Digital Electronic Circuits
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Lecture – 48
Algorithmic State Machine (ASM) Chart and Synthesis of Sequential Logic Circuit

Hello everybody. We have been discussing sequential logic circuit design, synchronous sequential logic circuit design and we had seen in the previous classes with example how state transition diagram is used to define the problem statement and then from that state transition diagram, we arrived at logic circuit. So, today we shall look at another way of representing the problem statement which is Algorithmic State Machine chart ASM chart.

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And we shall look at how what are the basic components of it and how these ASM chart looks like for Mealy Model and Moore Model.

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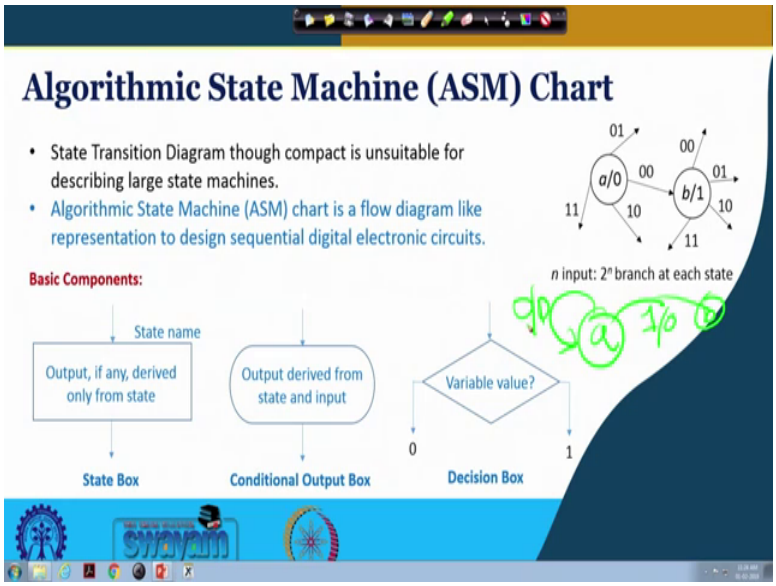

Now, as you understand from the name itself algorithmic state machine chart is something which is associated with the algorithm. The way we write codes or pseudo codes so, it is a flow chart like representation. Now why what is the usefulness of it? So, if you have noticed a state transition diagram, the one that we have taken as example. So, far every state depending on the input , we were having paths leading to other states ok. So, if there are 1 input we had in those example says a. So, say 0 to 0, it was here and 0 to 0, it was here and then 1 output was 0. It was going to b ok; this was the kind of thing right.

Now, imagine if instead of one, input there are two inputs. So, what would have been the cases? So, the case would have been would have been something like this from a, four such branches coming out from b, four such branches coming out and the circuit the state transition diagram would have been very complex and inconvenient to read and to make out something out of it. And if the number of inputs even is more so, you can understand that for 3 input. There will be 8 such paths coming out from one particular state ok. So, algorithmic state machine gives a more readable kind of representation ok. It may be bit long you know flow chart like you know representation, but it is easier to read and make appreciation out of it.

Now, what are the basic components? The basic components are this is called state box ok. So, in the state box, you have the state name. So, that is there and for Moore model,

you can understand the output that will be derived solely from the state that you can write down with the state box ok. For Mealy model, we will not write anything inside. Next is conditional output box ok.

So, this is another block another symbol that we shall be using. So, here we are writing the conditional output. So, output derived from the state as well as the input ok. So, this is the corresponding symbol; of course, it is useful for mealy model. So, it will not be useful for Moore model and finally, the important part of it is called decision box ok.

So, based on the input variable that input variable x y z whatever so, we will be taking a decision. So, the flow chart will move either in the direction of input sample as 0 or it will go in the direction of input sampled as 1. After sampling we found that the input is at value 1 or input is value at 0. So, one of these two paths will be taken ok. So, these are the three important components basic components. Now let us look at one example where there are more than one inputs ok.

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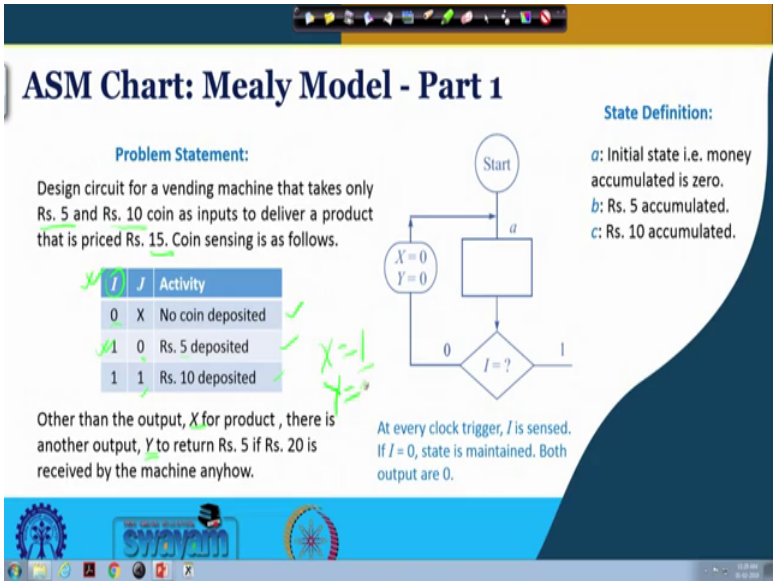

So, two appreciate the how ASM chart works. So, in this particular example, the problem statement that we have placed is design of a very simplified basic vending machine not all the features are there, but some of the basic features are there. So, it delivers only one product and that product is costing rupees 15 ok. So, that is what you have seen here and the machine is such that it can accept only 2 types of coin; one is that is of rupees 5 coin, another is of rupees 10 coin and to sense the deposition of coin; the coin that is deposited

in the machine ok. So, we have got two sensors as sensors are such that I is the sensor which just senses if anything is dropped or not ok.

So, if I is 0; that means, nothing has been dropped ok. So, that is no coin has been deposited right and when I is 1, then if J is 0 right. So, that is a kind of sensing mechanism which differentiate between differentiates between 5 and rupees 10 coin rupees 5 rupees 10 coin ok. So, if J is 0, then rupees 5 is deposited and 1 is J is 1 rupees 10 is deposited; is it fine. So, what is the other thing important here is that it has got 2 output ok.

So, one output is whenever your one is customer is depositing the coin whenever rupees 15 is reached ok. So, one output X; one output X is made one which is otherwise 0 ok. So, that accentuates that actually you know this is may be a spring or a magnetic coil by which a product which is a kept in a spring loaded manner. So, that is getting delivered to the output placeholder right.

So, that is X right, another is another output is there which is Y ok. If by any you know sequence the machine receives rupees 20. So, rupees 10 and then again rupees 10 has been deposited because two coin of rupees 10 was there with the customer ok. So, in that is in that case other than the product rupees 5 5 need to be returned. So, that is what your Y is. So, Y is otherwise 0 when Y becomes 1 ok, then rupees 5 is returned ok. So, there is a particular place where a stack of say rupees 5 is there. So, something goes out and then rupees 5 comes out and it is again return to the customer ok. So, this is the way the machine has been expected to machine has been is to be designed and is expected to work.

So, these are the two inputs right I and J and the outputs are X and Y. So, now, let us see. So, for that we are begin with the state definition and we also prefer plan to work out a Mealy Model ok. So, Mealy model so, the first thing that we decide is a is initial state that is no money has been accumulated ok. So, money available with the machine is 0. This is the initial state right b is rupees 5 has been received, c is rupees 10 has been received rupees 15 is not required because it is a Mealy model.

Whenever rupees 10 is there if it receives rupees 5, it will deliver a product. If it is receive if it receives rupees 10, it will deliver a product as well as rupees 5 will be returned and at b if it receives rupees 5 ok. That means, it is going to next state that is c

and if it is receiving rupees 10 ok. It will deliver a product and come back to the initial state ok. So, that is why rupees 15 is not required ok; is it clear.

Now, a since it is Mealy model right. So, we begin with the very first step. So, after the start the beginning initial state is a that is no coin has been deposited and the digital circuit the clock that is there that could be much faster than the human customer who is depositing the coin right. So, there may be many such clocks going on by between two successive deposition of coin ok; deposit of coins ok. So, there will a case that it is sampling I whether a coin is deposited or not ok. So, it will find that this is 0 no coin has been deposited. So, what should it do? It should remain in state a only is it ok.

So, that is the path it is showing and this is the conditional output box. If it is at state a and no coin has been deposited of course, output should be both the output should be 0; is it fine. So, that is if it is 1 so, some coin has been deposited. So, you have to take a decision right or the machine has to take a decision. So, initial c that at that time if it is 1, then it need to look at what is the whether it is J is equal to 0 or J is equal to 1. So, another decision box will come right.

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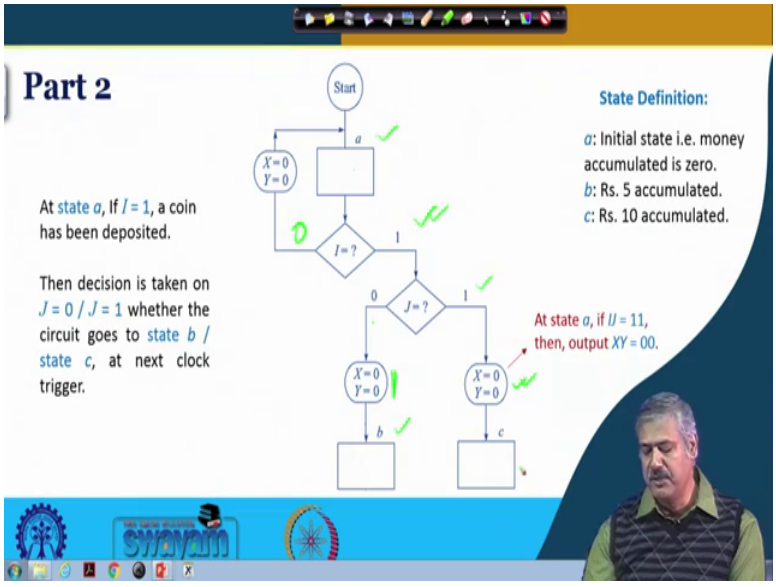

So, this is what you can see over here. So, at a I is equal to 0 if it is 0 it is output of course, is X is equal to 0 and Y is equal to 0 it remains at a. But if it receives 1; if it senses it finds that it is 1 then some coin has been deposited. So, depending on J whether 0 or 1 it will be rupees 5 or rupees 10. So, if it is 0, it is at state a rupees 5 has been

received no output; no output means no product delivery or rupees 5 returned. So, that is why these two are 0 0 and it goes to b that is rupees 5 ok.

So, this going to next state is synchronized with the time. So, a is there for one particular clock cycle and then next clock trigger it goes to b and it will be therefore, one clock cycle. Similarly when it comes if it is 1 so, it is rupees 10 a 0 and rupees 10 still it is not a case of delivering the product. So, no product is delivered that is what we can see over here and it goes to state c it goes to state c which signifies rupees 10 has been received is it fine ok.

So, next what we will it do it? It is either in state b or state c if 1 coin is deposited. So, initial examine each of the states right.

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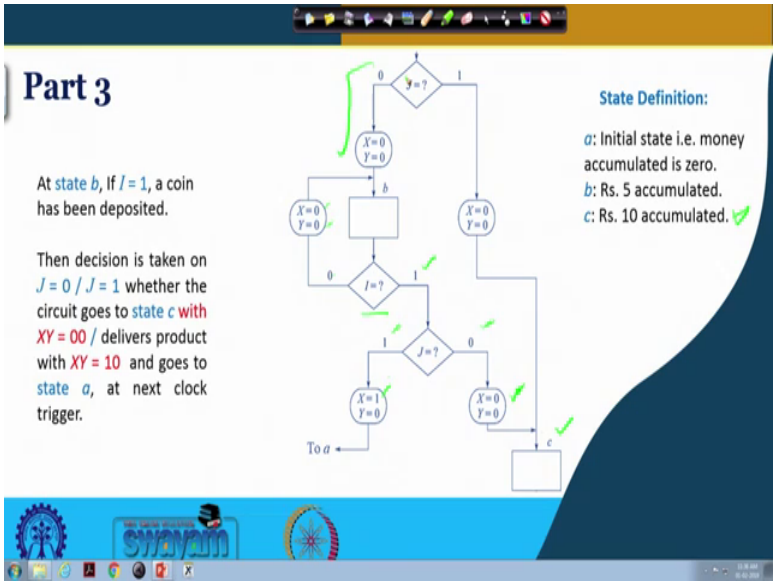

So, if it is at state b, consider the rupees 5 has been deposited just before it. So, it is at state b ok. So, we are following this path. So, we have following; we have following this path; you have come here right.

Now, as we said human response is you know slower than the machine the clock that is what is expected here that is usually what you will see ok. So, there will be cases before the next coin is deposited to get the product. So, it will find that no further coin has been deposited. The earlier coin that has been deposited that has gone that has been taken away of course, in that particular place where the sensing mechanism is there ok.

So, this is 0 right; I is equal to 0 so; that means, no coin has been deposited. So, what will happen? So, it will remain at state b and no product will be delivered right or no coin will be returned. So, that is what you see here; X is equal to 0 and Y is equal to 0 right. But at state b if I is equal to 1; that means, a coin has been deposited then there were two choices for J is equal to 0 and J is equal to 1; two things will happen ok. Now if J is equal to 0; that means, earlier there was rupees 5 and another rupees 5 has been received. So, rupees 10 still it is not the case of delivering a product. So, X is equal to 0 or Y is equal to 0 or rupees 5 of course, it is not reached rupees 20 ok.

So, rupees 5 and rupees 5 now it is rupees 10. So, it has to go to state c; state c signifies rupees 10 has been received is not it and at state b ok. When rupees 5 was there if I is equal to 1 and J is equal to 1, what does it mean? Rupees 5 and rupees 10 has been received ok. So, that is a case of delivering the product. So, that is why X is equal to 1 and Y is equal to 0 and after that what we will do what will the machine do? So, the machine will go back to its initial state ok. So, that next time the same customer or another customer deposits you know appropriate amount of money ok; another product can be delivered. So, that is why it is written to state; a is it fine.

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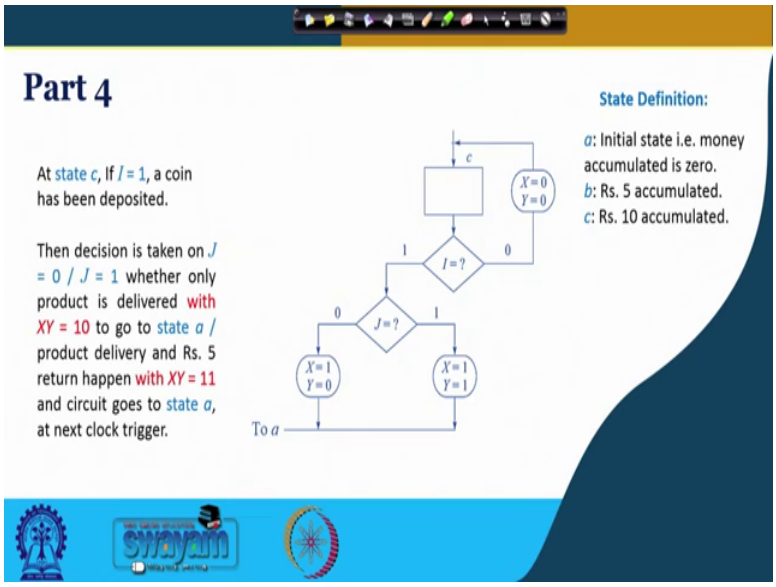

So, we shall examine now what happens when it is at state c right. So, when it is at state c right; that means, rupees 10 has been received so far right. Again there could be cases few cycles before the next coin is deposited ok; no coin is sensed in the particular place

holder where the coin is going after being deposited ok. So, this I is sensed to be 0 ok. So, no product is delivered and it is remaining at state c fine and if I is equal to 1 right, then either rupees 5 or rupees 10 has been deposited which depends on J.

So, again a decision is to be made based on J see. If J is 0 what does it mean, rupees 5 has been deposited. So, rupees 10 was there and rupees 5. So, rupees 15 has been received ok. So, within that clock cycle itself right the product X is can be delivered by making X is equal to 1 right and Y is equal to 0 and it goes to state a, but at rupees at state c whether you go via it deposit of rupees 10 coin or rupees 5 and rupees 5. After that you are depositing a rupees 10 coin; order does not matter. From c if you find a rupees 10 coin has been deposited so, what is the total worth of what has been the these coins? So, total value is rupees 20.

So, product is delivered and a coin is returned a rupees 5 coin is returned by making X is equal to 1 and Y is equal to 1 and then it goes to the initial state to deliver the next product ok; is it fine.

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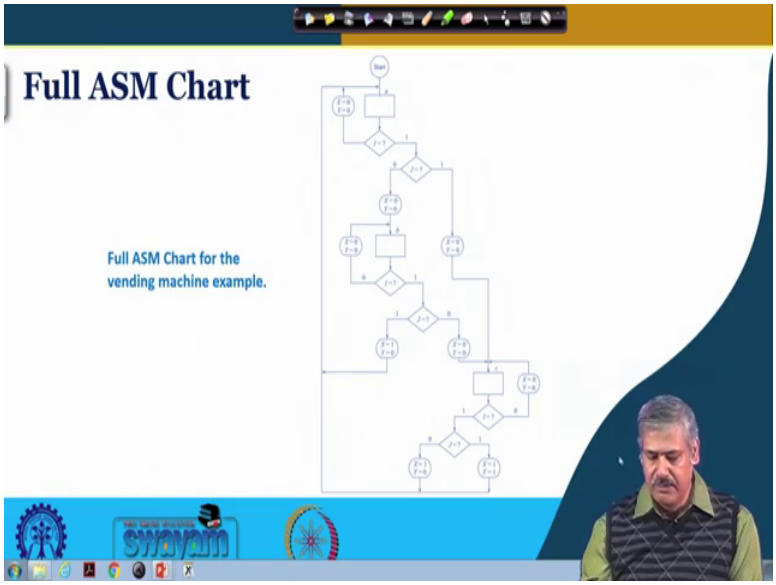

Now, if you bring all those components together so, this is the full ASM chart of that machine that we have just discussed is it fine. So, compare to state transient diagram, it is less compact you can say that was more compact and all. But you can see it is more readable, you can logically move from one particular instance to another one particular state to another state along with time and with those decision box is you examine what

are the input and based on that either you deliver the output or do not deliver and move to the next state ok. So, that gives a flow chart like or as I said algorithmic you know representation fine.

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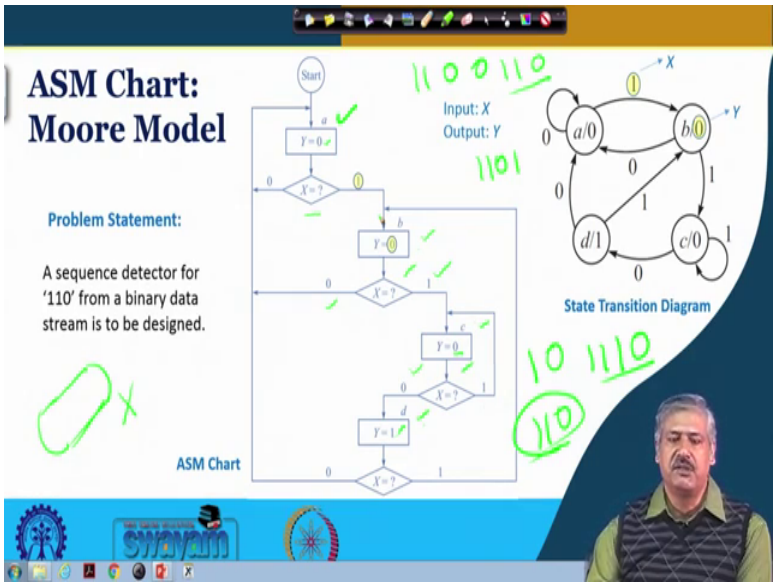

So, we would now would like to see the a this Moore model how it would appear in the ASM chart right and for that let us consider the example that we had seen before ok. So, it will be easier for us to compare with the state transition diagram also right.

So, the example if you remember, we have to detect sequence 110 from a binary data stream. So, there is only one input ok. So, for this one pin input, we have named it X right fine and then again what we will and the since it is a Moore model, output will be generated from the state right. So, conditional output box need not be required. So, the this kind of this symbol need not be required and these state output will be return within the state box right that we discussed as in the first slide in the basic component related slide right.

So, initialize with state a that is no bit is properly detected. So, the state definition remains the same as was the previous you know discussion as was there in the previous discussion. So, it is state a and at that time output is 0. So, no bit is properly detected ok. So, Y is 0, so, Y will be 1 when all the three bits are detected properly fine ok.

So, then it is looking at X. So, if X is equal to 0 and if X is equal to 1, now it is synchronized with the clock. So, these input you know these data that is coming is synchronized with the clock right. So, X is equal to 0 it will stay in a ok; that means, no bit is has been detected properly and if X is equal to 1, it will come to state b; that means, 1 bit has been detected properly right. One bit has been detected properly means still it is a it is not a case of generating the output. So, we will discuss about these ULO circles and all that highlights that you do not consider for the time being ok

So, it is Y is equal to 0 right. So, when it is at state b, again it receives an input data input bit which is X. So, if X is equal to 0 so, after 1, you have received 0 and you have to detect 110 so; that means, you have to start all over again. So, it is going back to state a that is initial state and if it receives 0; that means, two bit has been detected properly; received properly, so, that is state c.

So, since it is still two states that are detected properly so, it is output is Y is equal to 0 fine. And then at c again if verifies the input X whether it is 0 or 1 if it is 0 ok; that means, all 3 bits have been properly detected ok. So, it goes to state d and generates the output Y is equal to 1 as long as it is in state d output remains at 1 ok.

But if X is equal to 1 so, 11 then again you have received a 1. So, after that if you can get a 0 then it will be a properly detected. So, it goes back to c its ok; if it 1 is received it goes back to c. So, this is at being at d and at that time if X is equal to 0 right after 110. If it receives a 0, it goes to a because again it has to find out 110 ok, then next bit will be obtain, but if it is receiving a 1 ok; that means, first bit of the next sequence has been detected properly. So, it is going back to b; is it fine. The similar to the state transition diagram, but we are following the ASM chart route to get the corresponding diagram for the given problem statement.

Now, if you compare; if you compare what you can see that in the state this was the state transition diagram Moore model for this particular problem that we discussed in the earlier classes ok. So, this is the X the input that you see here right. And when it is 1 so, this is X and when it is 1 it is taking this path and it is going to b. So, it is going to b; if it is 0, it is going back to a. So, you can see that is staying at a ok. So, this is connected to this X 0 and Y and at b these value has 0 right inside the state transition diagram state that circle that we had written right. Here it is we are writing in the state box ok. So, that

way it is similar and but as we said if the number of outputs number of inputs becomes large so, this becomes a bit you know four such branches will be there.

If two inputs ok, then that is not you know read easy to read for state transition diagram is representation ok. So, ASM chart preferred for that ok.

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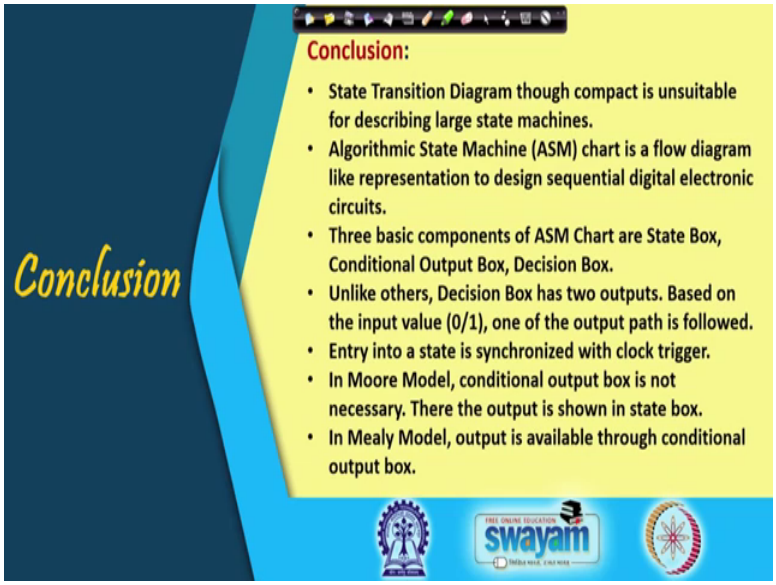

So, with this we come the conclusion of this particular class state transition diagram though compact is unsuitable for describing large state machine. This is what we have noticed ok. ASM chart is a flow diagram like representation which is useful for designing

sequential digital electronic circuit to convert the problem statement to a particular chart which is easier for you know getting the circuit implemented.

So, that part we shall take up in the next class. Three basic components of ASM charts chart are state box conditional outbox and decision box and compare unlike others decision box has two outputs. So, two boxes has got only one input and one output. So, decision box has got one input and two outputs based on the input value with the 0 or 1; one of the output path is followed ok.

So, entry into a state is synchronized with the clock and in Moore model conditional output box is not necessary. There the output is shown with in the state box and in Mealy model output is available through conditional output box.

Thank you.