INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

By Prof. S. Mukhopadhyay
Department of Electrical Engineering
IIT Kharagpur

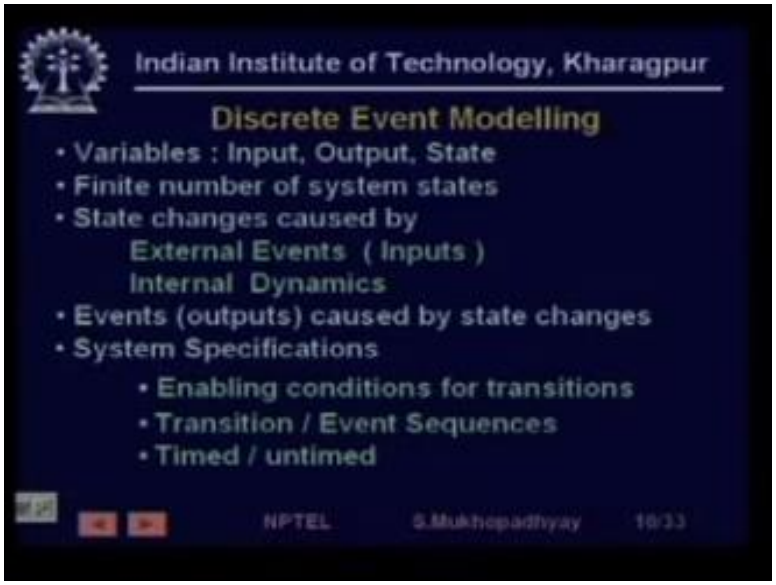
Topic Lecture – 23
Introduction to
Sequence Control. PLC. RLL
(Contd.)

Now in any control problem there is just like in analog control you have an open-loop plant and you have a closed-loop plant. So you have a plant by itself which is called uncontrolled or open loop, and you also have a closed loop plant which is controlled so, you know the control plant is actually has does not exhibit the all possible behavior of the of the open-loop plant, but exists but exhibits only a certain subset.

So there are so that is the job of the controller, so we have to specify very, I am talking about the controller design problem then we, there are two things that we have to do. The first thing is that we have to say what this system does by itself, what it is capable of doing, what it is capable of doing that we can get from its model. Then we have to give a specification that is of all these behavior we do not want sudden, some behavior.

So we want only some of them, so what is the behavior that we want for the controlled system that is called the specification.

(Refer Slide Time: 01:35)



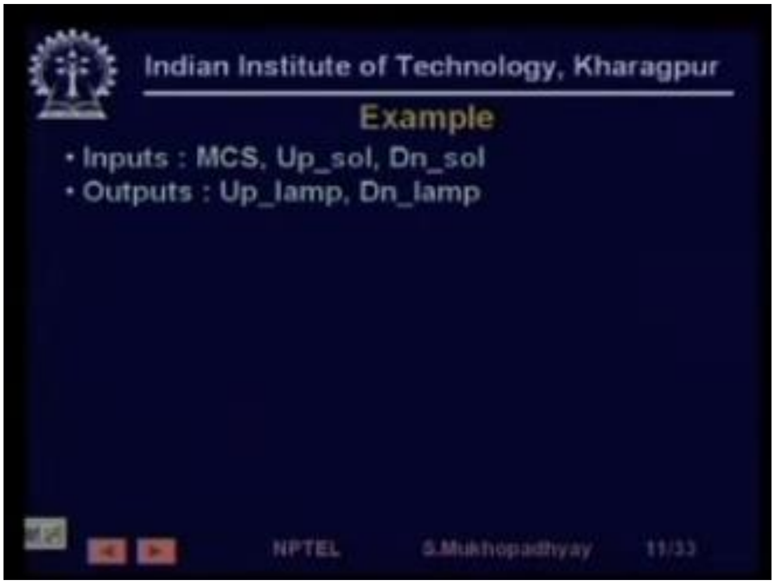
So this these specifications could be again stated in various ways for example, by transient transition even sequences which could be either time the run time or by, you know saying that giving the enabling conditions for some transitions that is, we may like to call some transitions in certain ways in the system. So in various ways system specification will be given and then the job of the controller design is to ensure that this system actually behaves like the specification system that is the problem of discrete-event or logic or sequence control.

(Refer Slide Time: 02:16)

So seems a bit abstract perhaps so let us see an example, so in our old example what are the external inputs, so depends on what you have you actually have to see. So maybe that you have in this system we may assume that either it has a, yet it has three external inputs one is the up solenoid, another is a down solenoid, and the third one is a is the master control switch, so these are the three input variables they are all external, external to the system.

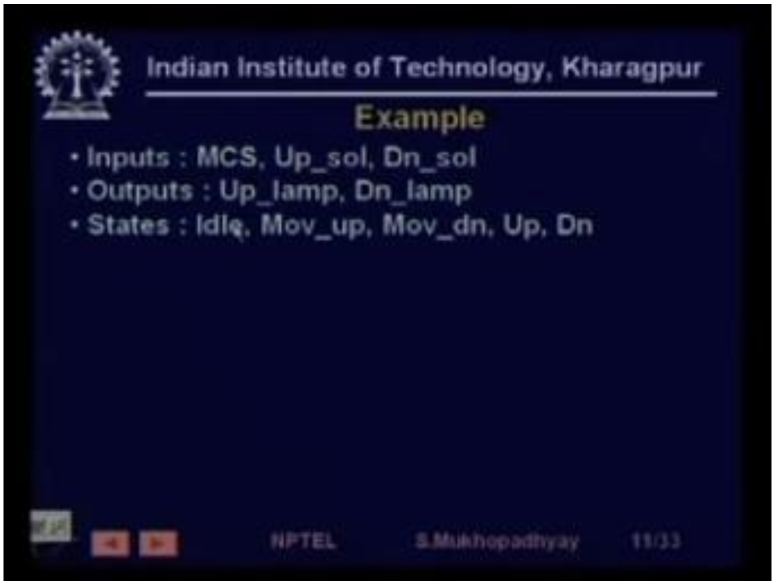
And each one of them for example, the up solenoid and the down solenoid maybe, may take two values either 0 or 1.

(Refer Slide Time: 03:10)



So what could be outputs for example, we could say that corresponding to limit switches we have some lamps. So whenever a limit switch is made we have an up lamp or a down lamp. So they are like indicators so corresponding to the limit switches we are having some outputs up lamp and down lamp.

(Refer Slide Time: 03:42)

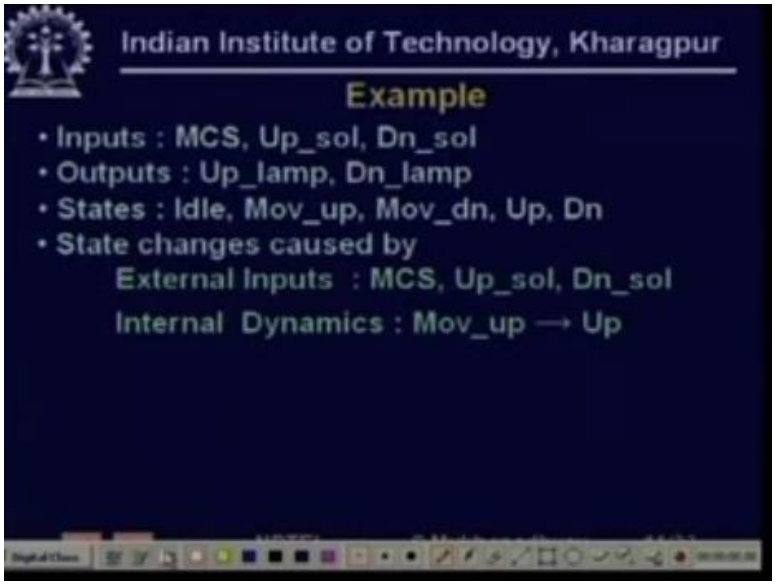


Similarly, the machine we assume is existing in three kinds of states, you know basically they are the motion states of the system. So the system could either be in the idle mode in which it is doing nothing, it is not in the active mode on among so we can say that this wherever the master control switch is one what is the effect of this external input that it will make the system from idle to any one of these.

And if it is off then from these any one of these it will actually come to the idle state this is what we are we are trying to describe the behavior of the system so otherwise among the active states the system could be either in move up moving up so it is moving up it is neither up nor down it is it the position of the press is neither up nor down neither down nor up it is somewhere in the middle but it is moving up.

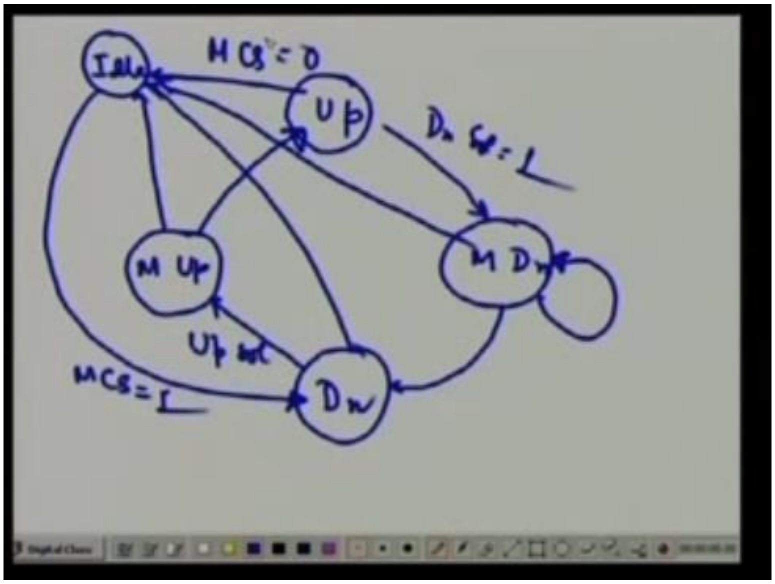
Similarly it could be moving down or it could be not moving but is in the up position or in the down position so we have chosen to model the system in such a manner so we assume that the system goes through such states now state change is.

(Refer Slide Time: 04:50)



What are the what are the typical state changes in the system for example we say that the external inputs are MCS up solenoid and down solenoid so if MCS is exercise system comes from idle to any one of these maybe it comes from idle to down and if the up solenoid is pressed and if the system is that is in the down state from there if the up solenoid state input is exactly exerted then it will go from the down state to the moving upstate so these are cases where a state change is caused by input we will presently draw a diagram similarly internal data for example let us draw this diagram.

(Refer Slide Time: 05:54)

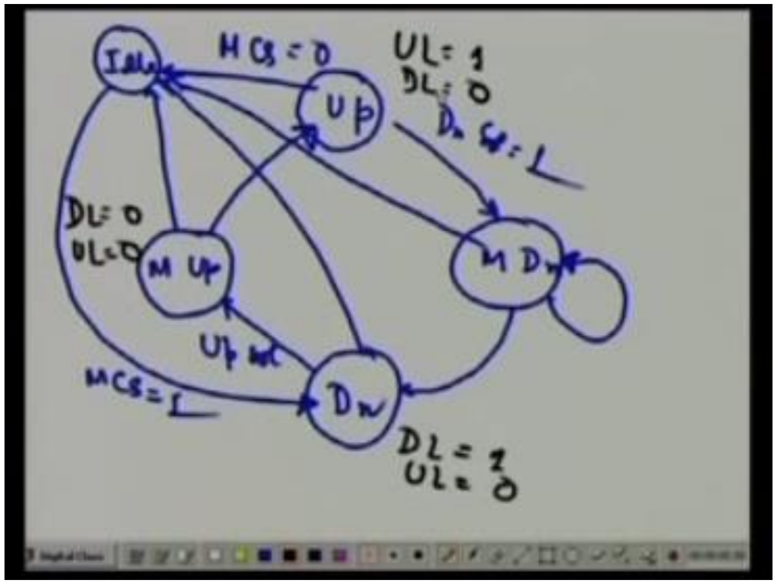


So the system we are saying exists in five states okay so maybe this is up this is down this is moving up and this is moving down and somewhere here you have idle so when you get so how does the system change states so you have from idle to down when MCS equal to one you are trying to describe the system behavior and then from down if you give a given up solenoid then it goes to the moving upstate from there by internal dynamics after sometime it will go to the upstate in the upstate if you give it down solenoid equal to one input then we will be moving down state and then by itself will come to the down state.

Right in between sometimes you know self loops that is you can you can write that in between if moving down is in this position it will it will be in the moving down state because it might take quite some time to for it to come down from up to down state, so and then we can say that from anywhere if you go to moving up then it goes to I if MCS becomes 0 at any point of time then it is it goes to the idle state.

So you know that we are we are basically graphically we are we are describing the how the system goes from one state to another because of various external inputs all because of internal dynamics, okay. And similarly we can say that for example.

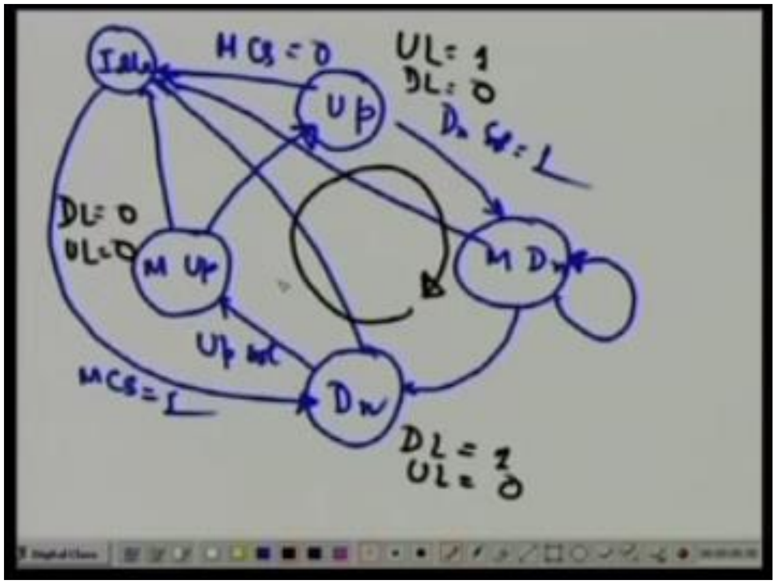
(Refer Slide Time: 08:20)



We can have we can have the various outputs so we have we have the two outputs so here we will have down lamp is equal to 1 and up lamp is equal to 0, similarly here we have DL= 0 and UL = 0 both are 0, here UL = 1 DL = 0 so these are the output so at the various states these are the outputs which are actually exercised and which may be also which may also be sensed by the sensor for the purpose of the controller.

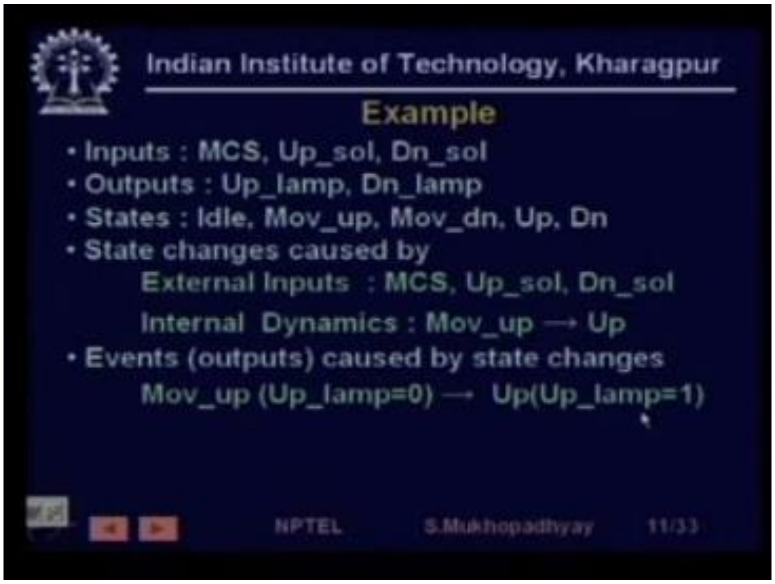
Now this is the behavior of the intrinsic plant, so now one has to ensure one has to ensure somehow that the specification that you give for the system that is actually first up solenoid E is exercised.

(Refer Slide Time: 09:11)



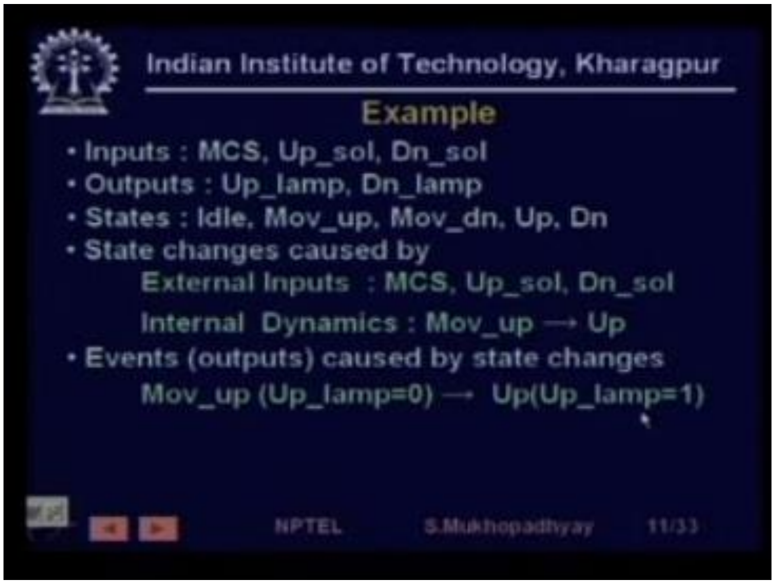
And it is held till it goes to the Upstate and then when it goes to the Upstate then the down solenoid is exercised so this actually this is the desirable cycle of the machine. So one has to exercise some device as to actually compute this when to apply this up solenoid and when to apply this down solenoid and it is the controller which is going to do that, so right. Similarly as we say that events are caused by state changes.

(Refer Slide Time: 09:57)



Because this we have already for example in moving up_ lamp is equal to 0 when there is state change from moving up to up, up lamp becomes one so state change is also cause outputs.

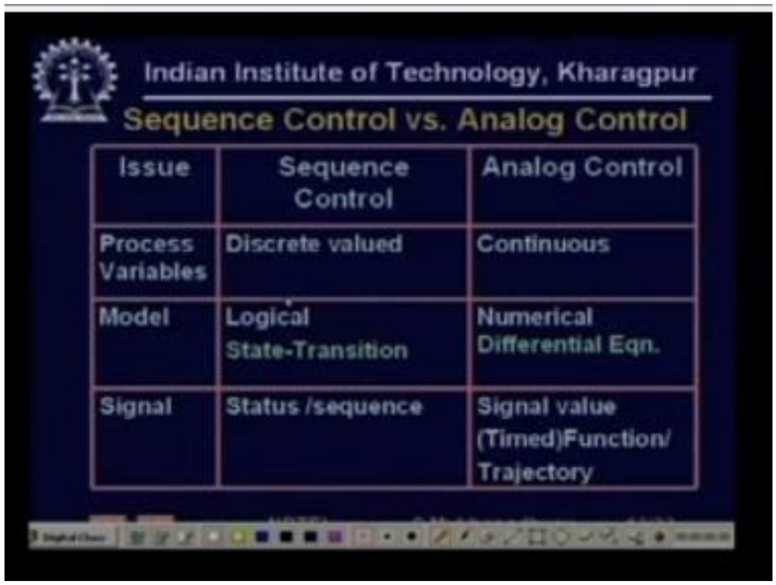
(Refer Slide Time: 10:13)



And a system specification as we said that the what is the objective of the machine the objective of the machine is that when the control switch is on at that time it must comedown go up come down go up this is must do a certain number of times till the MCS switch is put off if this MCS switch is put off immediately from there it must go to the idle state which we can describe what is the position of the place at that time whatever it is.

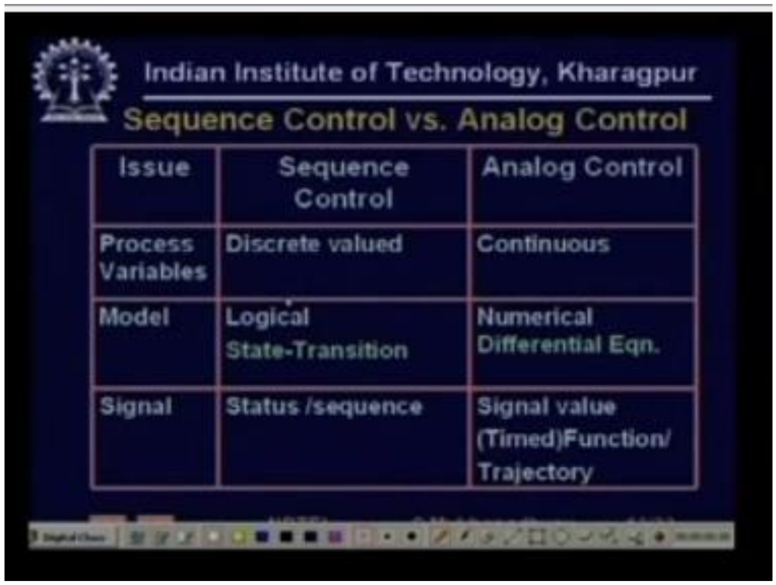
So this the system specification for this system could be an alternating sequence of up and down States so it must continuously go from up to down and down to upstairs, so having done this example.

(Refer Slide Time: 10:56)



We can take a look at some basic differences between sequence controller analog so firstly the process variables in the sequence controller discrete valued in analog their continuous valued the model as a consequence the model here is logical typically you know state transition kind of models while in analog control their numerical so you use either differential equation or you use difference equation. So use some equation with numerical equations.

(Refer Slide Time: 11:34)



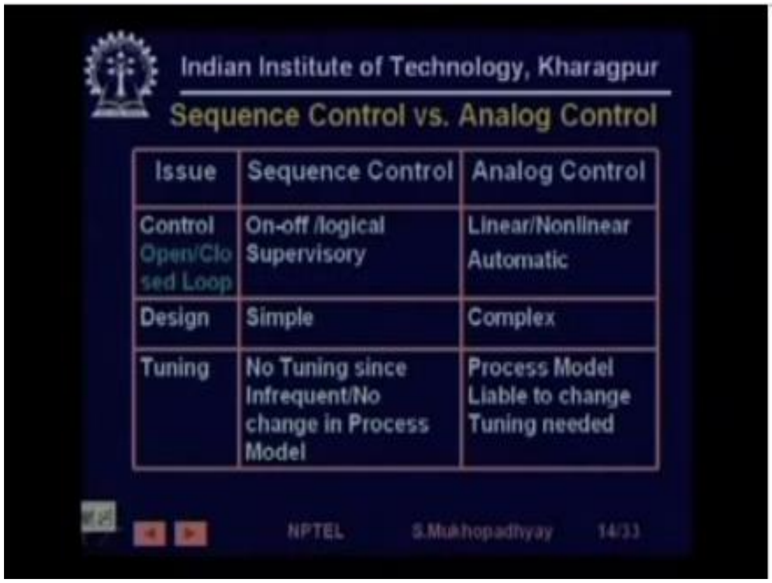
Issue	Sequence Control	Analog Control
Process Variables	Discrete valued	Continuous
Model	Logical State-Transition	Numerical Differential Eqn.
Signal	Status /sequence	Signal value (Timed)Function/ Trajectory

Similarly the signals generally the signals indicate some status so something is on off maybe a traffic light is either red or amber or green or we can we are interested in or they are sometimes you know signals are in this case sequence of symbols, so it goes from up down up down up down or maybe a maybe a conveyor for a buffer another part another part another part buffer empty another part another part.

So this these are you know sequences so another part is an event occurring whenever another part comes into the buffer and in between certain other event called buffer empty takes place so the signals bye-bye signals we mean the sequence of these events in the case of sequence control on the other hand we know that in the case of analog controls we want to specify actual trajectories you have to specify properties of trajectories rise time should be less than something.

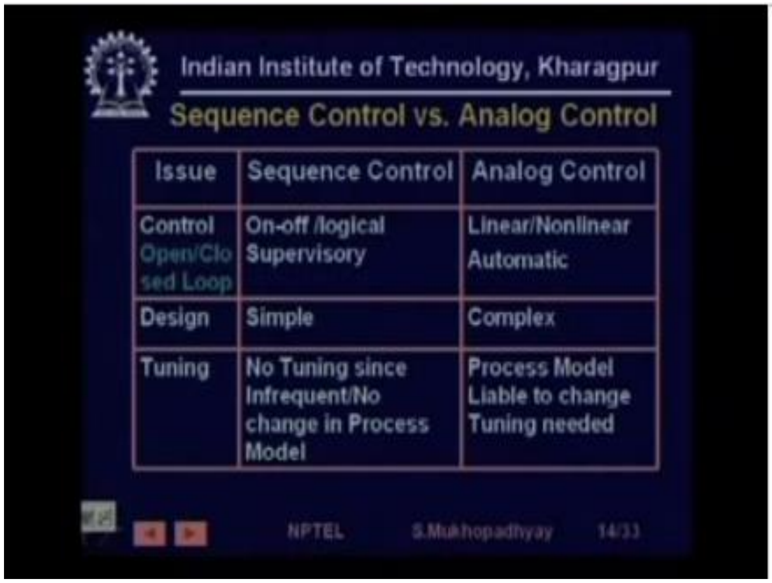
Maximum overshoot should be less than something so what are we trying to say describe some properties of the continuous trajectories in terms of their values while in the sequence control we are interested in either status of some signals and their sequences over time right oops similarly if you look at control.

(Refer Slide Time: 13:12)



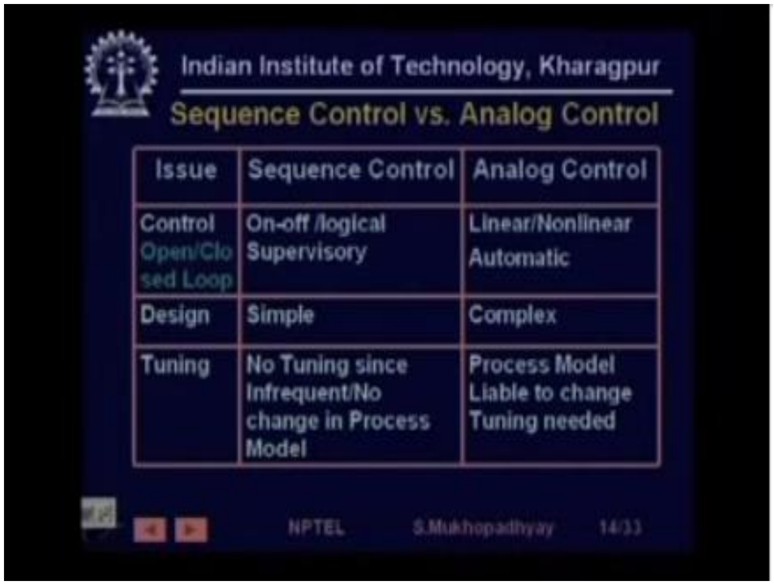
Control here also can be open loop or closed loop closed loop control is possible even for even for discrete event or logical control for example in our in our die press example we had those two limit switches so any controller that will work can take feedback of the state of the process using the limit switches and then decide the control input so in that sense logic control can also be feedback control right but.

(Refer Slide Time: 13:40)



It is generally on/off or logical kind of control and they are generally supervisory in nature that is there they are used to decide in many cases they used to decide the command sequences which are again realized in term in turn by the automatic controller when the automatic controllers we could have linear or we could have non-linear controllers and I mean which are actually working at an working at an automatic control level.

(Refer Slide Time: 14:10)

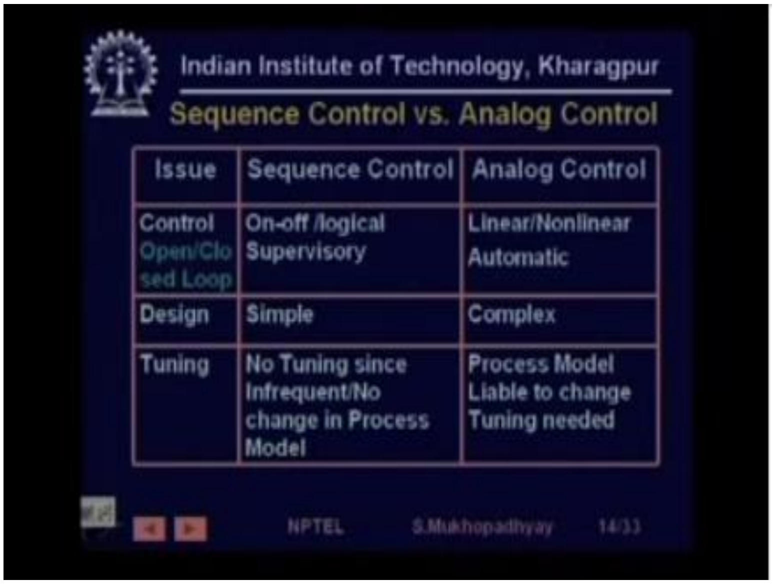


One very into design is of course you know since you have so much simplified the state space or the values that thing that signals can take into two three or four encodes I mean code so the models are much simpler so for example very linear non linear differential equations can then finite finally give rise to some you know five six seven eight or maybe 20 state finite state machine which is a much simpler model compared to the compared to the non linear differential equation so generally design is order of magnitude Cemal simpler than continuous automatic control designs.

One interesting thing is that tuning is generally not needed because the models are generally not physical they are actually you know abstract you know you information oriented models so unless you change the strategy of operating the plant the controllers will not be tuned while in the case of automatic control because you know systems heat transfer coefficient will change pipes will develop sludges inside I mean valve characteristics will change reactor characteristics will change.

So therefore automatic controllers continuously require tuning from time to time but these sequence control controllers they generally do not require any training in any tuning frequently because processes I am till you do not have a different automatic control system which will take different inputs or you have want to change the whole operating mode of the process there is no tuning of the sequencer logic control Lot to change.

(Refer Slide Time: 15:57)



(Refer Slide Time: 15:57)

So now we have perhaps understood the discrete event control problem now this is not new it is to be this kind of problems have been handled in the industry long time even before the even before the microprocessor came into existence so previously what people is to do is that people is to use relays and contactors to actually realize this kind of logical functions you know so that is why previously such logical functions used to be called relay logic.

In fact the name relay logic diagram delay logic ladder these are basically legacies of that past which are still being still being used of course they are gradually getting changed and probably after 5-10 years really little ladder logic may not be so relevant people will find on other graphical and other ways of describing these programs, but the fact that PLC is have actually as they started to replace the relay logic. And so why they are better than relay logic that we can see for example.

(Refer Slide Time: 17:20)

Regional logic is hard wired actually things are put relays contactors they are actually connected right while PLC is the logic is actually in a program so while if you want to change the logic little bit then you have a dismantle real logic certainly some parts and then again install a new one while in the case of PLC is because it is a microprocessor device all it takes is to change the program right.

(Refer Slide Time: 17:53)

Therefore these are you know radiologic is actually difficult to upgrade and maintained while plc is a very modular you can just take out one and you can put it another put another you can all the time put you know you can if you can expand your system very easily, you can put by new input you can then simply plug in, plug them into the racks without any problems. These are much more industry-friendly to upgrade and maintain.

(Refer Slide Time: 18:21)

Really logic is obviously much more limited in terms of size and complexity because you have to construct them using physical relays while in, while PLC is you can literally put I mean thousands and thousands of such logical functions merely in computer memories, so there in terms of speed size complexity and even reliability they are beating their relay counter, they have already bitten no question of beating they have already bitten their relay counterparts hands down.

(Refer Slide Time: 18:56)

So very old technology actually nowadays hardly anybody uses it in fact all the time anywhere you go to any factory you will find tens of PLC is all around. So what is the PLC, what does it do.

(Refer Slide Time: 19:16)

We have understood that it is a actually you know I looked at the internet and try to locate some definitions of the PLC and these are some of the definitions which I found on the internet. But somehow I did not like them, so somebody says it is a solid-state device designed to perform logic functions, solid-state device the term is actually not very communicative because it again because it described everything is a solid-state device even a small transistor is also solid-state device.

(Refer Slide Time: 19:54)

So solid state device designed to perform logical functions, what previously accomplished by electromechanical relays this is something which mentions the history. Devices used for control operation and integration of manufacturing processes. Yes, this is I like it more of manufacturing process equipment and machinery but it still it does not say what kind of device these are, it is very cryptic on the device side.

(Refer Slide Time: 20:21)

An assembly of digital logic elements this one element is very confusing what is mean by digital logic elements, designed to make logical decisions. So you know designed to make logical decisions and provide outputs, so I thought that I will find out my own definition. So I am calling it an industrial computer it is actually a computer which is used for industrial functions what kind of functions.

(Refer Slide Time: 20:46)

Which will accept inputs from digital or analog sensors which will execute logic for sequence control or analog contrary, in fact modern PLCs in many, many cases also contain capabilities for doing analog controls on the same device after all its a microprocessor so you can have several ate its speed is very high, it has lot of memory so why not also one since you are buying a device why not put the analog controls also, otherwise you will have to put by another device just for another controls.

So while logically they are different physically speaking one single PLC you know box can house even analog controllers in fact they do.

(Refer Slide Time: 21:36)

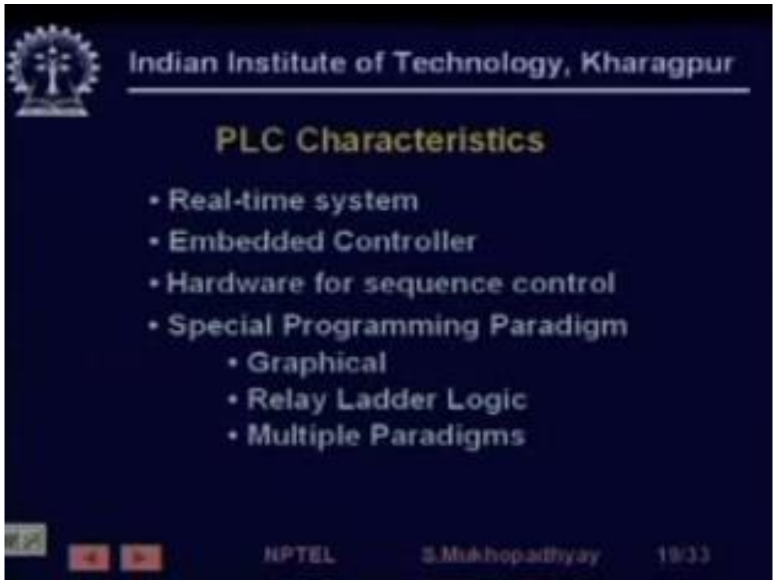
They could ride actuators or indicators or they could communicate with other computers. So what are these components its components are typical of a computer so you can have you know the sort of you know the backplane or you can have a power supply or you can have CPU memory or you have IO cards various kinds of IO cards are used so you can you can have digital or analog modules you can have some special purpose function modules like you know high speed counters which measure you know shaft angle encoder which measure rotational speeds or certain very fast and precise positioning commands can be generation modules PWM generation modules etcetera.

(Refer Slide Time: 22:30)

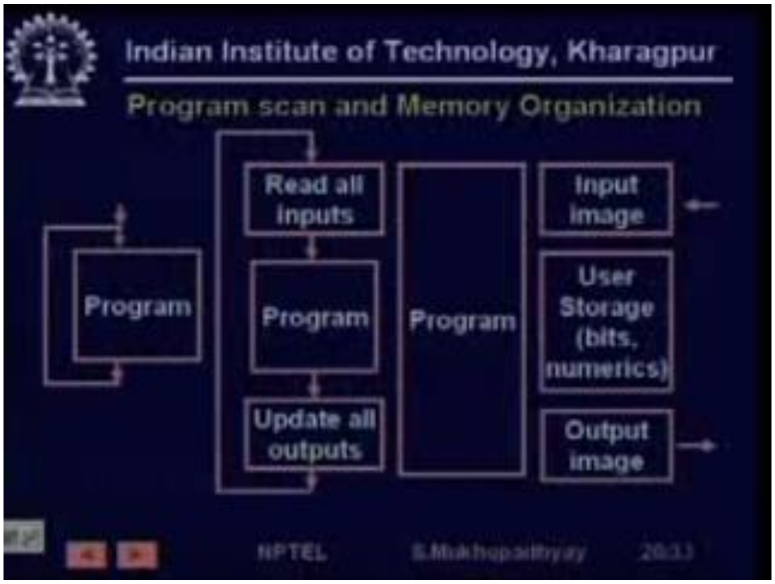
So various kinds of cards it uses obviously there is why adding and then you need two other separate devices with PLC mainly for you know for interacting with it one of them is a programmer using which you can download the PLC or you can see how variables are getting changed and the other is a man-machine interface which can display on the variables nicely so that people can see.

See how things are being controlled so actually what I will make a I have a little change of plan in this thing we since time is nearly up so I would skip the programming part in this lesson and then we will include it in the next lesson so I am going to skip the next few slides and then come to the come directly to the lesson review okay.

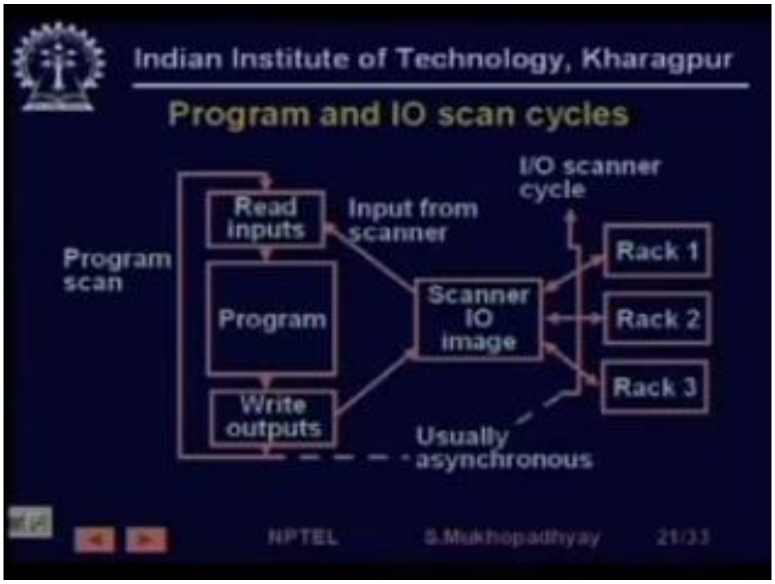
(Refer Slide Time: 23:25)



(Refer Slide Time: 23:29)

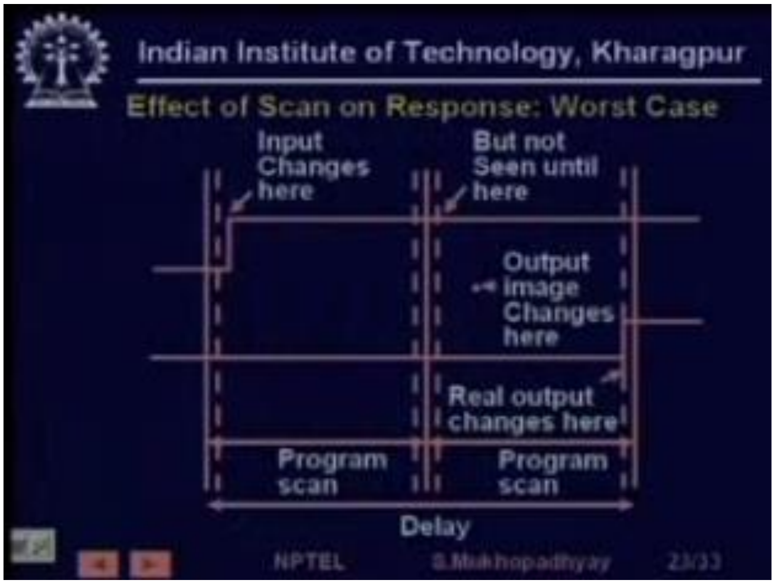


(Refer Slide Time: 23:30)

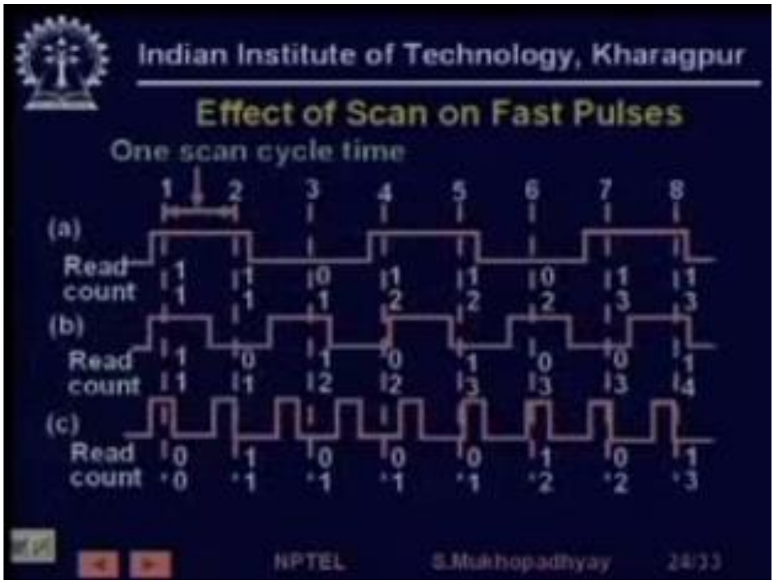


(Refer Slide Time: 23:31)

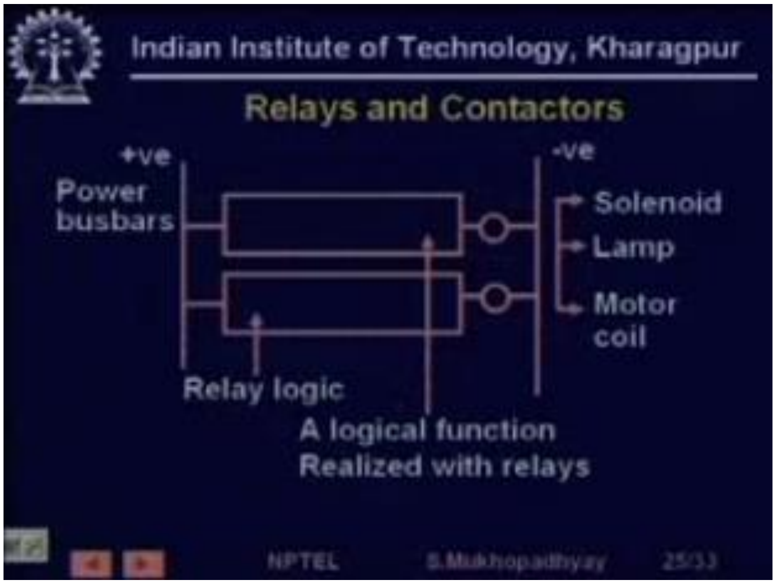
(Refer Slide Time: 23:32)



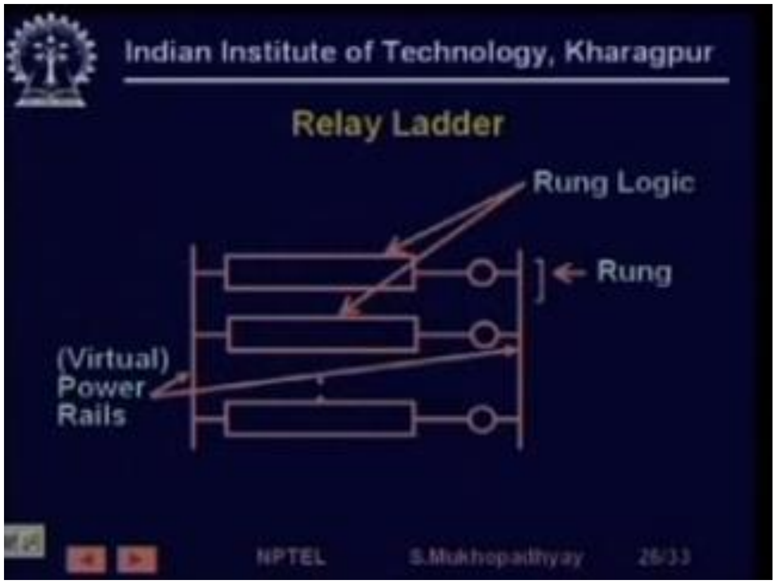
(Refer Slide Time: 23:33)



(Refer Slide Time: 23:34)



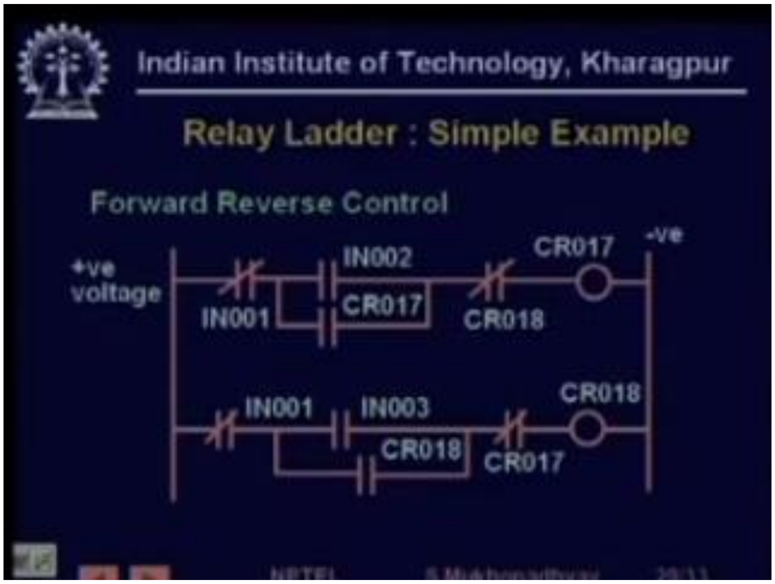
(Refer Slide Time: 23:35)



(Refer Slide Time: 23:36)

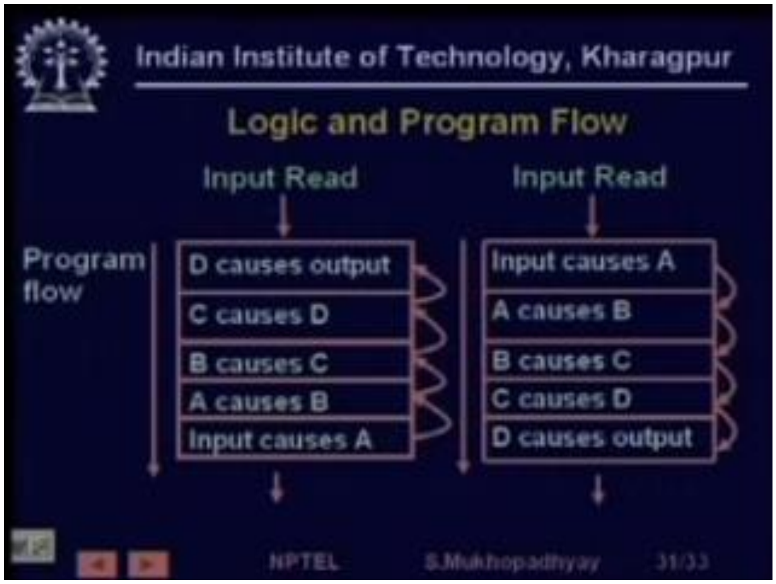
(Refer Slide Time: 23:41)

(Refer Slide Time: 23:42)



(Refer Slide Time: 23:45)

(Refer Slide Time: 23:46)

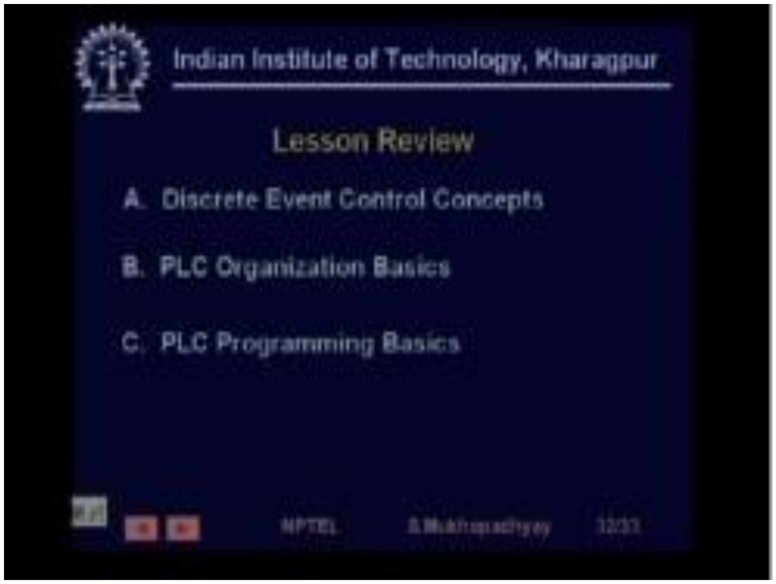


(Refer Slide Time: 23:49)

So all these things we will so we are going to see all these things in the next class which I thought I will include here but there is no time okay so yeah so we have the lesson review so what have you seen so in this lecture we have primarily tried to impress upon you the nature of discrete-event control problems you know the basically two things that there are some problems where analog controls are not required because they are too simple if you start a motor for a conveyer you do not need to control its speed just put full voltage whatever speed it will rotate let it rotate conveyor will move we are not interested in controlling the speed in an analog manner these are situations where analog control logic control is used.

There are another kind of situations where you are trying to design the control at a supervisory level so there is a whole set of sophisticated analog controllers existing and the moment you give them command you are you know that they will be they will realize them how they will realize is not your concern as long as you are designing at the supervisory level so because you are designing at the supervisory level your control problem is abstracted out so in that sense it is discredited. So we have seen that many such problems arise in the context of industry.

(Refer Slide Time: 25:03)



And we are going to in this module we are going to look take a look at how we are will handle them so we also define first introduced the program programmable controller we saw its we give it functional definition and we saw what it contains it is basically microprocessor based device with a lot of you know interfacing capabilities and this PLC programming basics we actually did not consider in this lecture and we will be considering in the next one.

(Refer Slide Time: 25:35)

So you have you could do several things for example you could find a typical industrial example take a let's see for example you can have see things like I will give you one example myself and you can think of other for example think of how to automate the do the overhead tank in your house using at using maybe some level sensor and a motor and a pump such that the water level never goes below a certain level so you are you are not you never surprise in the kitchen.

So try to model the system identify its input outputs and state variables develop its finite state machine model and then finally can you draw we you can do this now but you can but you can perhaps figure out that what when to how based on the feedback you are going to apply the different kinds of controls so construct an example of your own that is the assignment and,

(Refer Slide Time: 26:41)

That is all for today thank you very much you from the next class we will study on we'll start with the programming aspects of PLC's thank you.