Automation in Manufacturing
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Week - 02
Lecture - 01
Mechatronics based systems

Hello friends, I welcome you all to the course on Automation in Manufacturing. We are starting the second week. The lecture 1 of week second is on Mechatronics Based Systems.

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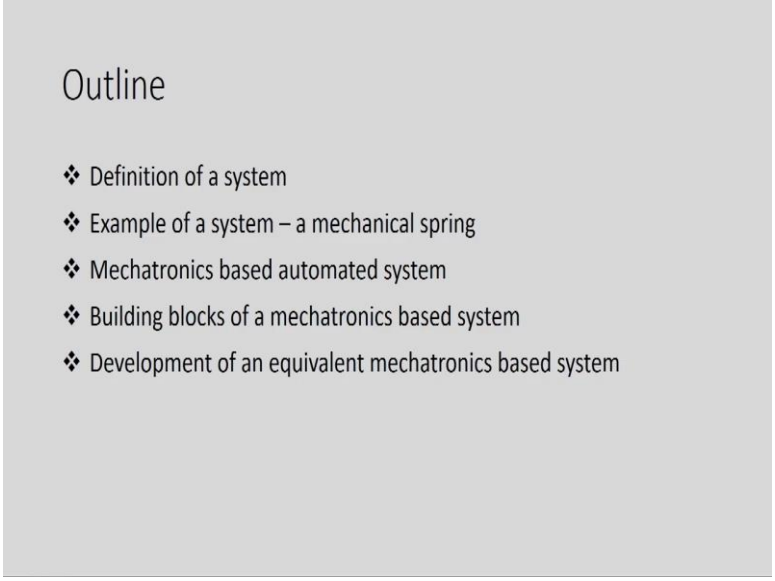

The outline of this lecture is as follows; at the start of the lecture, the definition of a system, the meaning of the term system which is often used in automation and in mechatronics based systems will be studied. Then, an example of a simple mechanical element i.e. a mechanical spring will be studied to understand the meaning of the term system.

Then, the meaning of mechatronics based automated system will be discussed. Its building blocks and at the end, how to develop an equivalent mechatronics based system will also be studied.

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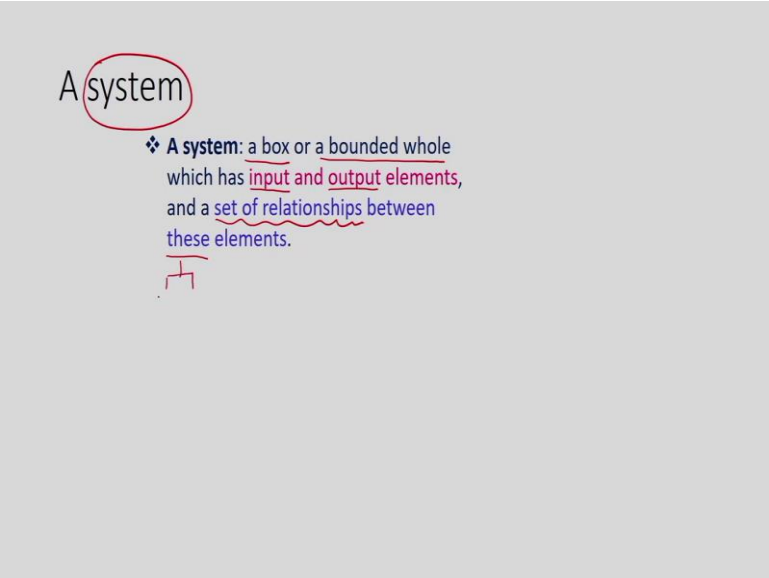

Till now, a term or a word has been very regularly used and that term is system. As per as engineering point of view, a system can be defined as a box or a bounded whole or volume which has certain inputs and certain outputs, where there is a set of relationships between the elements. These elements are inputs and outputs.

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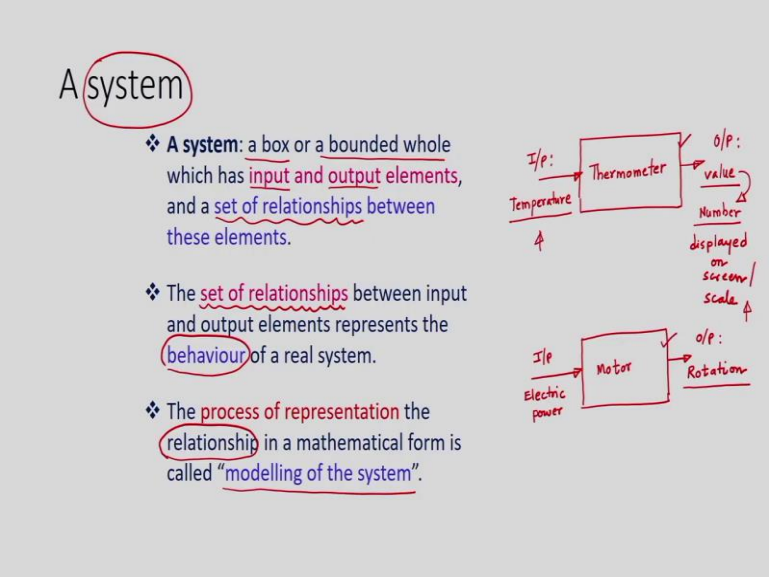

The set of relationship between the input and the output represents the behaviour of the real system. When this relationship is represented in mathematical form, then that process is called the modelling of the system. A simple example of a system is a

thermometer. Thermometer is a very common system that one can have. The input to the system or input to the thermometer is temperature.

Thermometer measures the temperature. The input element to this system is temperature and from this thermometer we get a value s or a number, displayed on the screen if it is a digital thermometer or if it is an analogue thermometer, then we can see it on the scale.

There is a relationship of this number with the input temperature, as the temperature is increasing the number is also increasing. So, it can be said that the number displayed on the screen is directly proportional to the temperature This relationship when represented mathematically is called the modelling of the system.

A motor can be taken as the second example. For motor, the input is electrical power and the output is a rotation. Again, there is a relationship, the rotation of the shaft of the motor will rotate at a high speed when more electrical power is applied. So, the motor or a thermometer can be called as systems which are having certain inputs and outputs.

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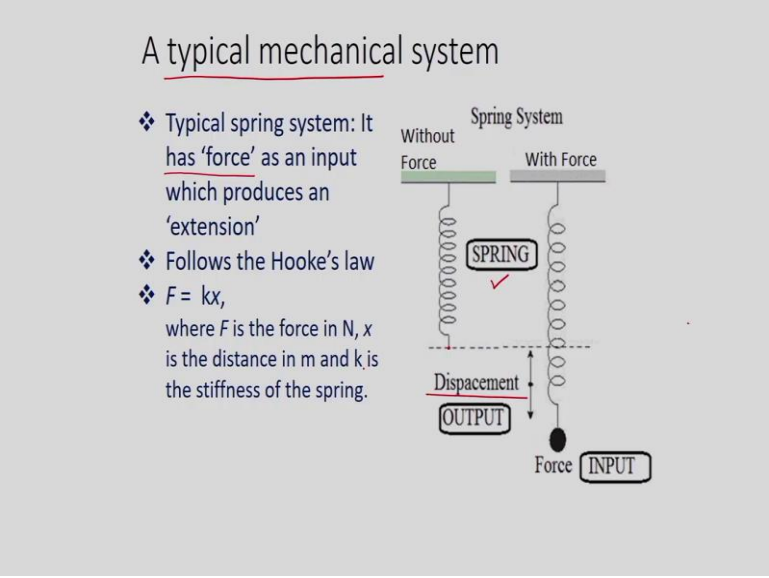

One more example of the term system is a typical mechanical system and that typical mechanical system is a spring. The spring is widely used in variety of engineering applications. The most important or the most common application of spring is in suspension of automotive. The springs comes in a variety of types such as; compression

spring, extension spring, torsion spring, coil spring and leaf spring. Moreover, another application of the spring is in our previous lecture that is in watches or clocks.

Now, considering a typical spring and a force arrangement; in the spring, when a force at the free end of the spring is applied, its end gets displaced. Thus, the input to the system is a force and the output is the displacement. The spring follows the Hooke's law.Hooke's law is a principle of physics, that states that, the force needed to extend or compress a spring by some distance is proportional to that distance itself. This law was given by a British physicist in 17th century. When a spring is stretched or compressed, its length changes by an amount x from its equilibrium length, then it exerts a force F, that is in the direction towards the equilibrium position. The force that the spring exerts is nothing, but the restoring force. It restores the spring to its equilibrium length.

Mathematically, Hooke's law can be represented as

$$F = Kx$$

where F is the force in Newton, x is the distance in meters and K is the constant of proportionality and it is called as the stiffness of the spring.

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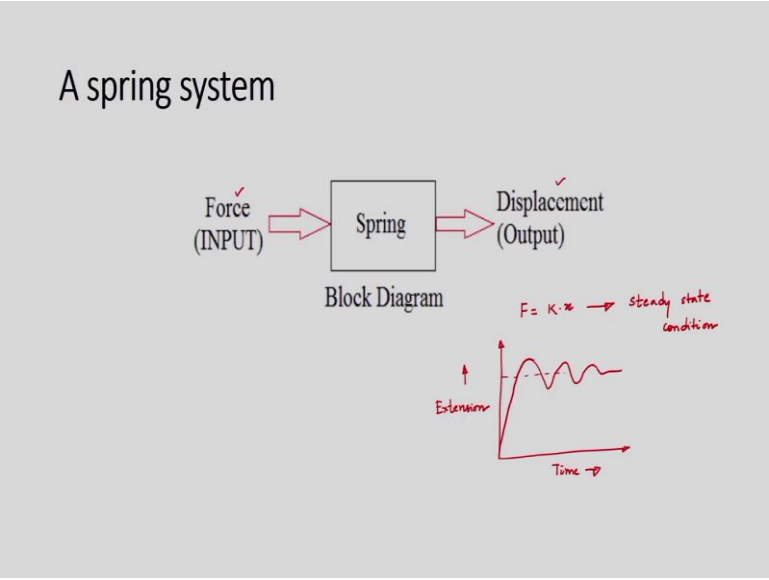

The block diagram of a typical spring system can be seen on the above figure. It is known that, a spring has a force and a displacement and it follows the principle of operation as $F=Kx$. So, this relation would be true in the case of steady state condition.

However, in reality, the spring will oscillate and vibrate about its equilibrium position and will achieve its equilibrium position after certain time.

So, if a force on the spring is applied, an extension of the spring is observed. However, this will not be the final extension or final value that we will be getting, the spring will oscillate and vibrate and after some time it will get stabilized.

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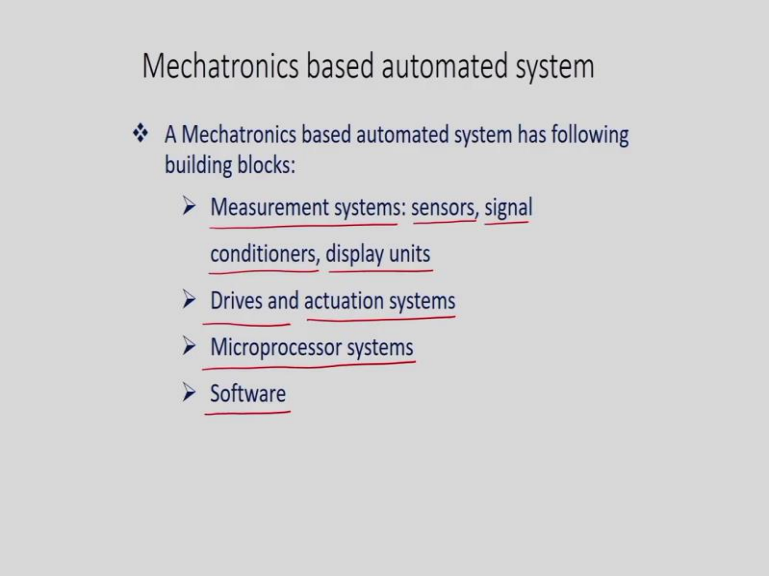

Now, the various building blocks of a mechatronic based auto automated system will be discussed. The first building block of an automated system is the measurement system. The measurement system has various sensors, signal conditioning devices and display units.

The second building block is the drives and actuation systems. The third one is a microprocessor system and the fourth building block is the software. It is known that, software is a set of programs which are controlling the operations of the microprocessor system.

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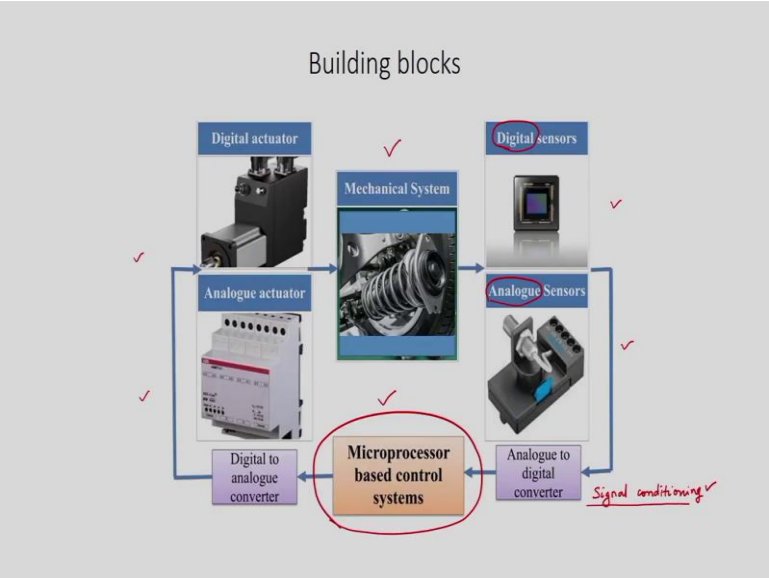

In an arrangement showing the building blocks of an automated system, a mechanical system which is basically being controlled by a microprocessor based control system can be seen. This microprocessor based control system gets inputs from various sensors, which may be digital sensors or analogue sensors. These sensors are further giving signals to signal conditioning devices.

The signal conditioning may be conversion of analogue signals into digital signals. It may also have the various functions like amplification, linearization, noise removal, modulation. This signal conditioning will be discussed in detail in our next lectures.

The microprocessor gives signals to the actuators through a set of signal conditioning devices. It is known that, the microprocessors are producing a series of pulses and based on that series of pulses we have to actuate the actuators. However, some of the actuators are using the analogue input as motor.

In this case, it converts the digital signal which is coming from the microprocessor into the analogue form and that analogue signal will be utilized by the actuator.

Actuators are actuating the mechanical system. This is a typical arrangement in which it has basic mechanical system and this is being controlled by a microprocessor based control system. It has the important blocks i.e. the measurement system and the actuation system. These will be studied one by one in this course.

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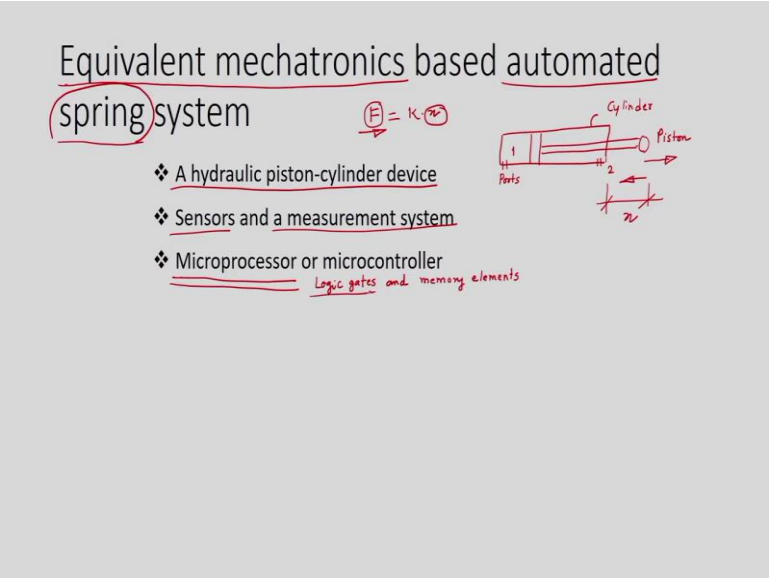

To understand these building blocks, let us take a very simple example of a spring system and let us try to develop an equivalent mechatronics based automated system for the spring system.

In the present lecture, the spring is considered as a model and that mechanical system model will be converted into mechatronics based system model. For this purpose, a hydraulic piston cylinder device will be considered. It is seen in spring that, it mimics the Hooke's law, i.e. $F = Kx$.

Thus, to have an automated system, here let us take a hydraulic piston cylinder device. It has a cylinder, the cylinder has a piston, the cylinder has two ports, port number 1 and port number 2. When we apply pressurized fluid through port 1 there is an extension of the cylinder, the piston will come out of the cylinder.

If pressurized fluid is applied through port 2, then there is contraction of the cylinder. The piston will move inside the cylinder and this is a typical hydraulic piston cylinder device. When a fluid pressure is applied, with force, F as a function of extension, an extension of the cylinder x will be obtained.

To make this process in an automatic way, sensors and a measurement system are required. Again, for the purpose of taking decisions automatically, a microprocessor is used. A microprocessor is nothing but a device which is having logic gates and memory

elements. Microprocessor carries out logical functions which are implemented by means of software. Consider, we might want an output if input A and input B, both are giving signals. We want an output when input A and input B, both are giving signals to microprocessor, then, we want to have the output.

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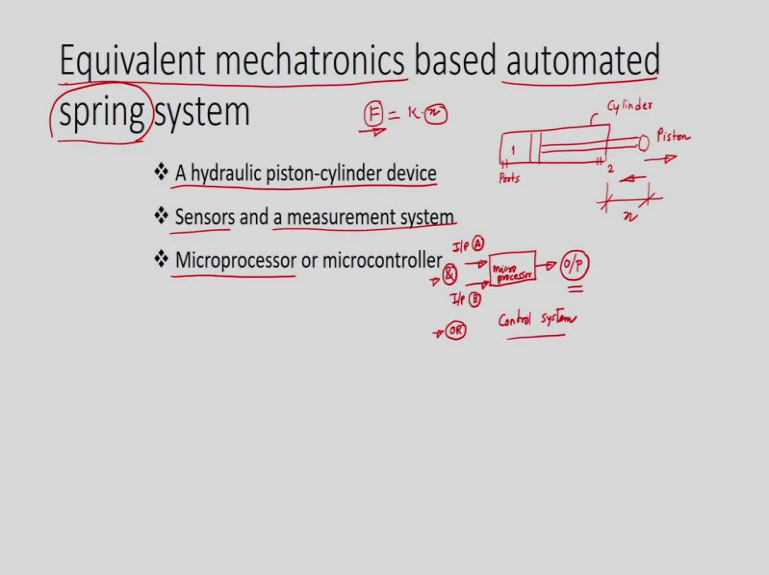

There may be a situation or there may be a program which is asking the microprocessor to produce output when either of input is present. These type of conditions, when the microprocessors are taught through programs, then it is said that we are developing a microprocessor based control system.

When the input-output ports, memory and all logic gates are integrated on a single chip, that is called as microcontrollers.

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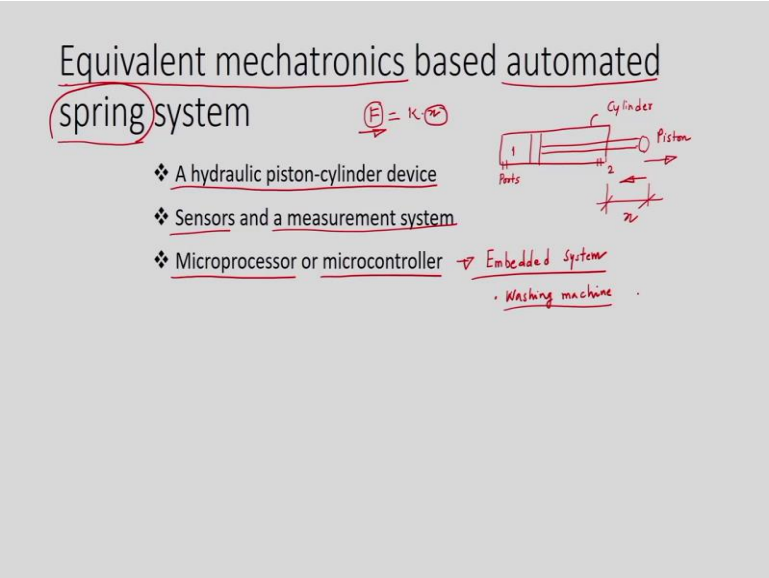

An embedded system is a microprocessor based system, that is designed to control a range of functions and not to be programmed by the end user. In other words, the meaning of embedded system is that, when the microcontrollers or the microprocessor based system is integrated to the mechanical system and the end user is not allowed to program it.

A simple example is washing machine. The user cannot reprogram or cannot edit the program of the washing machine. Whatever the designer or the manufacturer has given to us, so we have to use the same program or the same mode of operation.

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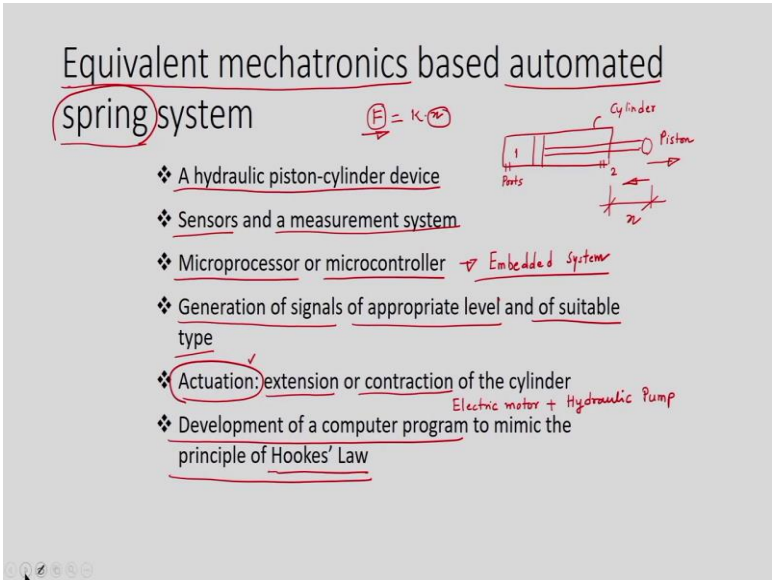

The next building block is generation of signals of appropriate level and of suitable type. Then comes actuation, which is nothing but the extension on or the contraction of the cylinder. This extension or contraction of the cylinder would be done by using pressurized hydraulic fluid.

That pressurized hydraulic fluid will be generated by using an electric motor and hydraulic pump arrangement. Pump and motor arrangement are the actuation devices. And then it is required to write a computer program, and a set of instructions which are mimicking the Hooke's law.

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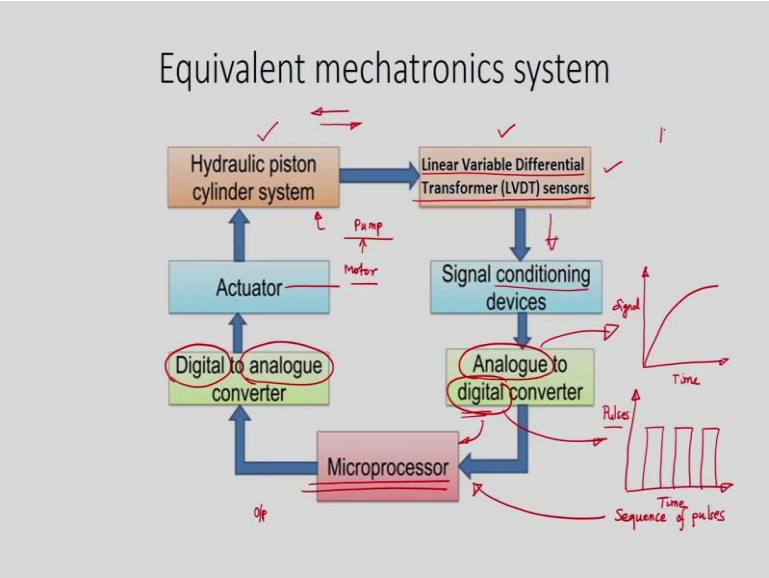

Now, representing all these elements as a block diagram, we have taken the hydraulic piston cylinder system, then we have to select a suitable sensor. In this case, LVDT is considered, which is a linear variable differential transformer. It is contact based displacement sensor.

The sensors are producing the signals which will be conditioned and the analogue form will be converted into digital form, and that digital signals are given to microprocessor. As it is known, the microprocessor understand the digital form of the signal.

What is the meaning of analogue form of the signal? In analogue form, the signal is continuous function of time. However, in digital form the signals are nothing, but sequence of pulses. We are getting the signals in terms of pulses.

Microprocessors understand the digital signals only, for which the analogue signal is converted into the digital form. Microprocessor has the program set by the programmer. It generates the output into the digital format and that output is needed to further convert into analogue format, because our actuator is an electrical motor.

The motor is running based on the electrical power, thus the digital pulses are converted into appropriate level of analogue signal and that analogue signal is activating the motor. The motor drives the pump, and the pump is driving the hydraulic piston cylinder arrangement.

It extends or contracts based upon certain arrangement of motor pump and few other auxiliary equipment, and based on that, again it generates certain signals at linear variable differential transformer sensors.

That sensors are giving input to the microprocessor, microprocessor again process the information and take the signal and give to the hydraulic piston cylinder arrangement. In this way, it is easy to mimic the Hooke's law i.e. $F = Kx$.

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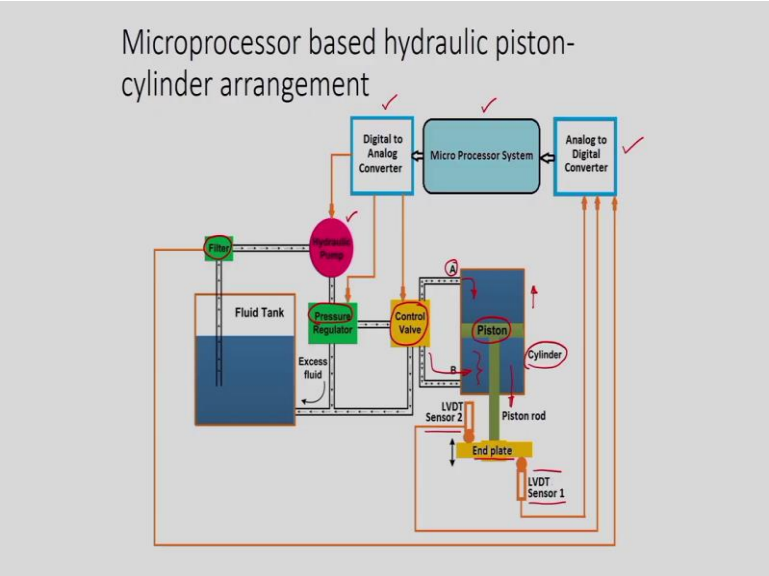

Based on the above discussion, how can we have the actual arrangements of all these elements can be seen. So, in the figure, we can see a typical arrangement that can be developed to mimic that to Hooke's law. In this case, if it is wanted to convert this equivalent mechatronics system into an actual mechatronics based automated system, what are the various things are required; will be discussed.

In the figure, we can see a typical arrangement. This typical arrangement has the hydraulic piston cylinder arrangement. At the end of the piston a plate is attached. There is a set of sensors, LVDT sensor 1 and sensor 2. Sensor 1 will sense the extension of the cylinder, sensor 2 will sense the contraction of the cylinder. Analogue to digital converter, microprocessor system, digital to analog converter are also present.

The microprocessor of the system is controlling the operations of the hydraulic pump, the processor is giving signals to pump, it starts the pump and switches off the pump.

The system is also regulating the pressure inside the system. The processor is also directing the flow of fluid inside the system.

The microprocessor is also monitoring the quality of the hydraulic fluid which is being used by monitoring the signals coming from the filter. If the fluid is contaminated, if it has many physical particles that may clog the system, that may harm the system, then the microprocessor we will give the alarm it will ask the operator to change the fluid.

It can be seen, how the microprocessor may operate the piston cylinder arrangement. For the extension, the microprocessor will give the signal to the hydraulic pump to pump the pressurized fluid at port A. As a pressurized fluid comes through port A, the piston will move away it will come out the cylinder will extend and that will be sensed by the LVDT sensor 1. LVDT is in direct contact with the end plate.

The sensor input will be used by the microprocessor and if the displacement is as per the desire, its fine, but if it is not as per the set value then it will ask the hydraulic pump to pump more fluid at port A till it achieves its designated value set value. To change the direction of the piston movement or for the contraction, then the microprocessor may ask the control wall to put the pressure on the other side of the piston, for that purpose, the control wall will be operated by the microprocessor and the pressurized fluid will be given at the other side of the piston. When the pressurized fluid come in this area, then the piston will contract till it achieves its designated position.

In this way, the microprocessor controls the pumping of the hydraulic fluid inside the piston cylinder arrangement, it regulates the pressure and it controls the direction of movement of fluid inside the system. In this way we can convert a system into a typical microprocessor based automated system. For this many equipment, many sensors, actuators are needed and one has to learn how to program the microprocessors as well.

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

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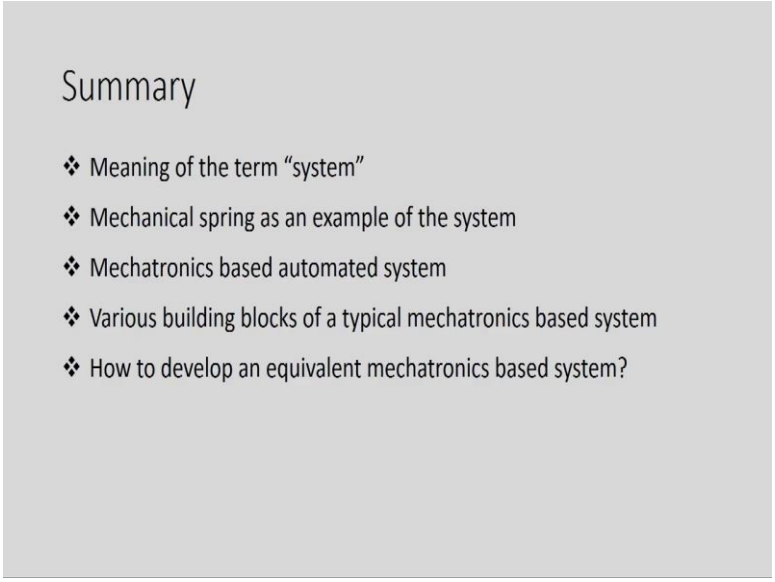

Well, my friends let us summarize this lecture. We have seen in this lecture the meaning of the term system. We understood the principle of working of a mechanical spring in the perspective of the term system.

Then we have seen what are the various elements of a typical mechatronics based system, various building blocks and at the end we have seen how to develop an equivalent mechatronics based system. To understand the equivalent mechatronics based system, we have converted the concept of a typical mechanical spring into a hydraulic piston cylinder based arrangement.

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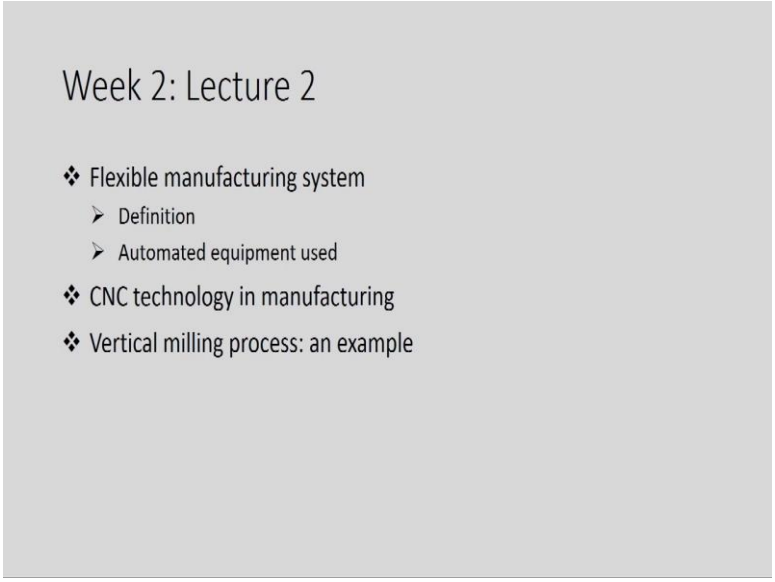

In the next lecture, we will study the definition of flexible manufacturing system, the meaning of flexible manufacturing system, various automated equipment which are used in the FMS. The FMS has the comprehensive use of CNC based technologies, conveyors, automated conveyors, automated guided vehicles, automated storage and retrieval system, automated inspection devices.

After this we will study the CNC technology that is being employed in the manufacturing domain. To understand the CNC technology in a better way we will be taking an example of a vertical milling process, a manufacturing process which is widely used in the two rooms.