Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Digital Switching

Lecture – 03

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Okay in the previous video what we had discussed was the Strowger a Strowger based exchanges and I talked about basic components like to motion selector and uni selector which are basic stuff by which Strowger or switches are built but remember those were mechanical systems and normally events they are mechanical there will be lot of veer entire in them you need to repair them very frequently and of course they can actually get faulty at the time when you do not need them to be faulty so reliability is poor and normally these kind of systems will have size was actually pretty large.

And there was another thing that we were using a pulsing mechanism so if I want to dial number 9 I have to send 9 pulses which will then lead to the setting up of these uni selector switches or two motions electro switches when to actually set of pulses were sent so the time was pretty large so people were actually already thinking to make it something which is going to be easier to maintain and less variant yet will be there so people came up with the idea of something known as crossbar switches.

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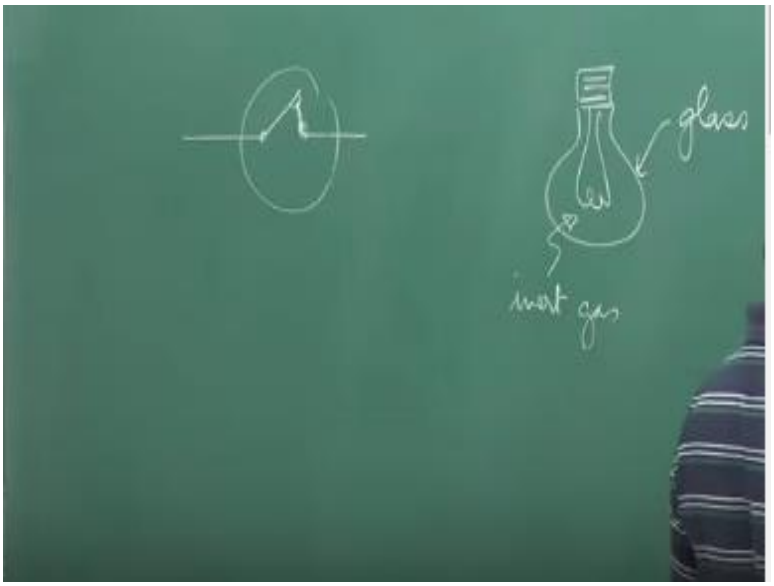

So essentially what we are trying is we are trying to set up a path so I need only a switch and these switches if they are actually in open air will lead to oxidation problem there will be sparks and all that thing so the way that it happened is we actually have been using incandescent lamps which were actually sealed in glass bulb and when this tungsten filament actually gets heated up it does not get oxidized because I'm actually going to put in inert gas inside or I am also actually going to do is I am going to use it at lower pressure so the oxidation problem will not be there I think same idea was taken that if I can accurate encapsulate this switch mechanical switch inside a glass bulb.

So oxidation will be much less so this switch can actually make a very good contact this contact can be made very good for very long duration for number of snaps for which this switch can be operated will be much larger and that start what actually lead to something known as cross point okay so this basic element of cross point now can actually be used to build a crossbar switch and of course this also leads to something known as cross point complexity estimation in the switches. So you will be actually let us look at this how this switch is going to be built.

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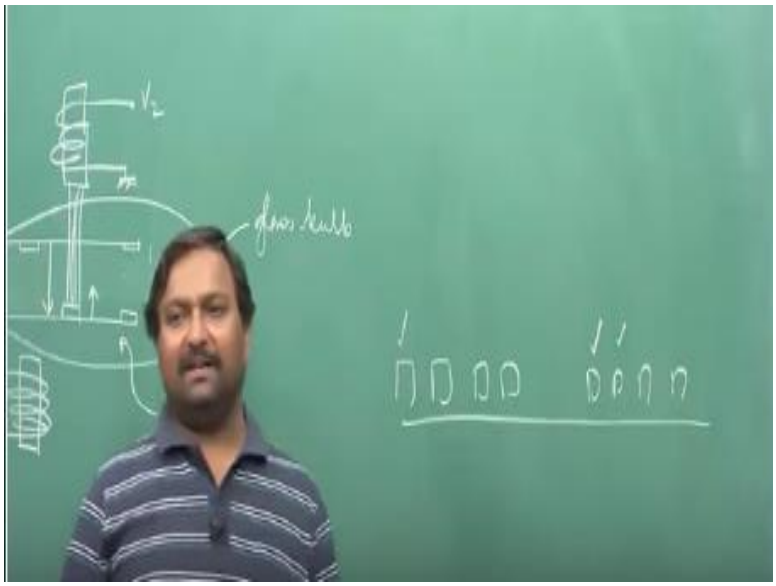

So mostly there will be cross point will contain two amps that was the basic structure and these are the two switching points so one point is being connected here the other path is connected here and whenever these two will actually move down so this move downward this moves upward so they will maintain make a contact like this and then the connection is there between the two arms but how this movement will actually happen so for this and of course now what we have to also do is we have to take care of this movement we also we have to also encapsulate this thing in a glass bulb.

So the dust particle will not actually interfere with the performance which was the problem with the mechanical system of Strowger this also is a electromechanical system so we will normally will encapsulate it into a glass bulb we can remove the oxygen from inside and you can put the inert gas or we can put anything which will avoid the oxidation of this cross points and they can operate for longer number of operations now before creating motion I can actually create these are magnetic paths.

So and then I can actually have electromagnet so which can be controlled by applying a voltage here similarly I can actually have the second electromagnet and the second control point is v_1 and

v_2 when both of them are being activated so in order to minimize the reluctance of this particular path it will pull up this particular arm upward this electromagnetic will pull this arm downward and the connection will snap in.

So technically there is a input there is an output and there are two control points when both of them are in excited state you will actually get a snap connection which will work okay which will lead to the setting up of the connection this was the basic thing now how to build up a switch with this so important thing is that I need not send the pulses I can send even DTMF multi-frequency key pulsing kind of phenomena whereby a number I can actually define various frequencies the two set of frequencies which are there.

So when I do set these two frequencies I am sending number zero when I do this and this I am sending number two so depending on which pair has been sent I can determine what is the number and that actually can be used to snap different cross points I did not do this giving key pulses the which will lead to what we call movement of the arm of a Strowger so that kind of phenomena is not required.

So this is what is the basic element so the basic structure of a cross point will look something like this a crossbar will look something like this.

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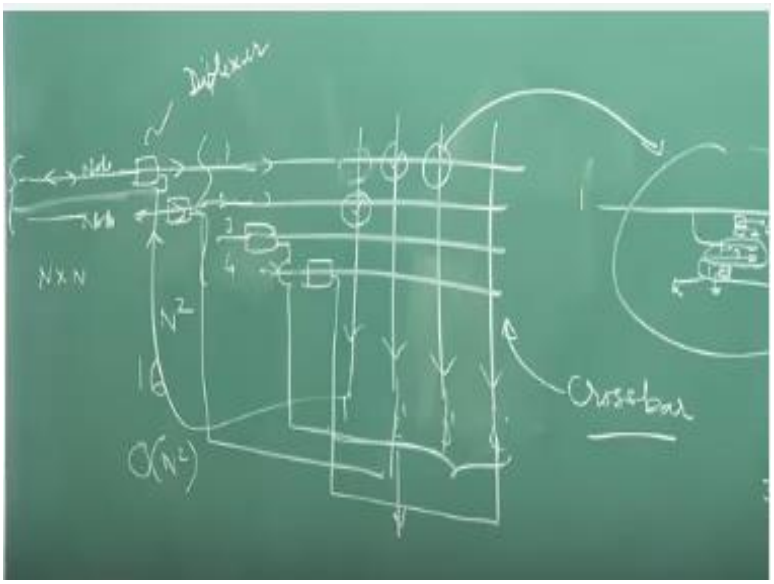

So this is the output arms I can connect the input arms also here so I am connecting 1, 2, 3 and 4 to 1‘ 2’ 3’ and 4’ and these wires where actually we will put the cross point so this will look something like this so whenever the cross point will snap the connection will happen and 1’ can get connected to 3’ this is the point n13’ so this is what it looks like and of course you will also have the electromagnets.

So this is the what we call a column control and this is a row control so when both of these are excited the connection will snap and 1’ one will be get connected to 3’ okay so that is what basically is how this cross point is being used at each one of these point where the two lines are crossing or two buses are crossing.

So in total number of cross points which will be required in this case will be 16 4^2 4 x 4 okay so in general for a n x n switch I require number of course points which will be equal to n^2 so complexity of the cross points will be $0(n)^2$ and of course there has to be logic whenever you dial number this number has to be trapped there based on that some analysis has to be done and then a logic will activate the cross points which will cause the setting up of the connection okay so we will do this particular basic controls of a switch maybe in another video.

So this mechanism is what is known as crossbar so I need to set up cross points for setting up your connection from the input side to the output side and normally these are unidirectional or these can also bidirectional okay. So if it is analog communication this can become the analog switch if it is a digital signals being transfer it becomes a digital switch okay, but it is it has capability of doing both.

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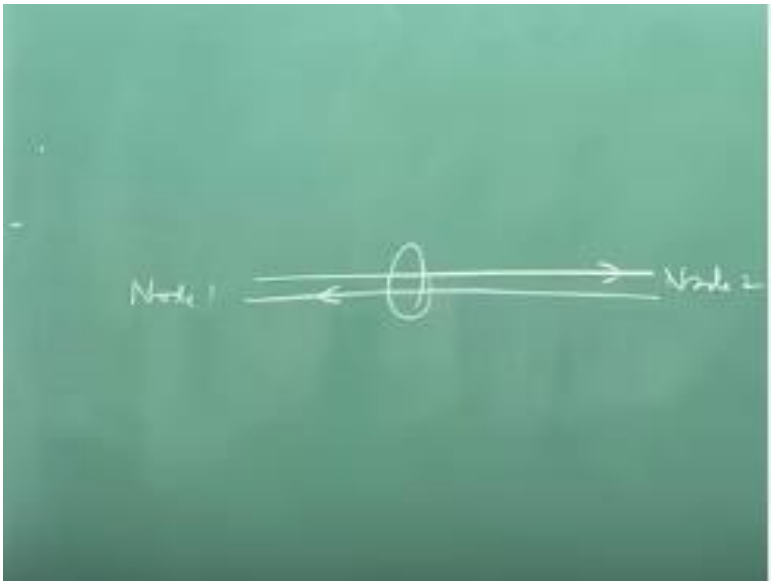

So if you want to set up a communication between node 1 and node 2 so node 1 is connected to one so this means a communication path has to be set up in both the directions.

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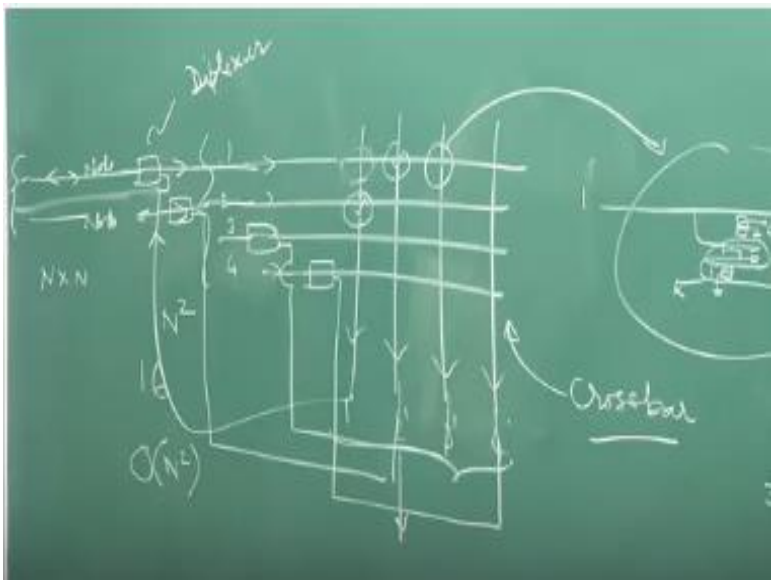

So which actually implies, that from node 1 I will set up a path 22' so which is going to node 2 this is the node this is also coming from node 2 remember so I need to setup this and I to set up to 221 so I need to snap this as well as this, so these two has to be snapped for setting up if connection between one and two because we always set up a bi-directional connection, okay. And normally the structure because I am taking this switch as a uni-directional system these are the input these are outputs.

I need to use something called diplexer because when I am connecting to node 1 I am actually connecting these two wires to the node 1 and normally there is only one wire pair which is going to the node, so on which the transmit and receive both will be happening. So we will be actually connecting something known as diplexer, so diplexer only splits incoming and outgoing signal so this is a signal going into the switch this is coming from the switch.

And this is a bi-directional, so same thing will be happening for four node 2 and I can do the same thing, for node 3, this for node 4. So I will have a bi-directional links going to the switch and this is basically how the switch will look like, so input and output are actually paired ports

which belong to the same node, so setting up a communication from 1 to 1 prime actually does not make any sense.

Because they are both connected to the same node okay, so this particular unit is what is known as diplexer, in digital systems of course we do not have a diplexer kind of thing this for analog telephony so analog signals which are coming in this direction analog signals which are going in this direction, these are basically two voltage waveforms going voltage waves which are moving in opposite directions.

Now if inside of this switch these are not unidirectional because those will be required if is a digital signal but if it is the analog signal I need not because what I need to do is I need to make a connection between this wire and this wire for a communication to happen, so if there is everything is bi-directional in that case number of required cross points will be less.

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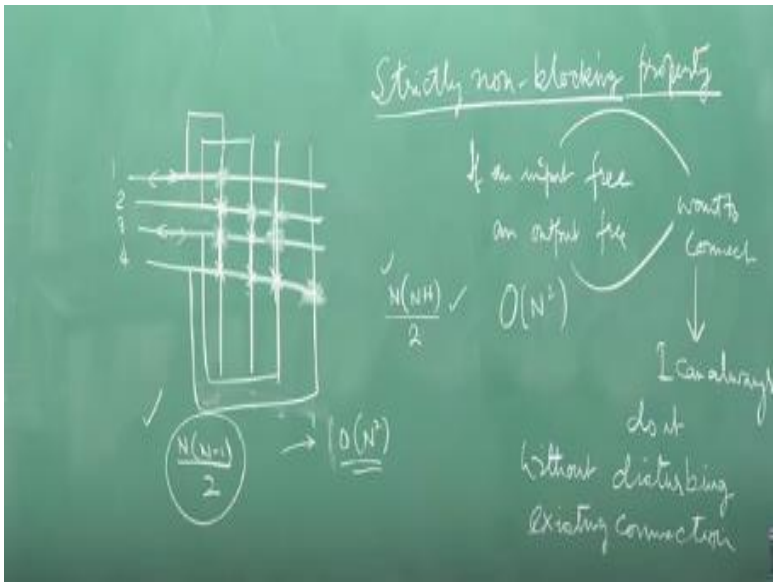

So let us see how actually it will happen, so in a bi-directional system so one wants to connect so these are actually meaningless in a sense because this can communicate in both ways, one is not going to talk to one but if one wants to talk to two, so too is this line, so these are only points

which are going to be used so that the communication can happen between one and two so I can snap in these two.

If between the connections has to happen between one and two, okay. If correction has to happen between now one and two I cannot use this wire remember I have to use some other wire, okay. So in that case if I want to make a connection between one and three I may not choose this I may choose these two snaps, so the routing between one and three is happening here if I want to do one and four I have to do the snap on this particular thing.

So one can get connected to any one of these actually but what about to if to once you get connected to one this route is already available only I need to bother about that too can connect two three and four, even if one is connected to any one of these things so I can actually have cross points which are available, so two can connect two three and four via this route, so one it can always connect through this.

So one is connected to anybody but two Can is to connect, so I am actually creating a special configuration whereby any earlier connection need not be dismantled for a new connection, so if 1 and for example 3, 1 & 4 are being connected via this route, so I can use the next one to connect two and three, so this to actually can be used in that case, okay. So then I will be requiring only these many that is what we will actually think.

Actually you do not need these ones if I actually short these lines with these input lines if I connect this one here permanently there is a permanent connection between 1 and 1, 2 and 2, 3 and 3, 4 and 4, so this is already connected to for this is already connected to three, the second one is already connected to two one is connected to one so these are straight lines so I only require cross points at these points, okay.

That is it and that is good enough for setting up of the connection anywhere, okay. So 3, 4 I need only bottom half or I need only the upper half diagonal half for making up the connection, so number of cross points which will be required in this scenario will be n x n – 1/ 2 and see two

combinations which will be required, if I even use these particular cross points in that case I will be requiring if I am counting even these.

Which of course is not required if this permanent shorting is not there, then I require n x n + ½ but both ways you can actually see my complexity is growing with $O(N)^2$ so this actually implies S/N number of nodes are growing number of cross bones required actually grows proportionally to the N_2 or it always remains what is it spring upper bounded by N^2 actually, so which is what is the cross points characteristic.

Ideally I would like to have if the number of these are growing it should be linear if it is possible, so you will be looking into this what actually best we can get, so either I will get this I will get this if I use even these cross points I will count in that case this one if I do not count this diagonal once only the bottom of or the only upper half this is a one if I have the complete cross point when all cross points are being used.

This unidirectional configuration which I was talking about I require N^2 in that case, so in all the cases $0(N)^2$ square will be the complexity, now there is one very important property which I would like to now put in explain this is known as strictly non blocking property which is being maintained by this switch, okay. In this switch if an input is there if an input is free the two conditions an output is free and I want to connect these.

I want to connect these two I can always do it without disturbing the existing connections. And that is what we known as what we call as strictly non blocking property, so if I want to compare any other switch design it should also be strictly non blocking then only I should compare the complexity of cross bar with that particular switch. Now question is how I am going to do the control.

I have already explained there will be two control points which are required both of them need to be excited together, so that the connection can snap, okay. So what I can do is I can join these R and C together and there is only one control point. So I require 16 control points for a 4/4

switch, in general for N/N switch I will be requiring N^2 control wires, so depending on this which particular cross point has to be activated.

I will activate one of these lines, so different pairs will be combined a different point of time, in this case how many cross points will actually be required, one cross point consumes one pair of nodes. So technically N/2 cross points will be required at any point of time remaining will not be used.

So you will have N/2 divided by N^2 that will be the cross point utilization, so I am going to use too many cross points but all of them will not be used all the time for making up the connection. So maximum utilization for a cross point will be n/2 divided by N^2.

Which is 1/2N so as switch size actually grows the switch utilize the cross point utilization will go to 0 this is something which is actually not good and of course a cross ventilation will go to 0 that I cannot control because I have to have those many cross points but my control wires I am going to have any square control wires this is also utilization of the control wires, can I take care of this, okay.

So can I actually make because I require only N/ 2 cross points to be activated. So I can probably work with less number of control wires I require in generally linearly scalable number of control wires so one option is that we define a common control line which will control all the column controls of these cross points and we will do it for the complete switch and similarly we will do it for the row and let us see how we can build up a control line.

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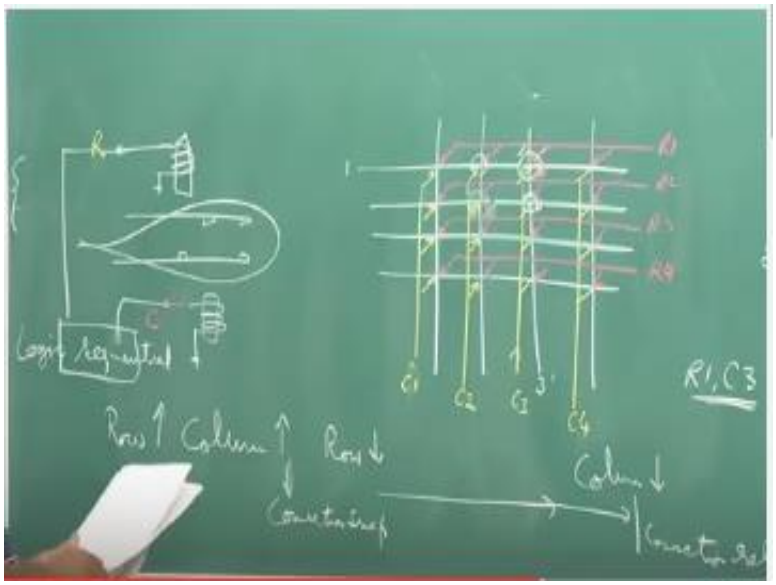

So we have again this 4 by 4 crossbar so I will take are d colored chalk can use it for giving drawing the control lines so i will have a control line for this so this is actually now exciting that electrode which was their electro magnet so this one is the column this one will be the row so I am actually drawing this red color this is a control line I call it c1 C_2 C_3 C_4 there are four control lines n similarly I can actually have a row control lines column control lines sorry this should be row actually.

So the column control lines will be these so whenever I want to snap a cross point for example this one I need to now activate our one NC three and then this cross point will get activated any connection will be set up between one and three prime okay so of course we can actually tweak with this thing and do it for this kind of configuration of cross bars also okay but let us take it in general sense here the same thing now can be walled even for the other kind of stuff so is it going to create a problem.

Or is it okay so we need to ask this question so let us try to set up two different kind of connections in see if this can work out so let me see if I say i want to set up the connection. Say one to two prime and 2 to 3 point there is a connection which I want okay i am not talking about

a bidirectional thing I am talking about unidirectional connection so for me one to two prime and 2 to 1prime are two different connections normally they will be done in pairs for voice communication for data communication they can be done one by one at a time so if i want to set up these connections my common sense is that i need to have depending on the which particular row i am going to activate.

I will choose that row and I will choose a corresponding column so I want to go from Row 1 2 column 2 so I should activate here row 1 and column 2and this will cause one to prime so this particular connection will get snapped okay so let me remove this because I need and for this one I will say I will do our 2 and C3 fine you do our 2 and C3 and this connection will snap in but our 1 C2 is fine r 2 C3 is fine but there is a R2 R2 and r 1 C3d is also combination is possible when you are activating these lines.

Which actually means R1 C3 R1 C3 means this particular connection and R2 and C2 move this particular will also get snapped in I never wanted this is undesirable this undesirable this is also getting snapped so this is scheme is not going to work though my number of control lines here are not two ends which will give me a complexity of a linear complexity so I have to use some technique so maybe one idea is that if we do it in an order say I do row first and then column then only the condition can snap in if I had to column first and bro later it will not.

So if we do that so I do this thing first and then I do this one so now what are the valid combinations which can form so i did R1 C2 so this connection snaps then I did our to C3 this connection snap but I also did r 1 and C this also is a valid combination because sequence is retained for this sequence is not as per our requirement so if I put a logic here that in this sequence the activation should happen I will set up 1 2 prime to3 prime and i will set up 13 prime also.

So this will be happening and this I will be able to block so I am successful at least partially now but this undesirable thing is also happening what to do with this so this scheme of maintaining a sequence that row first in column second will also not work so we have to now innovate further so what we can do is and of course we can also see that here we have to now carefully observe

that it is possible that one input can connect to multiple outputs this is a valid combination we call it a multicast we call this kind of configuration.

As a multicast configuration then you have only one input nu only one output to be connected this is known as uni- cast connection when one input is connected to all the outputs it is known as broad cast connection okay so since these switches can also operate as multicast and broadcast switches I need to look into this actually then this is a broadcast so we can actually see that one input can connect to multiple of these output.

But is it possible that one output can connect to more than one input this is not possible I am not going to mix the inputs coming from multiple outputs and put them into one output that is never going to happen so I think for holding on to the connections so which one of these lines have to be done my control lines are good enough to hold on to the connection I do not need row line to be activated.

So I can now use a sequence a time sequence to encode which particular cross points need to be activated so the logic which actually can be used which is which the clue comes from here is that I will activate the row first I will activate the column the moment this is done my connection will snap our connection will be made and if I am now put down my row the connection will still remain on it will not go off and now this whenever your column goes down then the connection closes connection will go till this Patrol time connection is free.

So I can use this encoding and this works beautifully so let us see how to work in this case and then we will do an example so for this particular case let us see how it going to happen I will set up this one so I will set up R_1 I will set up C_2 the connection will snap so one to two prime connection is on here okay this will start and then our one goes down connection will remain and then after some time you will have our two goes up this connection will remain C_3 will go up at this point 2 to 3 prime will get activated.

Remember there is only C_2 which is activated here and R_2 as R_2 C_2 the problem which was happening this R_1 C_3 so R_1 is down it is no more up so when C_3 goes up our one has not gone up

first so 1 3 which was happening here this also has been taken care of so 1 3 cannot snap in and we are 2 2 will also not snap in R_2 C_2 because this connection order actually has been changed so and then of course you put down R_2 the both the connections will keep on going when you will put down your C_2 will go down this will be closed whenever your C_3 goes down this connection will be closed no confusion for holding on to the connection I only need C_2 and C_3 that is what I was telling only these control lines which are required.

So I can actually use only two and control lines and row an end column and only just for holding on to the connection and control lines are good enough because there will be n outputs which can be busy and if for example now you will ask that how I am going to implement a multicast so if you want to have a connection where one is going to communicate to two prime 1Prime and for trying it is going to be simple you will put R_1 up then we will put C_1 C_2 up you will put C_1 up and you will put C_4 up you will find that one to 11 and 14 connections will snap in so at this point 12 at this point 11 in at this point 14 will snap in.

And then you can put R_1 down they will remain as it is till the time the corresponding control lines are maintained up the moment you actually put C_2 down 1 2 prime will go the moment you put C_1 down this will close and whenever you put C_4 down the last one we go that is how you will implement a multicast configuration and of course now you should ask that how I am going to implement this logic this particular sequence mechanism.

So what I need to do is I am not going to use simply these electromagnets I will actually use a logic hairs and it is not a simply a commuter logic it is going to also be dependent on the state the earlier state so it is going to be a sequential logic which have to be built so whether the switch was in ON state or OFF state and what is my current input that will decide what is going to my next state so that logic actually can be used to do the computation okay and build up a logic which will operate on this particular switch.

So I am just going to give you the logic table and then I will discuss this logic in the next video as a solution to the assignment this basically it becomes an assignment first for you that how this

logic is built so you do the logic thing after looking at my state table diagram and the logic will discuss later on or maybe this can be given as a solution to the assignment.

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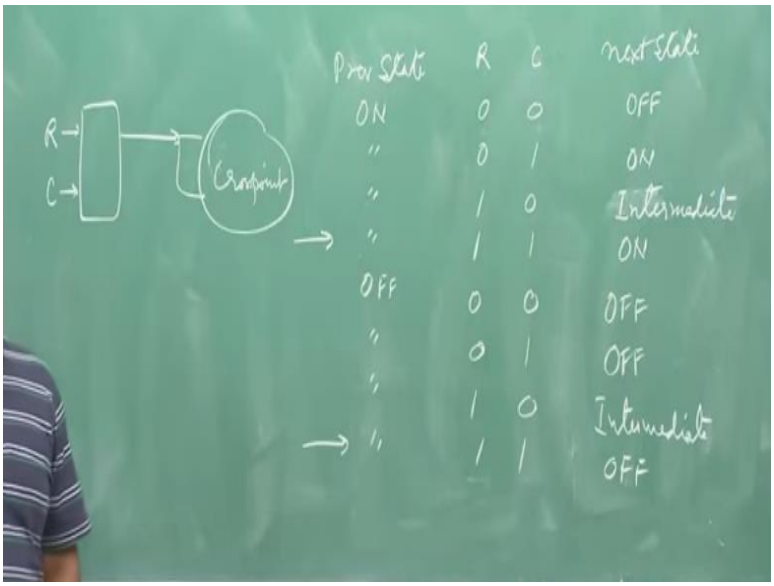

So you have R and C which are coming there is a logic which will maintain the state and this is the control line which actually goes to both the electromagnets of the cross bar cross point so this logic has to maintain the state so you have to essentially once you get the table you have to then use a logic to build up a sequential diagram sequential logic gate so you have to maintain what is the previous state okay what is the input R and C and what is going to be the next state.

Only this need to be identified okay so you can be either in ON state or OFF state so if you are in ON state you will have only four possibilities and you are in OFF state you will have again the four possibilities let us see what is going to happen with this we will decide the next state based on that so if you are in the only state both R and C goes to 0 next state obviously should be OFF the connection should be unsnapped or should be released on means the connection is stabbed or connection is maintained.

If connection in the ON state control line is remains up this is immaterial actually whether it is 0 or 1in both cases it should remain on okay if it is an on state my control line goes to 0 irrespective of whether row is high or low does not matter this should go to the OFF state okay so normally in my operation this issue has not come because I have not put my column down before the row has garage row has always gone down first it was R_1 C_1 both are going up and then R_1 going down.

But this actually means a different scenario but logic circuit has to take care of all kind of situations so when it is an OFF state both are 0 it remains an off when it is an OFF state it cannot go to ON state actually okay because only column has gone first so this has to be off when it is off row has gone up this actually means you are in I have to also maintain it third state actually here.

Because I have to maintain that row actually has gone first so I will call it ON OFF an intermediate state so let me put it that way so if it is ON this remains this goes to OFF this remains to ON this goes to OFF the column has gone down in fact this goes to the intermediate state okay if it is ON I cannot go at this both actually cannot both simultaneous over this remains ON.

Right this normally will not happen you have to always go to an intermediate state okay because from intermediate you can come to this so you will have intermediate and then there is ON state it will remain on if it is OFF it will remain OFF this is OFF remains of this goes to intermediate state it is OFF if both by chance goes to one this actually is not possible because you have to win the intermediate state before you come here.

Okay this is possible because from intermediate you can go to ON state by having 11 okay and then if there is a 11 is being maintained you will remain in ON but this cannot happen okay so but technically if this is somehow happens simultaneously this should remain in OFF state this cannot go to ON okay because C might have gone might have gone become one first and then R might have become second then this will remain in OFF so other way around you always go to first to the intermediate state.

And then of course the third option is intermediate state which I can write here based on this logic built on this table actually you can build up a switch.

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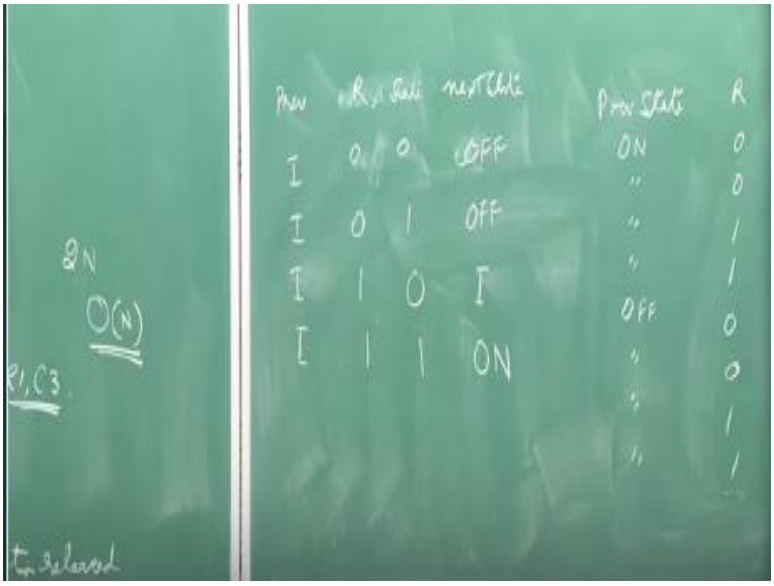

The previous state is I should put R and C and see the next state so if it is 00 so you are in intermediate state means the R has gone up and if I it goes 00 it next state will be 0 OFF okay so you are in this state 10 you cannot actually move from 10 to 01 so both again is flipping simultaneously so this is invalid thing so from 00 you have to go to 10 and then to 11 okay so you cannot go from 01 to 10 to 01.

So normally this will not happen but if it this happens simultaneously this should be OFF okay but this actually an implementation will never happen this you are in intermediate state you will remain intermediate state and if you are in intermediate state both goes one you will become ON in that case so that builds up the complete logic and I can actually build up a state diagram for this so this will become more clear so that is what the logic which has to be built here and this will become the full cross point module which will be used in the crossbar switch.

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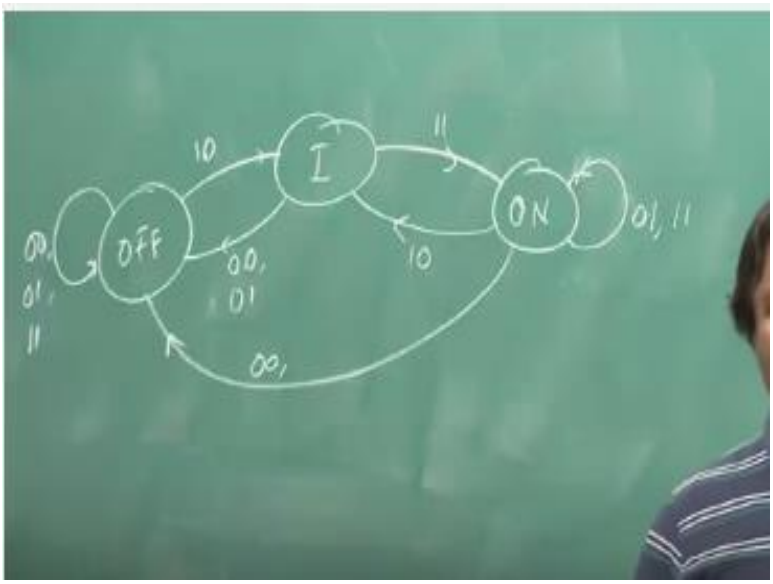

So you can actually you will be in either OFF state so you can apply from here you can figure out that if you are 00 you will remain there if you are actually 01 you remain there of if you are actually going to have 10 then you go to the intermediate state from where you can go to ON and if there is 11 remember both the inputs cannot go simultaneously from 00 to 11 so but 00 if it can goes to 01 it remains in OFF state then it goes to1 then it will remain there itself okay so you have to go through 10 sequence first to go to intermediate.

So you can actually go from 00 you remain in OFF then you apply 01 you remain in OFF then this one actually has gone one the next one this goes to 1 so you're now applying 11 you remain in OFF because of that so when you are in I state you can actually apply 00 you will go back here you apply 01 okay which both the digits which are getting flipped simultaneously which is not possible you cannot go from 10 to 01 at the inputs so they both they actually one of them has to flip so 10 only one bit will be changing at any point of time.

But this actually means it has to go to a 50 it happens so and if it is 11 then it will go to ON state okay and in ON state if it is 00 and if it is 01 so basically r has gone down that is what it means so it remain in the ON state and if it goes to10 somehow from 01 if you flip to 10 then you go to

intermediate state or if you go from 11 to 10 then also it comes to the intermediate state okay and of course then if it remains 11 it will remain in ON state so that what becomes your state diagram which has to be used to build up the logic to control the cross point.

So next video we will try to see that number cross point complex is 0 n^2 now question is if I want to build up larger and larger dimensional switches what problems I am going to face we look into that and we will see how we will go logically to the multistage interconnection networks.

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