Digital Electronic Circuits
Prof. Goutam Saha
Department of E and EC Engineering
Indian Institute of Technology, Kharagpur

Lecture – 01
Introduction

Hello everybody, this is Goutam Saha. I am a Professor of Electronics and Communication Engineering Department, IIT Kharagpur. I shall be working with you in this course Digital Electronic Circuits. And there will be teaching assistants, all of them are PG students over here. They will be also working together in this particular course. As you know, this course is named Digital Electronic Circuits.

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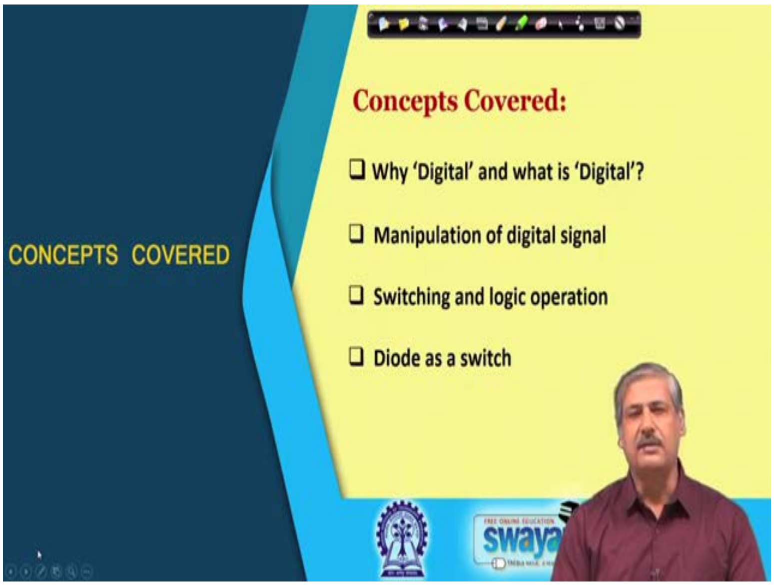

And in the introductory lecture we shall cover few basic things, why we are going for this digital electronics or digital technology. And what we actually mean by digital.

Then we shall see; what is manipulation of digital signal, how it is done the basic introductory part only, and importance of switching and logic operation in digital manipulation. And finally, we will end up with one small circuit that is use of diode as a switch.

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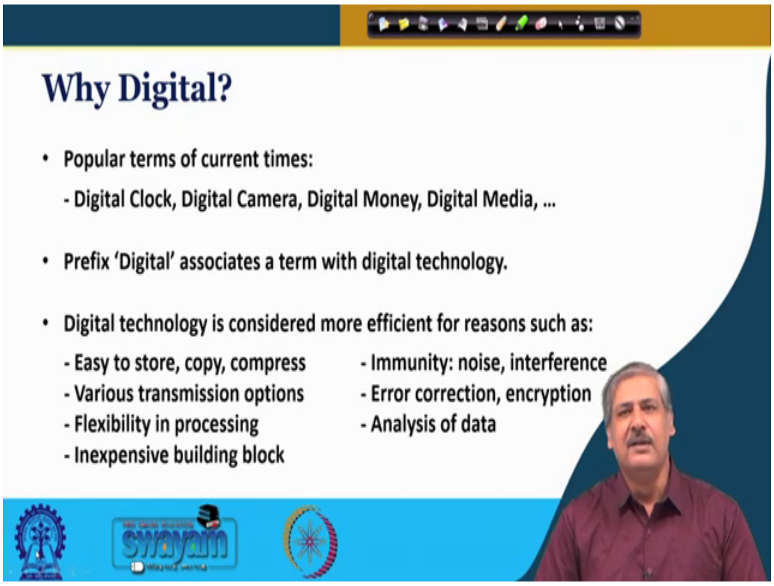

Regarding why digital? You are associated, you are familiar with many terms like digital clock, digital camera, digital money, digital media so and so forth that mean you can go on increasing this list; we have digital thermometer, digital weighing machine. And when we associate a term digital, with any particular entity what actually we mean that that entity is associated with digital technology. And this digital technology is considered more efficient, more efficient in terms of performance different kind of the performance metric, quality and at a given cost - the cost is also very important, for which the digital technology is so much prevalent, you know getting into any different aspects of our life.

And some of the features of this digital technology, if you look at it, they are easy to store, they are easy to copy from one place to another. All of us are familiar with you know copying a song from one device to another device. We can compress it, we can store the information in the compressed manner and then we can decompress it. It shows immunity to noise, different kind of interferences (in spite of) which retains the quality or enhances the quality (by use) of different algorithms, by which you can enhance the quality.

It provides various transmission options. There are serial then parallel, many way you can convert, transmit this signal from one place to another. There are options for the error correction and the encryption. You know, you (can) send the signal from one place to another in an encrypted manner. So, there anybody who intercept the signal may not be able to make any meaning out of it. Only the person who knows how to decrypt it what was the initial encryption algorithm, they are the ones who can make a meaning as the final recipient of that signal. It provides flexibility in processing. It is very, very important the flexibility aspect, that the probability aspect, the same device we can use for many different ways, the general purpose aspect of it. The data that we get, the digital data, we can analyze it to, you know, extract many information out of it. And data analysis, data analytics is, you know, kind of thing that we all are aware of, which is a very important field and emerging field. All are happening - it is because of this I would say, the burst of digital technology.

And, what comes at the end - this inexpensive building block. So, this is actually an important thing; this inexpensive building block. This actually forms the core of this thing – see, we can get lot of interesting features, but at the end that if it is very costly, if it burns the pocket, then it really is not something which were looking for. This inexpensive building block actually will take us to this particular course, that is, digital electronics circuit. It is the electronic circuits which are there at its core for which we are able to get whatever we are getting. Of course, there are many advanced algorithms so many other developments around it, but this building blocks are the primary things which actually has driven the digital technologies and digital transformations that we are seeing today.

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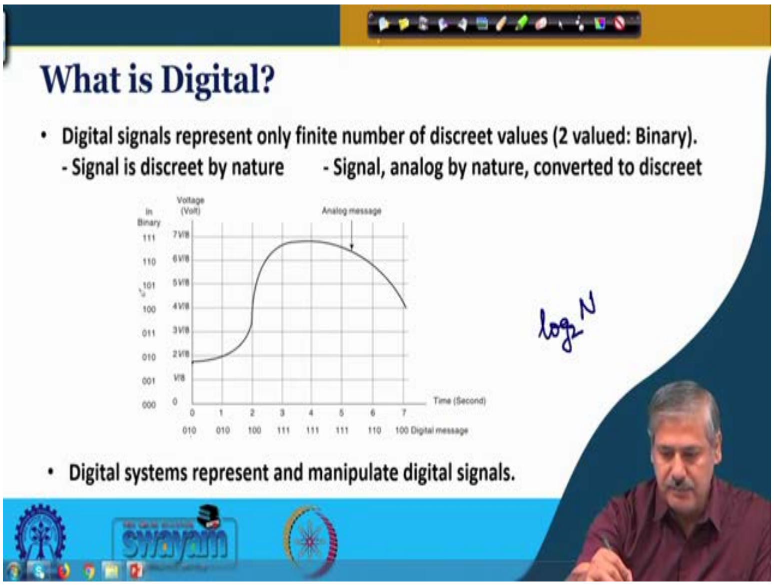

Now coming to I mean, since the term is so much used, so often used that digital everywhere we are seeing, what exactly we mean by digital? So, the first thing that you need to know is that what is a digital signal? So, digital signals represent only finite number of discrete values. Finite means because ultimately we are associating we are talking about a technology development. So, we are talking about certain number of bits or binary values that will be associated with a particular signal and it is representation. So, that only offers you a finite number of sets, finite number of representations.

So, that is why we are saying that this is a finite number of - and it has to be discrete, that is one important part of it, that these are discrete values. And we are in this particular context, when we discuss digital technology these discreet values are making a presentation of itself by a 2 valued representation, which is binary. There could be quaternary - 4 symbols can be associated and all, but we shall be restricting ourselves here to two valued binary representation. And a group of binary values or bits can be used to represent many different discreet levels. Now coming to the signal, the signal by itself can be discrete in nature.

The examples are, I mean what about - like the marks that we get in our exam, a salary that we get as a faculty member or all these things, I mean the most of these human generated signals are discreet in nature. But if you look at the natural signal, signals generated by the nature, that these they are mostly continuous in nature. Continuous in the sense that the all source of values that can be associated with that particular signal; now we need to analyze and process those signals as well - these signals that are coming from nature. Now, to do that - what we need to do is to discretize these signals, these continuous signals. So, for which we need something which is called analog to digital conversion.

And if you want to get back in the form of a continuous signal, then we need to do the reverse of it. That is a process by which we shall get the digital signal converted to analog form, that is called digital to analog conversion. And we can see one example where an analog signal is converted to a digital signal in this particular figure; the figure that we see here in the screen.

So, this is an analog signal what you see over here – right! And this signal can take any value and we need to discretize it and for that what we are having here is different levels. These are in the y axis - that you see the voltage, that you see at different levels to which the analog signal need to be associated with. So, there are no other values available there. So, either the value should be if the whole thing is normalized to say a specific one - V volt. So, this is $V/8$, $2V/8$, $3V/8$. so on and so forth up to $7V/8$. So, how many levels are there discreet levels are there you can count you can see it is 8 levels are there – ok!

So, the analog signal when converted to discreet signal, it can take one of these 8 values only – ok! And for that, what we will do, we shall associate when we look at a sample of the signal at a specific discreet value which is the closest. So, that could be one particular way of approximating the signal. And what we are doing? This is the time axis, x axis is the time. So, we are measuring, having a measurement of the signal at different time instances – ok! So, this is time instance 0, time instance 1, time instance 2 and so on and so forth – right!

Now, there are concerns like how close these time samples will be to truthfully represent the analog signal. One way of looking at it that we can we reconstruct we can get back the analog signal in the form that we are having over here – ok! So, we can reconstruct by interpolation of those samples. So, there is a specific rate that whatever is the frequency content of the signal, analog signal in the first place, we have to sample it at a particular rate, which is above twice the highest frequency content, if it is a band pass signal, then there will be something else. So, there is a specific way, specific rate by which it needs to be sampled, so that we can reconstruct the analog signal from the discreet samples. So, these are the samples – ok! So, these are the time instances and at each sample point, at simple value we can see the corresponding discreet value. So, at 0 we see the value is over here. So, we associated the close value which is $2V/8$– ok!. At 1 again it is $2V/8$. At 2 we see this is associated with $4V/8$. so and so forth.

Now, this is discreet level. Now as I said we are finally, representing it using binary codes – right! So, 2 valued binary. So, there are 8 levels if you want to represent it using only binary we need how many binary digits or bits, it is $\log_2 N$– ok! That is the number that will be required - that is. So, if it is 8. So, $\log_2 8$ is 3. So, 3 such bits will be required.

And you see, 000, 001 - these are the corresponding representations. So, at first time instant, what shall I get? I shall get 010, which is to be an approximation of 2 V by 8; 010 - I will again get at time instant 1. Time instant 2, I shall get 100 and so on and so forth. So, that way it will continue – ok! So, of course, we can reduce the approximation error, whatever error that you see, called quantization error, by reducing this gap, making it as close as possible. So, that is possible when we have more number of bits, more number of bits. So, if you have instead of 3 bits, if you have got 4 bits we will be having 16 such levels. So, approximation error will be less.

If we have 8 bits we will be having to 2 the power 8, 256 number of levels. So, that way the approximation error or quantization will be reduced. So, this is - there is some initial issues, when we get to know the error that we can see, from in the analog to digital conversion. After that we shall see that the digital signal itself is more robust in presence of noise and other things, processing aspect of it – ok! Now, if you look at digital systems. What do they do? They represent and manipulate digital signals – ok!. So, the digital signals that we see that would be, that are getting manipulated, that are getting processed by the digital signals.

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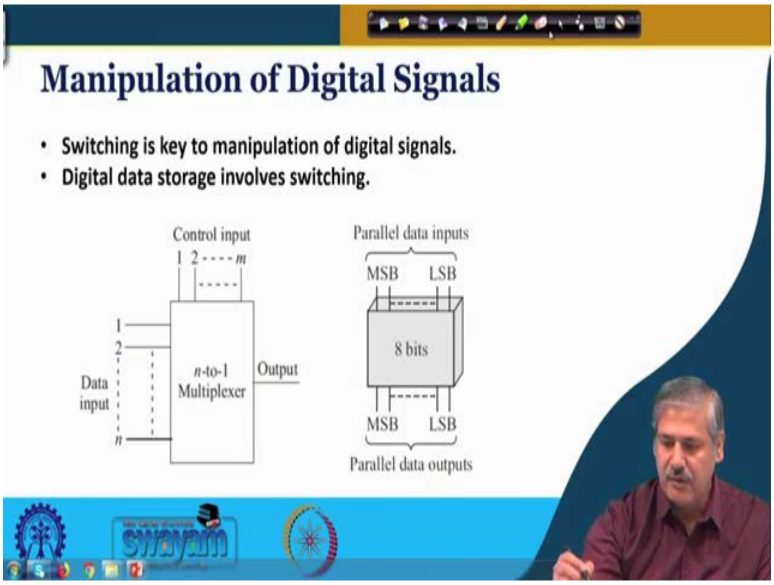

Now, we come to the manipulation of digital signals. As I said this is an introductory lecture - we are looking at some example cases. So, first thing, that is very important thing is that when we talk about manipulation of digital signal, switching is the key to it – ok! By switching what we mean that we shall see little later. Switching is - the kind of switch that we have seen in our household - like we switch on the fan – fan starts rotating. Then you switch or switch it off - then it stops. So, it is basically again an on-off kind of thing. A binary kind of activity that is associated with switching.

And just now we have seen the binary representations of digital signals in the form of 0s and 1s, that is also can be you know in that sense associated with switching. So, one is.

OFF say associated with 0 and, ON with associated with 1. So, this is one way of association there could be other way of association - is just its reverse. So, the standard process, standard understanding is that OFF is associated with say, 0. And ON is associated with 1 - so that that helps. So, this is one important aspect which we shall keep in our mind – ok!

And so, we look at one example where the switching is important. So, this is a n to 1 multiplexer – ok! We will discuss the circuit what is there inside - that is a part of our course, digital electronics circuit. So, we shall see what is this - it should not remain a black box, but for the time being let us see what does it do. So, this particular block actually takes any of the n inputs, which is present at this site at the input site and makes it available to the output. So, at a given time only one of the input will be available at the output.

Now; that means, if I wish that this channel will go to the output, it will go. If I wish the other channel will go to the output that will go. Now, who will decide that? Who will do, who will make the decision? Of course, the circuit inside will make the decision, but based on what? So, based on again another set of input this is called control input. So, this was data which is going to the output. So, this control input will be deciding based on certain combination over here, that who is going from here to the output –ok! So, if 1 and 2 and m- 3 and 4 and up to say, m all are 0 say - 1 goes to the output.

If 1 and 2 and 3 and all of them are 0, up to m minus 1 and m is 1, then 2 goes to the output; so in the statement itself - if you look at it the way I am phrasing it, that if A and B and C and D are 1 something happens. If A and B and C and D are 0, A and B and C are 1 and D is 0, something else happens. So, this involves a certain kind of a logical statement or logical build-up which is associated with switching, which can be associated with switching – ok!. So, this is one aspect of it. The other thing is the data that is storage the storage of data that you have stored. So, this is what you can see that an 8 bit data storage unit. It could be it made up of say, flip flops - what is that flip flop and all, those things, we shall see later.

So, there are parallel data inputs and these are parallel data outputs. So, in the data will be coming here that is decided by a specific logic and the how data will be stored. So, if you look at the internal circuits of it there are switching activity that is happening inside – ok!

So, this is as I said is one of the core aspect of digital processing, digital manipulation, when you look at it at the circuit level!

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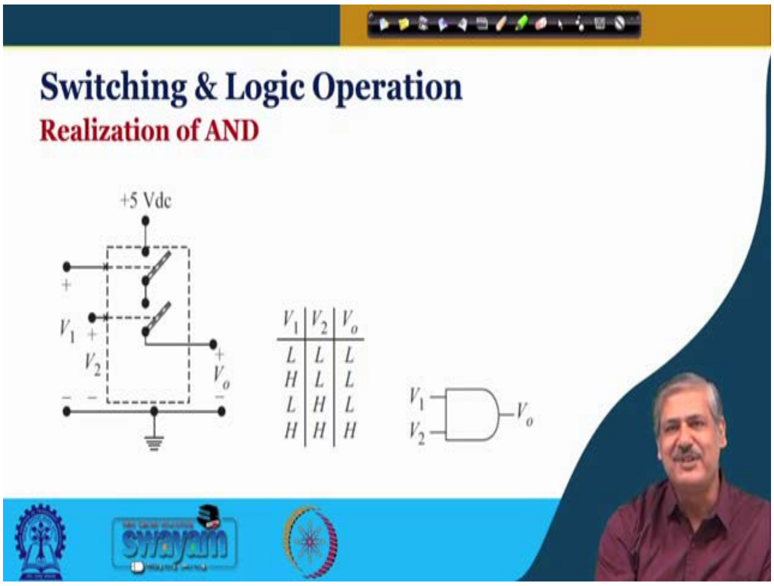

Right! So, now we look at the switching, the way we have already seen it, we have understood it – ok! So, this is an example, where you see, there are 2 switches. This is one switch and this is another switch right. And there is a 5 volt dc supply and this is the output and this is connected to the ground – ok!

And when at the input, voltage is placed, I mean high voltage say 5 volt is placed. So, what placed. So, what happens this switch closes and connects these 2 points, are getting shorted - these 2 points get connected. So, these 2 points will get connected ok,. when this is high. And if it is low that means, it is remaining the same. Similarly, for V2 – ok! Now let us see how this particular circuit it is inputs side and outputs side will be related. So, when V one is low; that means, this switch is this switch over here is this - is open right and this is V2 is also low that means, this is also open. So, at that time what will be the value of the output? The value of the output will be - this 5 volt cannot come to the output ok; so the value of the output is low. Is it ok?

Now if you close one of them, say this is closed, but this remains open, still these situation remains the same the condition remains, the same the output will remain, output will not get the value - this 5 volt. So, any of them is low you see the output is low. Only when both of them are both the both the switches are connected; that means, both of them are high. So, this switch you know changes site from here and gets connected over there. Then only the output of this 5 volt gets the path over here and you get you can see a high value over there ok.

So, when we look at it from the logic circuit point of view, it is V1, V2, Vo. So, what kind of logic do we see? That when both V1 and V2 are high, output Vo is high. That is how we read it. Isn't it? That is how we phrase it. And the table - the corresponding table is what you see over here, ok! And this is nothing but what is known as AND logic - this is your AND logic – ok! So, this AND logic when you know - represent in the form of a symbol logic – symbol, this is how we represent it. And this is the AND symbol which we shall be using in subsequent discussion – ok!

But still it is an electrical circuit - the electronic part and other things - that we shall discuss little later.

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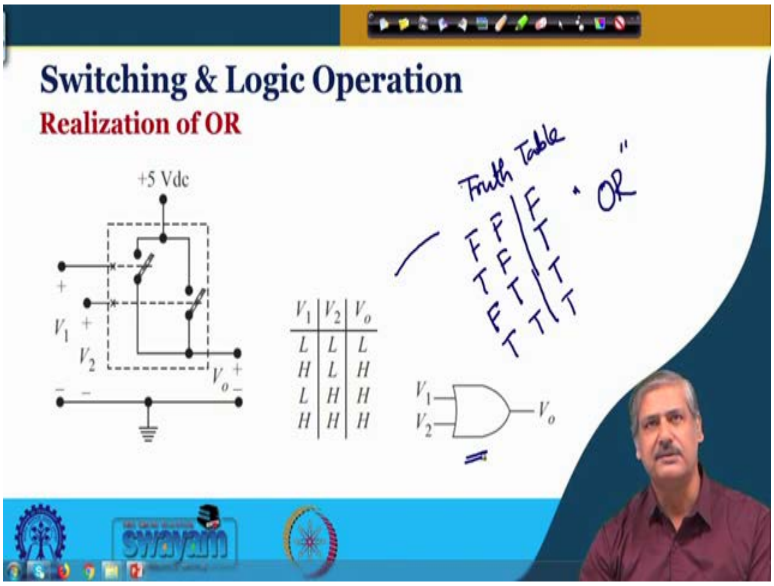

Now, we will look at another such circuit, a switching circuit where these are - there you can see there are 2 switches – ok! And – but, earlier they were connected in series, now you can see they are connected in parallel – right! And what difference does it make? The difference is, earlier both of them were to be closed. That means both the switches the input side needed to be high. So, that the 5 volt gets a path to the output – ok!

In this case since they are parallel, any one of them high any one of them high, this one switch gets closed and the path will be available - a 5 volt will get a path to the output and Vo will be high – ok! So, that is what is happening. Only when both of them are low, only when both of them are low - then only 5 volt does not get any path to the output. So, this is the corresponding truth table that we can see. These are called truth table when you are presenting in terms of low-high or true and false. So, False is associated with L - logic low and H is associated with True – ok! So, then it becomes a truth table.

So, this is another way we can say that - a representation of truth table, where this False-False gives you False; True-False gives you True; False-True gives you True and True give you True. And this is nothing but OR representation, OR logic – ok! And what is the corresponding symbol? So, this is the corresponding symbol that you see over here. Is it clear? Ok!

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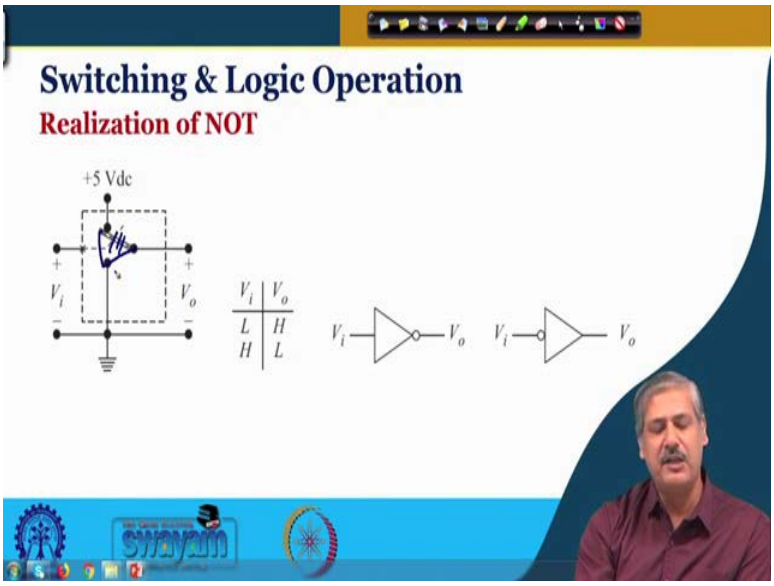

Now, we look at the other one which is NOT – ok! So, look at this particular switch this is another logic operation. So, what is happening now you see the difference this switch is connected in such a manner that if this input side is low this 5 volt is getting a path to the output ok. 5 volt is getting a path to the output.

If Vi is high, then this switch is drawn may be through a coil, magnetic coil. So, and it will get connected to this one, this side. So, this switch will get connected to this side. So, this will not be there ok. What does it mean? Now 5 volt does not get a path. So, if input is high the switch connects to this side and the output does not get a path. If switch is low input is low then the output gets a path. So, what difference does it make? The difference is that Vi is low output is high and Vi is high the output is low – ok! So, there is just an inversion. There is a, you know in terms of logic, it is just the invert of the other. So, it is called NOT operation and the corresponding symbols is like this.

This bubble is actually what is important over here - the bubble can be present in many other cases, we will see this happening.

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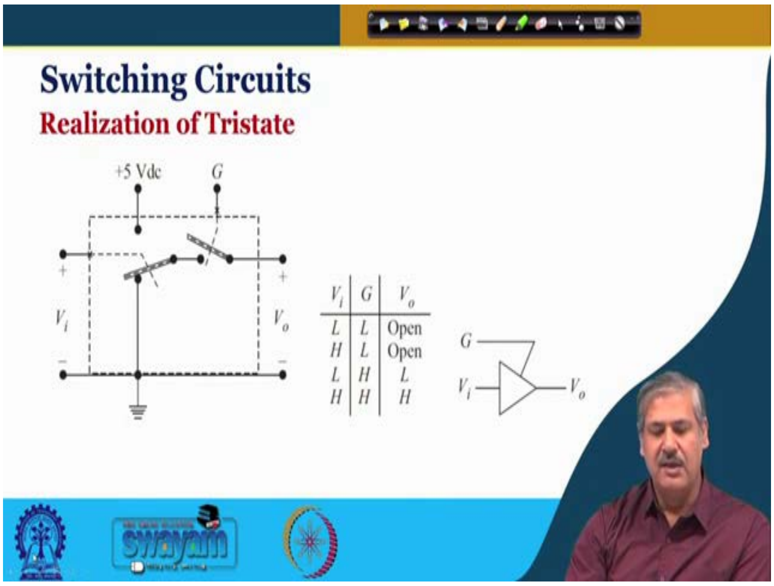

Now, so far we are talking about the 2 states binary states - ok. That is logic one, logic high, low, true, false, ok. So, this is one particular case where you are talking about something called tristate. This is also we will be seen and available in your digital electronics circuit, to the course and the discussion that we shall see - ok.

So, what is it? In this case you see there is an additional input called G - ok. So, what is the role of this G? When this G is in this case low; that means, it is remaining open, whatever you do at the input side it does not get reflected at the output sides. So, it will remain, it will does not get a path ok. Only when G is high then - if this G gets connected and depending on the rest is a circuit, where depending on Vi, if it is low the output will go low or high it will go high.

So, this is just going from this side to the other side, but G is what is making it enabled - ok. Now why it is called tristate? When G is low; that means, it is disconnected - the circuit, at the output does not get either 5 volt or ground, any of them it is not getting - ok. So, this is in a sense the output is open circuit - this is electrically not connected to the rest of the circuit which is there in the left hand side. It has got its interesting use - we shall see in the subsequent discussion - right.

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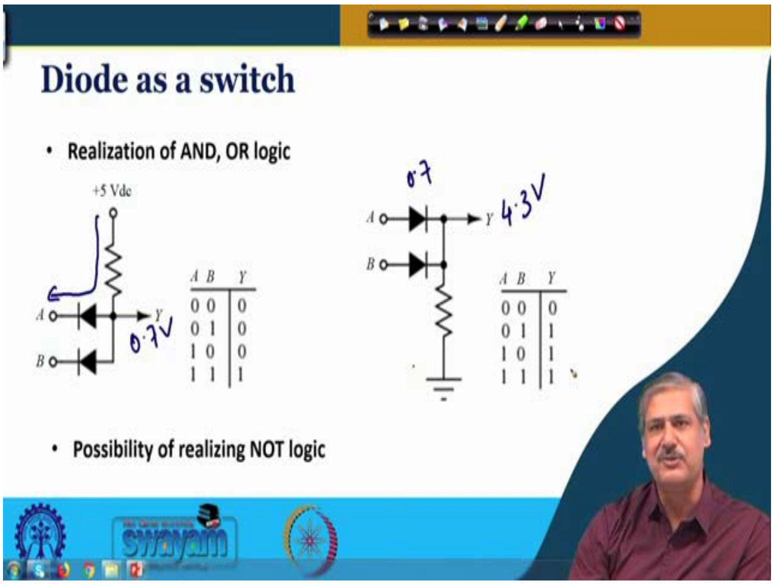

So, now this is the final slide of this introductory session, introductory lecture - more complicated circuit, more complex circuit - we shall see later.

So, here what you are seeing is a diode based circuit diode and resistances are being used - ok. And this is used for generating 2 different logic operations - ok. Let us see what are the. So, there is a diode - 2 diodes ok. Connected A and B you can have more such diodes and you know a become B and C these will get connected, but let us restrict ourselves to 2 only right. So, any of the diode is low ok; that means a 0 volt. What will happen? The current will start flowing in this direction current, will start flowing in this direction and 0.7 volt drop will be there ok. So, the output will be 0.7 volt.

So, this particular voltage which is close to 0 volt, we shall treat it as logic low and voltages which is close to 5 volt - little bit, treated as logic high. How much close and all those things we shall see later, what is the range - other things, that we shall see later. So, at this point it is sufficient to note that this 0.7 volt that we get here is treated as logic low ok. So, any of them, one of them is low - so, what we find, this particular direction current is going and the voltage over here is 0.7 volt which is the diode ON voltage and the output is low. On the other way when both of them are high, it does not, you know, the current is going, flowing in this direction – right! And the 5 volt and depending on the load current, a little bit less than 5 volt, might occur at this particular place which is digital logic 1. So, what sort of logic does it provide what sort, I mean, if you look at it, if you compare it with previous thing - we shall see that this is AND logic - ok. Both of them high, this is the output high - right.

Now, look at this particular circuit what is, what is it. So, A and B at the input either you present a 0 volt or 5 volt - ok. So, when you present both of them as 0 volt. So, no current is flowing. And when you present a 5 volt what will be the voltage here. So, 0.7 volt drop over here. So, voltage here will be some 4.3 volt earlier these this was 0.7 volt right which is close to 5 volt. Which we can treat as high and corresponding any one of them or both of them at 5 volt the output is at 4.3 volt and close to that depending on the diode drop which is in the range of 0.7 volt - ok.

So, any of them high, output is high/ What sort of logic is this? It is OR logic - ok. So, using diode as a switch we can see that we can generate, we can get AND logic and OR logic. Can we get a NOT logic using only diode and resistance? So, you could try, but you might see that using only diode and resistance combination you will not get a NOT logic, an inverter is not possible, for which we need to use transistor which we shall take up in the next lecture where transistor will be used as a switch.

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So, these are the references for these particular lectures. So, mostly I shall be using the first reference and more references I shall share later.

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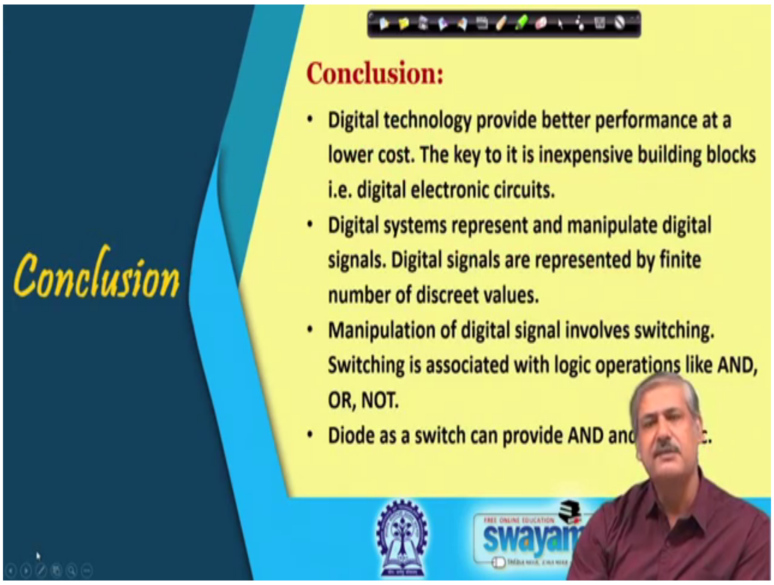

And to summarize what we see what we have seen in this particular lecture is that a short overview of what we have discussed so far. The digital technology provides better performance at the lower cost. And the key to it is inexpensive building blocks and these inexpensive building blocks are such that they it can handle digital signals and can manipulate. And this manipulation is all switching, and the switching is associated with logic operations like AND, OR, NOT. And we have seen the diode as a switch can be used to generate AND, OR logic.

Thank you.