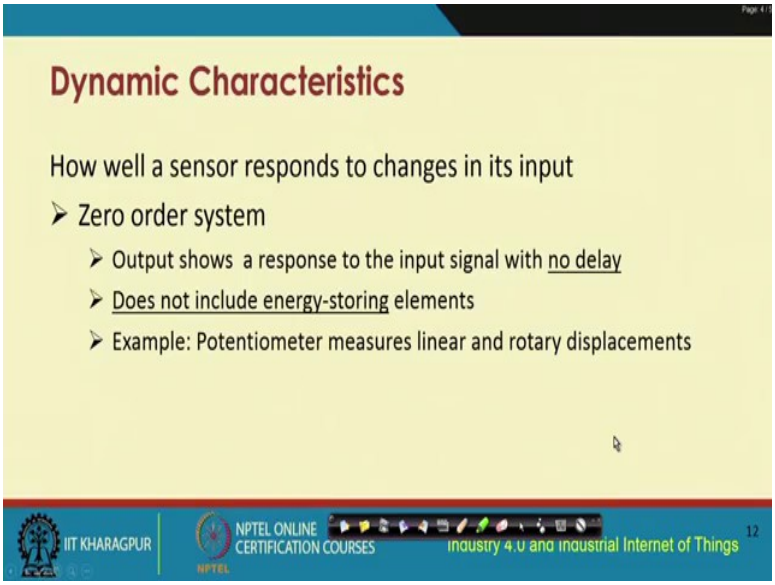

Dynamic characteristics is about if the inputs are changed, how well the sensor responds to its changes in the input. The transients are received or captured through the dynamic characteristic. For example, zero ordered system, which is basically a system where the output shows a response to the input signal, without any delay. These zero order systems do not include energy storing requirements. For instance, a potentiometer measures the linear and rotary displacements, so this is an example of a zero order system.

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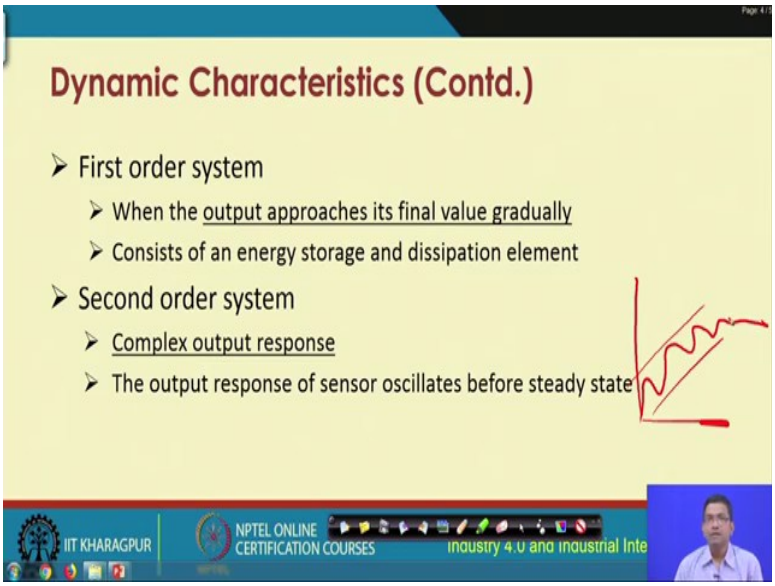

First order systems are when the output approaches its final value gradually. These systems will have some kind of mechanism for both energy storage and dissipation. For example, a capacitor will store this energy and dissipate over a duration of time, in these systems.

Second order systems will have complex output response not gradually, but a complex output response. And this output response of these sensors will typically oscillate before the steady state is arrived. So, this oscillates between certain values. These are the output response of these second order systems.

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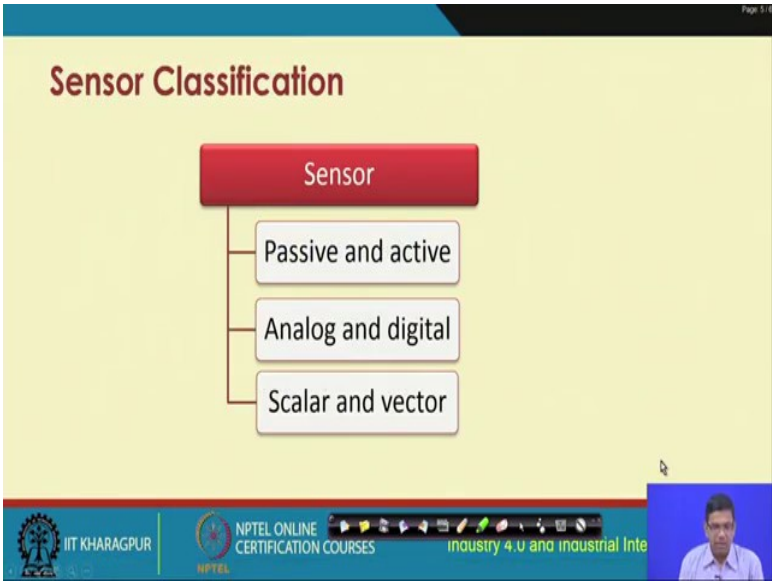

The sensors could be classified in different ways. They could be classified as either passive sensor or active sensor, analog sensor or digital sensor, scalar sensor or vector sensor.

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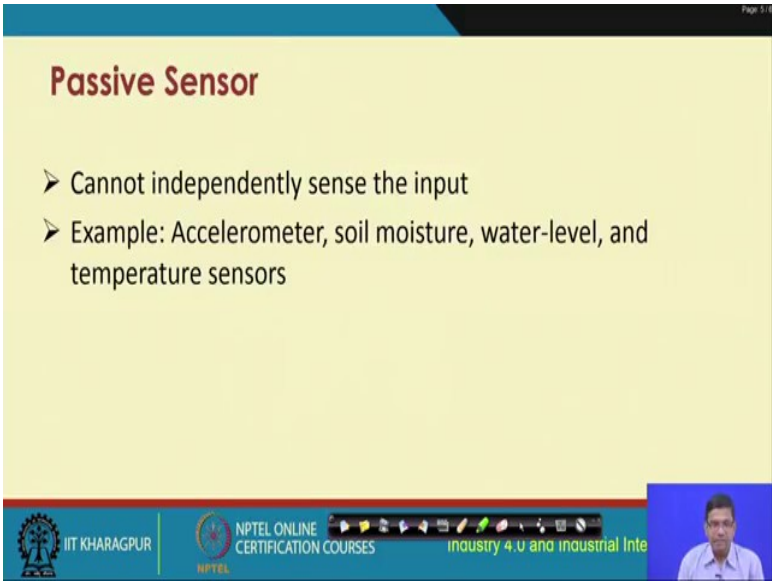

A passive sensor cannot independently sense the input. So, examples of passive sensors are accelerometer, soil moisture, water level, and temperature sensor.

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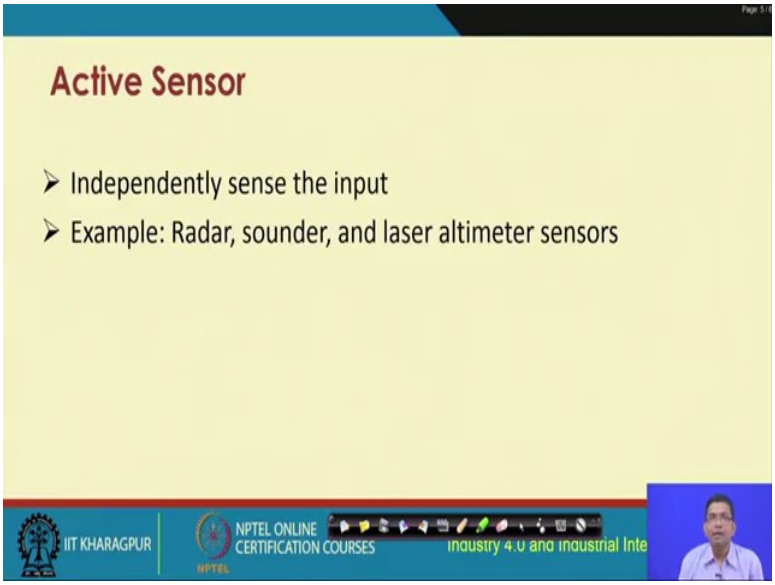

Active sensors are the ones, which can independently sense the input. For instance, radar, altimeter sensors are examples of active sensors.

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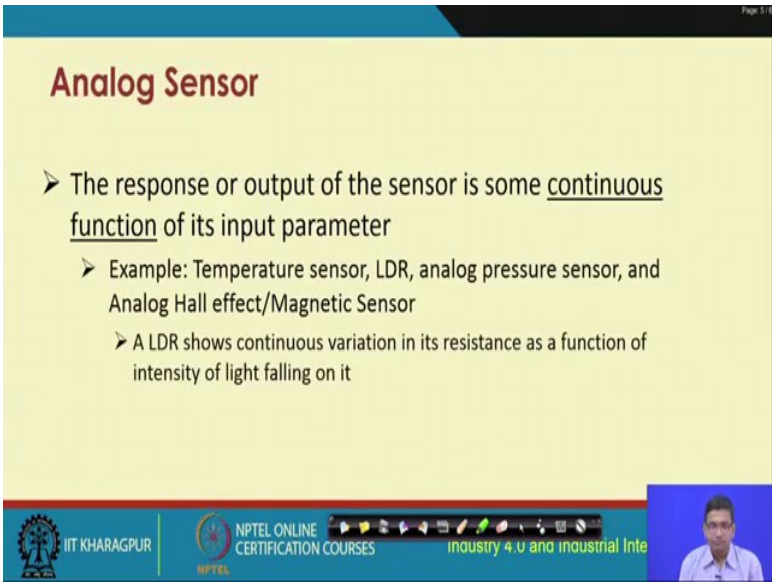

Analog sensors produce output which is some continuous function of the input parameter. For example, temperature sensor, light detection sensor, LDR, pressure sensor, analog pressure sensors, the analog variants of these pressure sensors, analog Hall effect sensor or magnetic sensors. A LDR shows continuous variation in its resistance as a function of intensity of light falling on it.

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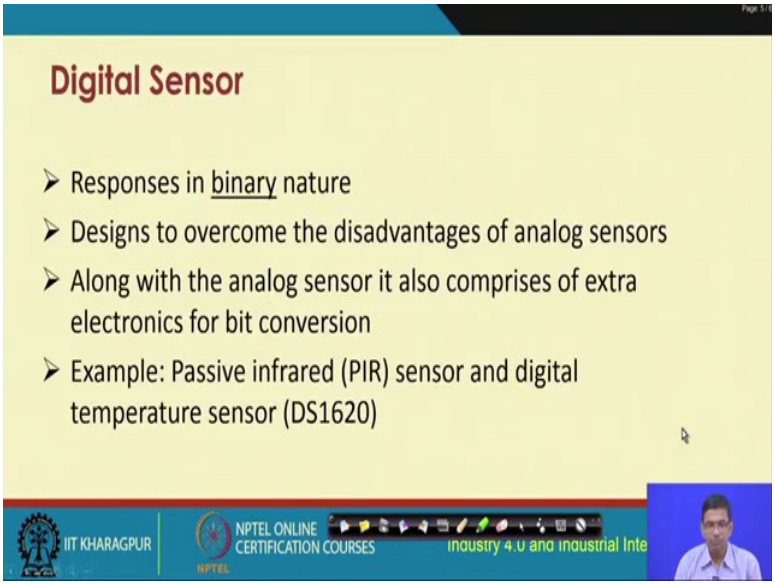

Digital sensors are basically the ones where the response is of binary nature. These have been designed in order to overcome some of the limitations of the analog sensors which produces

continuous function of the output with respect to the changes in the input characteristics. Examples of digital sensors are PIR sensor, digital, and temperature sensor.

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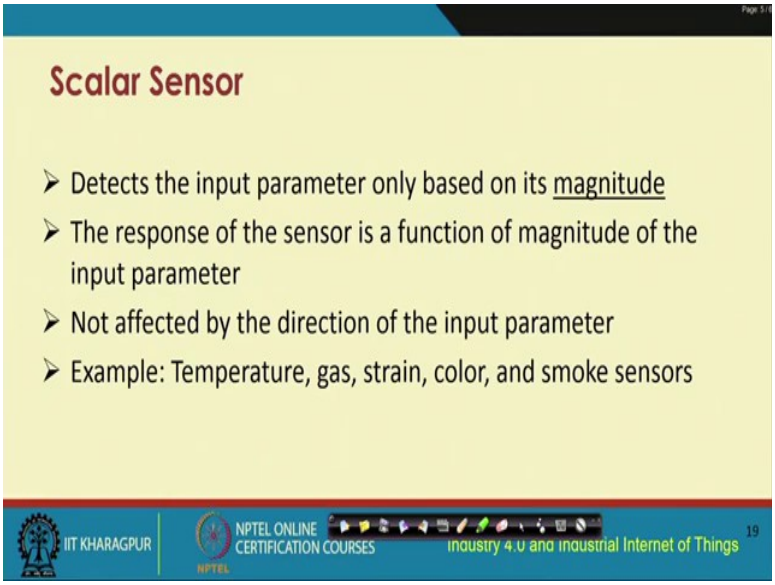

Scalar sensors are basically the ones which will measure only the magnitude of the input parameter. The response of a sensor is a function of the magnitude of the input parameter. And these are not affected by the direction of the input parameter. Examples are temperature sensor, gas sensor, strain sensor, color sensor, smoke sensors. The detection of these parameters do not depend on the change in the direction of the input, change in the direction of temperature, change in the direction of gas etc.

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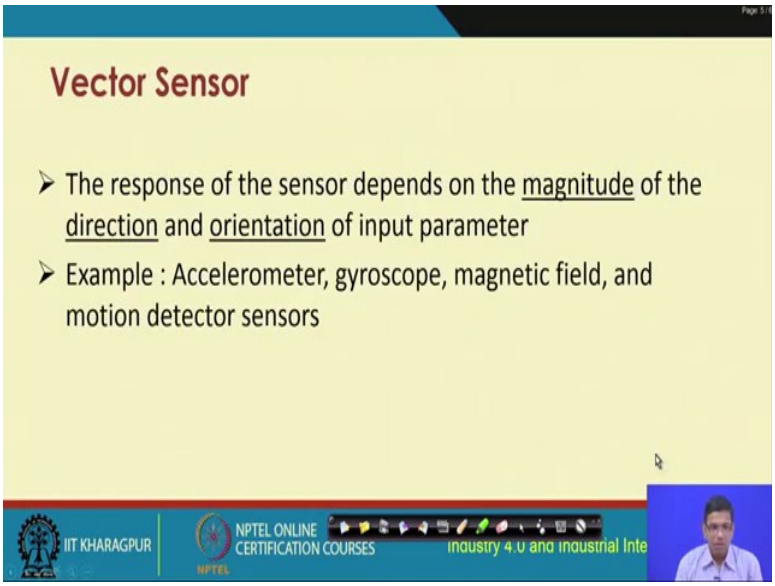

Vector sensors are those sensors whose response depends on the magnitude, the direction and the orientation. Examples are accelerometer, gyroscope, magnetic field, and motion detector sensors.

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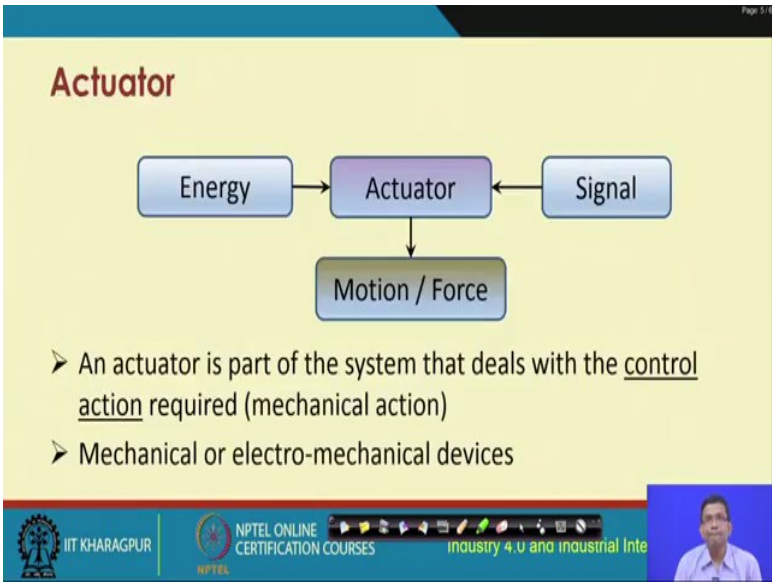

In this particular figure, an actuator takes two inputs, one input is the energy. And together the actuator produces some kind of a motion, such as the force or whatever.

So, an actuator is a part of the system that deals with the control action required, the mechanical action. There are many others, but these are some of these pictures of actuators.

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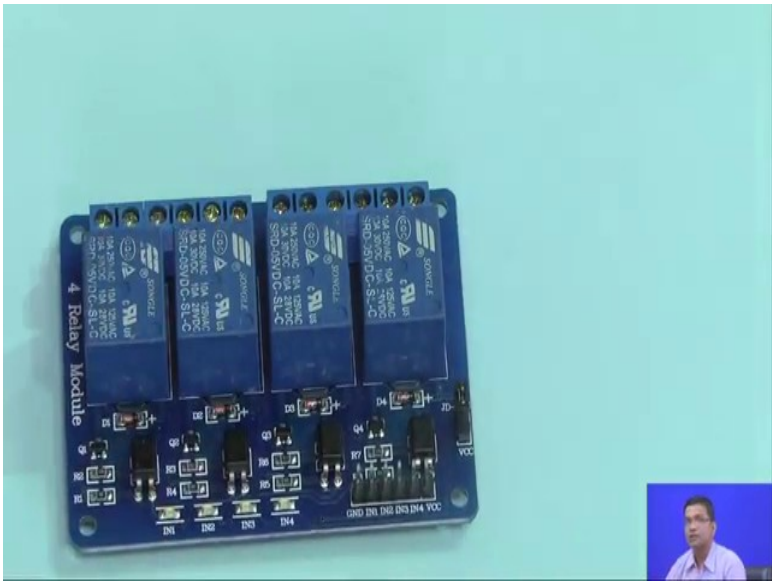

So, this is an actuator; an electric relay.

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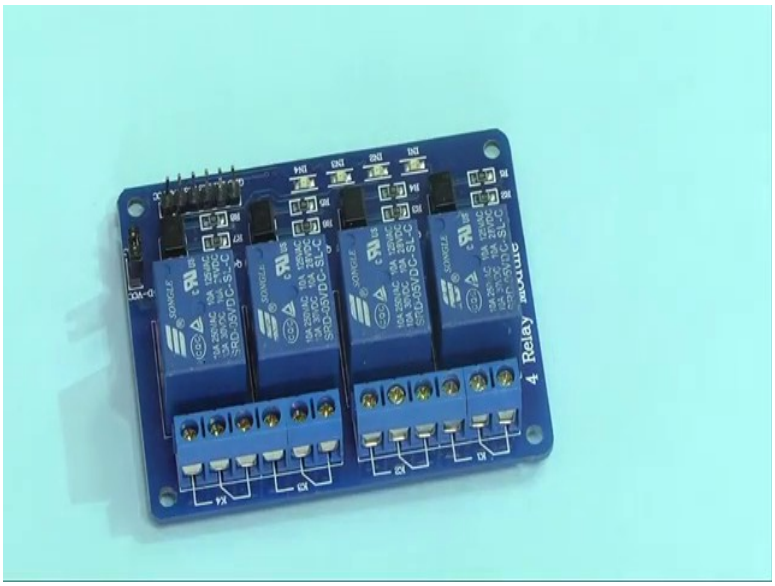

This relay transforms the electrical energy into some kind of mechanical action, or it could be electromechanical as well. These relays are useful for performing, taking an electric signal and performing some kind of mechanical operation such as turning on a particular valve, turning off a valve, turning on a device, turning off a device such as a compressor.

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Then this is a motor - a dc motor. There could be different types of motors, and each of these is basically an example of actuator.

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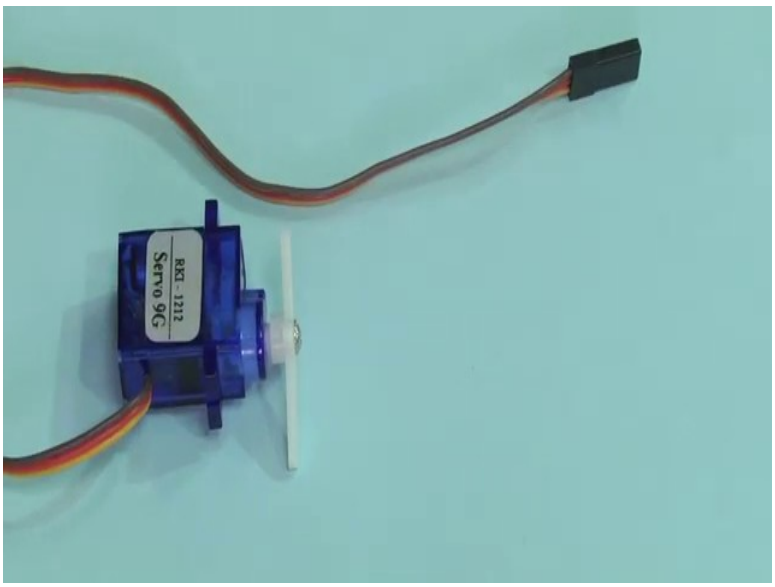

And let me show you another actuator which is basically another type of motor, which is known as the stepper motor.

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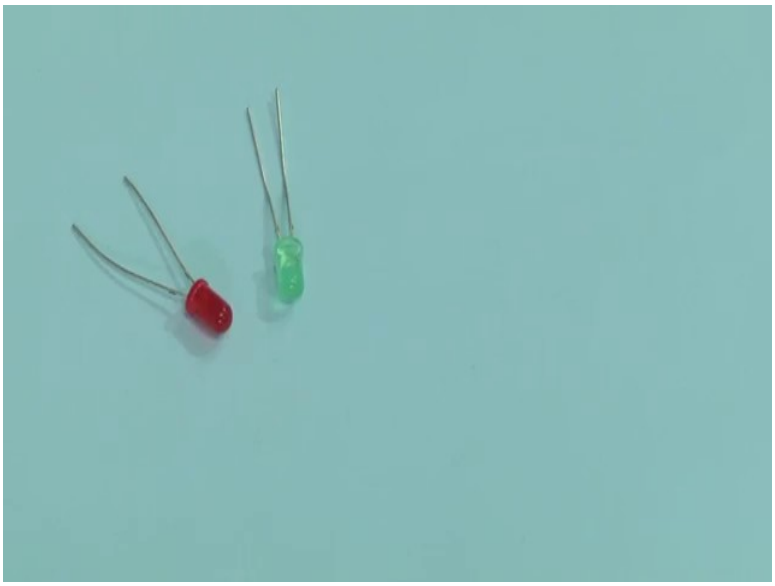

You could also have actuators like these which I think most of you have already seen right. These are the LEDs. So, an LED could be turned on or off in response to something, something being sensed. For example, a gas being present.

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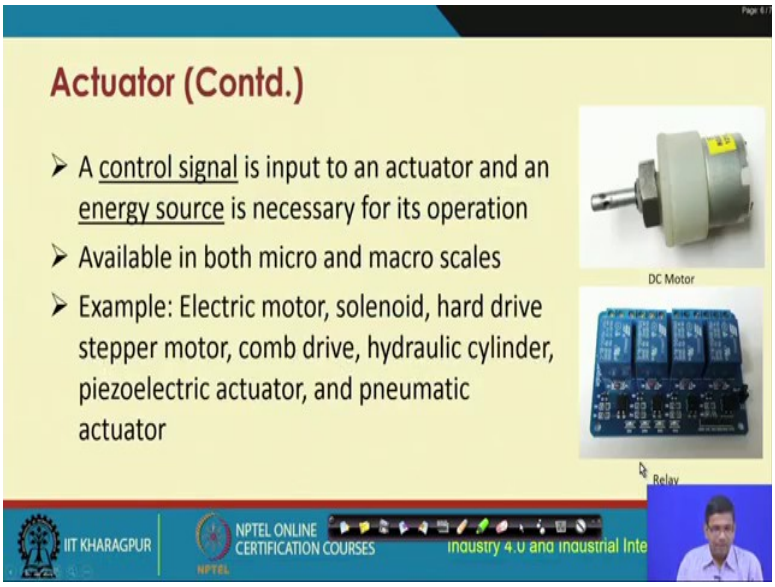

An actuator takes a control signal as an input and then it performs its operation. So, here is the picture of a dc motor. And I already show you showed you live the how a dc motor looks like. Similarly, a relay is another example, electric relay. These are different examples of actuators- electric motors, solenoid valves, hard drives, stepper motor, comb drive, hydraulic

cylinder, piezoelectric actuator, pneumatic actuators. These actuators can come in different shapes and sizes. These could be micro actuators, macro actuators, and so on depending on the size of these actuators.

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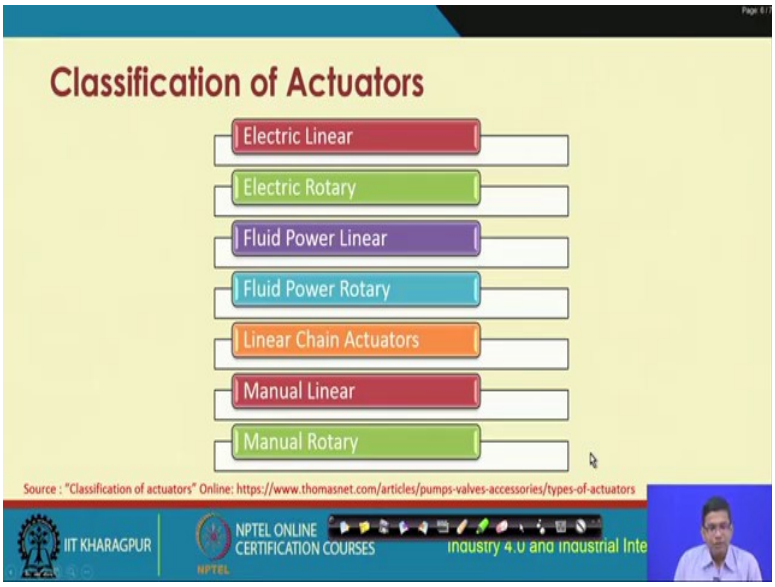

The actuators can be classified into different types, such as electric linear, electric rotary, fluid power linear, fluid power rotary, linear chain actuator, manual linear, manual rotary.

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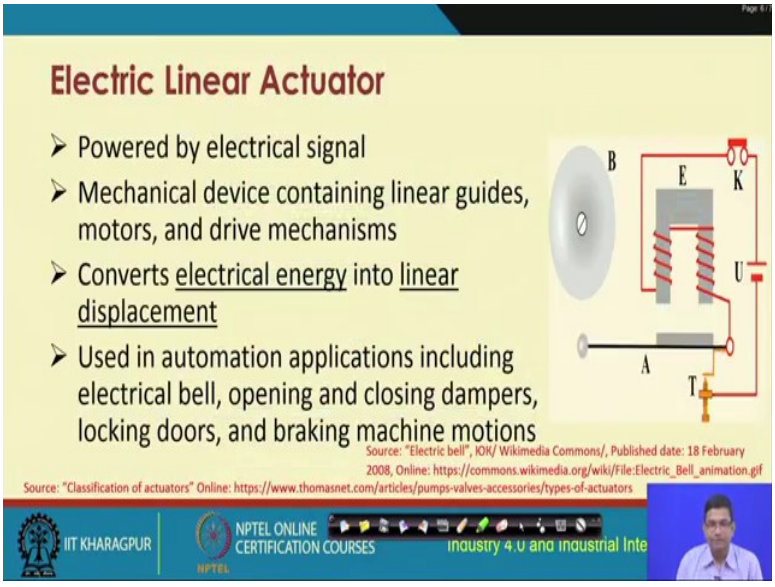

Now, let us look at this electric linear actuator. As the name suggests, these are basically powered by electric signal. The electric energy in these actuators is transformed to achieve

some kind of linear displacement. For example, electric bell, opening and closing of dampers, locking doors, breaking machine motions.

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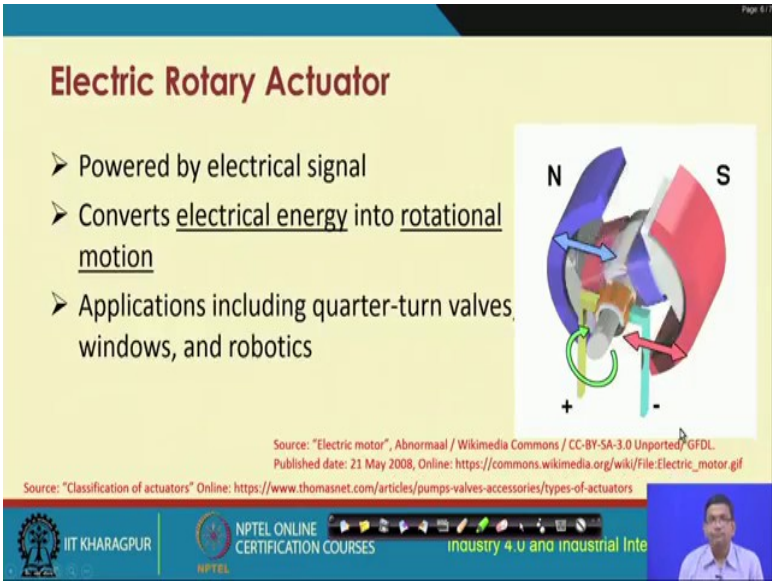

Then the next one is electric rotary actuator. These are powered by electrical signals. They convert the electrical energy into rotational motion. And this one is electrical energy into rotational motion. So, you know quarter turn valves, and other electrical motors are examples of electric rotor actuator.

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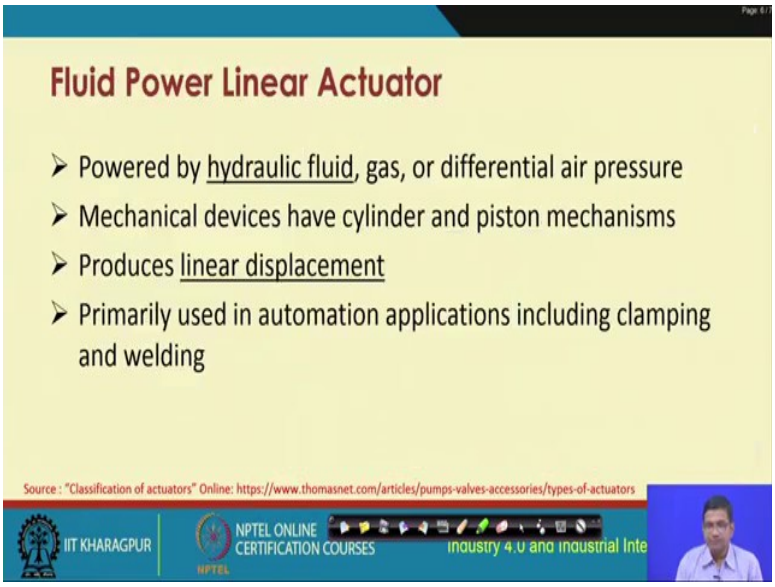

Then you have the fluid power linear actuator. These are powered by different electric fluid sorry hydraulic fluids, gas or air pressure, and produces linear displacement.

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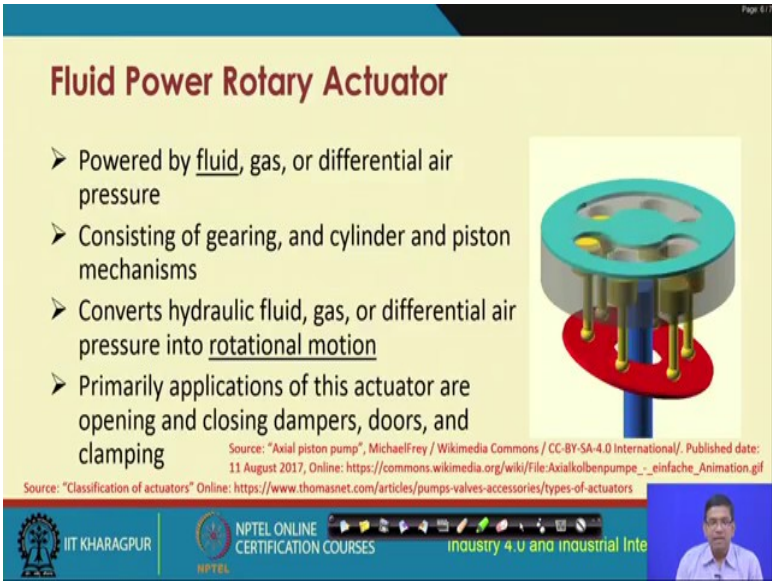

Then you have fluid power rotary actuator again powered by fluid, such as gas and liquids. They produce rotational motion, like the example that you see the picture that you see in the slide, rotational motion is produced as an output of these actuators.

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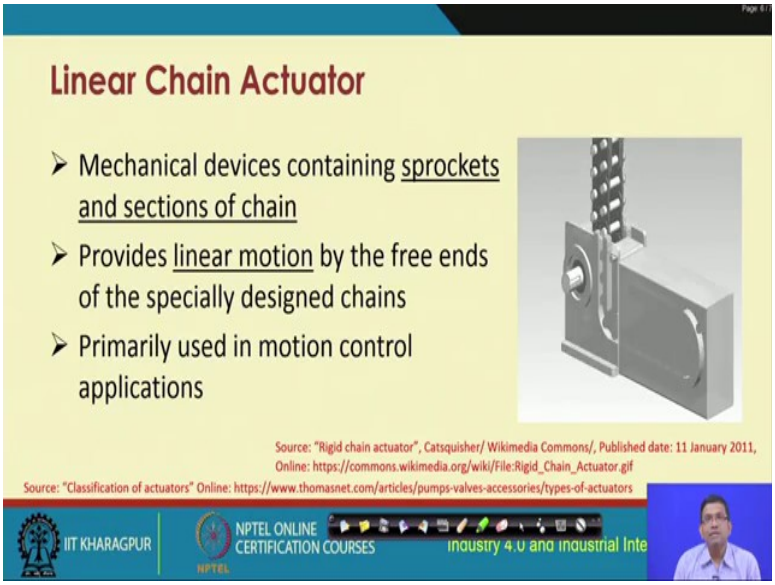

Then you have the linear chain actuator, consists of mechanical devices such as sprockets and sections of chains, which produce linear motion by the free ends of the specially designed

chains. And the slide helps to understand how these work. So, these are primarily used in motion control applications.

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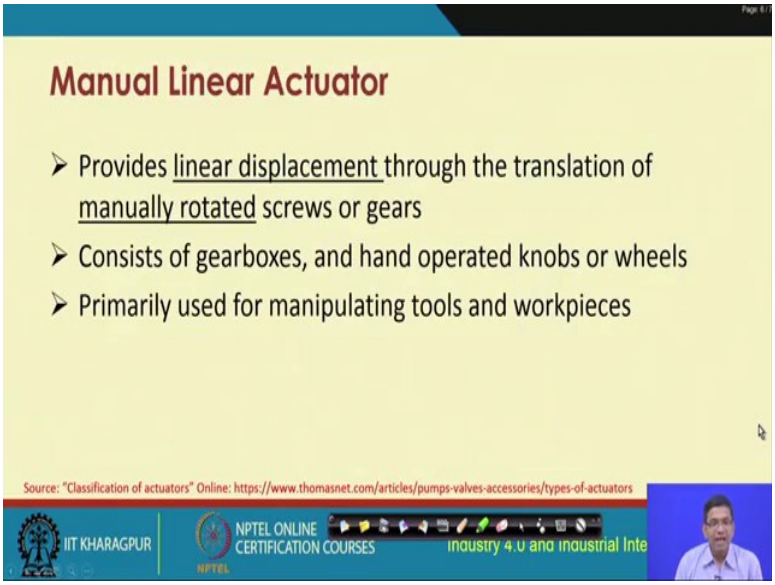

Then we have the manual linear actuator which provides linear displacement through the translation of manually rotated screws or gears. So, manual rotation is performed on some screws and consequently there is some linear displacement. Examples are gear boxes, hand operated knobs, wheels. These are primarily used for manipulating tools and work pieces.

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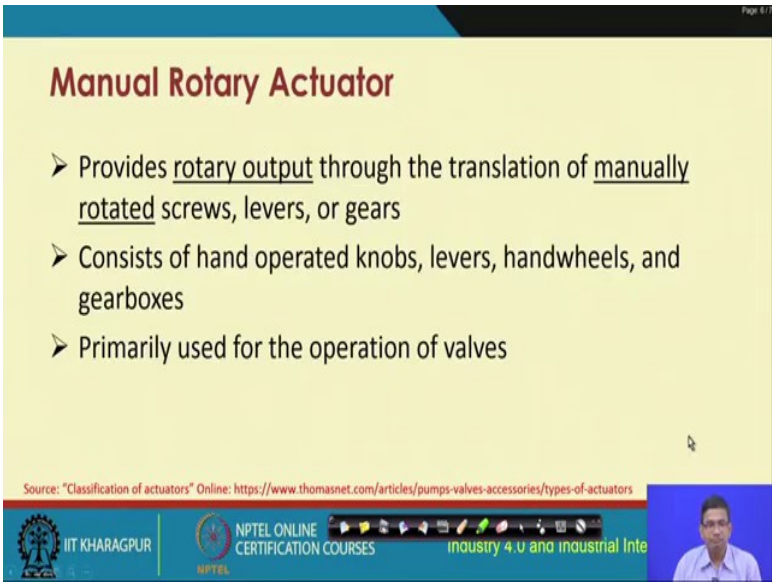

Then you have the manual rotary actuators which provide rotary output through the translation of manually rotated screws, levers or gears, gears. These are primarily used for the operation of valves.

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So, with this we come to an end of this particular lecture on sensors and actuators. And as I told you at the outset sensors are, and, actuators are basically key to the building of IoT and IIoT based systems. And, you know, everywhere throughout you will see that in this course, we are talking about the use of sensors and actuators, and this preliminary understanding about each of these, the sensors and actuators, is necessary for you to have an in-depth understanding about how IIoT works.

These are some of these references given in the slide.

Thank you.