Mechatronics
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Lecture – 01
Introduction

I welcome you all in this NPTEL online certification course on Mechatronics. I am Pushparaj Mani Pathak; Professor Mechanical and Industrial Engineering Department, IIT Roorkee. I will be taking this course for you. As we all know, these days many of the mechanical devices come with the electronics control. So, basically mechatronics as the name indicates, it is electronic control of mechanical system.

And these days, mechatronic devices are available all around us; whether it is industry or it is your home, there are we come across many mechatronic devices. So, the with time more and more such type of devices are going to come and we are going to be user of all such devices. So, the aim of this course is to enable students aware of the mechatronics technology, what are the various components of mechatronics and ultimately we would like to design our own mechatronic system.

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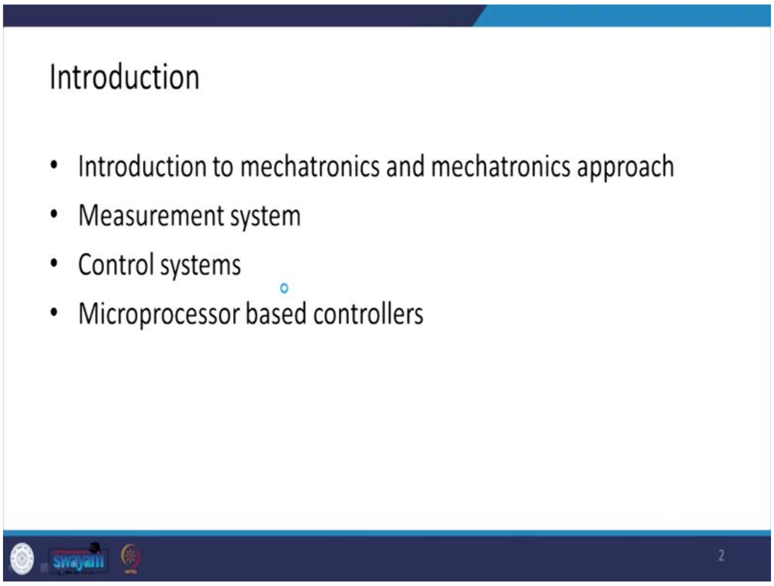

So, our course will be basically going through something like this. Initially I will be discussing the content of my course and then we will take up the introduction, introduction part that is which is the topic of discussion in this lecture.

So, in introduction we will be seeing, introduction to mechatronics and mechatronics approach; what are the measurement system, what do you mean by the control system and what do you do you mean by the microprocessor based controllers? So, these things we are going to see under mechatronics. Then the one of the important components of any mechatronic system is sensors.

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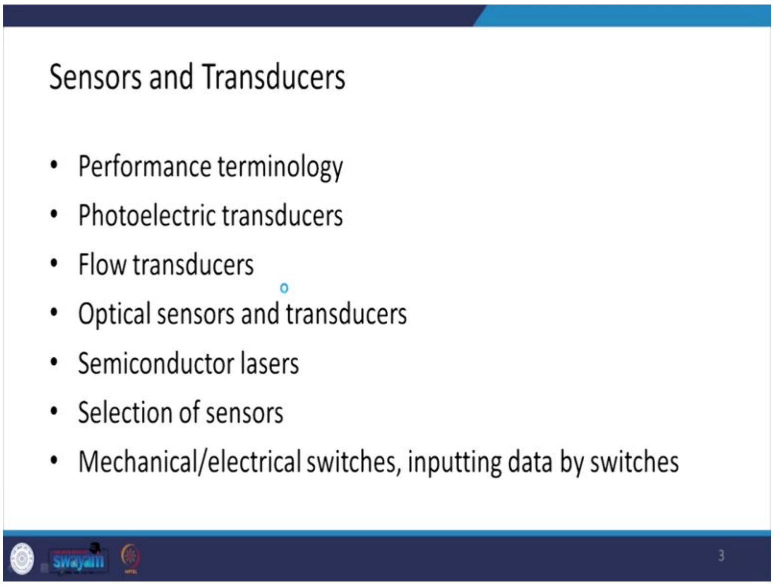

So, we will be discussing a lot about sensors and transducers and we will begin with what are the various performance, parameters or terminologies for sensors; then we will be looking at the photoelectric transducers, flow transducers, optical sensors and transducers, semiconductor lasers and various other type of sensors and what should be the selection criteria for selection of a sensor for a particular application.

So, all these things we will be looking at, and then we will be looking at many other mechanical and electrical switches, input data by switches and various other forms of sensors we will be looking at.

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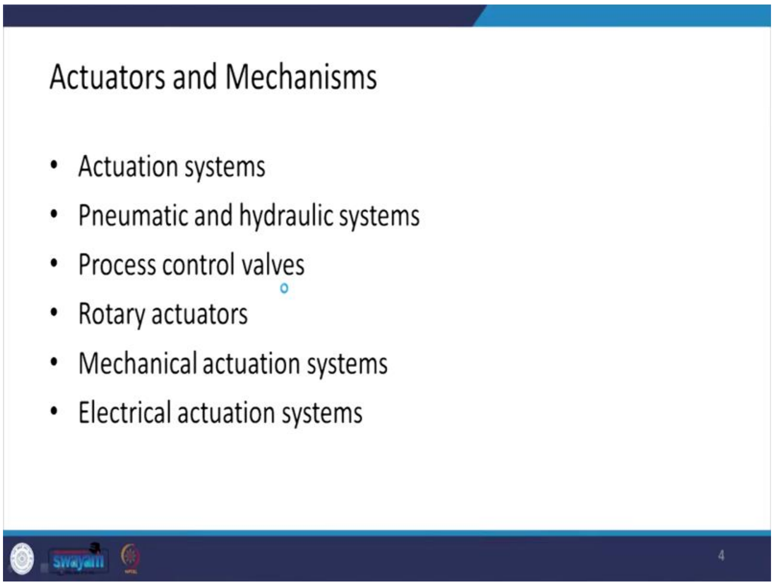

Next we will be seeing the actuators and mechanisms. As we know, actuator and mechanisms are basically the component of any mechatronic system which basically gives the motion or the one which is source of power. So, here in this content, we will be looking at various actuation systems pneumatic and hydraulic systems such as process control walls, rotary actuators, mechanical actuation systems and electrical actuation system.

So, these are the various actuation systems which are going to be associated with one way or other with a mechatronic system. So we will be looking at all these.

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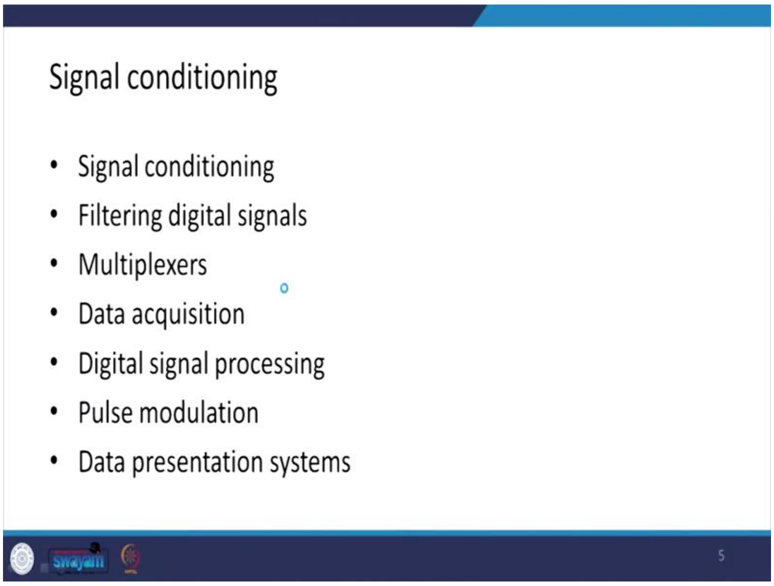

So, after actuation and the sensing, we will be looking at what do with the signals which we get from the sensors. So, there is a dedicated section on the signal conditioning; whatever signals we are getting from the sensors, we need to condition those signals, because those signals may not be appropriate to be used for the control purpose or to be suitable for the controller.

So, here we will be seeing the signal conditioning, filtering of the digital signals, the multiplexes; how do we acquired the data, that is we will be looking at the data acquisition system and we will be looking at further the digital signal processing, pulse modulation and the data presentation system. So, these are some of the things which I will be covering under the signal conditioning section.

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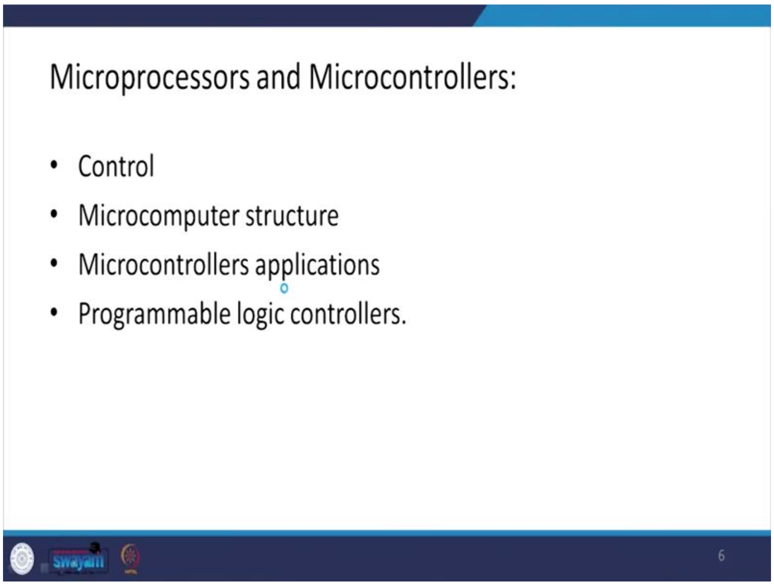

Next these signals are to be processed or send to the controller. So, we will have a dedicated section on microprocessor and microcontroller, where we will be looking at the control and we will also be looking at the microcomputer structure, microcontroller applications and the PLC's that is the programmable logic controller.

So, these are the things which we will be looking at. Now, these in design of mechatronic systems; before we actually make the system, it is always to better to model the system and see the system response.

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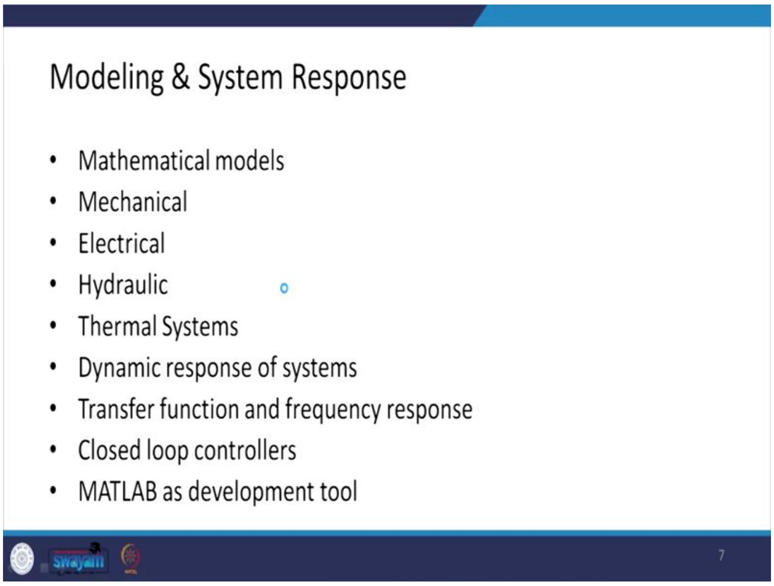

Then we actually go for the making of the system or manufacturing of the system or assembling of the system or whatever way we want to make it. So, here we will be looking at the mathematical models and these mathematical model corresponding to various say mechanical system, electrical system, hydraulic system, thermal system we will be looking at. And we will be seeing the dynamic response of these various mechanical, electrical, hydraulic and thermal system.

Then to analyze these systems, we will be looking at the transfer function and the frequency response approach for analyzing the systems and we will be also seeing the closed loop controllers here and MATLAB as a development tools. So, I will be touching a little on this and we will be seeing how can we use the MATLAB as a tool for the simulating the system.

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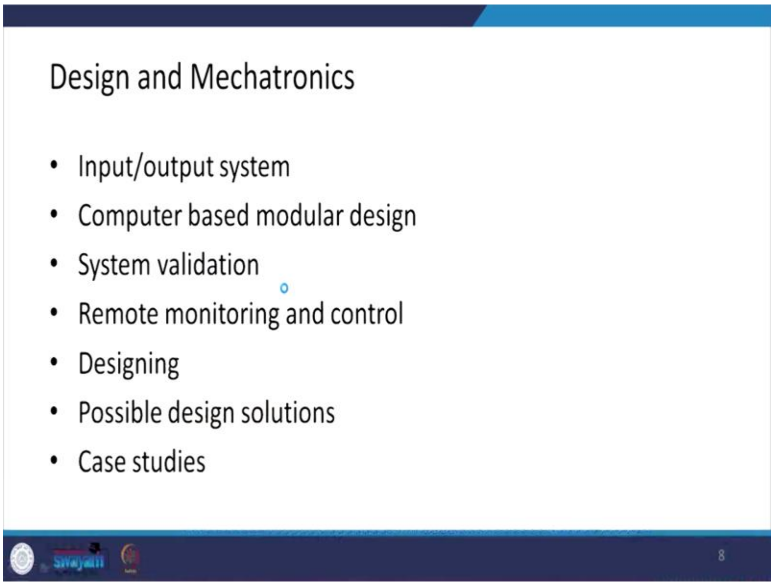

And the final outcome which is the desire of all of us to design a mechatronic system. So, here we will be looking at design and mechatronics. So, what are the various input output systems, then computer based modular design system, validation; once we have designed how do we validate the system, then remote monitoring and control designing, what are the various possible design solutions and we will be taking up few case studies for that.

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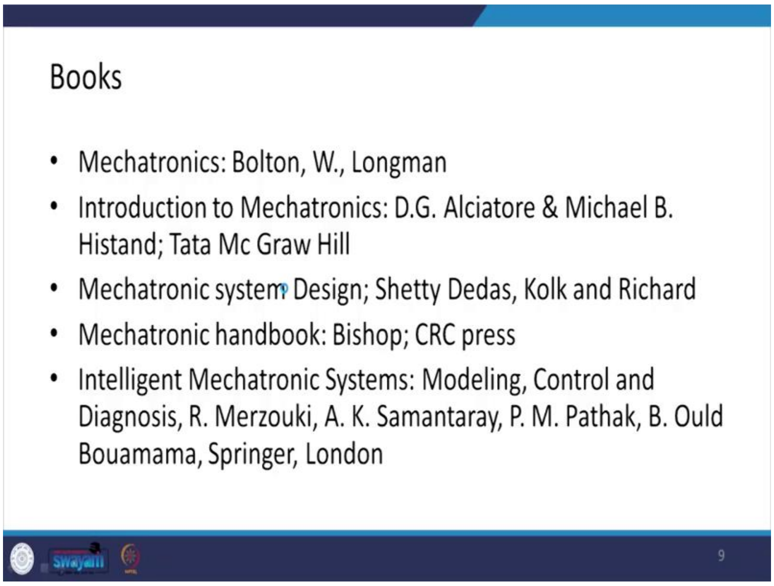

Here are some of the books which you may refer to enhance your knowledge further; these books are a very popular book on mechatronics by W Bolton, which is published by

Longman and Indian edition of this book is available. Then we have another very good book Introduction to Mechatronics by D G Alciatore and Histand, which is being published here in India by Tata Mc Graw Hill.

Then we have another book Mechatronics system Design, by the Dedas Shetty, Kolk and Richard; then there is another book by Bishop on Mechatronics handbook in fact, which has come from the CRC press. And there is a book, which has been co-authored by me; it is on Intelligent Mechatronic Systems Modeling, Control and Diagnosis ok, which has been published by Springer, London.

So, you can take up, you can refer any of these book to supplement your learning of this course. So, let us begun the course; coming to the introduction, first of all let us see what is the definition of mechatronics, how various people see mechatronics, how do they define?

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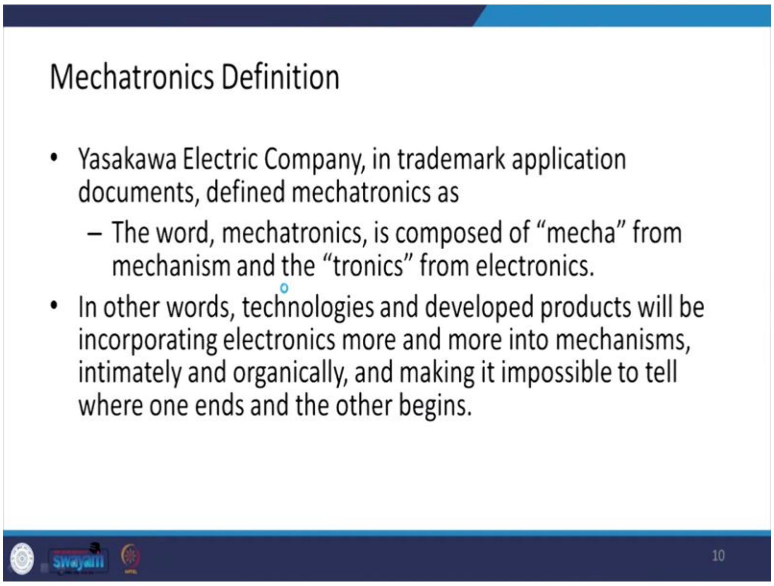

So, the Yasakawa Electric Company, in their trademark application document, defined mechatronics as; the word which is composed of mecha from mechanism and tronics from electronics. So, this is how they decomposed the mechatronics by splitting it in the mecha and electronics basically.

Or in other word we can say that, the technologies and developed products which will be incorporating electronics more and more into the mechanism, intimately and organically and making it possible to tell where one ends and whether where the other begins.

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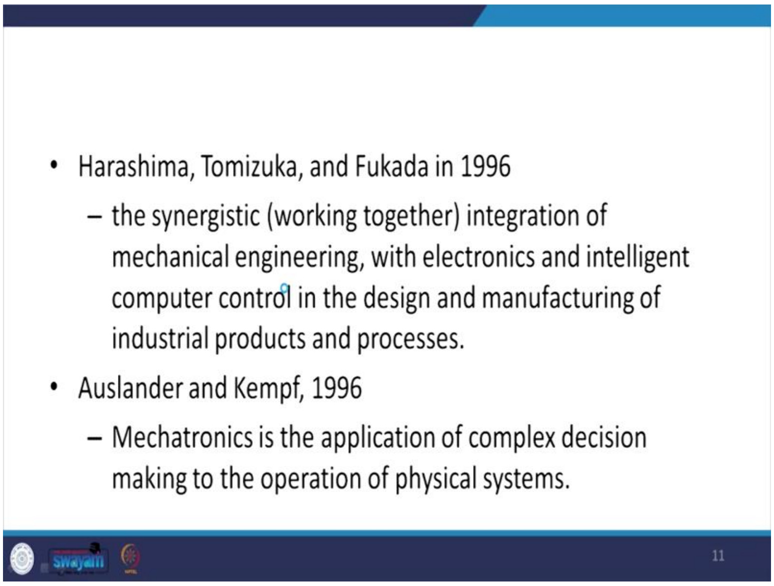

There is another definition given by Harashima, Tomizuka and Fukada in 1996. They said that, a mechatronics is the synergistic integration of mechanical engineering with electronic and intelligent computer control in the design and manufacturing of industrial products and processes. Another definition given by the Auslander and Kempf is that, mechatronics is the application of complex decision making to the operation of physical systems.

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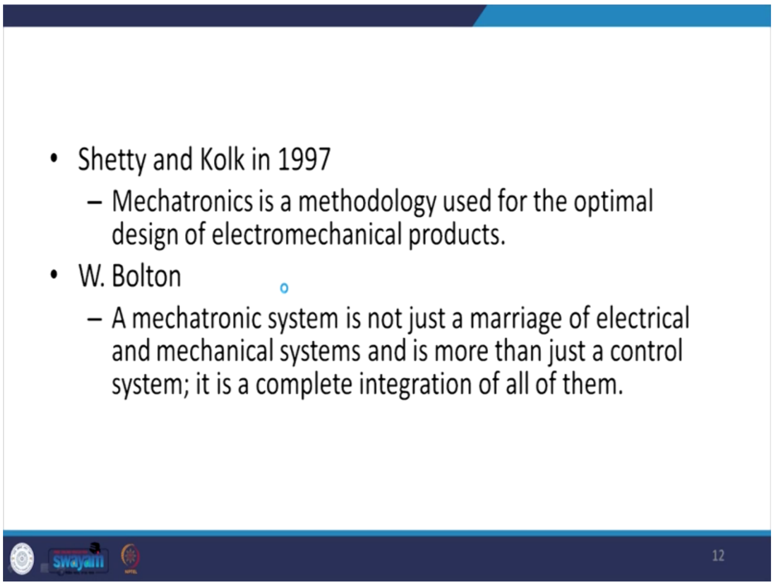

Shetty and Kolk in 1997 said that, mechatronics is a methodology used for the optimal design of electromechanical products. The Bolton defines mechatronics as a system which is not just a marriage of electrical and mechanical system, it is more than just a control system; it is the complete integration of all of them.

So, mechatronics is generally recognized worldwide as a vibrant area of study these days. There are various under graduate and graduate programs in India and abroad on mechatronics engineering.

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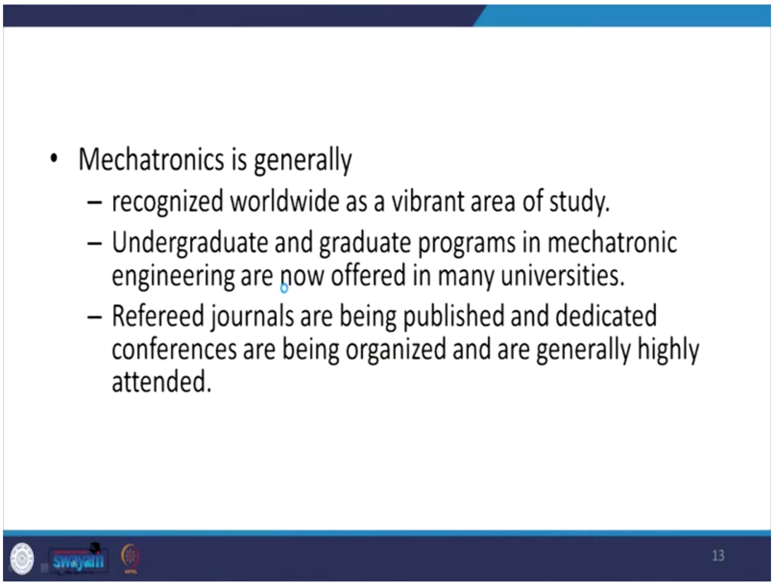

There are many courses offered in universities and there are many dedicated refereed journals are available, which publish papers related with mechatronics and there are many conferences which are held worldwide in this area.

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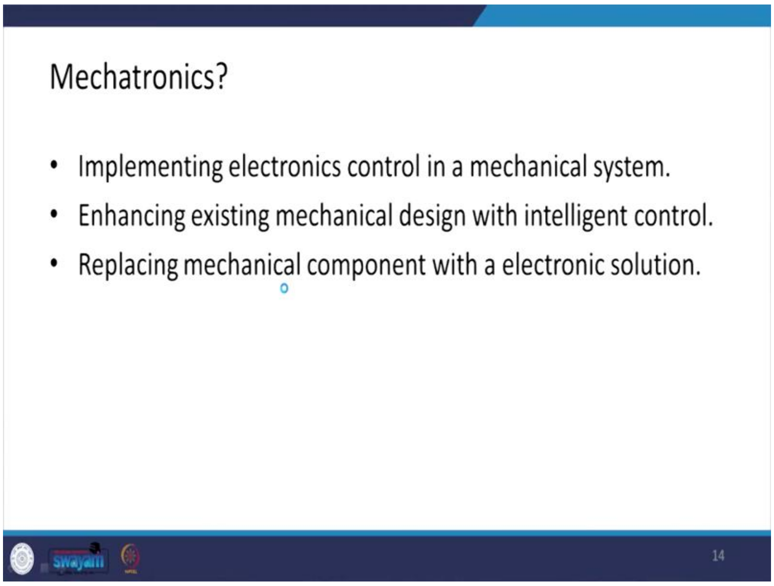

So, with this brief if I ask, what mechatronics is, what the mechatronic system is? So, basically we can say that, it is the implementation of electronic control in a mechanical system, which we call as the mechatronics. And this enhances the mechanical design with electronics control and there are many places where we are able to replace the mechanical component with the electronic solution.

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Here I will take an example of real life application of mechatronics; in the figure we can see, there are two house hold thermostat, ok. So, there are two pictures you can see; the left picture is of the thermostat which was used earlier. And in this the concept of mechatronics we used and the one which is shown in the right is that the one on which the mechatronic concept has been implemented or what you can say is that, the right one is the mechatronic solution of the thermostat.

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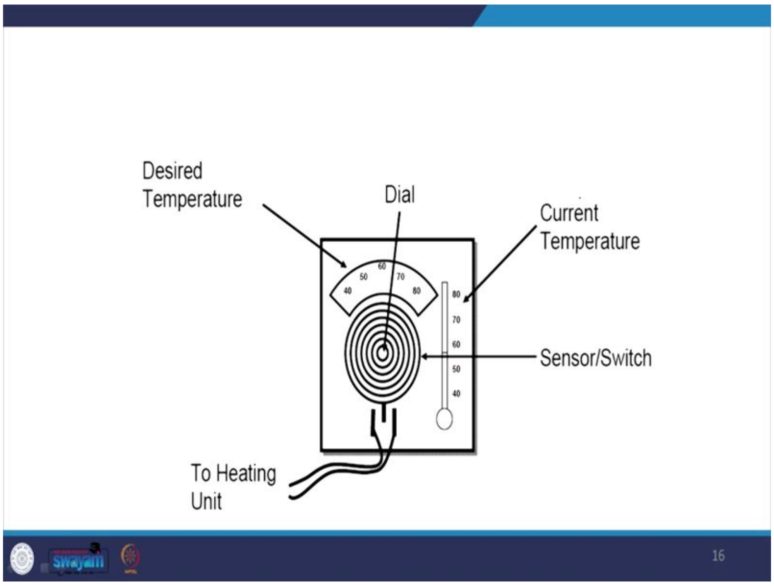

So, here is the thermostat which was used earlier. Here say we want to control the temperature. So, for that, so first we need to know the current temperature; so have a thermometer to tell the current temperature. And based on the current temperature, we would like to set a desired temperature; so there used to be a dial to set the desired temperature. And we have a sensor or a switch whatever we call it and then there used to be a heating unit. So, this is the earlier design of the thermostat.

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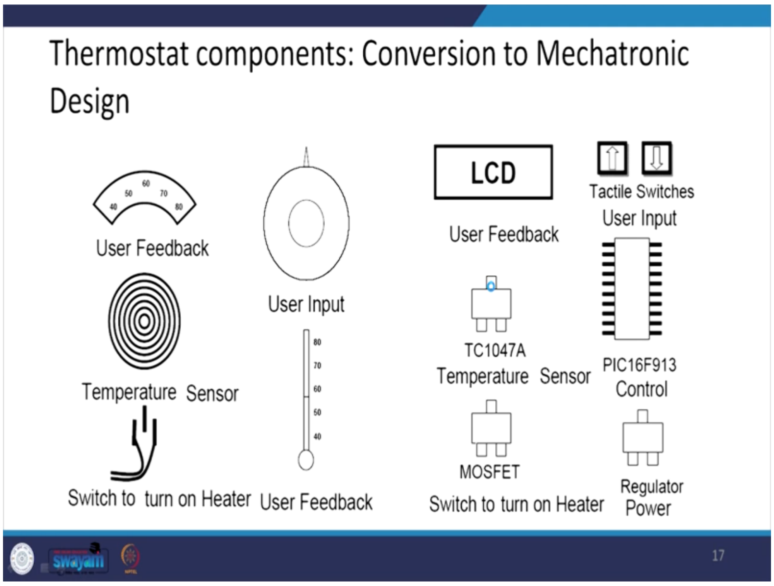

Now, if we want to convert this design, thermostat components, the earlier design into a mechatronic design; then here we can see in this light. So, let us decompose these things. So, for the user feedback, we have a say a thermometer and for input by the user there is a knob; then again the feedback is set through a dial and then there is a temperature sensor and there is a switch to turn on heater. So, these are say 1, 2, 3, 4, 5; these 5 are the mechanical components.

Now, if I want to replace this with a mechatronic design; then we can see that, for the user feedback, we have LCD display for the user feedback and for the user input, there are tactile switches with up arrow and bottom arrow indication with the aim to increase the values and the decrease the values. Then the temperature sensor is there, which is TC1047A which can be used as a temperature sensor and the switch to turn on the heater, a MOSFET can be used for that purpose.

And we can have regulator power for their and then for the control purpose, we can use PIC16F913. So, all these component integrated basically gives us the mechatronic solution and the outcome is what we have seen.

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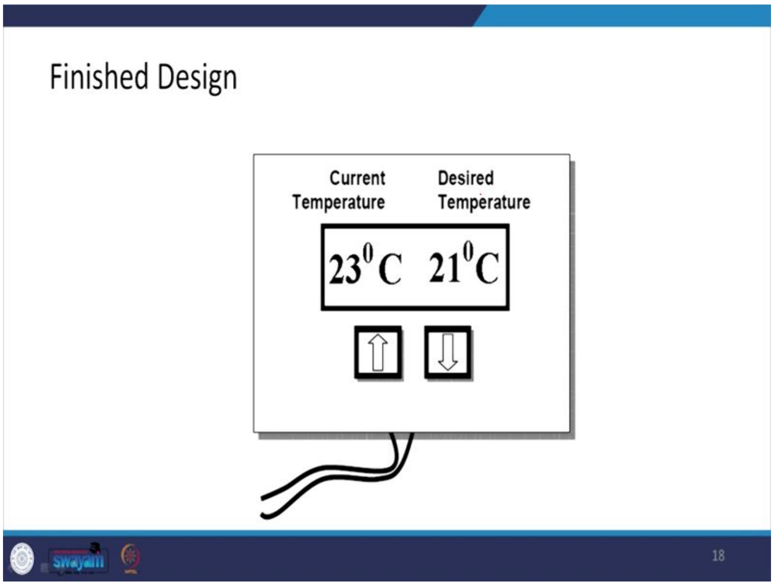

So, this is what the finish design is; here you have the current temperature in the LCD display and there is a desired temperature in the LCD display and we have the tactile switches for changing these values. So, this is the mechatronic solution and this is how the finished design is being seen over here. Now, we can classify the mechatronics products based on what extend and what stage mechatronics is being implemented.

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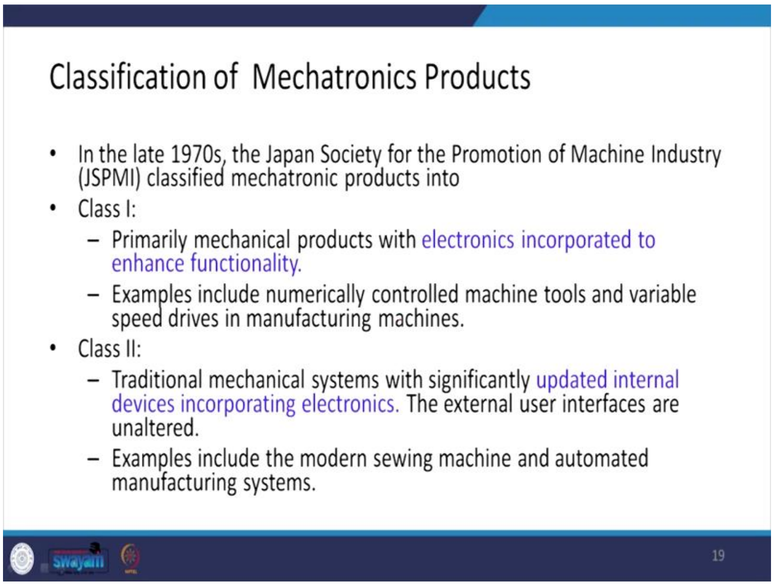

So, in the late 1970s, the Japan Society for the Promotion of Machine Industry classified mechatronics product into four classes. So, the class I is the primarily mechanical products with electronics incorporated to enhance the functionality. So, mechanical products there, they incorporated electronics to enhance the functionality. And the examples include say, numerically control machine tools and variable speed drives in manufacturing machines. So, this was the class I type of mechatronics product.

The class II type of mechatronics products are basically, the traditional mechanical system with significantly updated internal devices incorporating electronics. So, their internal device has been updated with the use of electronics and the external user interfaces are unaltered. So, external user interface is as it is. And the examples include say, the modern sewing machine and automated manufacturing systems. So, these are the class II type of mechatronic products.

The class III type is the system that retails the functionality of the traditional mechanical system, but the internal mechanisms are replaced by electronics.

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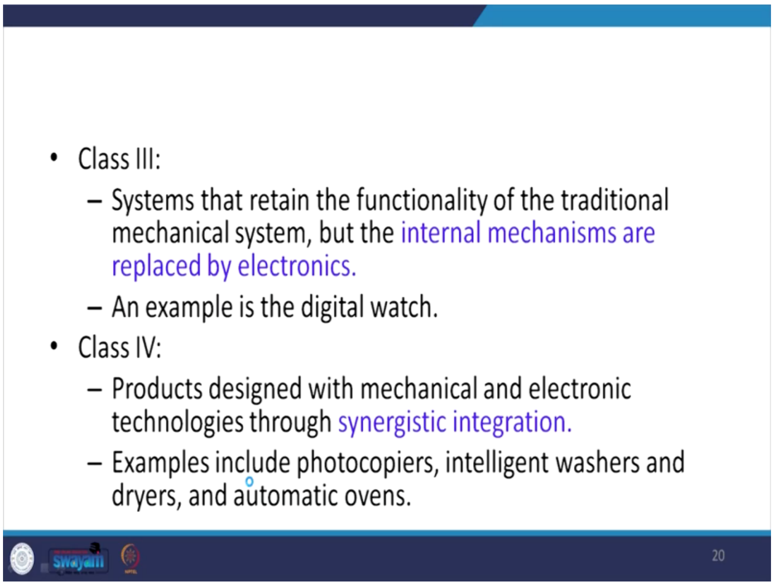

We see the digital watches these days; we have the digital watches which has replace the mechanical watches which used to be earlier in all 70s and 80s. And as well as we can take the example of say alarm clocks ok; earlier there used to be the spring doodle alarm clocks and these days we have the entire the mechatronic solution of that, where we have the digital alarm clocks. So, these are the class III type of products, where the internal mechanism has been replaced by the electronics.

Then we have another class called class IV type of products, where products are designed with mechanical and electronic technologies through synergistic integration.

So, these examples include your photocopier. You see the photocopier, we have mechanical system and we have electronic control; I will be coming in very much in details in my next lecture when I will be talking about the examples of the mechatronic system, but let me tell you the photocopiers are one of the best example of the mechatronic system.

As well we have the intelligent washers, which we used; All of us may be having the washing machines in our houses, which are the completely mechatronic system. Dryers are there, automatic ovens are there; all these are very good example of a class IV type of mechatronic system, where the mechanical and electrical technologies have been thoroughly synergistically integrated.

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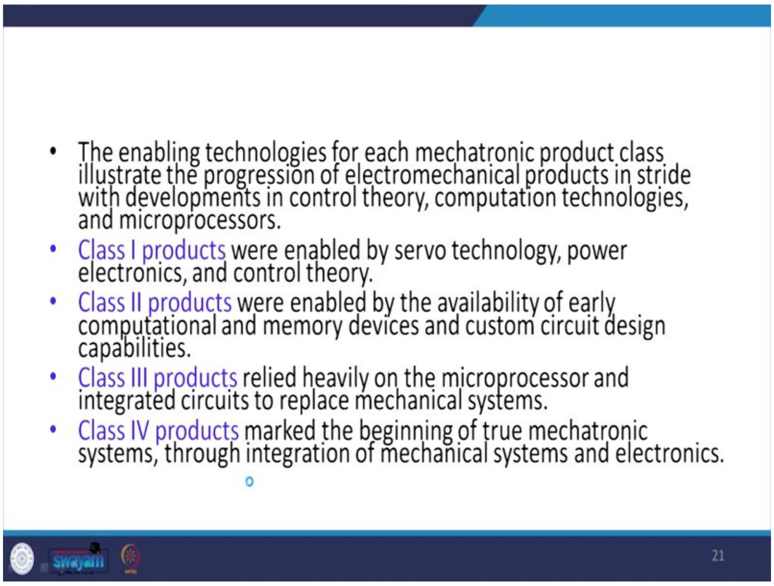

Now, the enabling technologies for each mechatronic product class illustrating the progression of electromechanical products in stride with development in control theory, computational technologies, and the microprocessor. Now, as I was telling you the class I products were enabled by the servo technology, power electronics, and control theory.

The class II product which I discussed in previous slides were enabled by the availability of early computational and memory devices and custom circuit design capabilities. The class III products relied heavily on the microprocessor and integrated circuits to enhance the mechanical system.

And the class IV products marked the beginning of true mechatronic system, through integration of mechanical system with the electronics. So, as I told you, say the dishwasher or your washing machine or your photocopier these are very good example of the mechatronic system.

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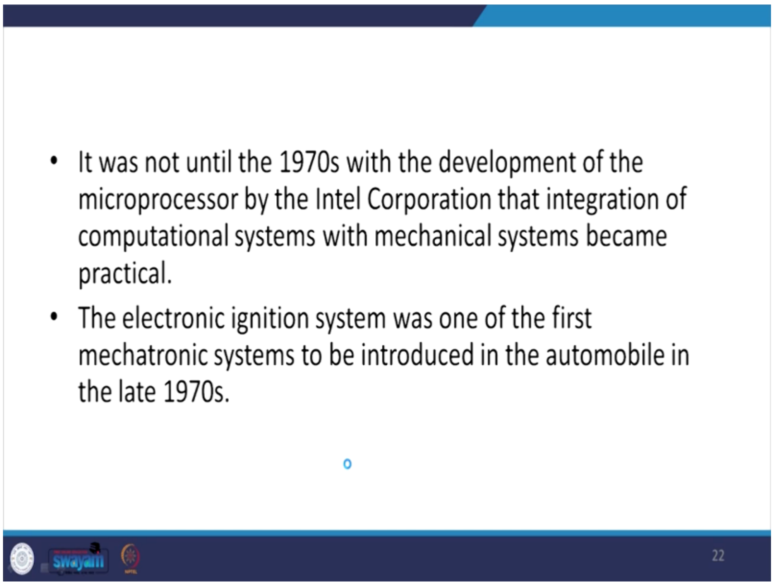

It was not until the 1970s with the development of microprocessor by the Intel Corporation that integration of computational system with mechanical systems became practical. The electronic ignition system was one of the first mechatronic system to be introduce in the automobile in the late 1970s.

In fact, the automobiles, our cars are best example of the mechatronic systems, where either we have say the automatic door closure or the door closure through a remote basically; we give the signal and there are actuators which close the door or whether it is the ignition system or you can say that the power steering, there are many more examples which we can talk about the mechatronic system application in the cars.

And these days we have a Google cars coming or the futuristic technology, where people are working on the autonomous driving or say driverless car, so that driverless car is complete integration of the mechanical and electronics. And a very good example of the mechatronic system, where we can see that there are so many sensors, there are so many actuators integrated over there, there are microprocessor, microcontroller and to implement the control actions and all other sub systems related with the mechatronic components are there.

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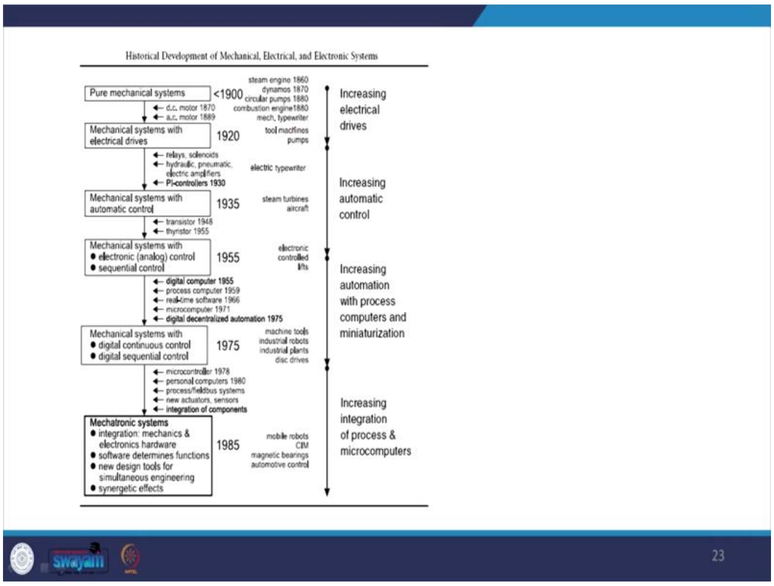

Historical development, before we begin with further with mechatronics; let us see the historical development. How with time things have changed and that will give us a really good feel of how things have progressed in this direction. So, before 1900, there were pure mechanical systems say, we can say steam engine which came in 1860 or dynamos which came in 1870 or circular pumps which came in 1880, combustion engines which came in 1880, mechanical typewriters, tool machine pumps all these things were there are before 1900.

Now, with increasing application of electrical drives. So, we can see that, in 1870 cames d c motor and 1889 cames a c motor. So, with increasing electrical drives, what we came across is the mechanical system with electrical drives. So, you can see in 1920 and we have the electric typewriter. And then came say the relays, solenoids, hydraulic, pneumatic, electric amplifiers and P I controllers that is proportional integral controllers came in 1930.

And then in 1935, we have mechanical system with automatic control; we can see the example of steam turbine. So, basically this is an era of increasing automatic control. Then came transistors in 1948 and thyristors in 1955; so this lead to the mechanical system with electronic or analog control and sequential control.

So, in 1955 and what we came across is electronic control lift. Then further digital computers came in 1955, process computer came in 1959, real time software in 1966, microcomputer in 1971 and digital decentralized automation in 1975. So, here you can see that, there is increasing automation with process, computers and miniaturization. So, basically with this, we came across mechanical system with digital continuous control and digital sequential control; this is an era of 1975 and the applications were machine tools, industrial robots, industrial plants, disc, drives and all.

Then came the micro controller in 1978, personal computers in 1980, process fieldbus system, new actuators sensors came and integration of available components were made possible; so we came with the mechatronic system. And here integration of mechanics and electric hardware is there, software determines functions, new design tools were simultaneous engineering is there and there is a synergetic effects are there.

So, here examples you can see the mobile robot, computer integrated manufacturing, magnetic bearing and the automatic control; so here increasing integration of process and microcomputers.

So, basically what we can see that, the factors which have been responsible for the development of the mechatronics; these are basically inventions on the electrical drives, then increasing automatic control, increasing automation with process computers, miniaturization, and increasing integration of processes and microcomputers. Now, let us see what are the benefits of mechatronics? Why we want to go for mechatronics?

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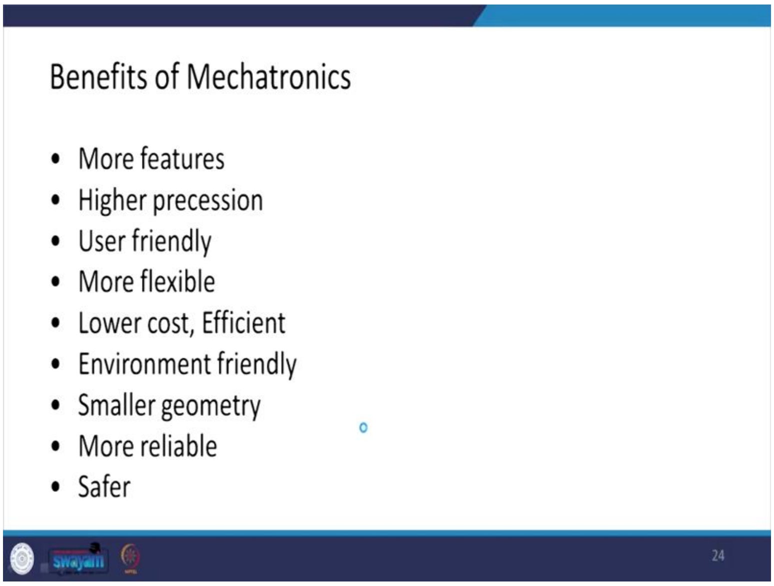

So, the primary reasons being there are more features, higher precession, user friendly, more flexible, lower cost, efficient, environment friendly, smaller geometry that is miniaturization is there, things are more reliable and things are safer. So, this slides summarizes the mechatronics system components.

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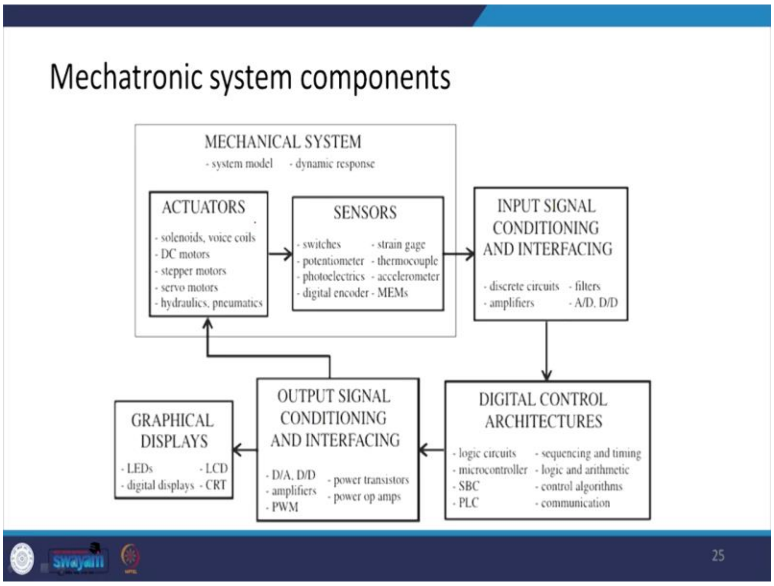

So, here basically we can see the mechanical systems, on mechanical systems basically we have the actuators and sensors; actuators could be say solenoid, voice coils, DC motors, stepper motor depending on what application you are interested stepper motor, servo motors, hydraulic and pneumatic actuators. Then we have the sensors that is the switches, strain gauges, potentiometer, thermocouple, photoelectrics, accelerometer, digital encoders and MEMS; then the signal of sensors they are to be conditioned, so we have the input signal conditioning and interfacing is there.

So, here we have the discrete circuit, amplifiers, filters analog to digital and digital to digital converters are there; then these signals are fed to the digital control architecture, where we have the logic circuits, microcontrollers, SBCs, PLCs, sequencing and timing, logic and arithmetic, control algorithm, communication. Now, these digital control signals are to be suitable for actuators has to be processed again.

So, we have the output signal conditioning and interfacing; again here we have the digital to analog convertors for example, the control signals from the digital control architectures are digital signals, whereas the actuators actually take the analog signals.

So, we need to have a digital to analog convertors; we may also require digital convertors, we may require the power transistors, amplifiers, power op amps and PWM. And many times we also like to see our output signals; so we have the graphical displace which could be in the form of LEDs, LCDs, digital displays or the CRTs.

Coming to the system, here basically when we are talking about mechanical systems; so as I told you in beginning of my this lecture, we before actually making or designing the system, you may like to see the system models and the dynamic response.

So, let us see what a system basically is? So, we can think of system as a box which has a an input and which has an output and where we are not concerned with what goes inside the box; but we are rather concerned with the relationship between the output and the input.

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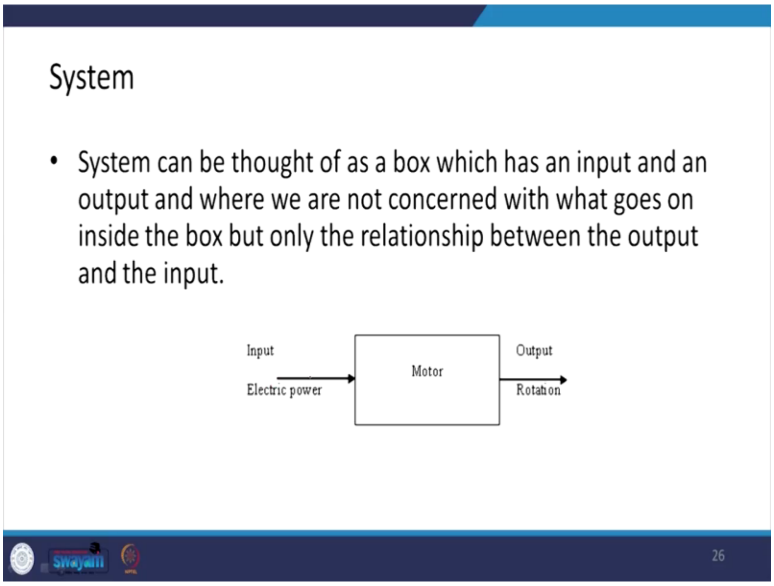

So, here we can take example of motor; a motor being a system, the input being the electric power to it and the output being the rotation of the motor shaft. So, this way we define the system.

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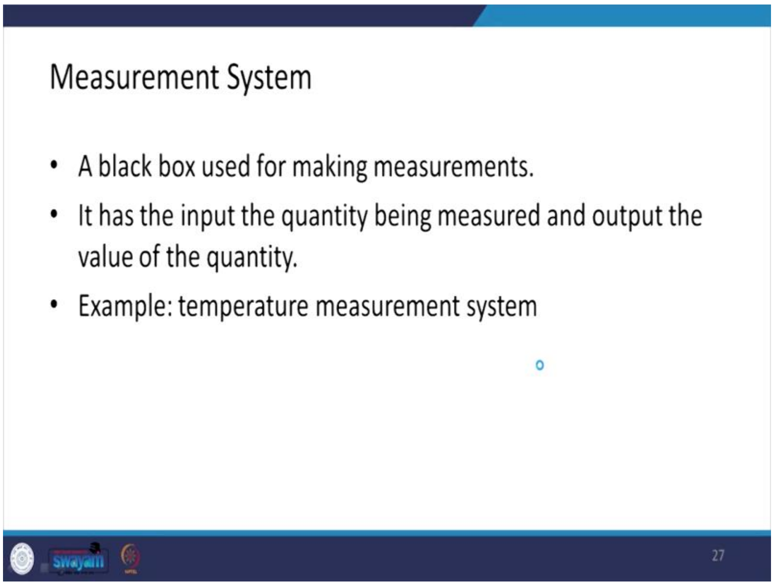

Now, measurement systems are basically a black box used for making measurements. It has the input quantity which is being measured and the output the value of that particular quantity. Example could be the temperature measurement system.

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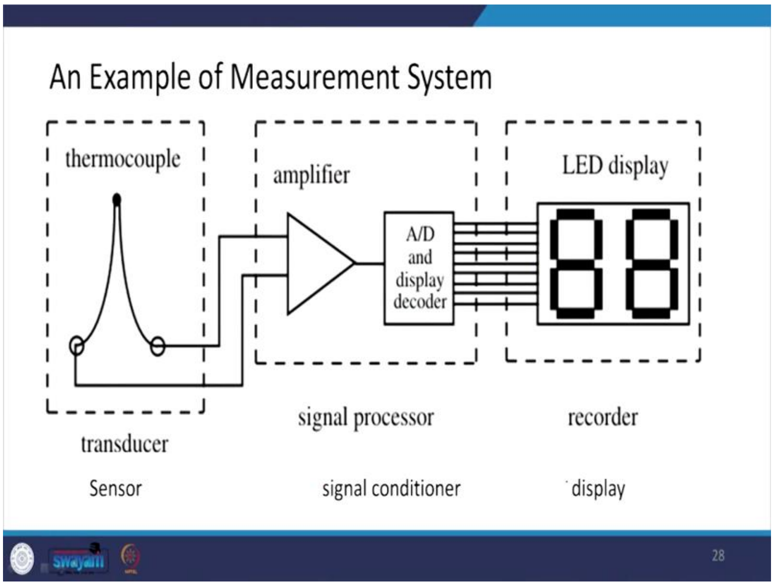

Here is an example of the measurement system, where we can see that we have a transducer which is a thermocouple; then we have the signal processor, the thermocouple signal has to be processed, these signals are actually very weak. So, we need an amplifier to amplify this signal and then this signal being analog need to be converted into the digital ones; so we need one analog to digital convertor and digital decoder and then this digital signal can be given to a recorder which is nothing, but LED display. So, this is how a measurement system consists of. So, we have thermocouple as a sensor, there is a signal conditioner, and there is a display.

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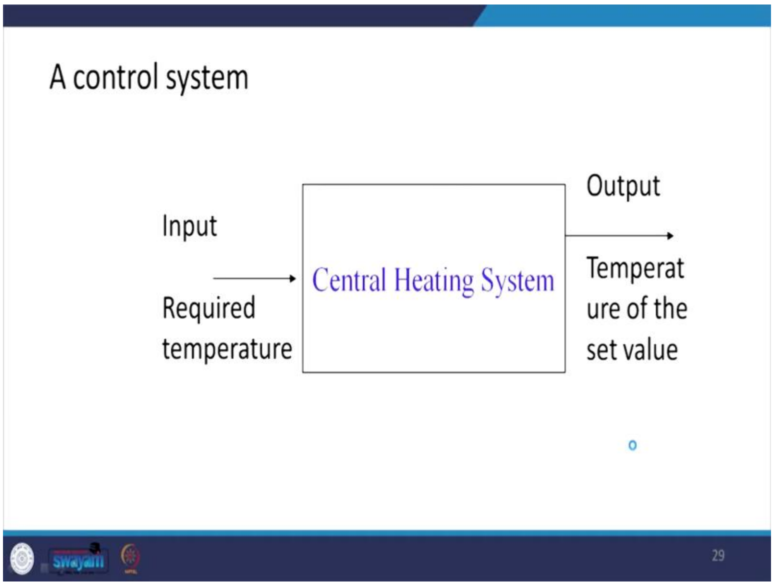

Now, a control system consists of again say an input an output; input is basically if you are talking about central heating system is the required temperature and the output is the temperature of the set value.

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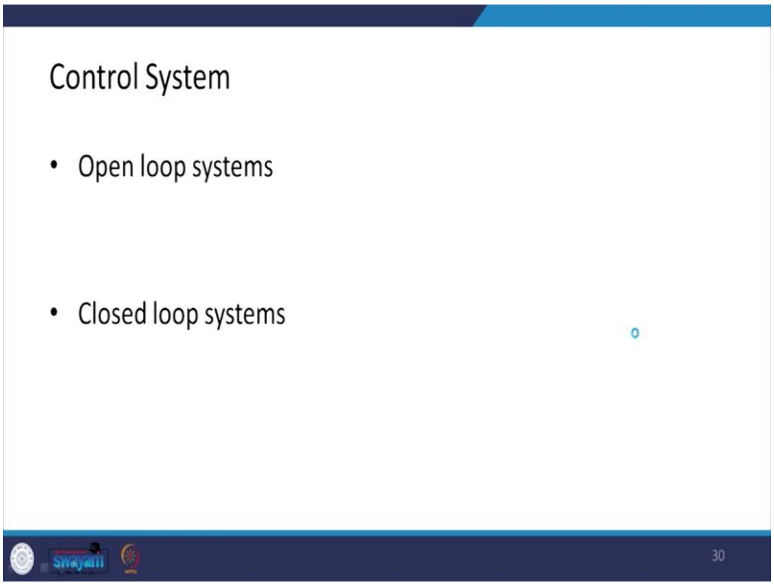

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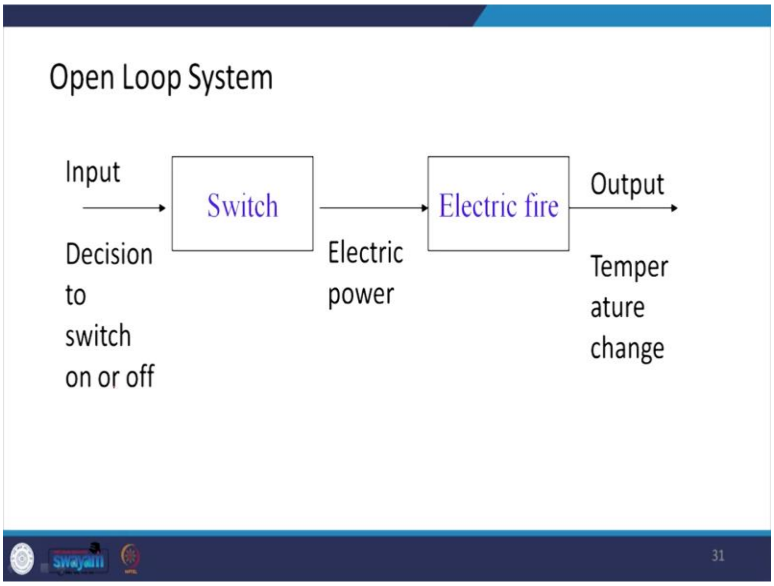

These control system could be open loop system or closed loop systems. The open loop system basically has got no provision of feedback. So, here that system which we are talking about is the central heating system; basically in the open loop mode it could consists of a switch and an electric fire. So, through switch basically we input the decision to switch on or to off and this switch basically supplies power to the electric fire and the output is the temperature change.

So, this is the open loop system; we do not have control over the temperature here. So, this is an example of open loop system; there is no provision of feedback here.

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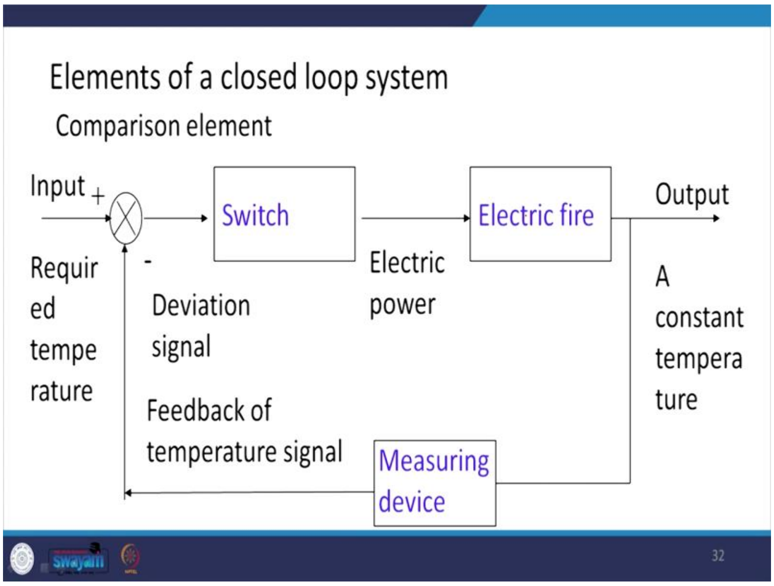

Now, if we talk about the closed loop one; then what we do here is that, form an electric fire or the output, we take that output through a measuring device and feedback this temperature signal to the comparison element, where the input that is what require temperature we want that is and the feedback is compared and a deviation signal is found and that deviation signal is given to the switch and again that switch supplies power to the electric fire.

So, this is an example of the closed loop system where we can see that, there is a provision of the feedback of what the actual output temperature is.

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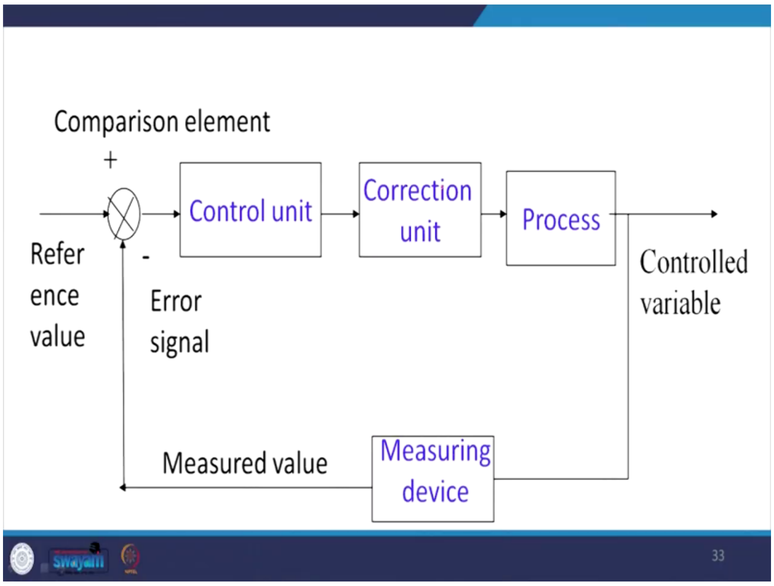

Now, here basically if we talk in general term; so we have a control unit, we have a correction unit, and we have a process. And the controlled variable of course, is taken from here through the measuring device and the measured value is given to the comparison element, where the error signal is found.

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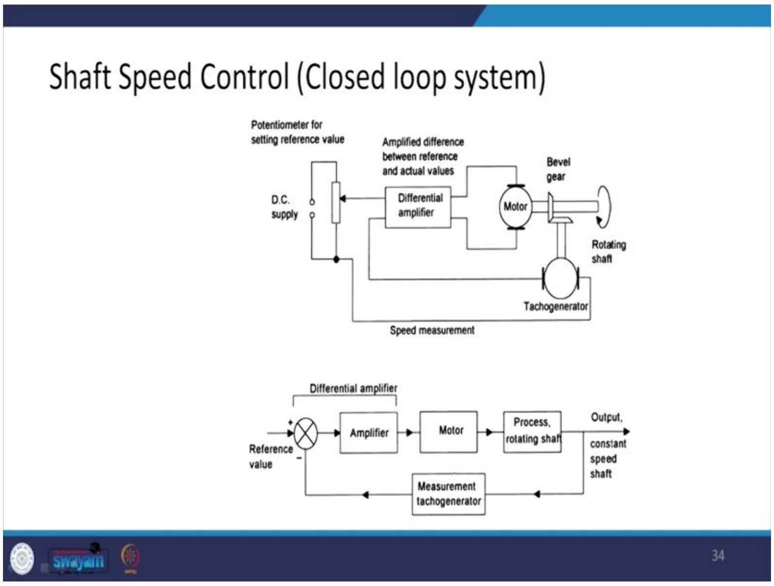

So, the example of this closed loop system is the shaft speed control, where we can see that, there is a motor here and we tap the output speed of the motor, so with the help of the shaft of the bevel gear in the bevel gear arrangement, a tachogenerator is driven basically.

The output of the tachogenerator is basically in the form of voltage and that we compare with the DC supply that is the potentiometer value, which sets the reference value and this difference signal is given to the differential amplifier, which does amplify difference between the reference and actual value and then it drives the motor.

So, this is the system for the speed control of the shaft basically and here we can see that there is a provision of the feedback and that feedback is done with the help of a tachogenerator, which acts as the measuring device basically.

So, in a block diagram form I can explain this, we have an amplifier which amplifies this error signal basically and then that signal is given to the motor and then motor in fact, through motor we get the rotation of the shaft and then we measure the output speed of the shaft with the help of tachogenerator, we take the feedback with the help of tachogenerator and that is given to the comparator here, where it is compared with the reference value.

So, with this I would like to conclude this lecture.

Thank you for listening.