Mechatronics
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Lecture - 06
Sensors Performance Terminology

Welcome you all in NPTEL online certification course on Mechatronics. From today in next couple of lectures, I will be talking about various Sensors. As we know, sensors are one of the prime components in any mechatronic system and sensors are used to measure the intended variable.

So, in this lecture, we will be looking after some of properties or performance terminologies of the sensors, and what should be the factors which one need to consider while selecting a sensor. So, this is the emphasis of today's lecture. So, first of all let us differentiate between sensors and transducers. Sensors are basically elements which produce a signal relating to the quantity being measured.

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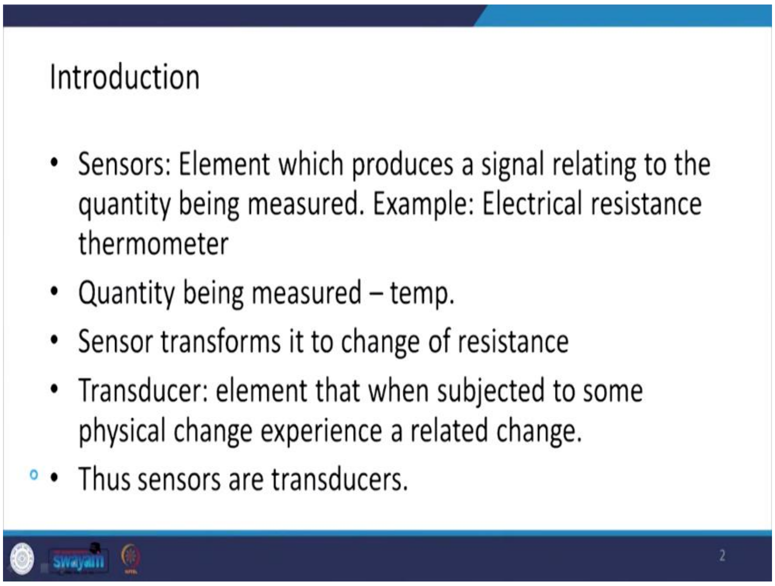

For example, an electrical resistance thermometer measures temperature. The sensor, what it does? Sensor transforms temperature changes in resistance. Likewise, if we talk about a thermometer, in the thermometer what we do?

We sense temperature of the body. And how do we sense it? Temperature of the body sensed in the form of height of the mercury column in the thermometer. So, by measuring what height the mercury has risen in thermometer we can measure the temperature.

There is another terminology which is used here that is transducer. Transducers are elements when subjected to some physical changes experience a related change. So, what we can say is that the sensors are transducers, because sensor is a general broader umbrella term, and the transducers are actually the elements which changes or which experiences a related change for one type of signal.

Now, coming to the performance terminology, here we will be talking about the performance of the sensors. One of the very important things is the range. Range is basically the limit between which the input can vary, up to what input the sensor can give us the output.

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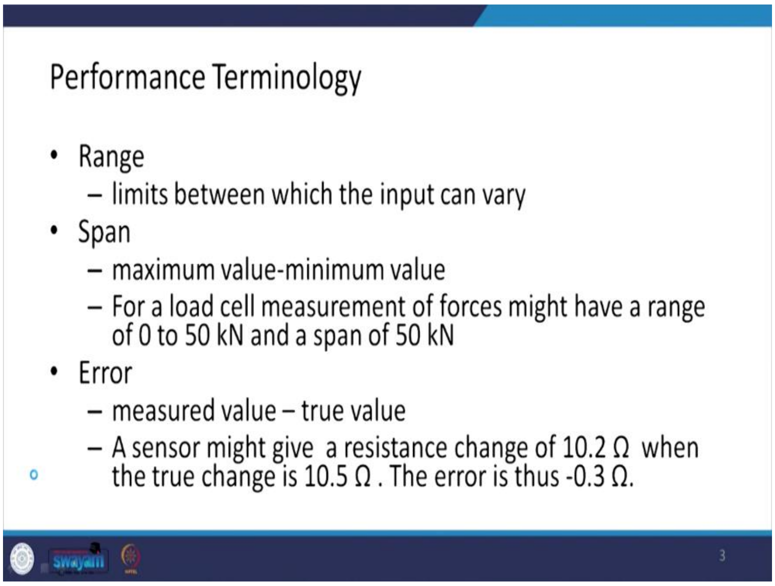

Another term there is span. It is the maximum value minus the minimum value. For example, if we talk about a load cell which measures the forces, it might have a range of say 0 to 50 kilo Newton, and the span that is the maximum value minus minimum value it is 50 kilo Newton.

Similarly, there is another term called error. It is basically the measured value minus the true value. A sensor might give a resistance change of say 10.2 Ohm when the true change is 10.5 Ohm. So, in that case the error will be 10.2 minus 10.5 that is -0.3 Ohm.

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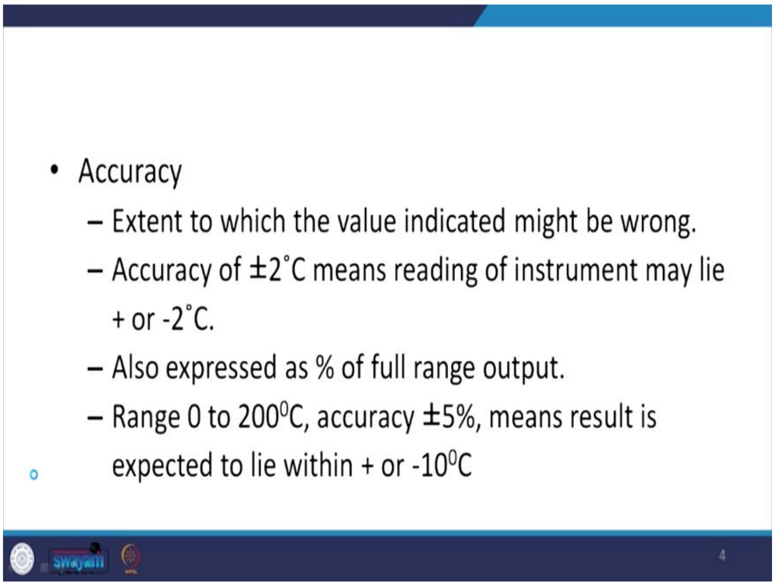

Then we often talk about the accuracy of the sensor, how accurate the sensors are? So, its definition is the extend to which the value indicated might be wrong. So, accuracy of ± 2-degree centigrade means reading of instrument may lie to '+' or - 2 degree centigrade. It is also expressed as percentage of full range output. Say if we are saying range is say 0 to 200 accuracies plus minus 5 percent means, result is expected to lie between plus or minus 10 degrees centigrade.

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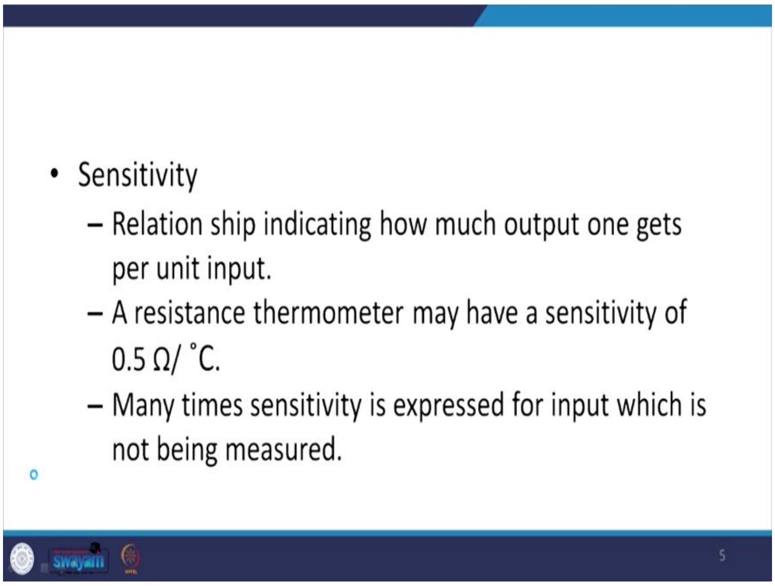

Then we talk about the sensitivity of the sensor. It tells the relationship indicating how much output one gets per unit input. A resistance thermometer may have a sensitivity of say 0.5 Ohm per degree centigrade.

Our input is the temperature basically which we are measuring in degree centigrade. So, the resistance thermometer may have a sensitivity of say 0.5 Ohm per degree centigrade. Many times, sensitivity is expressed for input which is not being measured.

Then there is a hysteresis error. Basically, you see that many times our sensors are say loaded and unloaded. So, hysteresis error is basically defined as the different output for the same value of the input.

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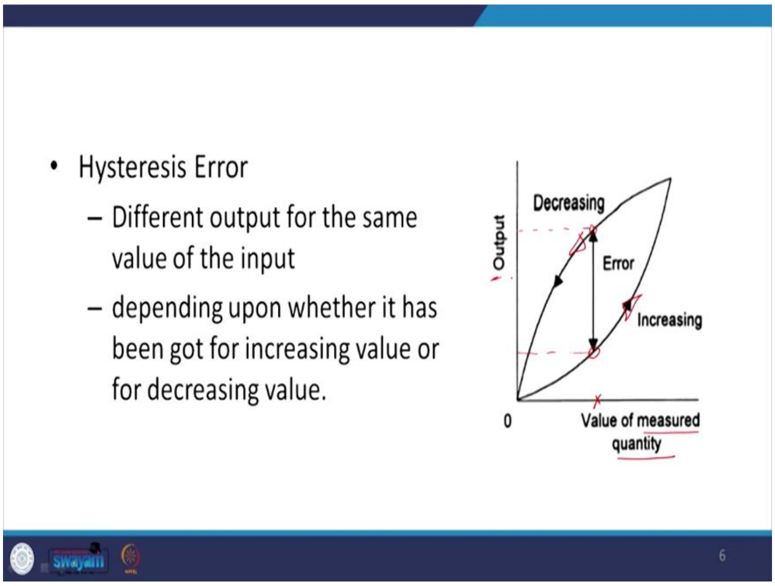

If we look at this graph, so here you can say that this is the increasing plot and this is the decreasing plot.

So, suppose my value of measure quantity is this one, now corresponding to this one if I am measuring it for the increasing one this is the value which I will be getting, but if I am measuring that for the decreasing one then this is the value I am getting. So, this is what we call it as the hysteresis error.

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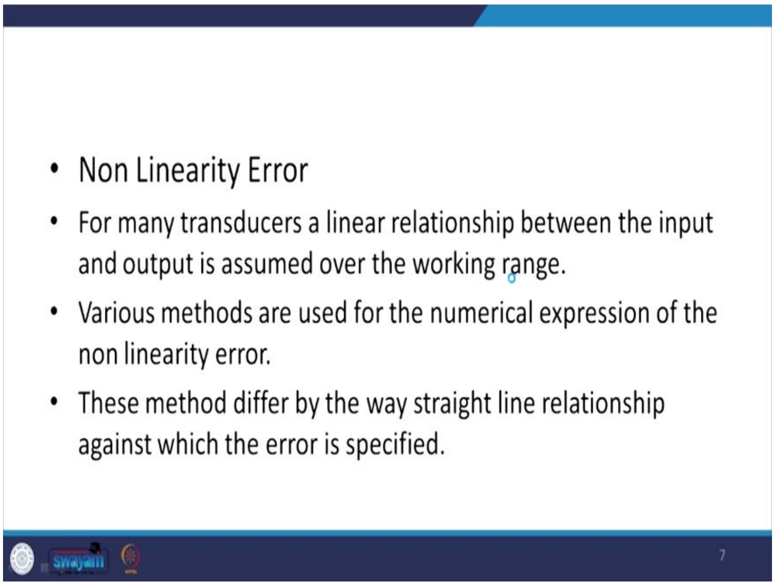

Then, we may have the non-linearity error. Non-linearity error is basically when we assume that the sensor behaviour is a linear one, but in the actual practice it may not be linear. In this type of situation the value predicted with the linear assumption that may not be correct. So, this is what is called as non-linearity error.

For many transducers a relationship between the input and output is assumed over the working range of the sensor. Various methods are used for the numerical expression of the non-linearity error. These methods differ by the way straight line relationship against which the error is being specified.

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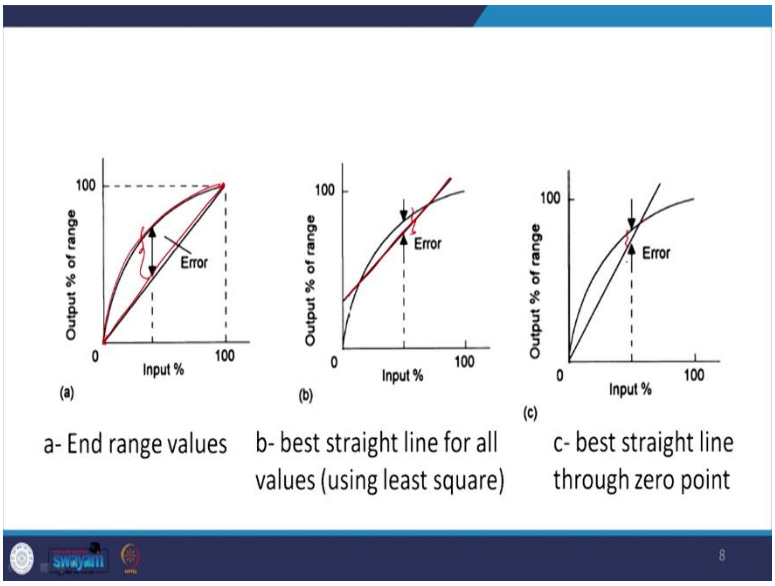

So, here is a plot where we can see that the actual non-linear relationship, but if we approximate this relationship by say a straight line which connects the initial and final state, then, we can see that we are incurring this much value of error.

Similarly, if suppose I am going from best straight line for all the values, say I am using some methods such as say least square method, and I am using the approximating the behaviour by say best straight line say this one. Then you can see that for the same non-linear graph this is going to be the error. That is the output percentage of the range.

Similarly, if I go for best straight line through zero point. In that case again I draw the line straight line through zero point and then I measure the error between the actual non-linear behaviour and the assumed straight line behaviour and this is going to be the error. So, these are the three ways by which we can approximate the non-linearity error.

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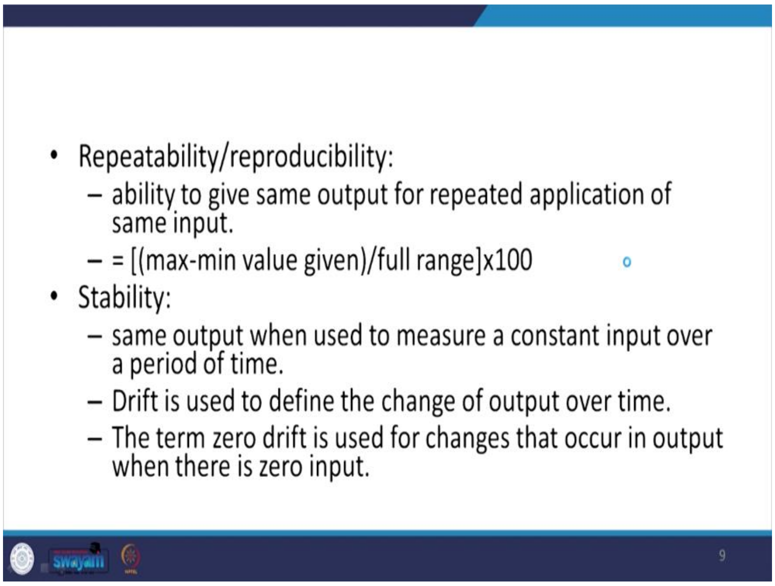

Then there is repeatability or reproducibility, as the name indicates we want to have our sensors repeatable. That is, they are able to give some output for repeated application of the same input. So, what we want that, if I am applying the same input number of times my sensor should be able to give the same output.

It is not that at different time the sensor is giving the different output. So, in that case we will say that the sensor output is not reproducible or other values are not repeatable. And this is expressed by the

$$= \frac{max - min}{full\ range} \times 100$$

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There is another term that is the stability, it is called as the same output when used to measure a constant input over a period of time. That is what we call it as the sensor is a stable.

Drift is used to define the change of output over the time. And the term zero drift is used for changes that occur in output when there is zero input.

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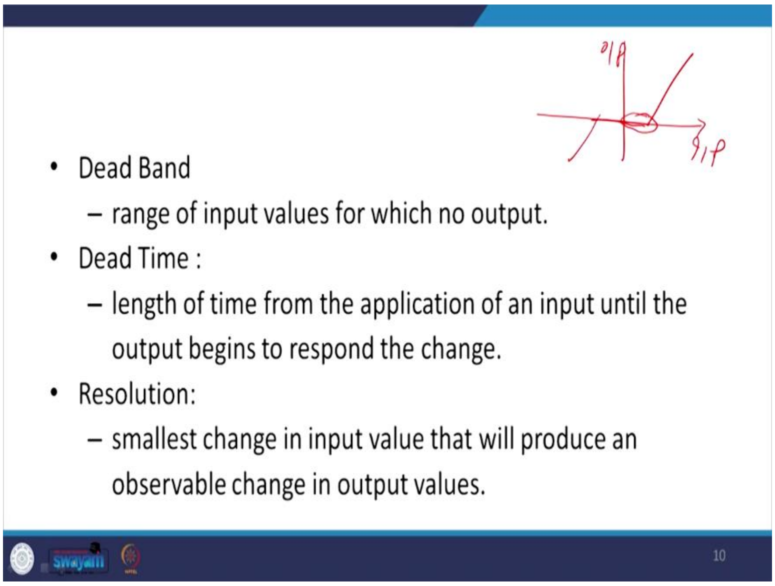

There is another term called dead band. And this is basically what we call it as the range of the input value for which there is no output. So, suppose we have input and output relationship something like this, the behaviour is something like this, then we can see that here although my input is changing, but my output is not changing. Then this is what we call it as the dead band.

So, range of input values for which there is no output. Then, similarly we define the dead time that is the length of time from the application of an input until the output begins to respond the changes. So, that is the dead time.

Then we have the terminology called resolution. It is the smallest change in the input value that will produce an observable change in the output value.

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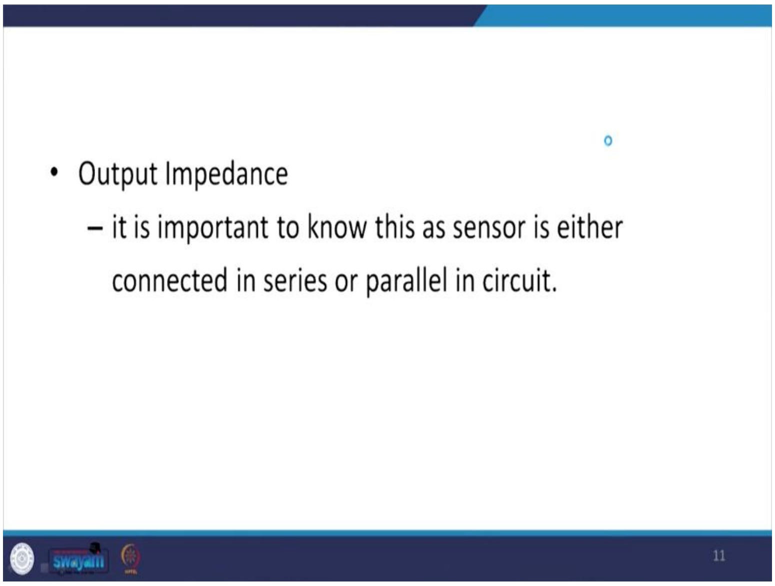

Then, we have another term called output impedance and it is important to know this, as the sensor is either connected in series or parallel in a circuit. So, how much output impedance it has that value we should know.

Then, there are static and dynamic characteristics of the sensors. Static characteristics are basically values given when the steady state condition occurs, that is the values settle down after receiving the input.

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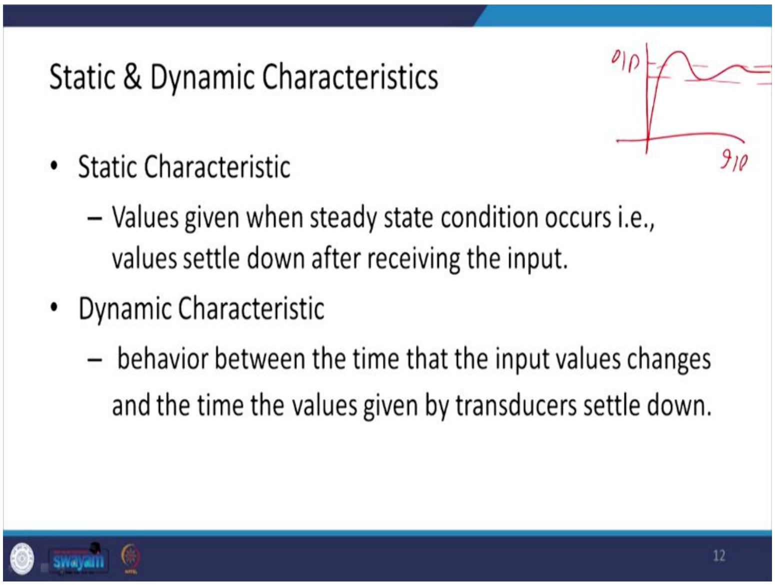

So, if I plot the input and output, we are interested in this zone that is the values gets settled basically. So, values given when steady state condition occurs that is value settle down after receiving the input.

Then, we have the dynamic characteristic, which is behaviour between the time that the input value changes and the time the values given by the transducer settle down. So, this is what is called as the dynamic characteristic.

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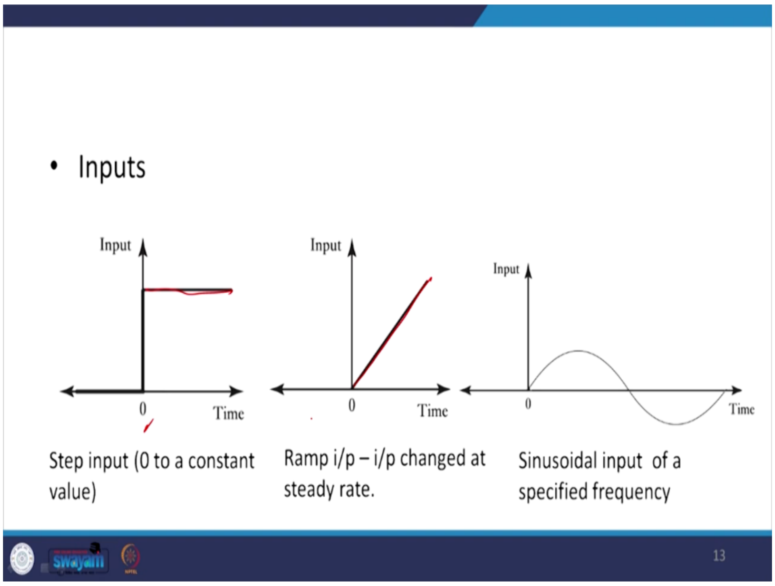

Now, the inputs which are used these could be the step input, that is the input varies from 0 to some constant value here. Then, the ramp input that is input changed at a steady rate as you can see here and which is given by a linear equation or we have the sinusoidal input. So, sinusoidal input of a specified frequency we may have like this.

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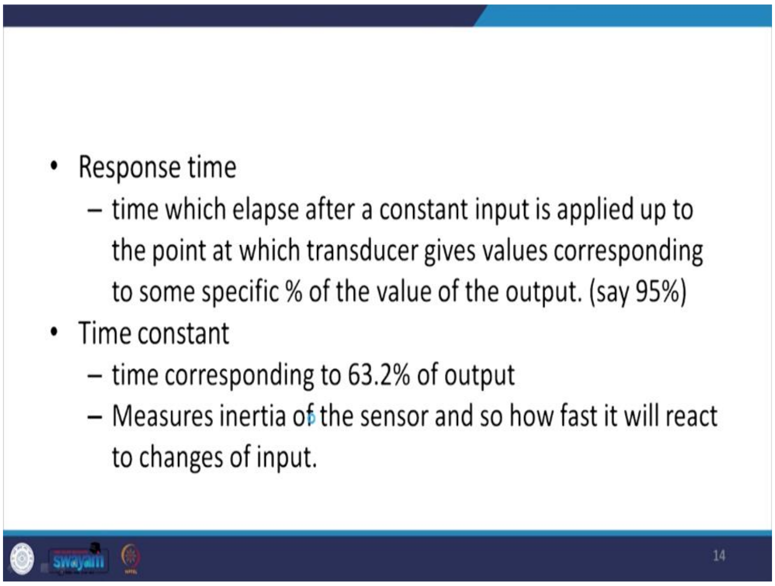

Then, there is term called response time, that is the time which elapse after a constant input is applied up to the point at which the transducers give values corresponding to some specified percentage of the value of the output, say 95 percent. So, your values are coming up to say 95 percentage of the specified value. So, what time it takes after giving the input that is what we call it as the response time.

Then, there is a terminology which is used in sensors it is the time constant and this is nothing but time corresponding to 63.2 percentage of the output. So, when your output value reaches the 63.2 percentage of the output value then that is what we call as the time constant, at what time this value is reached. And basically it measures inertia of the sensor and so, how fast it will react to changes in the input.

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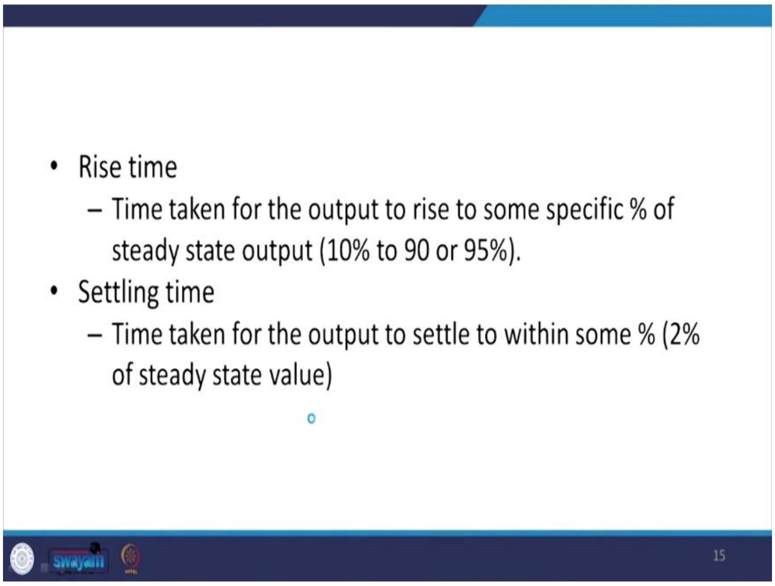

Then, we have a term called rise time. This is the time taken for the output to rise to some specific percentage of the steady state output. So, this could be 10 percentage to 90 percent or 95 percent.

Similarly, there is another term settling time. This is the time taken for the output to settle within some percentage that is say the 2 percentage of the steady state value.

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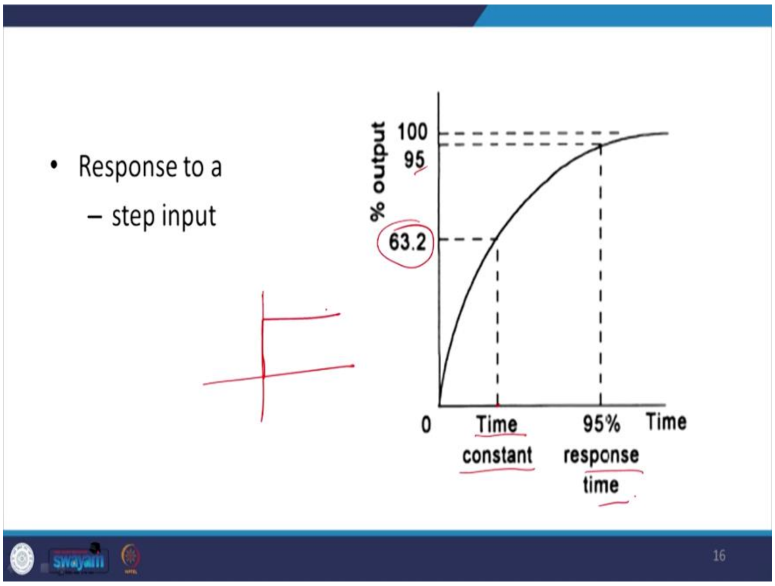

So, here basically we can see response to a step input step input signal. So, when the values reach 63.2 percentage then whatever time this much value is achieved that is 63.2

percentage of the steady state value. This is what we call it as the time constant. And when it reaches your 95 percentage here of the steady state value what we call it as the response time. And this is the case when we are supplying a step input. Step input as I said it is basically in the form of a step.

Then, selection of sensors. So, after understanding these terminologies suppose I am asked to select a sensor, so what all things I have to look at, in selecting a sensor that we are going to see now, ok.

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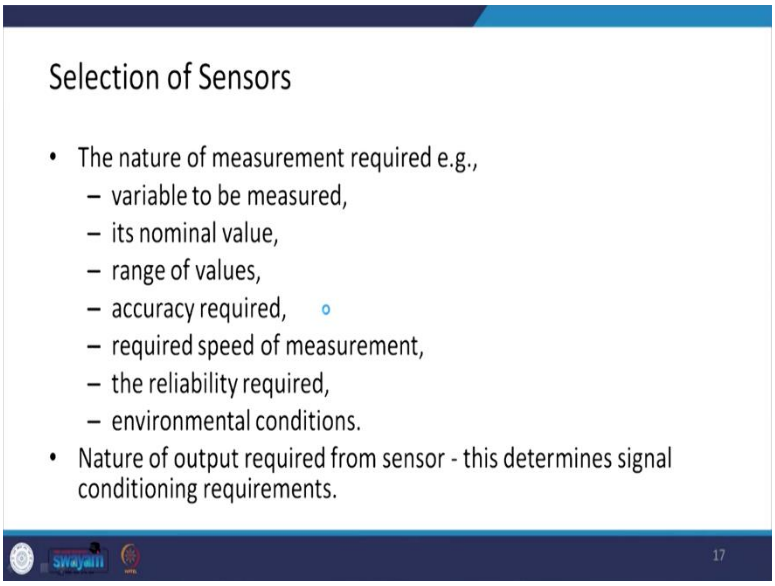

So, first of all what we see is that what nature of measurement is required, that is what variable is to be measured, then what is its nominal value, what is the range of values, how much accuracy is required, what should be the speed of measurement, what should be the reliability requirement, and what are the environmental conditions where you are going to use the sensors.

So, based on these parameter means before finalising the sensor we have to look at all these parameters. And the nature of output required from sensor, whether it is analogue output or digital output and based on this you will be thinking about what will be my requirement for the signal conditioner. So, whether my sensor will be giving the analogue signal, and I have to send my signal sensor output to a micro controller then naturally I need to convert this analogue signal into digital signal. So, I need one analogue to digital converter.

So, basically this requirement also we have to see that what form of output is required from the sensor and based on that we can determine what are my signal conditioner requirements going to be.

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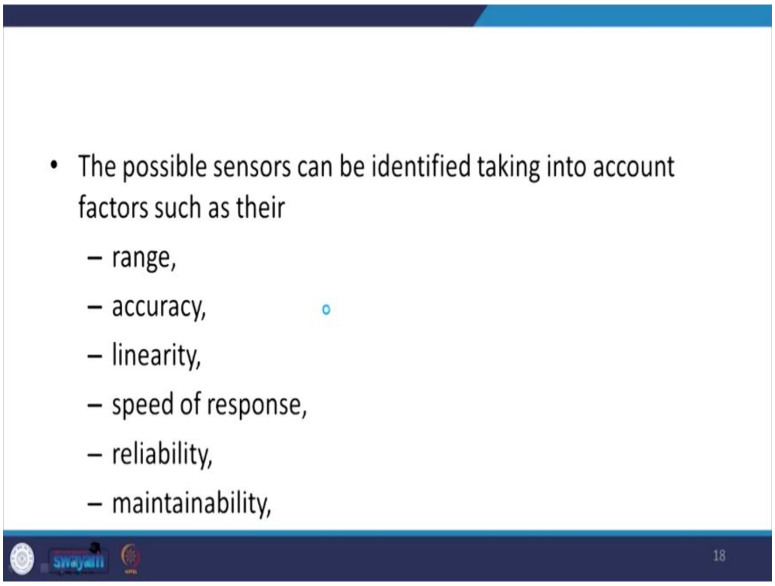

Then, the possible sensor can be identified taking into account factors such as, what is the range, what is the accuracy, how much up to, what value its linear behaviour is there, linearity, what is the speed of the response, how much reliable it is, how maintainable it is, what is the expected life.

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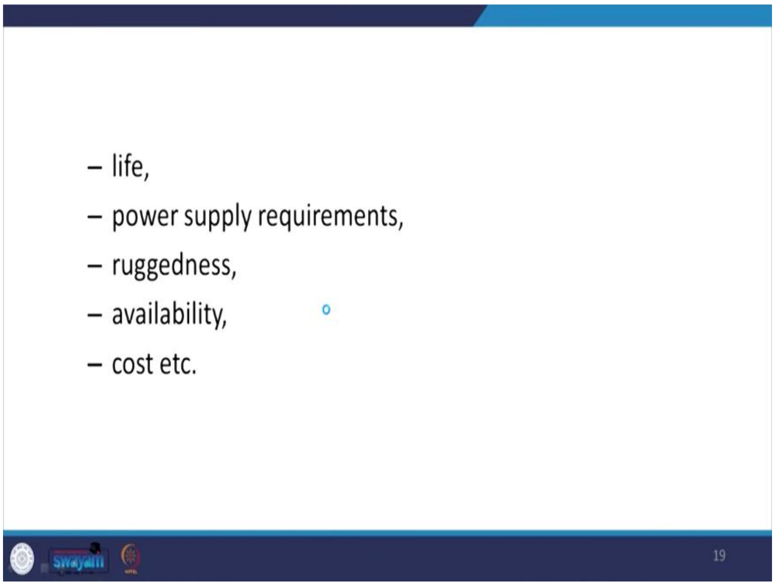

What are the power supply requirement because the sensor may require a power supply to operate it, how rugged it is, whether it is available or not, and the final and foremost thing what is going to be the cost of the sensor? So, and that cost whether it is there within our budget or not, based on this we can select the sensor. Then, there are types of output coming from the sensor, whether it is analogue or the digital one.

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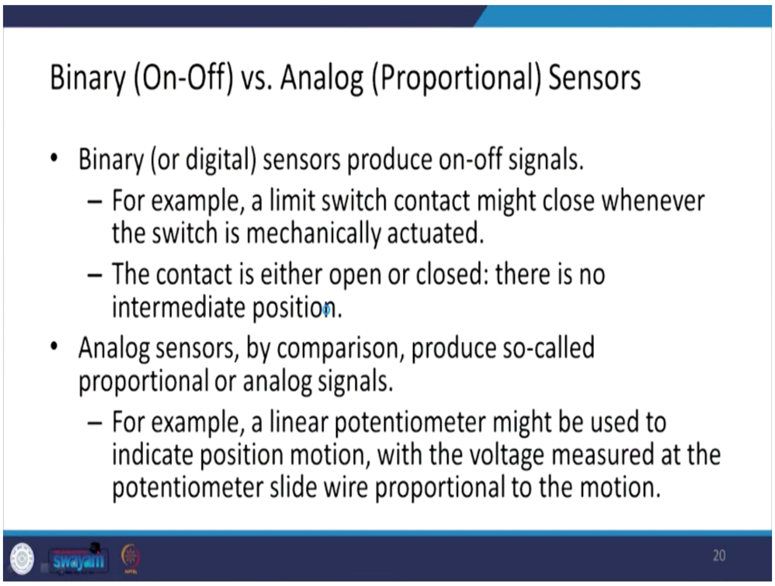

So, the binary or digital sensor produces on-off signal. We will be discussing much more about these digital signals when we will be talking about the signal conditioning section. So, but for here for the sensor's sake let me explain these things to you.

So, for example, a limit switch might close whenever the switch is mechanically actuated, and the contact is either open or closed there is no intermediate position. So, it is just like our ordinary switches which are used in our house, so they are either on or off, there is no intermediate position. And these on-off switches produce the digital signal basically either on or either off ,and we can use such signal.

Then, we have the analogue sensor. By comparison they produce proportional signal or analogue signal. For example, a linear potentiometer. Potentiometer might be used to indicate the position motion, and which with the voltage measure at the potentiometer slide wire proposal to the motion.

Many of you might have done experiment in your 12th class or in your physics practicals, where basically we are measuring the position, the knob of the potentiometer at what position it is based on that we get the voltage. So, these types of sensors are called analogue sensors.

Then, what are the frequently used sensors? The frequently used sensors, which I will be covering in my lecture on this topic on sensors.

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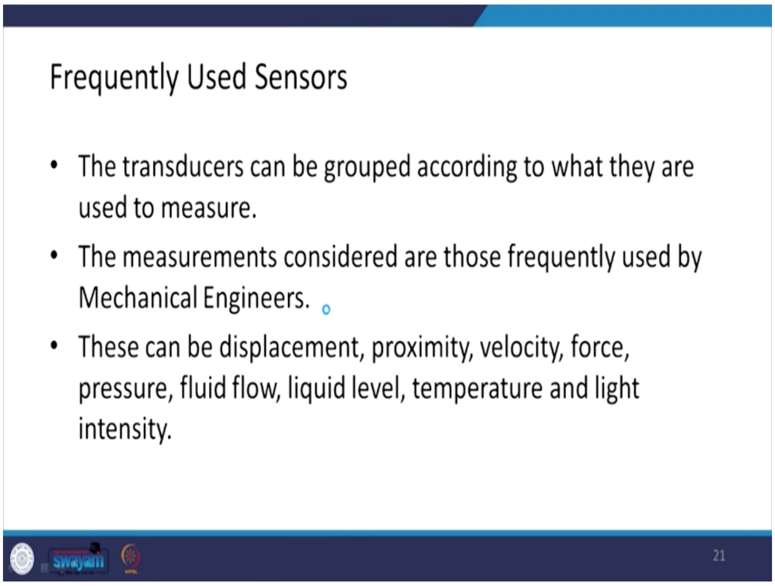

So, the transducers can be grouped according to what they are used to measure. And the measurement considered are those frequently used by the mechanical engineers in particular and other engineers in general. So, here what I will be talking about in my future lectures is the displacement sensor, which measures the displacement, or the output given by sensor is rather proportional to the displacement, then proximity sensors which tells about the proximity the velocity sensors.

The force sensors, pressure sensors, fluid flow sensors, liquid level sensors, temperature sensors and light intensity sensors. So, these are the some of the sensors which I am going to cover the basic principle, how they are working and what is the mathematics behind their working. So, these are the some of the sensors which will be taking up in our lectures.

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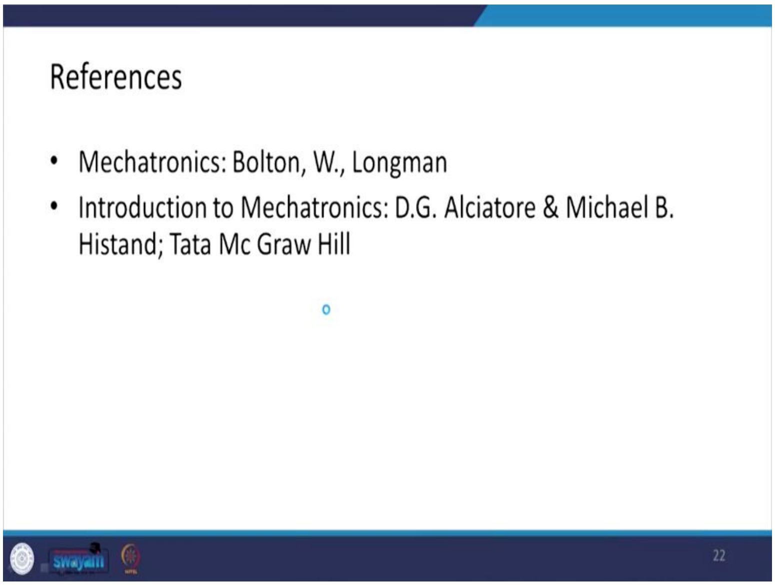

So, these are the references for your further reading. You can refer Mechatronics by Bolton, and Introduction to Mechatronics by Alciatore and Histand to cover some of these aspects of the sensors.

Thank you.