Digital System Design
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Lecture No. 01
Introduction

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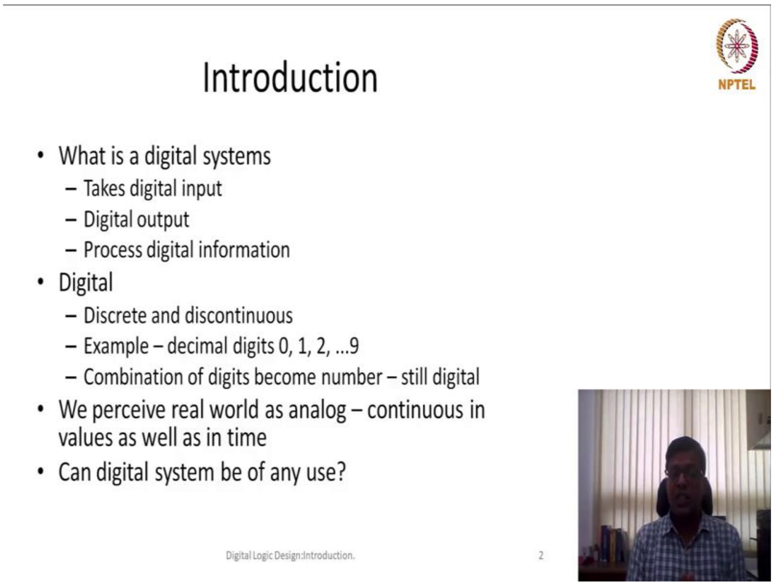

Hello, everyone, welcome to this course of digital logic design. I am your instructor, Neeraj Goel and I am Assistant Professor in Department of Computer Science and we will keep interacting during the course and you can, so let us try to start this course with digital logic design.

Before going into detail, in this particular lecture, we will try to understand what is the meaning of digital logic design or a digital system. So, digital system is formed with these two words digital and system, what is digital? Digital means discrete and discontinuous. Discrete means this is certain like 1, 2, 3,4, discontinuous means it is not continuous, neither it is continuous in space, nor it is continuous in time. Space means we can also say continuous in values.

So, you all of you might have heard this, you might have used this phrase as a decimal digits. Because in our decimal representations of number, we call 0, 1, 2, 3, 4 up to 9 as a digit that is called a single digit and when we form, when we club together multiple of such digits like 23, we have two digits 2 and 3, this 23 became a number, it is still a digital number, because it is still discrete and discontinuous.

What do we mean by discrete here? So, for example, there is a number 23 and the number 24. So, in between these numbers 23 and 24 there is a, there is a infinite number of possibilities, infinite number of numbers, which could be possible between 23 and 24 you can see 23.1, 23.11, 23.10001. So, in such a way we can have infinite possibilities between any two numbers but because a digital number are discrete, so there is no possibility of anything between 22 and 23. So, if we combine multiple such digits, it will become a large number, but it will be still digital in nature. Now, this is what is the meaning of digital.

What is the meaning of digital system? System is usually a close entity which has some definitive input, some definitive output. Now a digital system will take a digital input, means some discrete numbers as input and it will also give digital output, plus it will also process this digital input, it will also process this information as a digital input and we will do some sort of calculations and give this output.

Because it is taking digital as a input, it is bringing out digital as output, so all the processing inside will also happen using digital logic or all the intermediate inputs or intermediate signals or intermediate values will also be digital in nature. So, in other words, my digital system will be will be taking digital input will processing digital input and will be giving digital output.

Now, let us see on the other hand, if we see a real world around us, so what we see, let us say we are sitting in a home, we see walls around, we see TV, we see mobile phone, all of these things. So, whatever we see whatever we hear, whatever we speak, that is not discrete, that is all continuous and continuous not only in terms of values, but also continuous in terms of time.

So, for example, when we are speaking, we are speaking continuously. So, there is a notion of time there, plus there is a notion of volume and this volume is also, is also perceived as continuous. So, essentially, whatever around us whatever senses we have hearing, seeing or observing, watching, so all of these senses are perceived as continuous and continuous in space as well as continuous in time or continuous in terms of values plus continuous in terms of time.

So, there is one important question that can be raised here that if we see, we perceive all the world around us as analogue means not digital as a continuous word, then why are we talking about a digital system or in other words, can these digital systems be of any utility? Can there be any advantage of a digital system which is discrete in nature? So, to see the, this particular question, whether it can be of utilisation, whether there is any benefit chorus in with respect to analogue we will see in some of our later lectures.

But let us try to see, can we see an example of some digital system around us? So, let us try to think a little bit what example we can think, what example comes to our mind, when we see digital information processing. So, because we are talking, we are defining digital information in form of digits.

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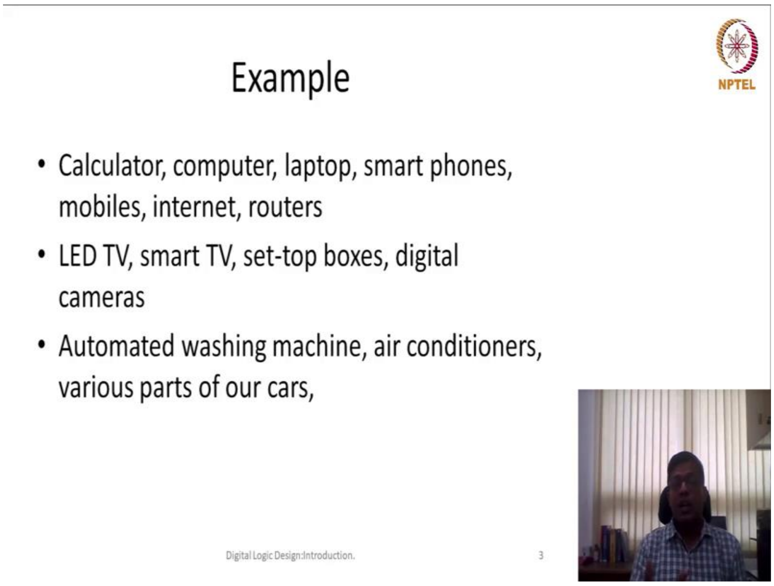

So, probably mathematical calculations looks like the best example of our digital system. So, maybe a calculator is an example of a digital system. Very small digital system although, so but similarly, we also understand because most of you are from a computer science background, so you also see all the word of computing, like your computer, your laptop, smartphone, mobile phones, all of these things are also digital in nature, that is what we understand.

So, we do not know how, but we at least understand that all of these take some sort of a definitive input, so that whenever we press a key on a keyboard, then it is a discrete value, it does not associate with the time. So, because it is a discrete so it would be converted somehow in the system but it would be a digital system.

So, these are the good examples which we see around, can we think of more. So, outside computing, outside computer like computer laptops, smartphones, they are all equivalent these days, can we think of something outside then we can say probably internet or the devices associated with the internet, they are all also digital in nature.

So, can we think a little bit outside, can we see in in our homes in our houses, do we see some more digital systems? These days like most of us would have LED TVs or LCD TVs, some of us some of us also has smart TVs. They are also a digital system completely digital systems. A smart TV which is governed by internet, which is taking input from internet which is showing in phones, small LEDs, each LED is a discrete entity, whatever colours each LED shows that is also discrete in nature.

So, similarly set-top boxes, set-top boxes are also a digital in nature, which is helping our TV to browse through various channels and give us various guide information guides or selection of various channels. Similarly, digital cameras, so all of these things are, are essentially part of our consumer electronics goods or helping us in making our life smarter. They are all digital in nature. And it is not only these consumer goods, but also other things which are which are becoming more and more smart.

So for example, automated washing machines, some part there would be a digital that is why it is being automated. Air Conditioners will also have some sort of a control unit that is why people sell it like a like automated system and the things which we do not perceive as digital but also in our cars whenever you use this particular word, power window, power steering, power brake so, most of these components in this car is also digital in nature. So, this this way we see all around us, lot of things, which are, which can be termed as a digital system.

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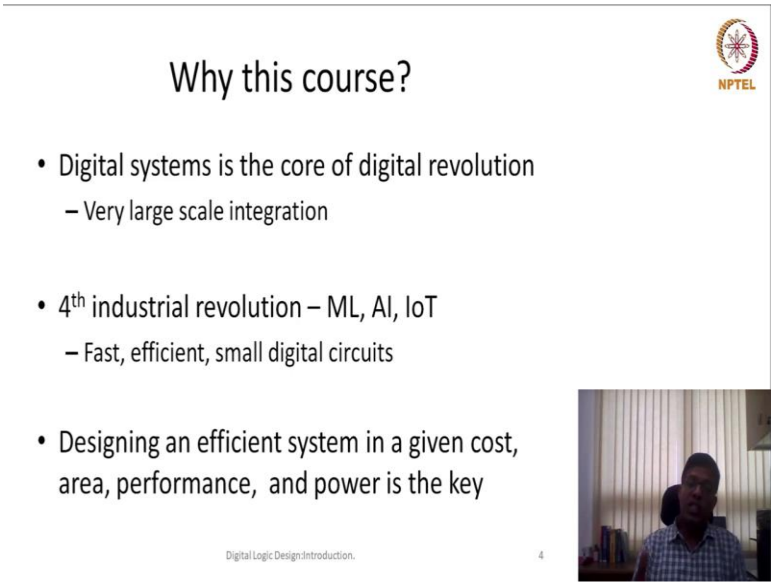

Now, if we go back in the history, then we can also see the 4 industrial revolutions, which happened, first one was because of steam, steam engines, that was the original industrial revolution and then after that, because of birth of electricity, more automation happened. There were birth of like, you could see in that era electronics computers as well as electronics computers as well as some mechanical computers also, large scale industrialization happened, but the major push to industrialization happened because of digital revolution in starting from early 80s.

So, because of because of invention of something called large scale integrated circuits or integrated circuits that means lot of these transistors could be packed onto one chip. Now, because of that integration, a lot more number of transistors could be pushed into a single chip, this is now called Very Large Scale Integration or VLSI. So, that is the heart of the digital revolution, because of that we could see more and more processing systems and all the digital products what we see around there all because of that, and eventually just because we had computers, internet changed the way we use to see system.

And particularly in this crisis of COVID, where we cannot talk to each other face to face, this digital revolution is on the rescue, we can record lecture, you can see it offline, we can have own, we can have one to one correspondence, we can have one to one discussion, face to face discussion, we can also have one teachers instructor speaking to thousands of hundreds of students at the same time in online teaching.

So, all of these things are possible because of digital revolution because of internet and all of these things happened because we had this digital system in place. So, this also answers one of the important question, which is why we are teaching this course? Or why you as a computer science undergrad student is listening to me? Or is doing this particular course? This particular course is a core course for computer science students and this is a are elective for maths and computing students.

So, why this is core because whatever computer we build, whatever computer programming, we do, underneath the hardware, which is doing all the processing is a digital system and it is very important for us to design an efficient system so that we can we can produce a system which is less in cost, good in performance, less power consuming and you can see the effect of these 3 keywords area performance and power in the fourth industrial revolution, which would be led by machine learning artificial intelligence, Internet of Things.

So, some of you may be knowing that this machine learning is not a new technique, it is a technique which was which we had which we know from last 50-60 years, but it became prominent now, suddenly prominent, why? Because of availability of hardware which is fast, which is efficient availability of lot of storage, which can be done. So, because now we can do a lot of computation in very short span of time. That is why we could deploy such algorithms which require that complexity. But can be done in fraction of seconds.

So, that also emphasise a requirement to design such a hardware, which can do enormous amount of computation, which was probably not possible in past but would require in future. So, with this invention of new and new machine learning and AI algorithms, we would require our system to be more complex. So more computation have to be done within the same area or within the same cost.

On the other hand, the other part of this fourth industrial revolution Internet of Things, IoT. So, this IoT requires all the computation nodes to be as small as possible as low power as, as low power consuming as possible. So, this low power consumption this small area is also another conflicting requirements. So, at one end we would require very fast and efficient systems.

On the other hand, we also require very small power consuming, very small systems. So, because hardware design or understanding at least how hardware design works on understanding or designing efficient hardware is the core of computer science. That is why we will study this particular course and what we will do in this course?

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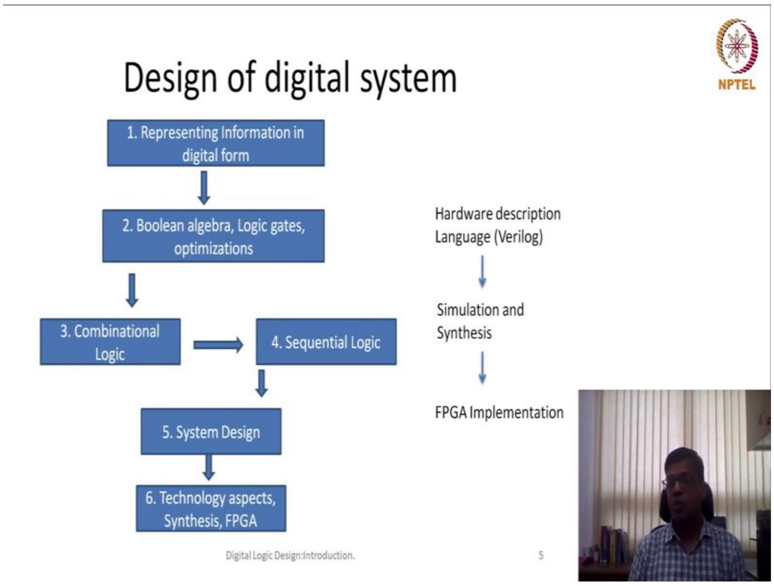

We will try to design digital systems, we will try to learn how to design a digital system. So, for designing digital systems, first thing we have to understand is how to represent any sort of information in form of in digital form. So, for example, information could be continuous in space, continuous in time, how we can represent that information in a digital or discrete or a discontinuous form. Still, we do not have any kind of loss in information.

So, that would be our first module and after learning how to represent information, then we will learn the basic algebra, this algebra is called Boolean algebra. So, along with Boolean algebra, algebra will tell us how to process this information and then, to implement that Boolean algebra, we will also have, we will also learn different kinds of logic gates and how optimization can be done, how the same logic can be represented with smallest number of gates or smallest area.

So, this would be our second module after learning Boolean algebra, basic logic gates, then that are two kinds of digital systems one is called combinational logic, another is called sequential logic. So, in module 3 we will learn about combinational logic and after finishing combinational logic in module 4, we will do sequential logic. So, after doing this basic understanding of combinational logic and sequential logic, then we will try to learn or integrate both of these components in some system.

So, this module five would be essentially a number of case studies, number of examples, so that we can form we can design a little complex system using both combinational logic as well as sequential logic. So, all the components which we have learned from module 1 to module 4 we will try to design a full system. So, whenever we are talking about design, it is more at conceptual level. But, you see all the digital system are essentially hardware in nature.

So, in our last module we will talk about technology aspects we will try to synthesise things onto hardware and hardware specifically, we call here FPGA, Field Programmable Gate Array. So, this is a piece of prefabricated chip on this prefabricated chip, we can configure any digital design whatever we can, we have designed during the course. So, this was the theory part of our course and this is how we will flow our way, this is how our modules will go time to time.

Now, what about the lab part, in the lab part what we will do is we will try to learn to represent a digital system in a hardware description language like very low. This Verilog is easy. C++ like language, but it is more suitable for representing or for describing hardware or describing a digital system.

So, this Verilog hardware description language so there many were a hardware description languages but we have, we will choose a Verilog among them. Now, this hardware description language will use for simulation and synthesis using simulation we can see whether the behaviour whatever we would like to model is coming out same as not same or not, after simulation and synthesis then we can implement the same design onto an FPGA hardware.

So, this third part would require actual FPGA boards. So, this may not be possible until we are we are working from home or home or we are studying from home, when you people will come back we will be hearing IIT, then we can at least have some demonstration or some time we can spend to do actual FPGA implementation. But, so for the time being the assignments will be mostly describing things in Verilog and then doing simulation and also some time during synthesis to understand how it would be fabricated on FPGA. So, this would be the overall course about.

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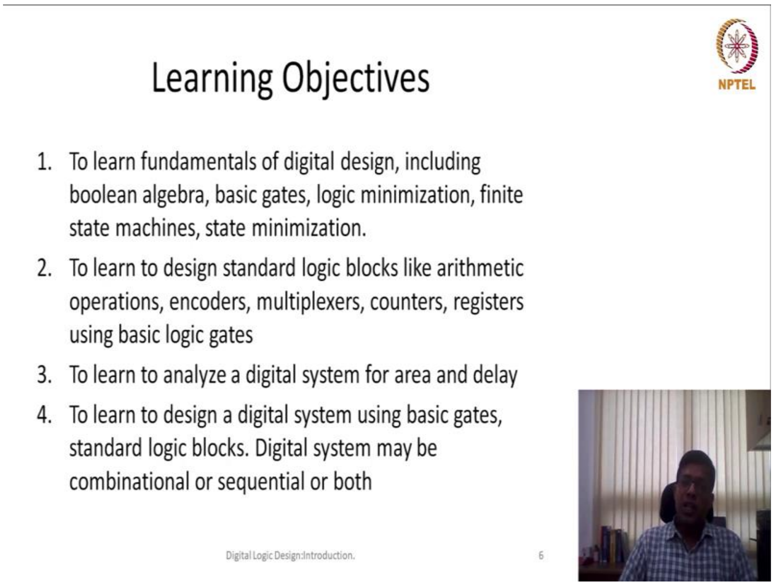

And then let us look at some of the logistics. So, what do we expect after doing this course by the by November and what should we expect to learn? So, first thing I expect you to learn is fundamentals of digital design. So, what is fundamental here, fundamental is algebra, Boolean algebra, basic gates, logic minimization. So, these are the fundamental things fundamentals about combinational logic fundamentals about sequential logic. So, state machines are the fundamental basic fundamentals of sequential logic.

So, these fundamentals is most important thing we learned and along with this fundamentals then the second part which we will also see is using these fundamentals designing some kind of a standard logic. So, the standard logic could be arithmetic operators, encoder decoders, multiplexers counters registers, many such standard logics will try to design using basic logic gates using combinational style or sequential style.

Another thing which I expect that we learn by the end of this course is that given a digital system, we should be able to analyse that what is the cost of digital system and cost would be a represented in usually in terms of area, because area is directly proportional to cost of fabrication, area and then what is the delay or latency what is the time this particular system will, a task will take to complete a particular task. And there could be other cost matrices like power that we will try to see how much we can cover but at least we will we should be able to analyse delay and area of a system.

Now, based on first 3 learned things, then we will try to design a whole system. So, this whole or a bigger system is also one of the objective. Like we should be able to break the system into smaller parts and then use our skills of designing combinational logic sequential logic to design a bigger system. Along with this learning objectives, these 4 learning objectives, we will also during the course, we will also learn how to describe a digital system in a hardware description language like Verilog.

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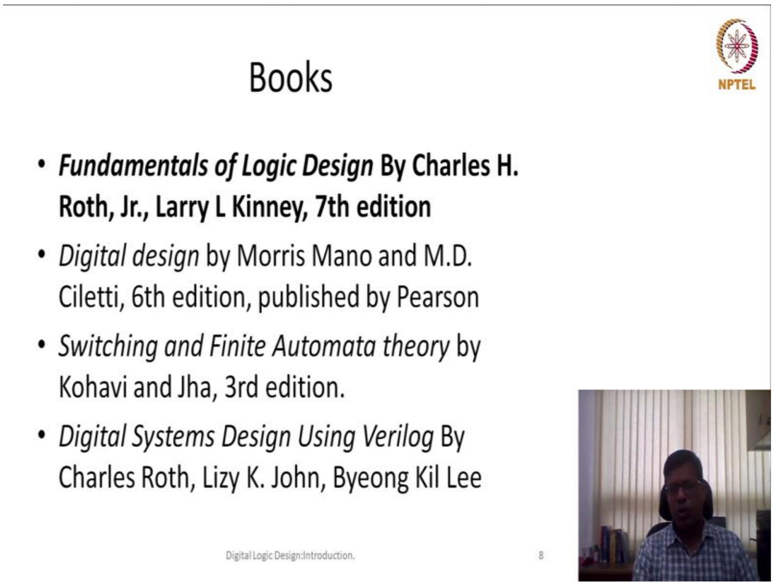

There are 4 books which are mentioned here. First one is fundamental of logic design. So this is the primary textbook, which we will be following during the course and all other from the other books like from Morris Mano or from Kohavi or from again, diesel system design using Roth, by Roth. So, all of them from the rest of them will take one or two topics and I will mention it, explicitly that which book we are doing a particular topic.

All of these 4 books are available online. So, you can search on Google and we can get a PDF of all of all four of them. If you are not able to get, then you will shoot me an email or ask TA, then they will tell you about the PDF.

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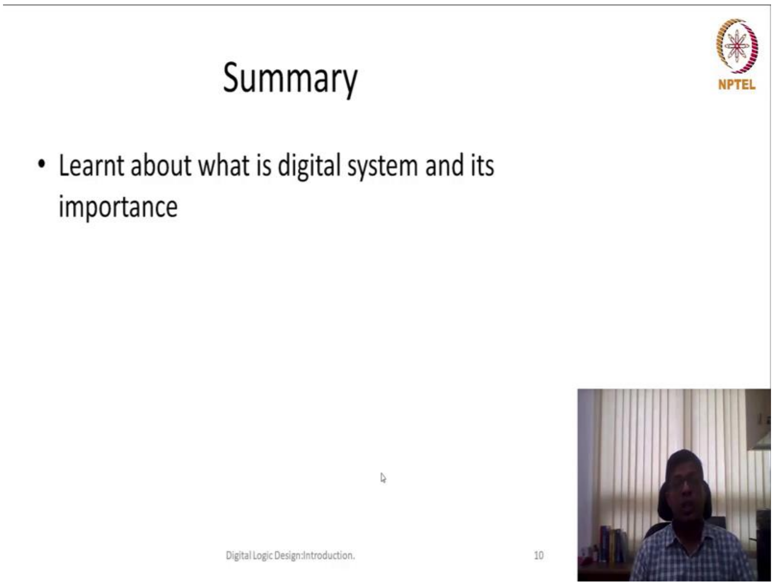

So with this, I will close this particular lecture. So in summary, we have learned about what is a digital system. What is the importance of this course and what would be different modules in this course. Thank you very much.