Introduction to Internet of Things
Prof. Sudip Misra
Department of Computer Science & Engineering
Indian Institute of Technology, Kharagpur

Lecture - 03
Sensing

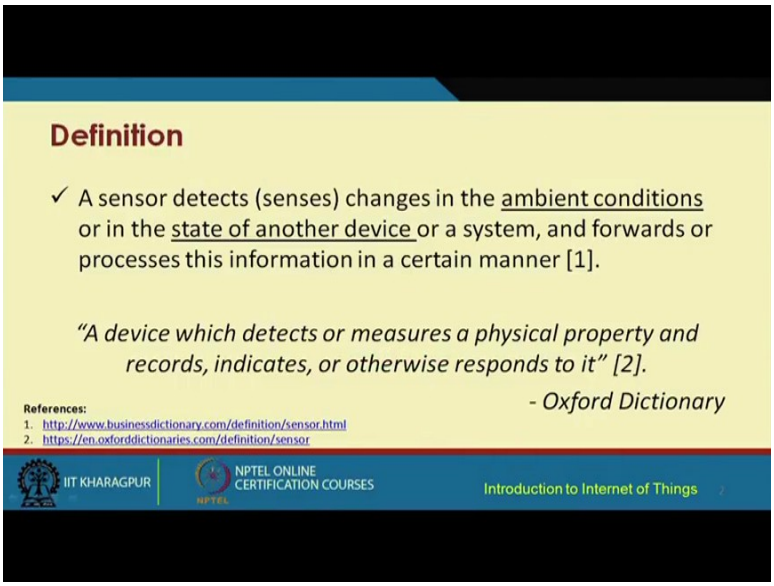
So, we have already understood the basics of internet of things. Now, let us try to understand that what are the essential building blocks of internet of things. So, one of the very essential components of internet of things is sensors and the other one is actuators whereas, the sensors basically sense the physical phenomena that are occurring around them and the actuators basically based on the sensed information. The actuators, they actuate. That means, they perform some actions on the physical environment. So, they take some actions based on what has been sensed.

So, essentially if we see that we have a gradual phase wise approach to building internet of things. So, we have sensors which are sensing the sensors, they sense different parameters depending on the sensor being used. For example, temperature, pressure, humidity conditions, lighting conditions and so on. Then, what will happen is these sensed information are going to be sent over a connected system. That means, over a network that information will be passed, it can also involve cloud and so on and finally, that information is going to be transmitted based on what has been sensed and based on the requirements, some physical action is going to be taken by an actuator.

So, may be a bulb might be turned on if certain conditions, in an agricultural field has happened, maybe if the field based on the sensors it is found out that in an agricultural field, the field has run out of stagnant water that is required for paddy crops. Then, what might be required is based on that sensed information automatically the valve of the water pump, the deep to well that is used or a shallow tube well that is used for irrigation, automatically that valve will be turned on, so that the field gets irrigated.

So, that can be done through the process of actuation. So, we have sensing. we have IoT or simply the network and then, we have this actuation. So, sensing network actuation we start with the sensing component. Now, in the next lecture we will try to understand how actuation is done.

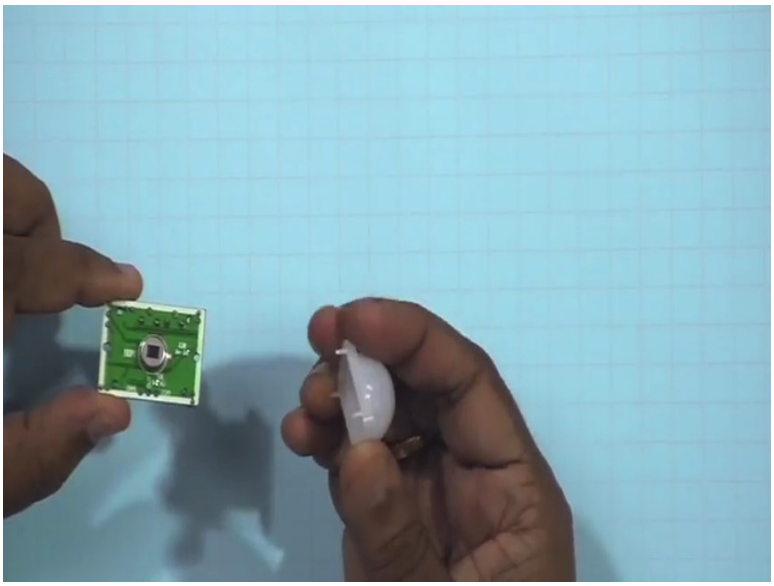
(Refer Slide Time: 03:17)



So, when we talk about sensing, we need to understand what is sensing. So, basically a sensor it detects or senses the changes in the ambient conditions or it can also sense the state of another device. So, maybe one sensor can check, can sense how and what is the state of another device. So, this is what he is done with the help of sensing. So, some physical property of the ambient conditions of the environment in which the sensor is in or of another machine or a system a separate one, these can be sensed with the help of sensors.

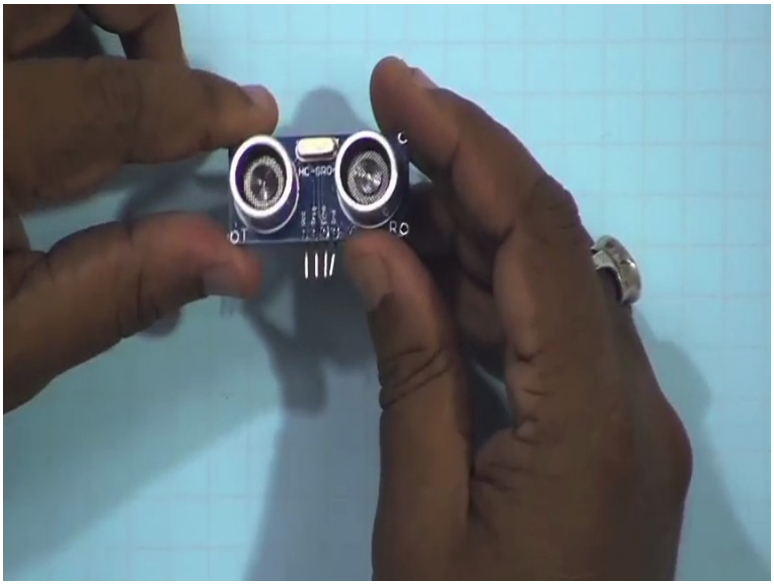
So, let me now show you some sensors, some real sensors that we have.

(Refer Slide Time: 04:06)



So, here are few real sensors and this is a sensor that is used for obstacle detection. This is a PIR sensor passive infrared sensors. So, this passive infrared sensor here can be used for detecting if there is any obstacle. So, this is an example of a PIR or obstacle based sensor.

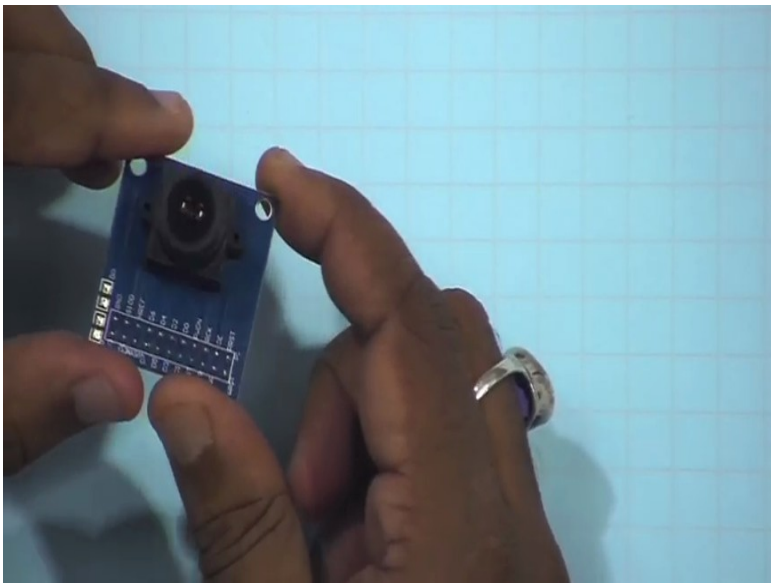
(Refer Slide Time: 04:45)



Then, we have another sensor this is the ultrasonic sensor. This basically detects that how far that obstacle is. This is another sensor. So, here as you can see that there are like two eyes kind of things. So, what happens is these ultrasonic sensors may send

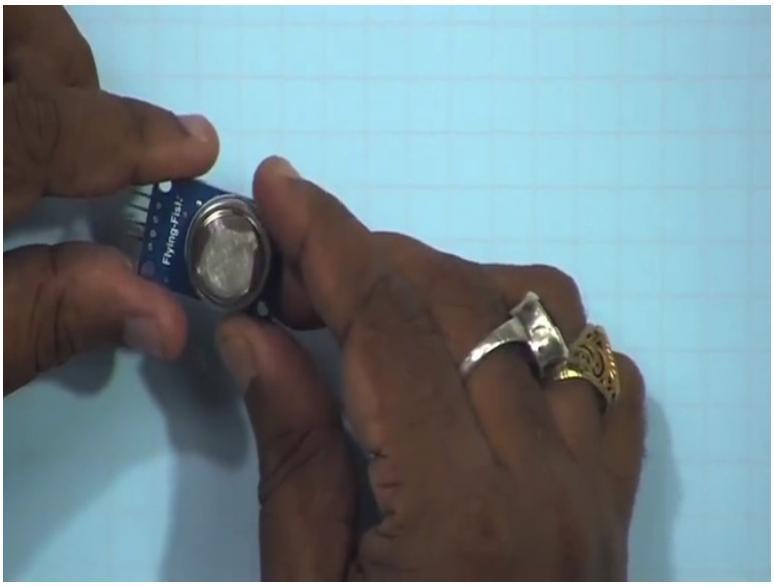
ultrasound waves. So, these ultrasound waves are sent and then, that sound wave is going to get reflected back. We already know what velocity is and then, depending on how much time has elapsed from the point sound wave was sensed and the deflection is received back, based on that the distance is calculated. So, this sensor helps in basically getting an idea or sensing how far an obstacle is from a particular point where the sensor is.

(Refer Slide Time: 05:46)



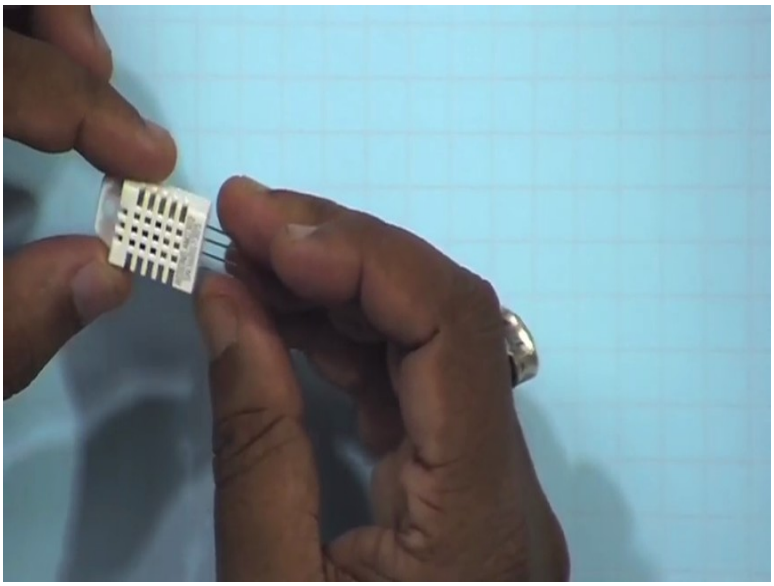
Then, we have another sensor which is the camera sensor. This is as you can see over here is small IoT camera. Since the camera sensor, then we have this one here which is a smoke detection sensor. So, this sensor can help in detecting the smoke.

(Refer Slide Time: 06:08)



Finally, I would like to show you another sensor which is the temperature and humidity sensor. This is actually, this measures both of these together this particular sensor.

(Refer Slide Time: 06:23)



So, these are some real life sensors, real examples of sensors that I have just shown you like this. There are different sensors that can be purchased. These sensors, they have different functionalities and these functionalities are typically unique. That means that one sensor which is fabricated to do, to measure a certain physical property, it cannot

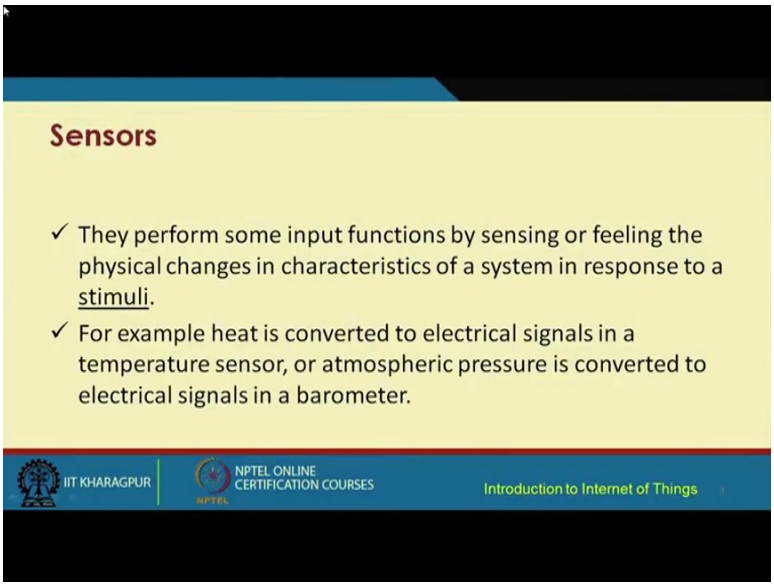
measure another one or more specifically let me give you an example to illustrate this point because this is something that many people make a mistake.

So, a temperature sensor can measure temperature only. It cannot measure for instance smoke or it cannot detect smoke. So, these are very much application specific you know specific things, specific properties, basic specific physical properties can only be detected by these sensors.

Now, the sensors they come in different shapes and sizes. They can be very small, they can be very big. The same sensors can be mechanical sensors, these can be electrical sensors, they can be electronic sensors, they can be chemical sensors. There are so many different types of sensors and fabrication of a sensor is a completely different ballgame. So, whether it is a mechanical sensor or an electronic sensor, electrical sensor or you know a chemical sensor, whatever it is a completely different ballgame. Typically people who are into building of IoT, they focus more on the networking aspects. They focus more on the networking analytics aspects of IoT.

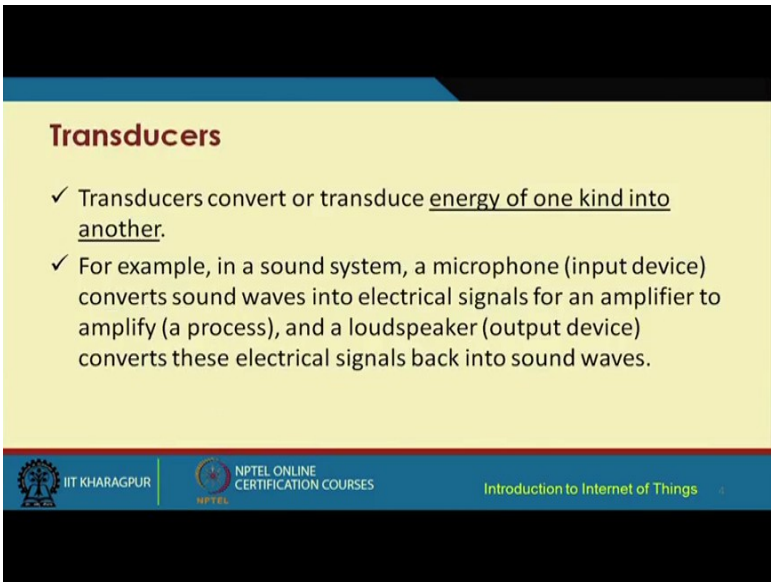
There are separate researchers who work on the design of these sensors. Some of these sensors that I have just shown you, the sensors you know that complete the design, the fabrication it is a completely different story altogether you know. So, you know this is and typically this is done by those who are focusing on sensor design and fabrication. So, typically they are concerned only about how these sensors can be developed, they can be fabricated and they are not bothered about building IoT as such. Of course, there can be some researchers who might also take interest sensors. You know not just the fabrication of the sensors, but also going beyond building of the IoT. Some people might be taking interest in that, but in general it is not.

(Refer Slide Time: 09:22)



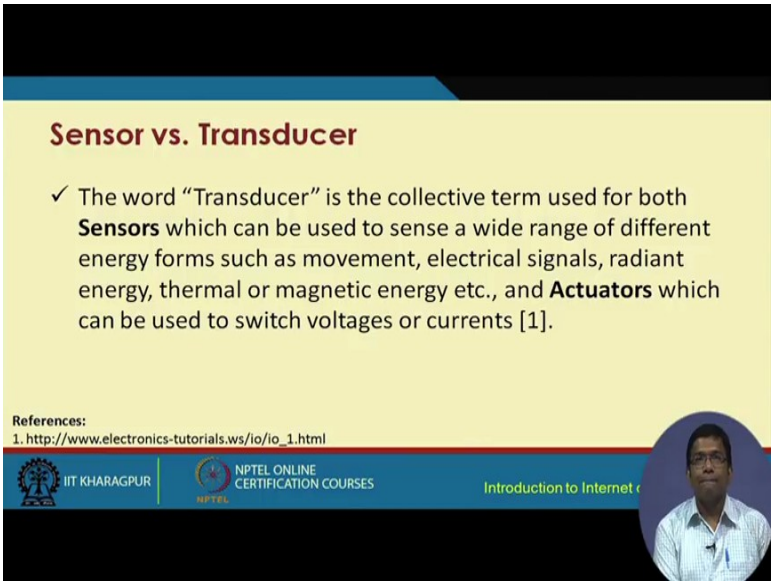
So, the sensors based on certain stimuli, the different stimuli might be there. They can measure the thing in the physical characteristics of the environment of the system and so on and these changes are basically converted to electrical signals. For example, for a heat sensor this heat is converted to electrical signals and this is for temperature sensors. I am sorry, this for temperature sensor, the heat is converted to electrical signals and for sensors such as atmospheric pressure sensors, the atmospheric pressure is basically converted to electrical signals. So, we have different sensors which measure different things, but then these sensed values are converted to respective electrical signals.

(Refer Slide Time: 10:30)



Now, there is an associated terminology which is for the transducers. The term transducers basically convert one form of energy into another form of energy being converted into another. For example, in a microphone what we have in a microphone. So, the sound waves are converted to electrical signals and then, to a output device like a loudspeaker and we are able to hear that sound. So, this is an example of a transducer.

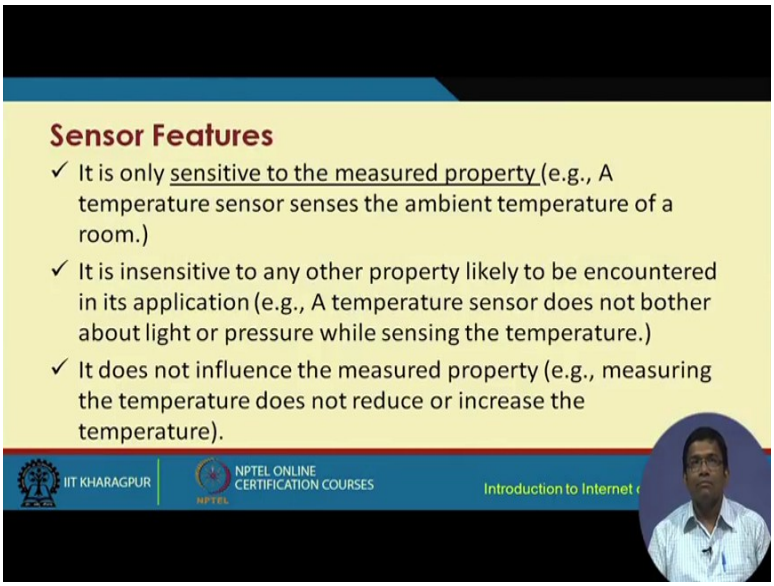
(Refer Slide Time: 11:09)



So, these terms sensors and transducers are very common. They have lot of overlap and we have to understand the distinction between these two. There is lot of misunderstanding people conceived sensors and transducers. We use these terms almost interchangeably, but there are differences.

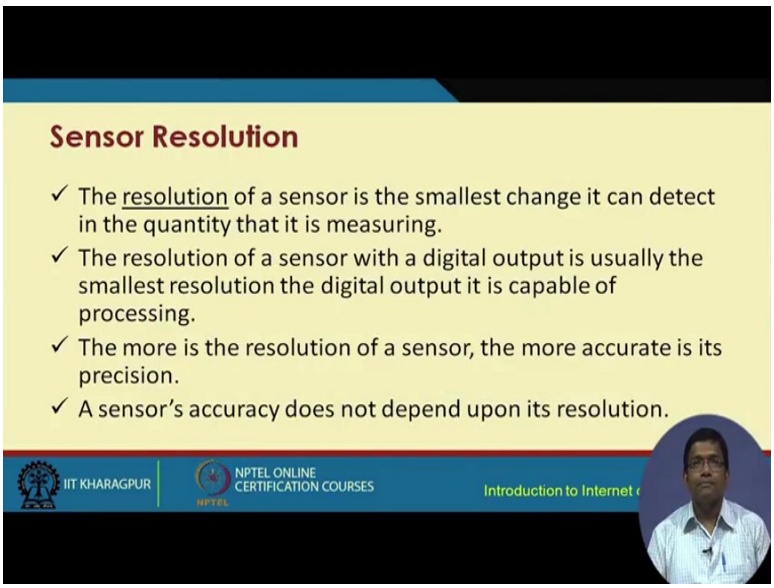
So, the word transducer is a collective term which includes sensors as well as the actuators that I was telling you. Before the sensors can sense what is going on around them and convert to electrical signals etcetera and the actuators can basically perform these actions by maybe switching voltages or currents.

(Refer Slide Time: 12:00)



Now, the sensors have different features. They are sensitive to the property, the physical property that is being measured. So, they can do all. They are sensitive only to that measured property. So, basically a temperature sensor can sense only the ambient temperature of the room and it is insensitive to other changes, maybe changes in the atmospheric pressure or changes in the lighting condition of that room.

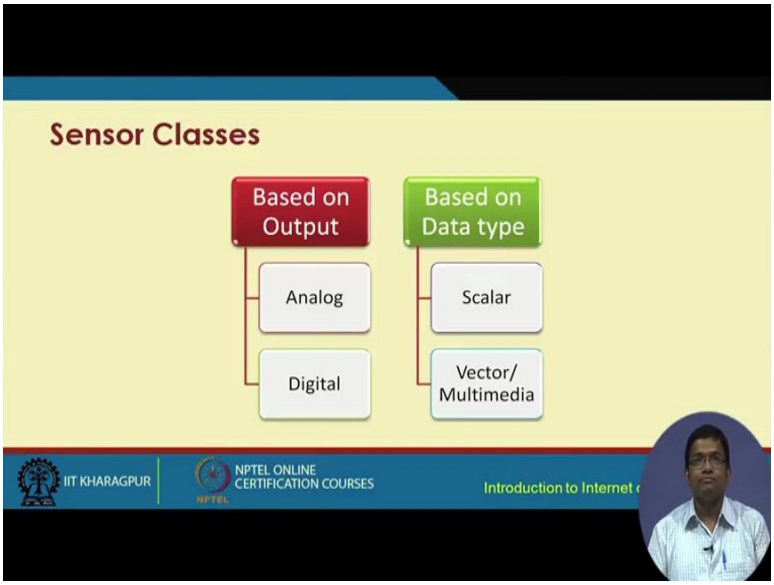
(Refer Slide Time: 12:31)



There is a terminology which is called the resolution. The resolution of a sensor is basically defined as the smallest change that it can detect in the quantity that is being

measured. So, the smallest change that it can detect the resolution of a sensor with a digital output is usually the smallest resolution of the digital output. It is capable of processing.

(Refer Slide Time: 12:54)

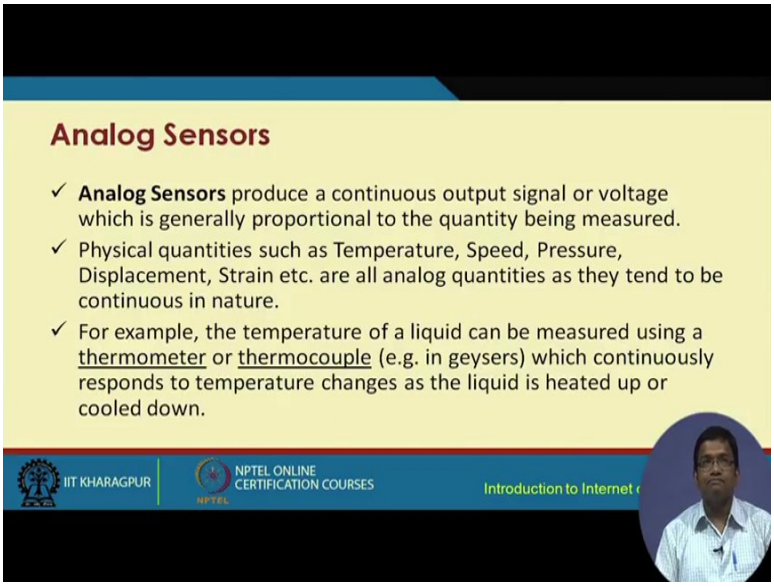


So, based on the output, the sensors can be classified as analog or digital and based on the data type, they can be classified as scalar or vector sensors. So, in the analog sensor, what we have these sensors give continuous analog output. So, for example, tint temperature sensor continuously changes in the temperature are going to be sensed, measured and the output is going to be an analog signal. Digital sensors basically gives digital outputs on and off for example, and like this come you know discrete digital values are given as outputs by these digital sensors.

Then, scaler sensors basically measure scalar variables which can measure only the changes in the magnitude whereas, the vector senses not only the magnitude, but also the direction. So, scalar sensor example would be temperature sensor is an example of scalar sensor because you know irrespective of which orientation you put, the sensor temperature sensor or in which direction you are taking it, it is going to give you the magnitude value. Only the changes in the magnitude of the temperature, on the contrary we have the vector sensor. For example, the camera sensor or the accelerometer sensor whose values are dependent on the orientation on the direction and so on direction in which the sensor is being put and the weight is measuring. So, it is dependent on that. So,

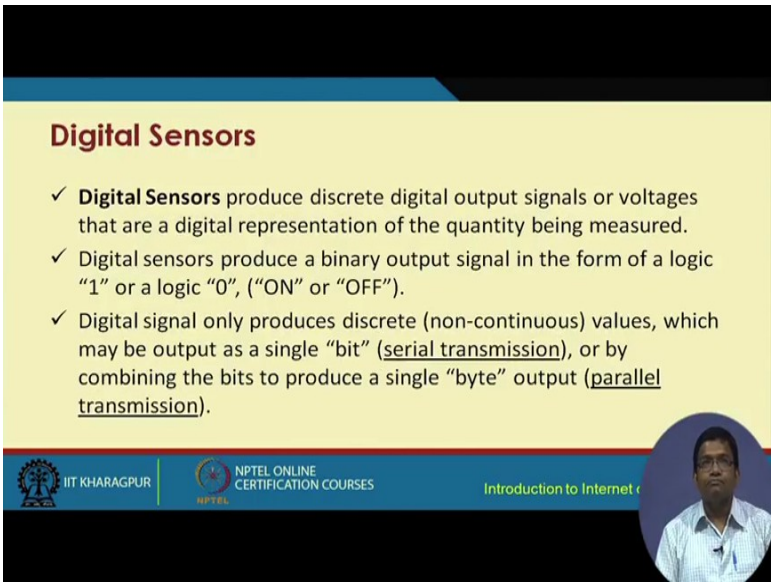
we have analog sensors, we have digital sensors, we have scalar sensors and we have vector sensors.

(Refer Slide Time: 14:44)



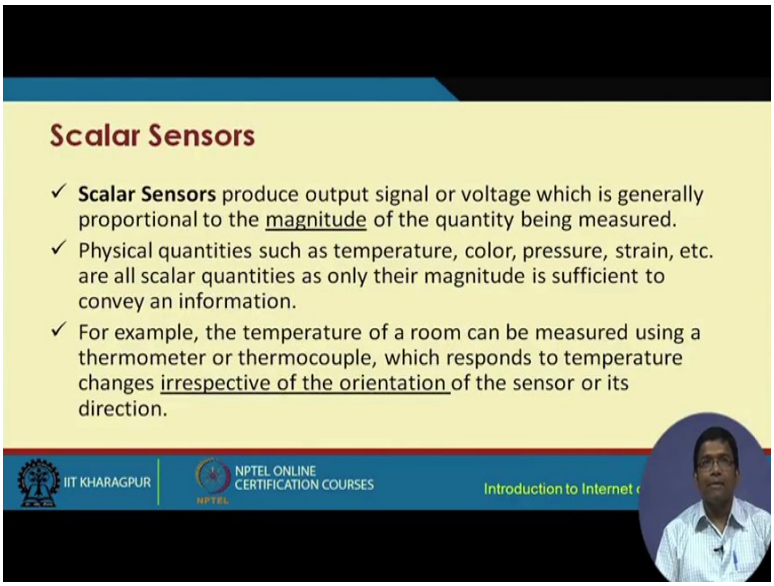
So, analog sensor I already mentioned about analog sensors, temperature sensor. You know temperature is typically measured with the help of thermometer or thermocouple thermometers are quite common, but thermocouple is something that is used in the geezers for example, you know. So, you have two different metallic strips for instance and these strips they know they can, in the thermocouple they can bend and so on. So, these based on that you know based on the amount of bending etcetera. You know they measure the changes in the temperature. So, if you calibrate the thermocouple you know, so accordingly it is going to give how much the temperature has changed and depending on that one can understand how much the liquid has heated up or has cooled down.

(Refer Slide Time: 15:36)



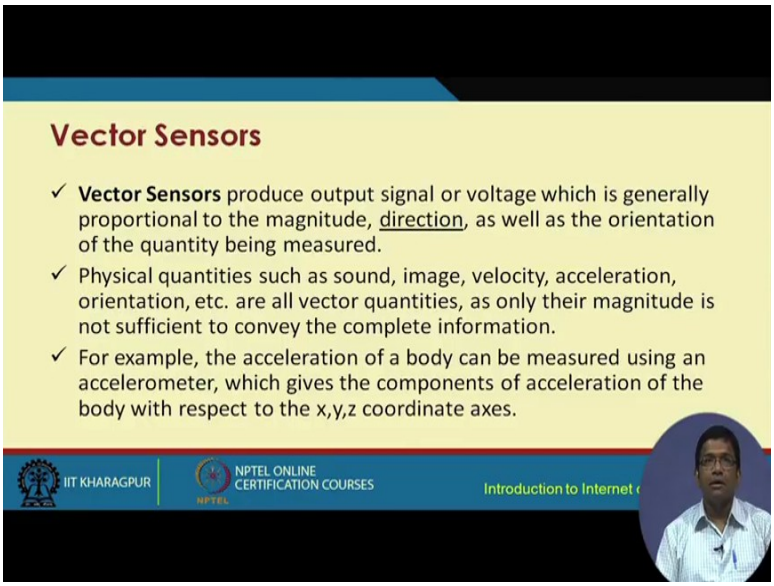
Digital sensors produce digital discreet voltage levels or signal levels. So, binary values like 0 and 1 or on and off or output the digital sensors.

(Refer Slide Time: 15:53)



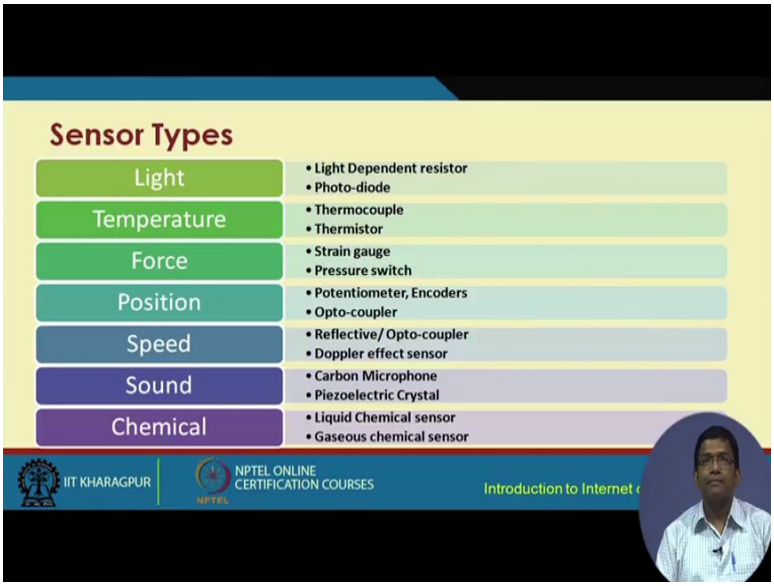
Scalar sensors measure only the magnitude physical quantities, such as temperature, color, pressure, strain etcetera. These are scalar quantities and measurement of the change of magnitude is sufficient to convey the information.

(Refer Slide Time: 16:13)



On the other hand, vector sensors produce output signal of the voltage which is generally proportional to the magnitude as well as the direction and orientation of the quantity that is being measured. So, physical quantities such as the sound, image, velocity, acceleration orientation, these are all vector quantities and their measurement is not just dependent on the magnitude, but also on the direction. So, for example, accelerometer sensor, they give outputs in three dimensions x, y and z coordinate axis.

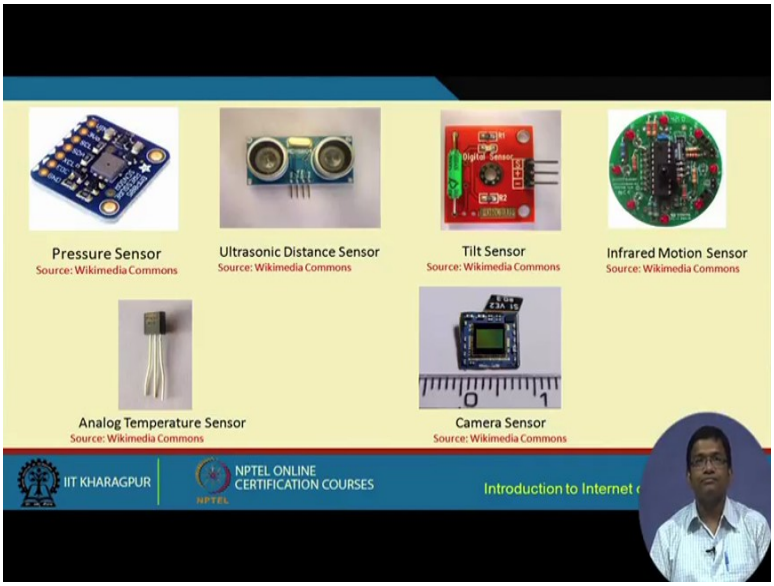
(Refer Slide Time: 16:50)



Here are some examples of different sensors, light sensor for measurement of light. We have the lDR which is the light dependent resistor photodiodes. This can act as sensors for measurement of light for sensing of light. For sensing of temperature, we have thermistor and thermocouple. Thermocouple briefly I told you, but thermistor is sort of like thermal transistor kind of thing, ok.

Then, we have for force, we have the stain, strain gauge and pressure. Pressure switch for position, we have potentiometers, encoders, opto couplers. Opto couplers basically you know. So, the optical signals are the optical rays are basically obstructed and based on that you know the position information can be obtained. So, opto couplers then we have the speed for speed sensing. We have reflective sensors, then doppler effect sensors. So, doppler effect based on the relative velocity for example relative velocity of sound you know. So, based on that you know this doppler effect sensors, they work. Then, we have the sound sensors, we have the carbon microphone like our existing traditional microphones, piezoelectric crystals and so on. For chemical sensing, we have the liquid chemical sensors and gas chemical sensors.

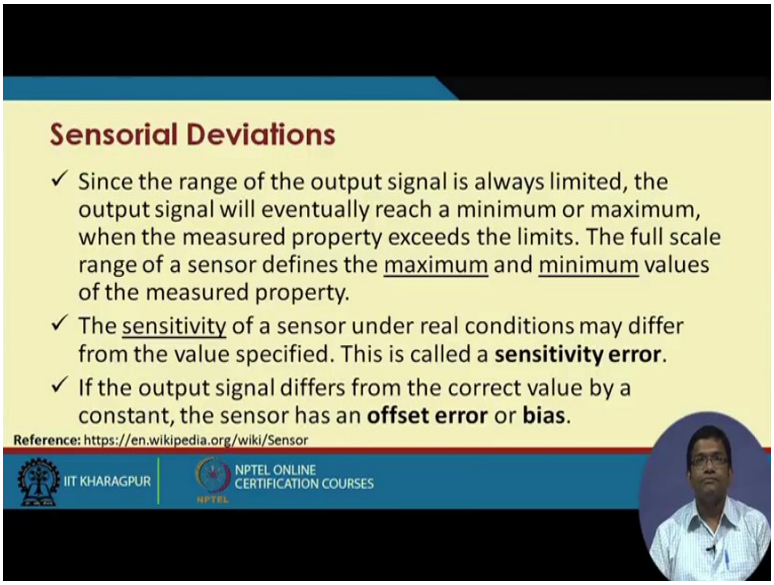
(Refer Slide Time: 18:18)



So, I had already in at the outset of this lecture, I had shown you some real physical sensors. Here are some other pi pictures of few other sensors, here is a pressure sensor, here is an ultrasonic distance sensor, tilt sensor infrared motion sensor, camera sensor, analog temperature sensor. So, analogs in temperature sensor, it has you know in

addition to the output, it has 2. So, it has three pins. Basically one is for the plus 5 volts and the other one is the ground zero volts and this one is the middle pin is typically used for the output.

(Refer Slide Time: 19:04)

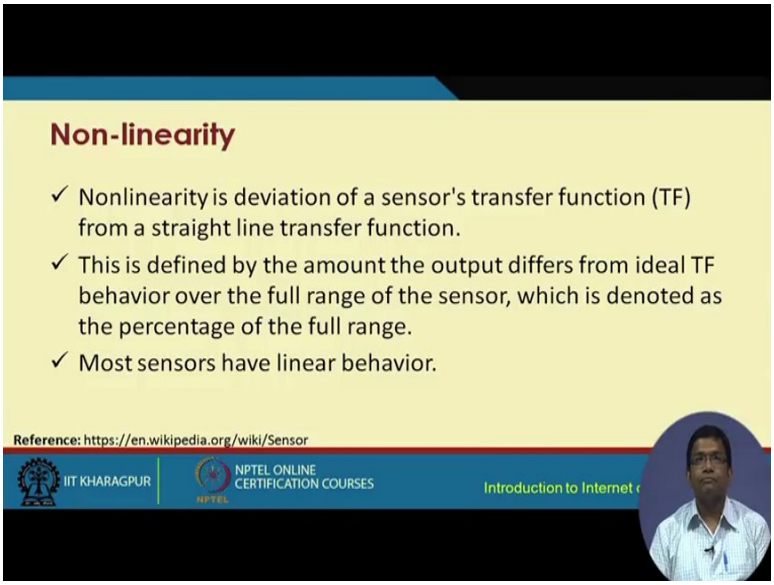


Now, the sensors often they do not give data that is accurate you know. So, there are some sensorial deviations. So, these sensors they have each sensor and they come with certain specifications. These specifications will give you the maximum and the minimum values that it can measure of the physical property that it is supposed to measure. The sensitivity of a sensor under real conditions may differ from the value that is specified and that is known as the sensitivity error and then, each sensor there can be given you know a value which is constantly the same, constantly different. So, what I mean by this is the correct value might be something and always it will be giving this particular sensor, might be giving a value which is an offset error or a bias and that might, so that many units of offset error reading will be giving at all times and that will be constant. So, for example, two units of offset might be given by a temperature sensor at all times. So, that is different from the sensitivity error that I told you.

So, sensitivity error is more about being sensitive to the changes you know under real conditions, basically how it is being sensitive. Then, what is specified in their actual specifications, it might give certain actual specifications, it might suppose give certain values, but in real conditions, it might be sensitive to certain things. So, this becomes the

sensitive error and there will be some error that will be due to that and that sensitivity error that can change over time and that is different from the offset error which is constant over time.

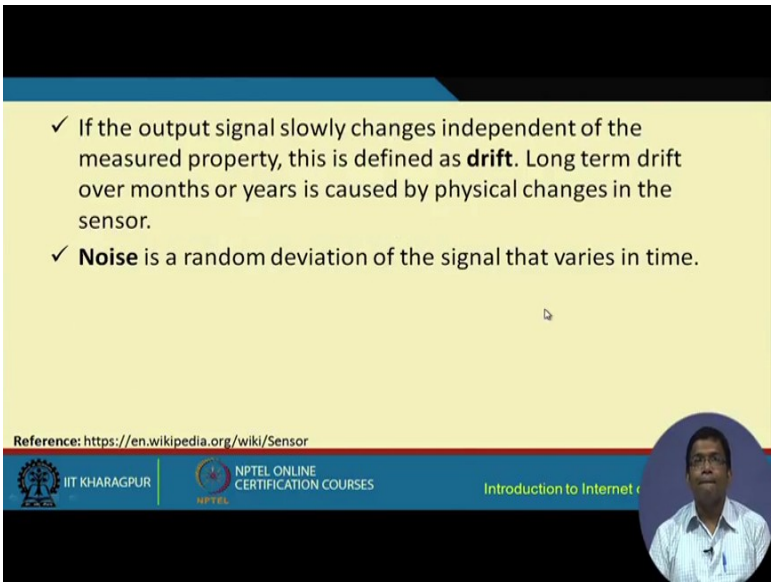
(Refer Slide Time: 21:17)



Now, these sensors typically have linear behavior. Most of the sensors, not all have a linear behavior, but there is often in practice a non-linearity behavior that is exhibited by the sensors and ideally they should behave linearly, but in practice stays off will behave non-linear. So, this non-linearity is the deviation of the sensors transfer function from linearity.

So, this is basically defined as the amount of the output that differs from the ideal transfer function behavior over the full range of the sensor.

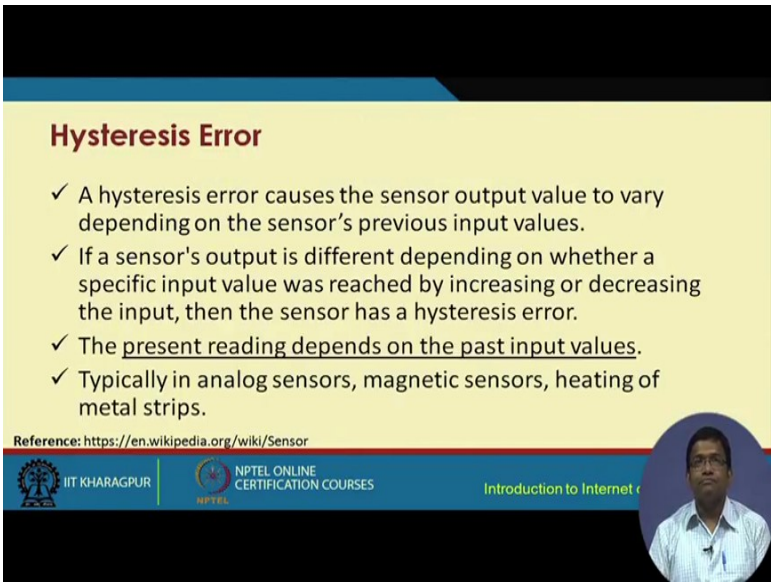
(Refer Slide Time: 22:09)



So, if the output signal slowly changes independent of the measured property, this is known as drift. So, it might happen that a particular sensor at one point we give a certain value and then, if you use the same sensors for measuring the same condition due to the drift, you might get a drifted sensed value. So, it will be different; it might be different. So, it induces some drift if you keep it overtime.

So, the other type of error is the noise which is basically due to different other external factors and it is a random deviation of the signal with time.

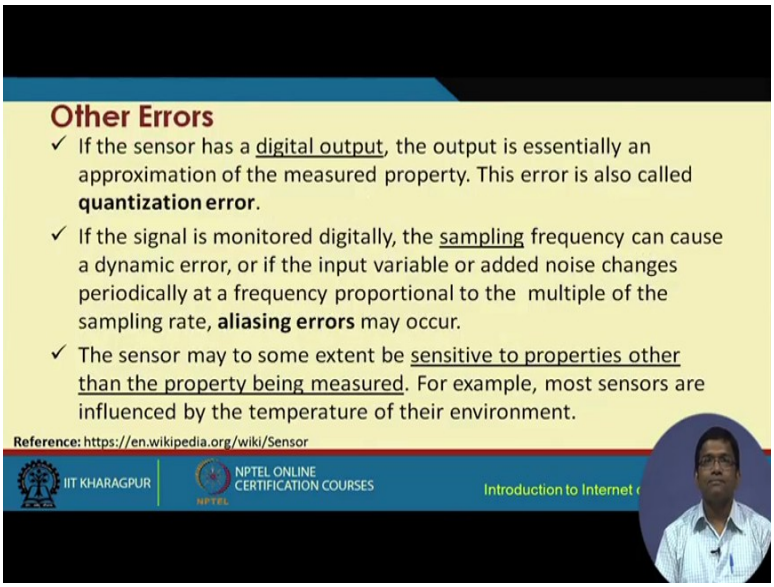
(Refer Slide Time: 22:52)



Hysteresis error is bit different and typically it is exhibited by analog sensors, magnetic sensors heating of in sensors that use the principle of heating of metal strips and so on.

So, in these sensors, these analog sensors or magnetic sensors and so on sometimes what happens that the present reading depends on the past input values. How? It is maybe because it uses some metal strips and maybe the property or the functionality of that sensor is such that when you heat it, it is going to the metal strip is going to bend. So, so you know if it has bent once to come back to its original position, it will take some time. So, this type of error basically talks about that you know if it is heated once you will get something. So, based on that if you heat it once again, you know your output is going to be dependent on the previous value. So, this is an error and this is known as the hysteresis error.

(Refer Slide Time: 24:06)



There are different other errors, such as quantization error which is basically if the sensor has a digital output, the output is essentially an approximation of the measured property and this is known as the quantization error. If you are sampling the signals, this leads to a type of error which is known as aliasing error and the sensors may at times be sensitive to the properties. Then, the property that is being measured for example, a temperature sensor might also sometimes be sensitive to few of the other things that are not directly being measured, maybe you know the humidity or pressure at times or maybe light, this will depend actually I mean this is not a perfect example that I have given you. So, it can

be constitute, this particular error can be constituting this way that sometimes the physical property that is being measured that may get affected, that sensor may get affected by few of the other properties that are not directly being measured. So, this also leads to some kind of error.

So, with this we come to an end of the topic of sensors. So, here we have already seen that there are different types of sensors and I have shown you some real life sensors that can be used for building of internet of things. I have also shown you pictures of many other sensors and these sensors are used in something known as the sensor nodes. The sensor nodes are eventually going to get connected, they are not going to be networked together, internetwork together and together that is going to form an internet of things and this internet of things is going to be used for improving the overall service quality in the society of the business of the environment as a whole.

Thank you.