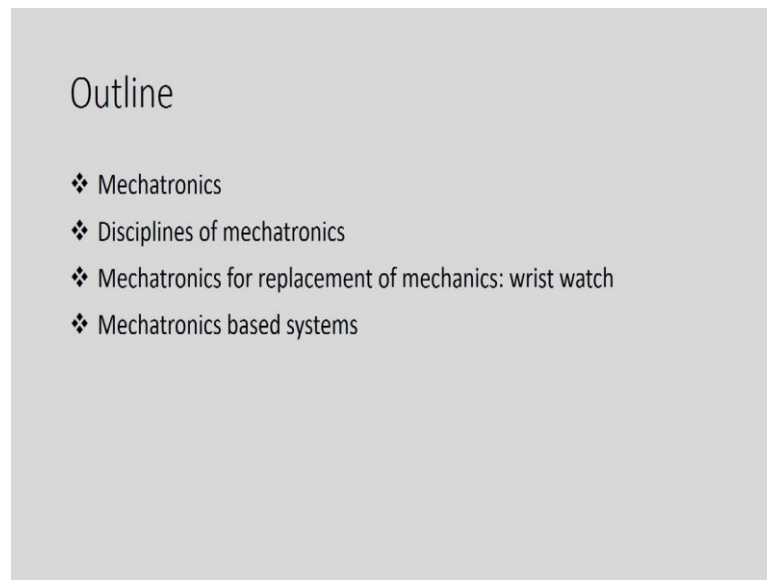


Automation in Manufacturing
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Module – 01
Lecture – 02
Mechatronics

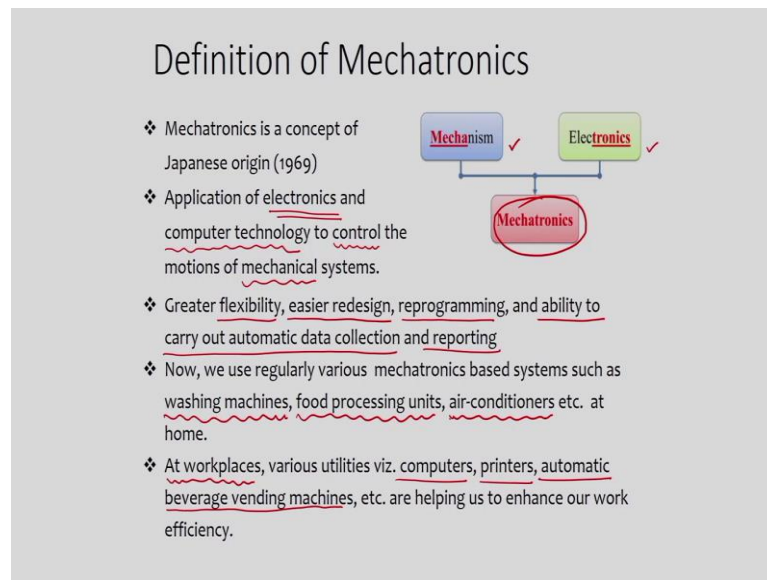
I welcome you all to the NPTEL online certification course on Automation in Manufacturing. We will be starting the lecture 2 of module 1.

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The outline of the lecture is as follows. At the start of the lecture, we will be studying the definition of Mechatronics and related concepts. Then we will study in detail, the various disciplines involved in the development of mechatronics based systems and products. After that, we will be taking an example of wristwatch and study how mechatronics is helping to replace the mechanics. The various mechatronics based systems will be introduced and then we conclude the lecture.

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Mechatronics is a term coined by Japanese scientists or Japanese engineers in 1969. The term mechatronics has been derived by two basic terms, namely mechanism and electronics. Mechanism comes from mechanical engineering and tronics or electronics from the electronics engineering. Mecha of mechanisms and tronics of electronics combined together, makes the mechatronics.

What is the meaning of mechanisms? If we take any machinery, it has various links, various elements. These elements or links are grouped together, which form a mechanism. In mechanism, if we apply a force to an element of the system, it will generate motion in the other connected links. It will generate force in the other connected links and the motion or the forces, which are generated are used for our application.

In general, a machinery has many such mechanisms, which are grouped together and used for our intended purpose. Electronics is a branch of engineering that deals with emission flow and control of ultra fast moving electrons in vacuum or in matter. We can say that, when ultra-fast moving electrons are moving in vacuum or in a matter, it can be used for transmission of the information.

Electronics provides us rapid and accurate communication in various devices. As such, fiber optics communication is very good example of the electronics application in our day to day life.

Utilizing the advantages of the electronics in enhancing the efficiency of mechanisms, the system which are developed are called mechatronics based system. Mechatronics has the application of computers nowadays. Basically, computers are used to control the various activities of a mechanical system through electronic circuitry. Computers are used to program the electronic circuitry, to model the work parts, and to simulate the systems.

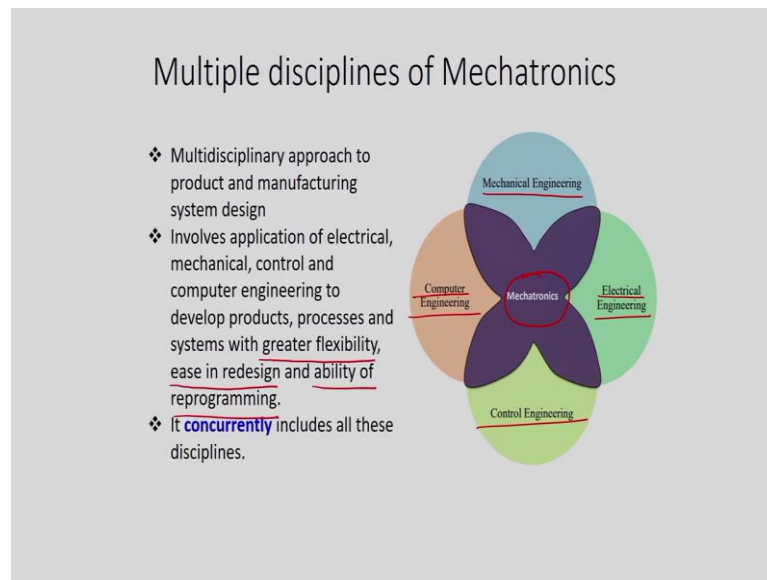
What benefits this mechatronics offer to us? The mechatronics provides greater flexibility; flexibility in terms of the system design, the product design, and operation. We can easily redesign the system, modify the system, reprogram the system the way we are reprogramming in CNC machine tools and the same machine tool can be used for machining of various products.

For that purpose, we have to load different programs to carry out the operations, thereby making the reprogramming easy. Mechatronics also help us to carry out automatic data collection and reporting. We can collect the data through sensors and that data will be used for report generation, which further can be used to take decisions regarding the manufacturing operation.

At our home we are regularly using mechatronics based system. If we look around, we will find various mechatronics based systems available, such as the washing machines,. Some companies say that washing machines are intelligent, which means that, they are taking decisions on their own, we need to just put the cloths inside and all decisions will be taken care by the washing machine itself.

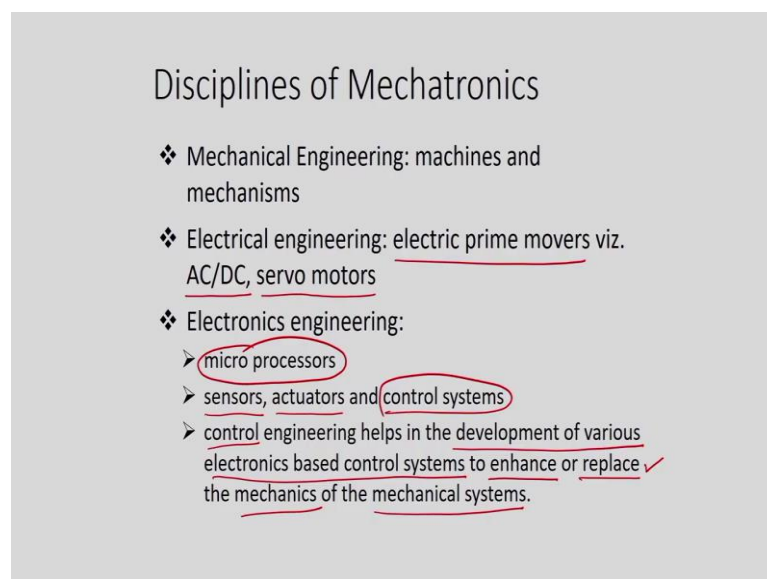
At workplaces, in our institutes, in labs, in offices, we are using computers, printers. For coffee or tea, we are using automated beverage vending machines. All are helping us to enhance our work efficiency.

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Mechatronics is a multidisciplinary approach for the product and manufacturing system design. The disciplines are mechanical engineering, electrical engineering, computer engineering and control engineering. The mechatronics is the amalgamation of these branches of engineering. All these disciplines are simultaneously being applied in the system design or in the product design, for which the mechatronics system design approach is called as the concurrent approach or concurrent engineering approach.

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Mechanical engineering contributes in mechatronics by providing various machines and mechanisms. Electrical engineering, provide the prime movers, the electrical energy will be converted into mechanical energy and that mechanical energy will be applied for the intended application, the movement of the various links of the mechanism. For this purpose, we need various motors; AC motor or a DC motor or a servo motor.

Electronics engineering is providing the microprocessors, which are the brain of the mechatronic system. The control engineering provides the sensors, actuators, and the control systems circuitry.

It is helping in the development of various electronics based control systems, to enhance or to replace the mechanics of the mechanical system. We will see how exactly this mechatronics is helping to replace the mechanics of the mechanical system in the following section.

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Contribution from computer engineering

- ❖ Development of software to control the hardware of a machine / mechanism
- ❖ Provide “user friendly” interaction and control of machines and mechanisms to the human being.
- ❖ Manufacturing of a product
 - to create newer product designs – computer aided design (2D / 3D)
 - Computer aided manufacturing simulations
 - to plan the manufacturing activities which include materials and manufacturing resource planning, record keeping, market survey, and other sales related activities.

The contribution from computer engineering is in the development of software. A software is a group of computer programs and a program is a set of instructions written by the developer. By following this set of instructions, the control system or the microprocessor will take the actions. These software also control the motions of the hardware i.e. machines and mechanisms.

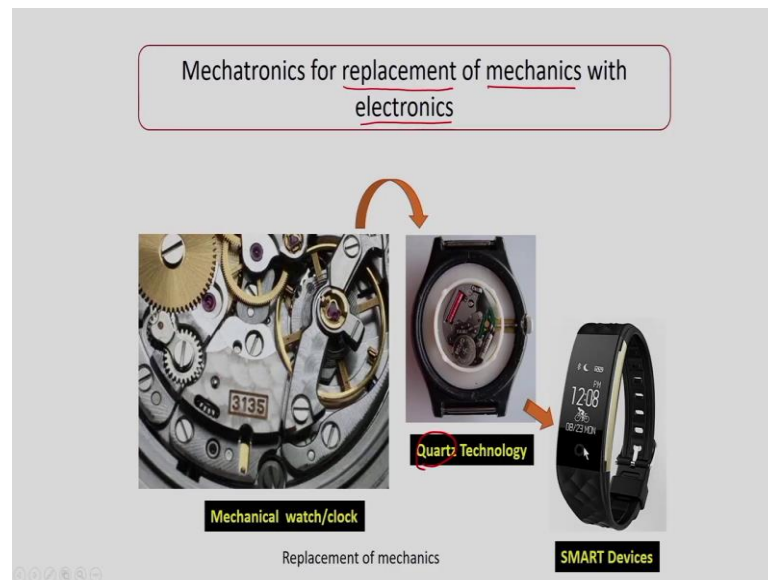
The computer engineering is not only helping us to control the hardware of a machine or a mechanism, it is also helping us to provide an interface for user friendly interaction with the mechanism or with the machine tool or with the equipment. Thus, user friendly interaction and control of the equipment is an advantage, which is provided by the computer engineering discipline.

In addition to these two features provided by the computer engineering, this discipline helps us to develop newer product design. Computer aided design are useful to develop 2 dimensional or 3 dimensional drawings of the product or the elements or the parts of a product. This is very helpful for us to visualize the product in early stage of the development.

Moreover, the computers are helping to carry out the simulations. Simulations means analyzing or predicting the things in a virtual way by applying some analytical tools, by applying the mathematics and by considering the knowledge or experience, which is available. We simulate the process, we predict the things beforehand, which are helpful to get certain guidelines in the planning. Based on these guidelines, based on the initial input, we can take certain decisions, that may be related to the production planning, or may be related to the product design.

The planning of manufacturing activities includes the materials planning, manufacturing resource planning, record keeping, market survey, and other sales related activities. In the definition of mechatronics, we have seen that mechatronics is considered as a replacement to the mechanics by the electronics.

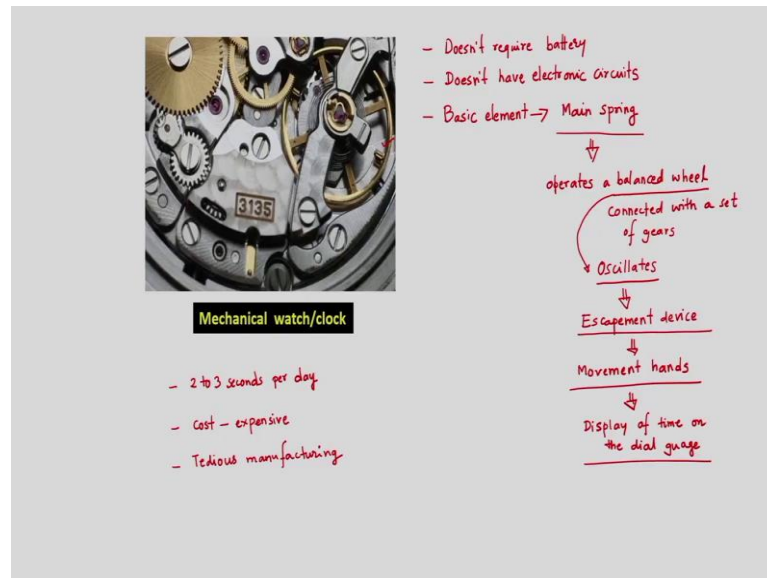
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To understand this definition, let us take a simple example. We can see a mechanical watch or a clock in the above figure. There are a lot of components or parts and the construction is very complex. But nowadays, these mechanical watches or the clocks are replaced with electronics clocks or watches. In electronic clock or watches, we are using quartz based technology.

We will come to know the meaning of this quartz based technology and how it is replacing the existing mechanical technology in the upcoming section. Since the last few years we are getting more advanced watches and clocks. These more advanced watches and clocks do have a lot of sensor technologies associated and with the addition of these sensors, the watches or clocks have become smart devices. So, we can call this as a smart clock or smart watch.

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We are using these smart devices regularly. Now, if we look at the mechanical watch, it does not require any battery, it does not have any electronic circuitry as well. All operations are mechanical.

The basic element of mechanical watch is the spring and that spring is called as the main spring. We have to wind this spring by using a screw. We have to pull out the screw and then rotate the screw. That rotation of the screw will give mechanical energy to the main spring. The spring stores the mechanical energy.

We have to periodically wind this main spring. The main spring operates a balanced wheel. This balance wheel is connected with a set of gears. The balanced wheel oscillates, it moves back and forth and these oscillations drive a device called the escapement device. The ticking sound that we get from mechanical watch is of this escapement device. The escapement device moves the hands of the watch by a small amount with each swing of the wheel. Thus, the watch hands move at constant rate with the oscillations of escapement device. The movement or the sweeping of these hands can be seen on the dial gauge.

So, the operation is very simple. However, the construction of mechanical watch is very complex. As we can see, the mechanical watch has many gears, many pins, many screws and all these are of very small sizes, meso size and micro size. So, manufacturing of such

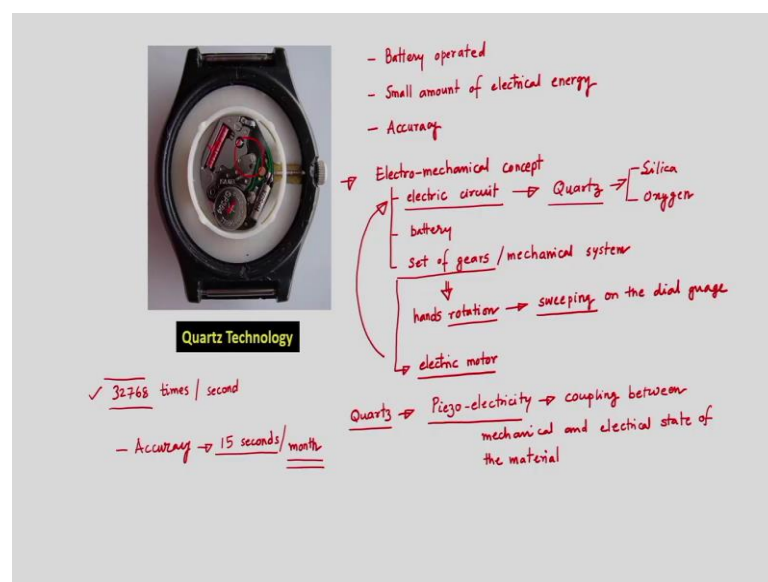
small mechanical elements is a very difficult task, it requires advanced machining processes, advanced manufacturing processes.

Therefore, the cost associated with the mechanical watch is also quite high. Moreover, we are manufacturing them mechanically. So, there may be certain imperfections associated with all these elements. So, due to this, the accuracy of these kinds of mechanical watch is around two to three seconds per day.

So, this error is attributed to the imperfections associated with the mechanical watch and the periodic winding of the springs. , If we miss the winding, then the watch will stop working and to restart the watch again, we have to wind it over to start from the previous time or to start with the previous locations of the hand. So, these may add to the error of these kind of watches.

Thus, the cost is high and the manufacturing is also a tedious or difficult task. That is why, the engineers or scientists tried to develop an advanced technology, known as the quartz based technology.

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These newer watches are battery operated. In the figure, we can see a typical quartz watch. These watches require a very small amount of electrical energy, as we can notice in our quartz watch, the battery may last long for few months or in certain cases it may go for 1 or 2 years as well.

The amount of electrical energy required is less and the accuracy of these watches is also high. So, how these watches work? They are working based upon the electromechanical concept. The system of these quartz watch does have an electrical circuit, a battery and a set of gears, which can be called in general, a mechanical system.

The set of gears rotates the hands. Hands may be the second hand or minute hand or the hour hand and these hands are getting rotated or swept on the dial gauge, if it is analog type of quartz watch. But if it is a digital type of quartz watch, then we are getting the digital display. So, how we will see, that these hands are getting rotated?

We have to move or have to have the mechanical motion of the set of gears. This set of gears will be operated by an electric motor or micro or small electric motor. Now, who operates this electrical motor?

The electrical motor will be operated by the electric circuit. The electric circuit is again being run by a crystal material, that we call the quartz material.

The quartz is nothing, but a common mineral of earth and it has silica and oxygen. The quartz has a peculiar characteristic, i.e. they are piezo electric materials. Piezo electricity is nothing but a coupling between mechanical and electrical state of the material.

What is exactly the meaning of the piezo electricity? When a mechanical stress is applied on the quartz, it produces electricity and this ability to convert the voltage into a mechanical stress is called piezoelectricity.

This process is also carried out in a vice versa, i.e. if a mechanical stress is applied on the material, they produce electrical charges on their surfaces. This property is used in watches or clocks. As we apply electrical energy to this tiny crystal, it vibrates at a very precise frequency and that precise frequency is about 32768 times per second.

Thus, when we apply electrical energy, it vibrates for 32768 times precisely. If we have an electronic circuit, which will count these vibrations, and generate a pulse when the counter reaches at 32768 number..

We can say that, on applying electrical energy, the crystal will vibrate and the vibrations will be counted. When it reaches 32768, the electronic circuit will generate a

pulse, a voltage pulse and that voltage pulse will make a display on the screen if it is a digital watch and that display is nothing, but one second.

If it is not a digital watch that pulse will give energy to the motor. The motor will drive the gears and these gears will drive the hands, the hands which are sweeping on the dial gauge.

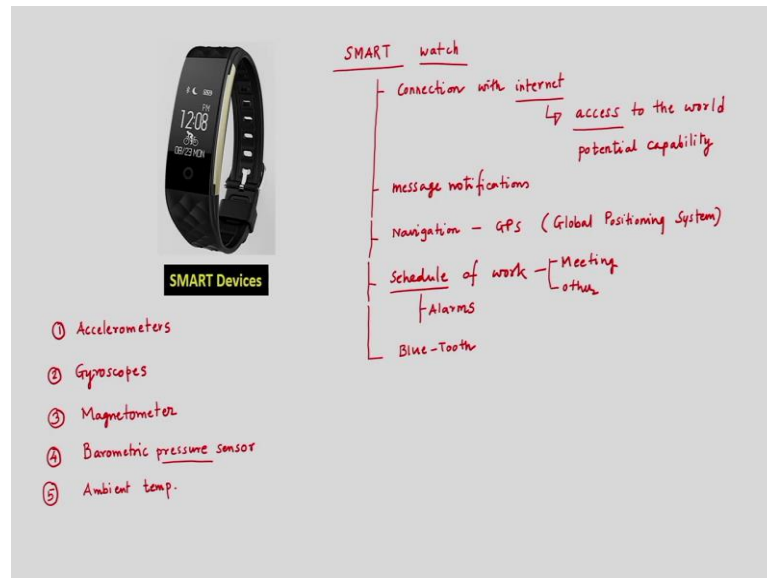
In this way we can generate number of pulses and that pulses gives us time on our display; it may be a digital display or the analog display. If we look at the construction of quartz watch, the construction is very simple, it has very less number of parts. As the number of parts are less, the manufacturing cost of these watches are also less.

If you look at the construction we can see that, there is a battery and this is the quartz element. In addition to that, there are very few parts which are shown in the figure. The accuracy of quartz technology is also comparatively high than the mechanical watch. The accuracy is around the 15 seconds per month. There may be a chance of having an error of 15 seconds per month; however, in all the advanced watches, the accuracies are further improved, the errors are further reduced, say 3 to 4 seconds per month.

The idea behind this all discussion is that, the complex system of a mechanical watch can easily be replaced with a simple electronics based system. Though we are using mechanical parts here; however, we are taking help of the electronic circuitry and electrical energy together, and we are applying them on the mechanical systems mechanisms and the machine systems.

This is enhancing the efficiency of the system; it is reducing the cost of the system as well. So, that is nothing, but the mechatronics, so we are replacing the mechanics, we are replacing the spring system, the escapement device, many set of gears by using a simple tiny crystal and a set of electronic circuitry.

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Now a days, we are getting the smart technologies and we are calling them as the smart watches. Needless to mention that these smart watches are again mechatronics based watches. What are the features of these smart watches? We are adding the connection with internet, connection with outside world.

That connection with internet gives access to the world and this access is the potential capability of this smartwatches. Smartwatches are giving us message notifications. They are helping us for navigation through GPS technology.

What is GPS? Global Positioning System technology.

The smartwatches are helping us to arrange our day to day activities. We can schedule our work; it may be meetings or any other work. This scheduling again have the feature of alarms. The smartwatches are giving alarms to us on a regular basis. They do have the Bluetooth technology as well.

This Bluetooth technology is helpful for sending the calls or to receive the message or to get connected with the available electronics devices around without the internet. As far as technological point of view, the smart watches has various sensors. So, what sensors it has? The first sensor it has is accelerometers.

Accelerometers measure the body movement. This measurement of body moment helps us to track our steps and sleep patterns. Based on tracking our steps and sleep pattern,

the sensors are helping us to monitor your health conditions as well. The gyroscopes measures the rotation. If we turn our wrist, the phone display will wake up.

As we rotate our wrist, the phone is getting on, the display is getting on. Third, sensor it has is magnetometer, which enables to have the compass in our smart device. This compass also helps to track the motions. In addition to these three sensors in general, the smart watches do have barometric pressure sensor for sensing the pressures and ambient temperature sensor.

So, with this sensor technology, the watches are not only showing us the time, they are helping us to manage our day to day activities. They are helping us to maintain our health as well.

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Mechatronics based systems

- ❖ Modern CNC based production machine tool
 - The work table of a can now move in a step of few microns with high level of precision
- ✓ ❖ Domestic washing machines are now "intelligent"
- ✓ ❖ Four-wheel passenger automobiles: safety and comfort
 - Air-bags, parking (proximity) sensors, antitheft
electronic keys, comfort, entertainment,
communication etc. Navigation GPS

What are the other mechatronics based systems, as far as the manufacturing industry is concerned? In modern production houses or modern production systems, CNC is the best and simple example of the mechatronics based system.

Computer numerical control based systems are boosting the productivity of the automated manufacturing systems.

We can have a work table movement nowadays with a high level of precision. We can have the movement of the work tables with resolution in microns. In addition to that, the

mechatronic systems are helping the community or the society, particularly at domestic level: the washing machines which are the intelligent washing machines.

The mechatronics are helping us for conveyance, for movement. It may be a human being movement or commodities movement, or movement in the industry or factory, large scale or small scale. We are using various automotives. With the use of the mechatronics now, the automobiles are become more safe and they are more comfortable.

As we know that, there are a lot of features in the modern automobiles or automotives. These are; airbags, parking sensors, anti theft electronic keys, etc. The automobiles do have various comfort facilities; air conditioners, which are also intelligent, entertainment facilities and communication facilities.

So, in addition to that they do have nowadays the navigation facilities as well through GPS. So, mechatronics based systems are not only helping the manufacturing industry, they are helping the household domestics as well as in general the society. With this we are concluding lecture 2.

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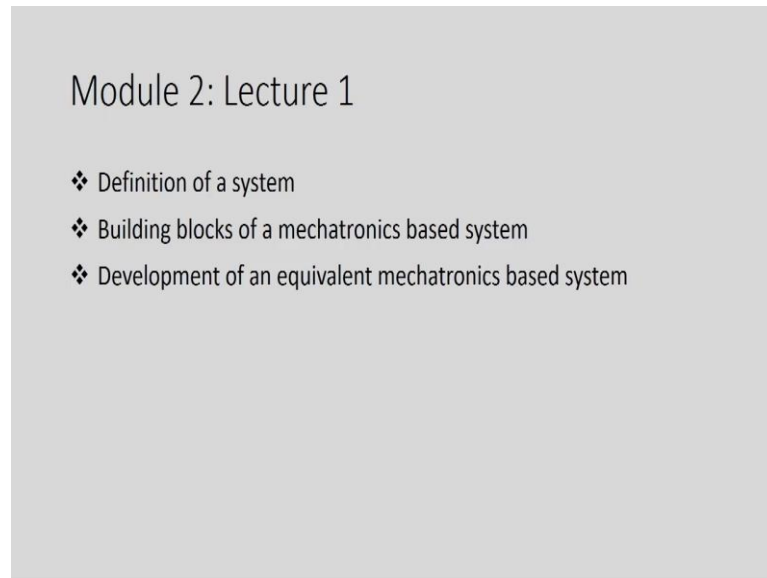
Summary

- ❖ Mechatronics: definition
- ❖ Disciplines of mechatronics
- ❖ Mechatronics for replacement of mechanics: wrist watch
- ❖ Mechatronics based systems

In summary, I would like to say we have studied the definition of mechatronics. We have seen various disciplines of mechatronics, then we had an interesting example of a wristwatch and how mechatronics is helping to replace the mechanics involved in a

typical mechanical watch. Then we have seen various mechatronics based systems which are used in the industry. Well, what will be in the next lecture; that is module 2 lecture 1.

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In the coming lecture we will be studying the definition of a system, what are the various building blocks of a mechatronics based system, . Then we will take an example to know how can we develop an equivalent mechatronic based system for a typical mechanical system.

With this, I thank you all.