Design of Mechatronic Systems
Professor. Prasanna S. Gandhi
Department of Mechanical Engineering
Indian Institute of Technology Bombay
Elements of Mechatronic Systems – Part I
Lecture 2

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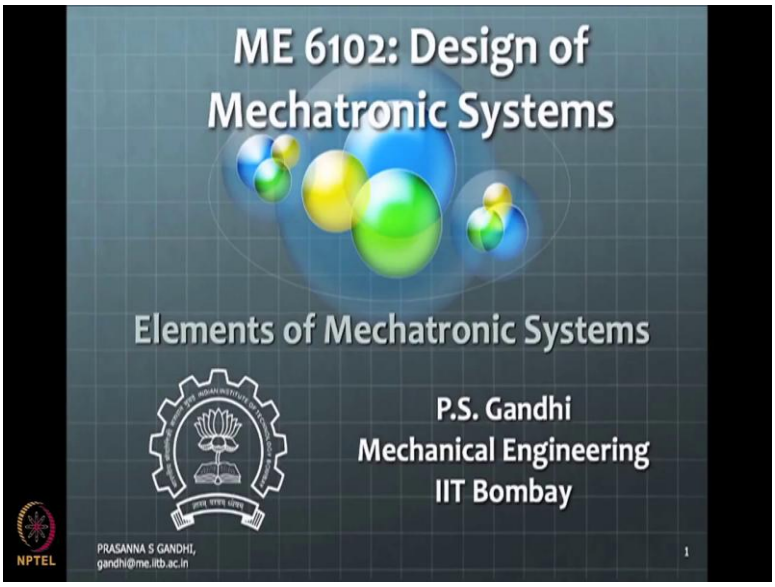

So, in today's class we are going to look at elements of mechatronic systems. Why do we understand, why do we need to understand these elements is basically if you take any system like a CD ROM drive or your scanner or any mechatronic system, it can be broken into different parts to understand, for our consolidated understanding.

It can be broken into chiefly four parts. We will look at these parts in this, in this part of the course and then we will be in a position to think about many different systems that I was talking about in the last class in terms of these elements. So, let us understand what are these elements? So, let us go back to the slides.

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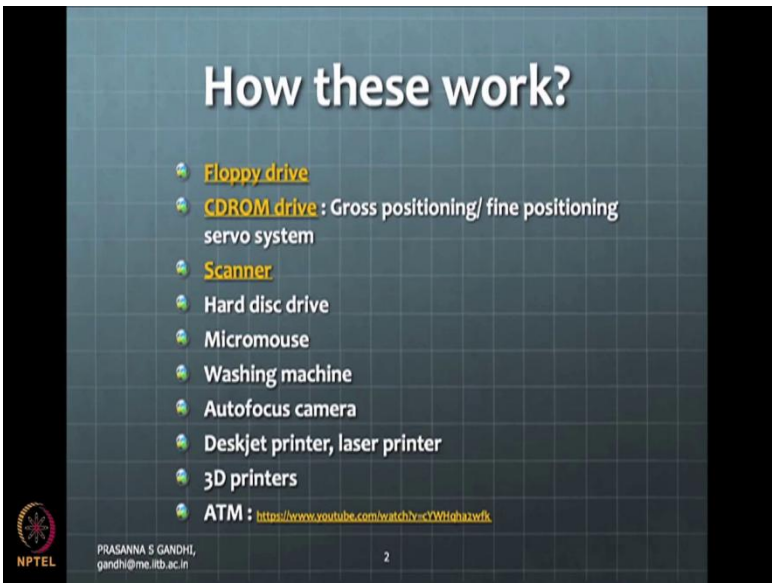

Now, we have seen these different kinds of systems, mechatronic systems. So, maybe scanner, hard drive these are more a sophisticated systems; once you understand these then the simple system understanding may not be too difficult, I would say. So, these systems are where, a good amount of what you say the knowledge have gone into actually working in practical.

So, we will look at some of these systems in much more detail in the future classes to come and then we will talk about as we go along some of the important parts how this theory whatever we study in different, different courses have gone into actually building these components and what works and what does not work from the theory to practice, that discussions we are going to have as we progress.

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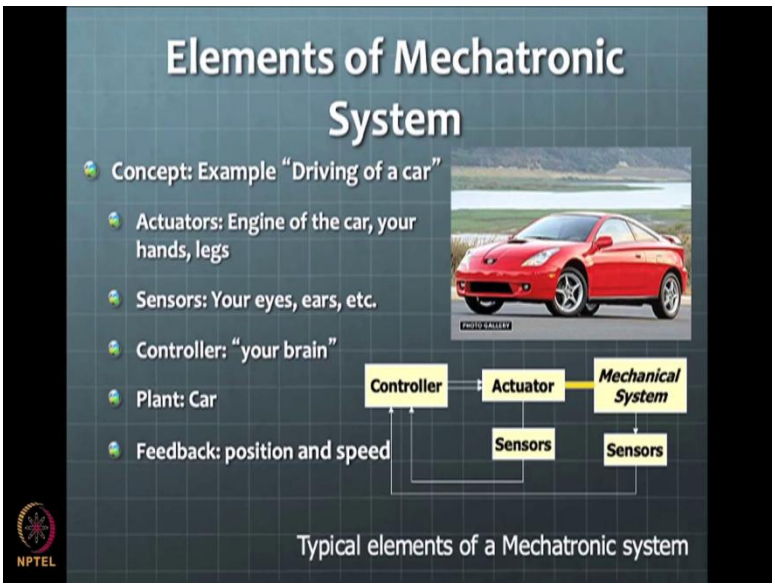

So, let us focus on what are the elements of mechatronic systems. See as you might have already known or guessed or whatever, the mechatronic systems chiefly consists of these four elements sensor, actuator, controller and the mechanical system itself. So now, let us understand this with the example of say you as a driver, driving the car.

So, you are sitting in the car at the steering and you are driving a car, what do you do? Can you imagine yourself driving car? You have, can you think now, what are the actuators for your system, you as a driver for the car as a part of the system, what are the actuators? So what you are controlling the car with is your hands and legs and there is an engine to support you in terms of some sense of power.

But engine does not have a smartness to know when to give acceleration to car or when when not to or when to stop, that kind of thing we do not have with that smartness is not there with engine, smartness is there with you as a driver there. Then sensors are your eyes and ears. Then what do you do see suppose you are driving a car and some curves comes then you naturally tend to steer at the car in the appropriate direction to keep your lane.

So, you are sensing your position with respect by using the sensors like your eyes and then, you are taking a decision in your head, that is a controller, that is acting in your head and it gives a command to your actuators which are hands and legs to make sure that the curve is negotiated properly. So, this is how things happen when we see ourselves as a part of some mechatronics system.

So, the car is really not a great mechatronics system, I mean, in terms at least the driving part of it. There are many small other subsystems in the modern cars nowadays anyway, but we are not talking about that for now. For now, we are just focusing on some basic car which is having just an engine and these different steering systems and things like that. And so, the plant itself is car, a car with its mass with your mass also included in that and some kindof force coming from the tyre tractions and things like that.

So, I am sure some of you might have worked with the Formula One car and you can imagine, if you want to offer now, this smartness more and more on this on the system rather than human, what are the things that we need to think about? So see, from this perspective, if you see I mean, in our life, we are as a human being, we are having a lot of these a built in mechatronic system in ourselves, in walking or in talking or in whatever you think of, we are sensing somethings, then processing it in our brain, our brain acts as a controller and then we are, actuating something.

Our hands and legs act as actuators. So, this is very simple way one can understand what are the different elements of mechatronics system, you just think of yourself as a mechatronics system and you see that, you have different senses, you can sense things, process in brain some decisions and then offer those control decisions to the actuators, your muscles and legs and then they will start operating.

You do that, very often, I mean, you can imagine. If you are playing any game or you are doing any activity, you can think about how you are really taking those decisions. Now, the crux of the matter here is that how you can translate the way you are taking decision to machine that is where the whole skill lies.

So, say for example, we do it by using our brain naturally, we do not need to process any mathematical numbers or something that does not happen really when we process anything. Say for example, you are playing badminton the speed of shuttle and position of the shuttle, it is, somehow correlated in the brain somewhere and then you take an action to hit it.

So, this whole calculations happen in a fraction of seconds inside our brain as a controller. So, now our job is to think see this is we anyway do these. So, now our job is to think what mathematics can work the way same way as our brain is working. So, that is how we can start thinking and you can come up with different-different control strategies, analyze them and think them.

So, that part we will do in the future at some point in that course. So, these are the main elements of mechanic systems and now, we are going to look at more and more details about these elements, with the examples.

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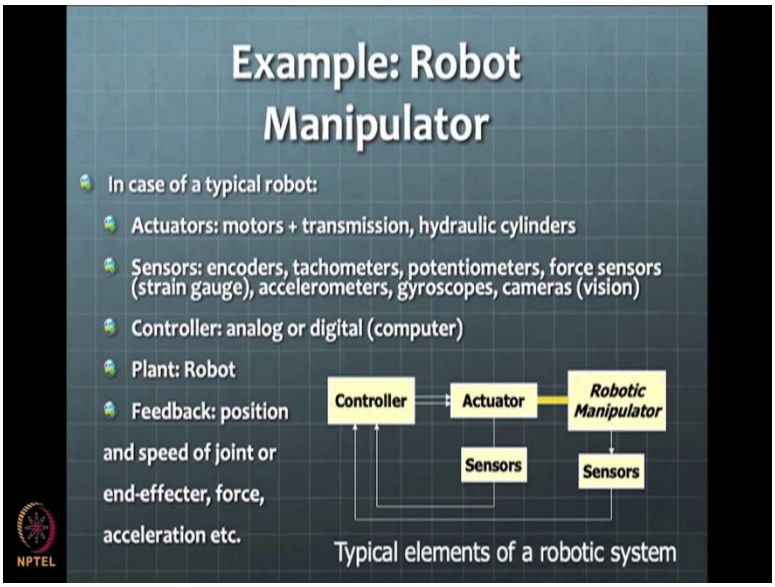

So, see first example is simply a typical robotic system if you see the actuators there are motors or there might be some a gear transmission system along with or there might be some hydraulic actuators as cylinders, hydraulic cylinders as actuators or pneumatic actuators something like that. Then you can have different kinds of sensors for a robot. Can you think of, what are the sensors?

You will have position sensors, so encoders is a position sensor or potentiometer it will be another position sensor or you can have tachometers which are the speed sensors, potentiometer, again they can be linear or rotary potentiometers, multiple turn potentiometer possibility then you can have four sensors typically when you want to grip something in by the robot, you need four sensors to sense the force of gripping and you want to grip it without breaking it that.

So, suppose you want to hold an egg or something then this will be of very useful. Then you may have accelerometers, you may have gyroscopes and cameras for vision sensing and things like that. Then controller in a typical robotic system can be analog or digital, so we will see what is analog and digital, you know these terminologies but when do you use what, those kind of aspects we will have a look at later.

Then plant itself is mechanical construction of robots with the different links and mechanisms. So, if you want to analyze robots as well, some fundamentals of kinematics and dynamics would be required and of course, feedback is, maybe all the sensors or some of the sensors giving you feedback.

Say for example for some applications may not need a camera as I said, as a feedback sensor only position sensors are ok to have a feedback from, but camera can be just used as a monitoring vision. Say for example, if you have a drone in that the camera is usually used for just taking pictures when the drone goes from one place to another place, but it is not used as a feedback. But you can have robotic systems or say assembly systems where camera is indeed used as a feedback. So, it depends upon what application that you decide to drive by using these robots.

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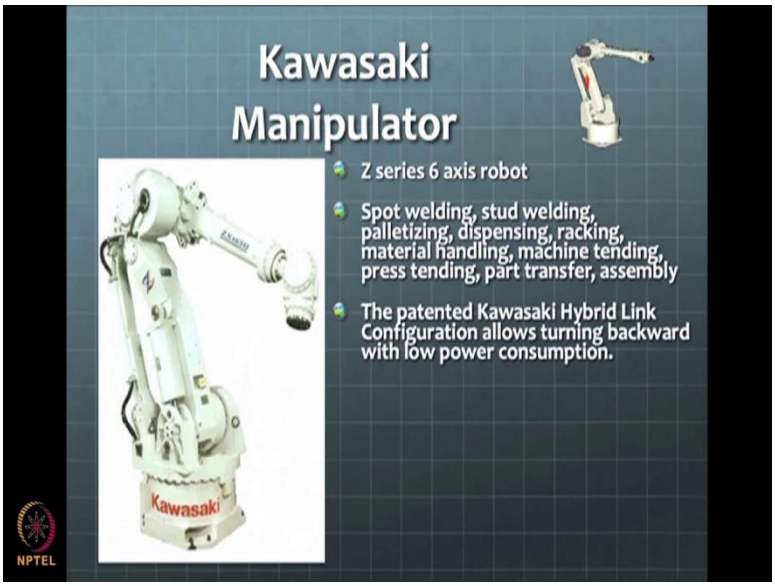

We, this is one of the techno industrial example of robot. So, many different applications can be done with these you can have spot welding application or welding application or material handling system, assembly system or some kind of actually doing some metal forming operations and things like that. So, we will not get into construction of such robots and things that, but one can see once we have some basic fundamentals of this course in terms of design strategies understood.

One can look at the construction of such robot why people have taken such decisions to kind of have certain places only the links or certain places only the joints and things like that or placement of actuators at some certain places. So, those are the things one can start thinking

and understanding how these fundamentals that we talk about in the course will be actually implemented there.

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Then you can have these autofocus cameras as another mechatronics system. Now, think of this again, what could be the sensors here. So, one can see that there are systems like auto focusing. So, suppose here you have auto focusing what is, what is the sensor for the system. So, you can have the image taken by the camera on the digital screen that itself as acting as, that image itself acting as a feedback for whether it is focused or not.

You can have some parts of the image which has sharp and blur, identify the blur part and move the lens and again see the image getting sharper or not, that is a way one can see whether the image is in focus or not. So, we will see that some sensors are of this kind are there for in especially the modern, the digital cameras still have these systems in place.

One can see, everyone can think of other system for autofocusing that can sense a range of the object. So, you can shoot a light from, it is invisible ray that can go from the camera to some object and from that object the reflection of this ray comes back, you sense it and you gauge the distance and once you have the knowledge of the distance you can adjust the lens according to them.

But that is again somewhat feedback system, but the intent of user may not get captured there. So, previously the older cameras were having that kind of system in place. But now modern cameras, they will have actually image sensing kind of a system and in fact, some of

these high ended cameras will also have, which part of the image you want to be in more in focus than other choices can be there resting with the user.

Or they can be set automatically. There is a lot of different options that will be possible in the cameras. Of course, there are older versions of cameras where having a film, you might not have seen now nowadays, nobody can have processes the film for the camera. So, this is somewhat historical thing. I do not know whether we have some kind of a things maybe I can try to find out some films if we have.

This was the, then the film loading and film advancing, those features were needed that were automatic in the previous versions of camera. But nowadays and we have, we all have all these digital image sensors to capture the image. So, we do not need that.

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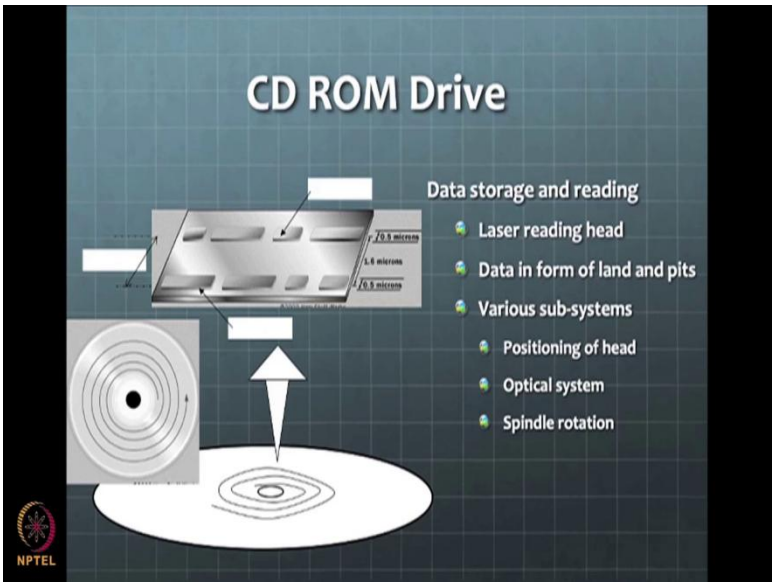

This is another kind of a very interesting mechatronics system which is used for data storage. So, nowadays this CD ROM drives also are nowadays getting somewhat extinct, because we have the pen drives or this RAM that is there for the storage device which is much compact and much more reliable way the data can be stored, it is less prone to damage, physical damage, there might be electronic damage possibility, but at least physical damage you can, may not have.

So, this CD ROM technology is also very interesting opto-mechatronics technology. We will go in much more details about this technology, as it opens up a lot of interesting fundamentals to be exercised in many of the designs that you may carry out in the future. So,

it has multiple subsystems, one is, one of course will be a positioning of the head or the laser which is reading the data from the surface of the CD.

Now, if you see the distance if you see here the distance between the two tracks is 1.6 microns. Can you imagine what is a 1.6 micron? Can you have a feel for this number 1.6 micron? If you think as compared to your hair size, your hair size is about 100 microns. So, with respect to that, you can imagine this is roughly 2 percent of your hair size.

So, that kind of a small number or small kind of motion that you want to have. So, how do we design system which can position something which is one, within the distance of at least, now if you will, this distance is 1.6 micron, we are positioning should we at least take 10 percent of the distance that is given. So, maybe within, 0.2 microns or 200 nanometers, if you want to have the positioning, how do we do that?

So, those are the questions that we need to address while developing the fundamentals of how do we sense this position? How do we actuate, what kind of actuator will be there? How people will take care of friction for such a positioning, how friction will not bother such positioning? Now, those are questions that would be raised and as we, as we go along, we will see some answers to such and such questions.

What technologies people have developed to really drive this, very fine mechatronics system application. Then there might be some additional systems which is, where you just press a button and the CD comes out of your CD ROM drive. Those systems are also known to have some a small mechatronics thingy happening there.

So, we will see some of those actually. So, we may do this by, actually, I will show you some pictures now. To open such a drive and see what is there inside and then look at different parts and see what those parts are for. If you have at your home or somewhere accessible some older machines like CD ROM drive or some floppy drive or some older computers may some systems hard disk systems which are gone.

Do not you open some new system; it is going to be, you may not be able to fix it back, so that it will still be in working condition. So, you typically tamper with which system which I would like not working. So, you may go to shop and repair shop and they will have a lot of systems to give away. So, you can take some of them and start opening and checking older mobiles, maybe for example. So, if you do yourself this kind of exploration that has a lot of value.

So, I would suggest that you do that in in some way if possible. Otherwise, anyway we are actually showing you in this course, one or two systems I will take and we will open up and let us see what are the things are there inside and then we will talk to details about that. So, this just opening is not sufficient, we need to observe that carefully and make sure that, we understand what learning that is, that it has to offer from.

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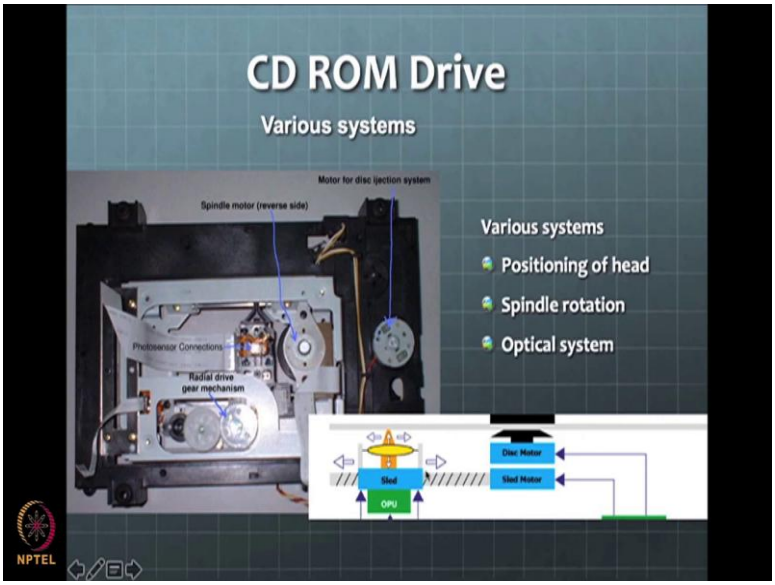

Say, for example, this is one of the CD ROM opened here. So, you can see this some of the systems here. So, we have some motors which are driving these gears here and then they are driving this slider which will slide around this around these rods here, then there will be motor on which the CD, the CD will be kept and then the motor will be rotated and then this will be sliding.

So, in this sliding how people are making this slider? See slider is there so that means the friction will be there here. So, how can one can have a system with the friction, but we saw that with friction you cannot position below 50 microns for example. So, how do you kind of position to nanometer range? Then what additional systems they will have. So, there are some systems which are very close to the lens, which are doing this positioning. So, we will see all the details in the classes to come.

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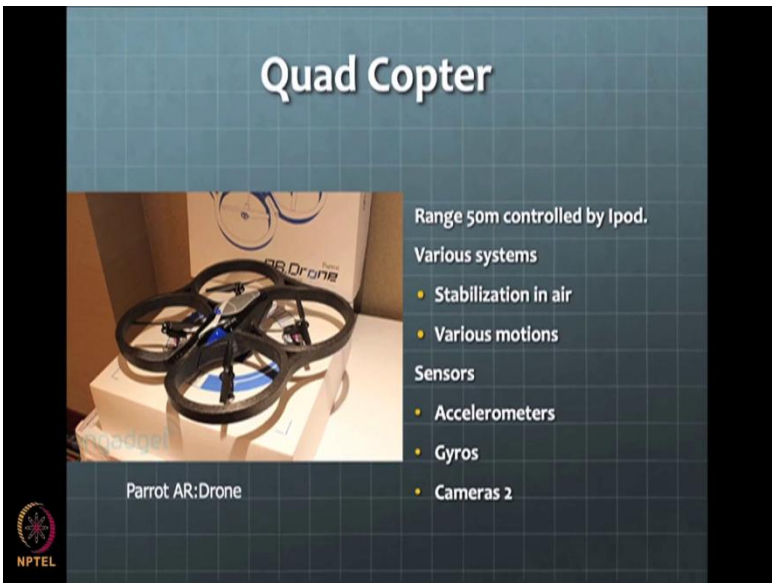

These is another kind of system that you might be familiar with as a child or as an adult this is an interesting system both for childs and adults to play around with.

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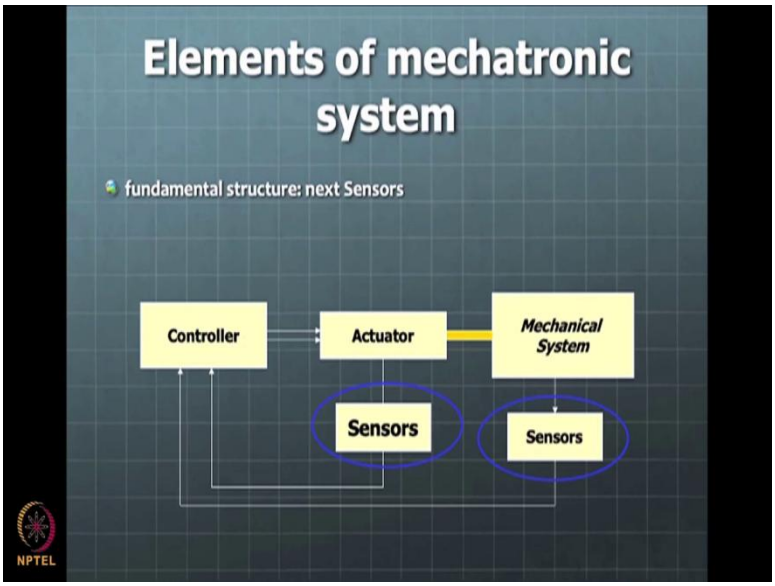

Then we can have more details about these elements seen here. Now, so these are different elements of mechatronic system we are looking at and we will now get into little more details about the sensors. Sensors you might have already studied, this is somewhat revision also and there are some things from the perspective of mechatronic systems also.

So, you if you want you may skip this part of the thing or you may to brush through this is fine. No problem, what we are going to talk about is many different kinds of sensors and how they are, there is some relevant of that, for the mechatronic systems or their fundamental principle of operation, if you are familiar with the sensors, fundamental principles of operation, part of this somewhere utility into mechatronic system is a part which you might be needing to look at.

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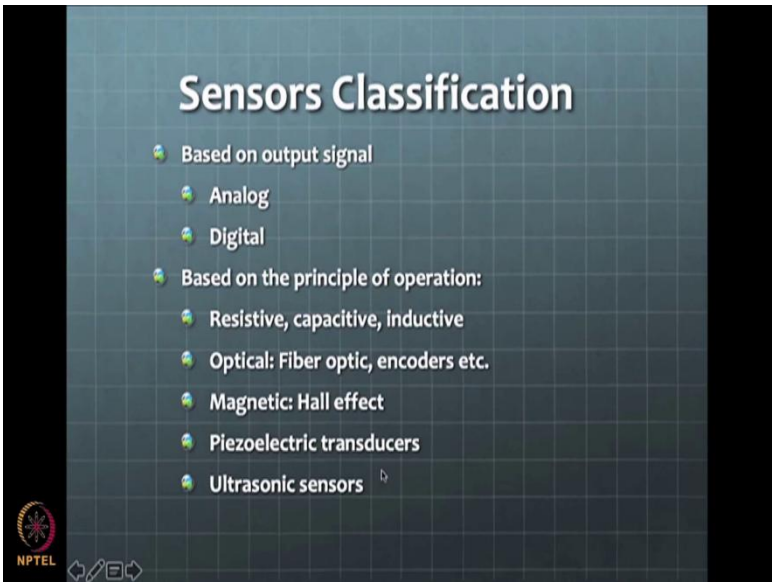

So, sensor classification is basically based on output signal, the type of the signal that is coming out of the sensor and then based on the principle of operation. These are two major classes that one can classify sensors into. Based on the output you can have analog sensor or digital sensor. As the name suggests the analog output will be a continuous signal that is coming from the sensor and digital signal will be some number after some time some other number will come, in the form of a number or digital number which is discrete number that that will come.

So, analog to read into microcontroller or digital domain you need some convergence, possible convergence to be done and so these digital numbers, you need to have some way to read it again, but there is no conversion that will happen. So, this is, these are the two domains of output that the sensor can have.

We will talk more about analog sensor, analog versus digital what you will prefer? I mean if you if you think simply what based on whatever knowledge that you have so far, or some common sense, what you would prefer as output type for the signal. Some of the people who

are more familiar with electronics and electrical, I mean you have also you are familiar with you have taken some course in electronics also.

But I do not know whether it is sufficient to say this answer. So, if you think in the depth if you see analog sensor on the oscilloscope for example. You will see that typically analog sensor will have a lot of noise, this noise is coming from many, many different sources there is ambient noise that is there. Now, we are talking of this electric noise electronic noise actually.

So, this is any wire you keep it on, and start measuring something across the voltage across it, you will see that this wire acts as an antenna and the wire keeps on giving some noise as a signal. So, in the electronics domain if you see people have to take care of this, lot of wires or a lot of tracks that are laid on the PCB acting as antennas and they are putting in some a noise into the system.

So, when that scenario is there, you are, you have it has a lot of repercussions on our mechatronic system design. So, for example you need to filter noise or you need to do something about it, if it is coming in your way of getting the higher accuracy that you require for a given application.

So, from that perspective, you should look at sensors, which will have analog as an output. They are not generally preferred sensors in the system or if they are, they have to be used then people will have way to use it with a lot of filters and processing circuits and at that is an additional cost maybe they will have to incorporate. As compared to digital sensors which is have directly a digital output and while we just need to read it from the sensor and that is it, it would to be ready for using the microcontroller.

However with digital, one will have a resolution issues, resolution may be little poor than analog, depends upon how many digits you use to represent the signal, it really depends upon that.So, one cannot generalize the statement, but analog by theoretical a means analog sensors will have infinite resolution.

If you just talk about theory not consider this practical noise considerations, then analog sensors will have infinite resolution, but it is not possible because of the noise that you get on the system. Based on the principle of operation we can have other classification for sensors. You can have resistive and capacitive, inductive sensing, then optical sensing or magnetic

sensing or piezoelectric sensing. So, we will just briefly look at these different-different kinds of classes of the sensors.

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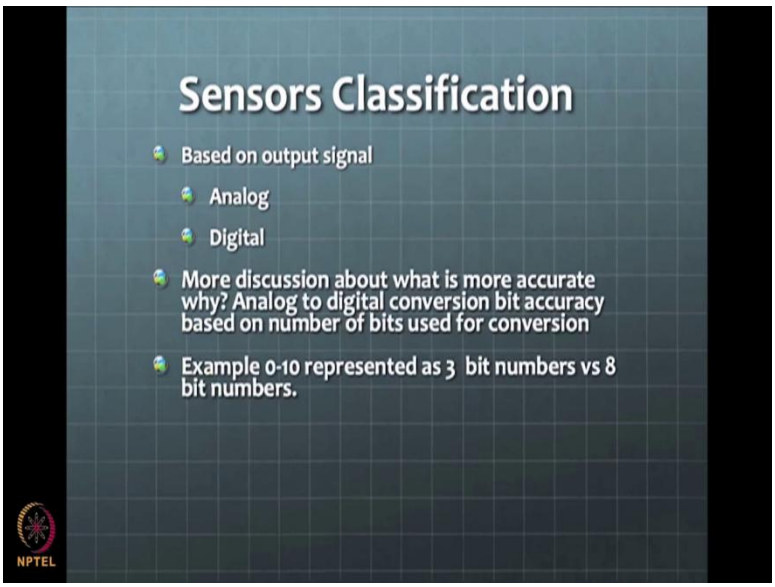

So yeah, so we have just seen this analog-digital discussion.