Digital VLSI Systems Design

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Lecture - 1

Introduction to VLSI Design

Hello Everyone. In this lecture, we are starting a new series of lectures on the topic of Digital VLSI System Design. VLSI has been a very popular word off late. Almost everyone talks of VLSI, not necessarily people of technical knowledge. I can say it has even become a household word. We find news paper articles in the science section on VLSI. What is all this VLSI, we will see in a while. In this series of lectures what are the things we are going to learn? That also we will see. But, you can also see in the title the lecture is not simply VLSI system design; it is a digital VLSI system design.

First, I need to explain to you what is digital system designing; so this is again an advanced course. As far as an as per digital system design is concerned, we have earlier lecture series on digital system designing basics. For the sake of introduction, all electronic systems have two types of components: one is analog and other is digital. With the advent of digital computers, it was easy for people to process signals in a digital domain.

An electronic system essentially processes signals. What is a signal? A signal is any variation of a quantity with respect to time. For example, we can monitor the temperature or even the speech that I am now giving is a signal because of the amplitude variation with time. These signals can be earlier in the analog domain. For example, we had a simple system of microphone amplifier speaker - standard PA system, public address system. The signals will be taken as it is by amplifier, amplified and then delivered to the speaker. Such a process is called analog signal.

Analog signal had a few things which are not very friendly. One is this signal varies continuously in time and continuously in amplitude within given limits. In order to store and reliably reproduce it, it becomes difficult because we do not know how reliable the stored signal is when you take it back. We need capacitors in which signals and the values of [resulting] amplitude are stored; how many such capacitors are used, all those things become the problem. So, they went to additional and discreet time signals, where, instead of storing the signal at every instant of time, you do it at discreet intervals of time and it is possible to re-construct them; let us not go to the theory of communication. It has been proved that with samples of a signal at frequent intervals one can reconstruct the signal in full, without any loss. Using this principle one could store the discreetized time; signals with discreetized time intervals are called discreet time signal. There again you have the problem of amplitude.

What is the amplitude stored? When you read that amplitude, whether the amplitude was corrupted either by external noise or by a leakage? We went to a third possibility of discretizing the amplitude also. When you discreetized the amplitude what happens? At every discreet time, we have a value but we do not store the value. We only have a given fixed value; the nearest value to the amplitude at that time will be stored. That way there is a limit, there is a variation allowed in the signal storage. If the signal leaks by a small amount it does not matter or the signal picks up a little noise on the way, it does not matter because these levels are discreet levels and within those levels, as long as the signal is stored resize within that level becomes easy to reproduce it. Storage and reproduction and transmission of digital signals are much easier compared to analog signals.

The second thing is, I want to improve the accuracy of a digital transmission or digital system; I need many more stages. In analog, we can improve the accuracy. Improvement of accuracy in analog is an exponential [pass] of the difficulty level, the complexity level involved in improving the accuracy of an analog system is much more difficult compared to digital system where all you have to do is replicate. If you have more hardware you have more accurate signals. If you have less hardware, you can have less accurate signal. So the implementation is sure. Implementation point also, digital signal becomes easier to handle. These were the reasons why people went for digital.

With the advent of the computers it became very easy. All you have to do is to transform a signal to digital domain. Once you transform a signal to digital domain, they become numbers, mere number representations. These numbers are handled by computers for digital signal processors and then after the manipulation again they are given out as numbers. Those numbers are converted back into signals and those signals are displayed or stored or transmitted. That is why digital has taken an enormous importance in recent times. But, we should not forget that analog is also equally important because most of the naturally occurring signals are analog signals. As I said, a person’s speech, audio of a music or instrument, video signals, any variation in any parameter that you want to monitor in a system, these are all analog variations.

An analog variation has to be discreetized both in time and frequency to get digital signals; both in time and amplitude to get digital signals which can be processed. There is a little bit of analog processing involved in any system. Now the trend is more and more digitized. Now the order of about 90 to 95 percent of all signal processing in electronics is in digital domain; remaining 5 to 10 percent is in analog domain.

The difficulty of those 5 to 10 percent will almost match the difficulty of this 80 to 90 percent both in terms of the cost in the design and the time involved in doing this properly. Of course we have now circuits in which both digital analog reside simultaneously; these are called mixed signal processors. So, there is wide popularity and wide activity – a large activity in digital system design and that is why we are concentrating on digital system design. Of course we need to do analog also if you want to become a complete VLSI designer.

No one single person can be an expert in all these fields of VLSI. VLSI is a large field, extensive field. So, one can concentrate on digital signal processing or digital aspect design, somebody can concentrate on analog aspect of design; layout, tools for VLSI design and on improving the power of performance etcetera. This course as I said, we are only concentrating on the digital design aspects of the VLSI. Let us take the second point. What is VLSI? Why is it so important? This is again a historic evolution mostly because of technological advances. Early 50s we had the transistors, the advent of transistor of bell labs, a single transistor was first used in application plus amplification.

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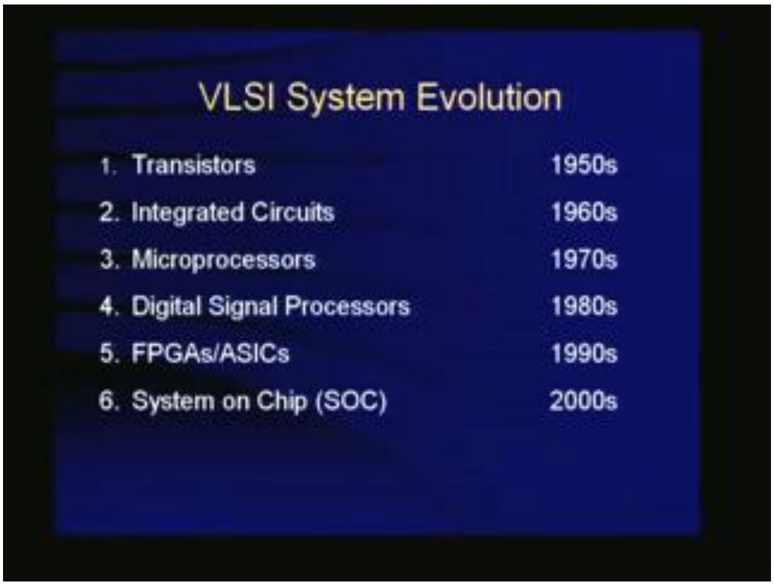

When people wanted to make system using transistors they had to build their circuit with a transistor resistance capacitor; discreet elements had to be wired up, they had to be connected, soldered, whatever. Then they thought of more complex system with more transistors, a couple of transistors make a digital differential amplifier all of you know that, or many more transistors in many circuit applications. Doing all these inter-connections there are couple of problems; one is the matching. I would like to the have the characteristics of the transistors as close to each other as possible. When they are fabricated – manufactured at different processes, times, and different lots, the matching of these characteristics of this transistor becomes a difficult job. Whereas when you can fabricate a few transistors, manufacture a few transistors together, all in one single process in a single crystal of silicon it is more likely that the characteristics match.

Second thing is interconnection. I have transistors, resistors, capacitors; all these are integrated – connected. The reliability of the connection when it is done in a chemical processing as you fabricate the device, as you manufacture the device as a process, it is much more reliable compared to taking these devices externally and connecting them. The integrated circuit became very popular. What is an integral circuit? It is a circuit which is integrated onto a single silicon crystal, all the components transistors, resistors, capacitors and etcetera. But, then they found it difficult to make capacitors. It takes more area and the reliability of the value of the capacitance is not that good. Resistors are less complex than capacitors but still more complex than transistors. So they make all sorts of changes in the design to have as many transistors and active devices as possible in the system and have very few resistors then if possible eliminate capacitance completely. This type of circuits become popular; these are called integrated circuits and about ten years into evolution of transistors and discreet transistor circuits in early 60s, integrated circuit became very common where simple transistors that connected together along with the other things all in one form in one single wafer - one single silicon crystal.

Once you have a technology of making things together as a complex circuit, we have so many applications, so many complex requirements of a system. People started experimenting and they can make a transistor amplifier, a differential amplifier, or a simple PLL, or a simple TTL gate using an integrated circuit, can I push this further and make a bigger system? Yes of course.

People started pushing more and more as technology advanced - VLSI technology, the amount of money spent in research and creating infrastructure in VLSI grew enormously and we went to the stage of microprocessors (Refer Slide Time: 13:45). In eearly 70s, entire 60s, integrated circuit of different description multiplexers, memories, all those came into picture and then early 70s saw the advent of micro processor. What is a microprocessor? Microprocessor is nothing but the CPU of a computer. All of us know that any computer will have a central processing unit and you have to make a computer by using the central processing unit along with input output devices, memories. In order to build this central processing unit earlier I used to have discreet components. They had to have this arithmetic logic unit and they had to have address unit, all those things connected together.

Then they thought if they can put all of them in one place on one silicon wafer (it is not even called a wafer) silicon die, then it is possible to make this interconnection. It is very simple, reliable and the speed increases. The advantages of the integrated circuit are many; one is the cost. We are going to make a batch fabrication; the cost is shared by all these devices. Of course there is a development cost, in the initial development cost but then as you make more and more of these devices, as you fabricate more and more of these devices, the cost get reduced.

I already told you the reliability; when things are connected internally in a silicon-bonding process or a chemical process, the connectivity is perfect. Whereas, when you connect these externally you have loose wire, dry solder, things like that. So, cost cuts down drastically; the connectivity increases, reliability of connectivity increases the power consumption also decreases because we power up the whole thing which a single power source and then power dissipation decreases. All the advantages that you want to have; speed also increases because they are so close to each other and again you can design very fast access devices. All the things that we wanted to have: high speed, low power, low cost; all those things can be achieved in integrated circuit; that is the idea.

That is all the technology has pushed into larger and larger circuits and of course you have to compliment the VLSI designers, system designers – VLSI technology people who came up with all these things you can look at; the designers wanted this, the technology people provided that. So, microprocessors early 1970s, 1972 was the time that 88 with the most popular microprocessor. All of us are familiar with Intel 85 bit microprocessor; it came in 1972, which is being used even today in instruction all over the world; many books have been written.

Digital signal processors (Refer Slide Time: 17:00) became a new family of device processors. The difference between microprocessor and digital signal processors in the sense, digital signal processors have specific functions. They can perform them which are not possible using microprocessors. Like, there is the hardware multiplier; a microprocessor may not have a multiplier; even if you have a multiply instruction it is performed by some sort of micro program. Whereas, the digital signal processor has the hardware multiplier; it has other features like hardware, Harvard architecture and all that. I will not go into details of the integrated processors.

As the technology improved, lots of signal processing requirement came for digital system design, in many appliances, industrial and commercial needs, domestic needs, household, military, DSP (Digital Signal Processing), it has become a standard tool. It was there all along, but, there was no hardware; there was no electronics with which you could do these things very efficiently, effectively and in a cost effective manner. With the advent of this VLSI technology DSPs became affordable for many applications. People thought of designing hearing aids, designing chips for cell phones, designing so many other gadgets. That developed into digital signal processor. It alone can only do so much. Then you want to make it such that in the process it is an useful device; in the useful application you can make what lot of application specific integrated circuits.

DSP or digital signal processor is a general purpose processor in which something similar to a microprocessor, it has lots of features which are common to microprocessors, which are different from microprocessor for signal processing application. They are still programmable where as ASIC's are applications specific integrated circuits which came about in 1990s. These were processors - Application Specific Integrated Circuits were specific IC's like a hearing aid, like a cell phone, even a simple device like a controller for a TV or a washing machine. Anything which is specific to that application and if cannot be used for another application, became an application specific IC.

This application specific IC concept became very popular when million volume sales would be very important. You want to make a cell phone at least you need to sell 1 million-2 million pieces only then it is worthwhile, because you need to have an initial cost and the system cannot change, their performance cannot change once the program is fixed its design is fixed. So, you have to go for volume production. On the other hand we have another complimentary part of this called FPGS - Field Programmable Gate Arrays (Refer Slide Time: 19:49). Field programming gate arrays are similar to DSPs. In the sense they are programmable but, they are not DSPs. The analogy stops there.

These have specific functional as against DSPs. DSP, is an evolution of a microprocessor for signal processing applications. A microprocessor is used more as a data processing application like data base; huge commercial type of computers whereas, the digital signal processor was used for signal possessing which is most important in filters, FFT, and things like that. In that sense, microprocessor and DSPs have the commonality. Similarly DSP, FPGA, ASICs have a commonality. In the sense they are functionally related but then DSP is the programmable which can be used for different functions; whereas FPGA as ASICs are meant for a specific function. It has the advantages of the ASIC and the advantages of DSP. The programmability of DSP and all the features in architecture of innovative features of ASIC, both put in FPGA. FPGA becomes a very widely popular device for prototyping small scale application universities for example research. In this course, we will see the extensive use of DSP FPGAs. All the applications we will talk about FPGA because we cannot make an ASIC for every application.

There are software tools you develop the programs in the software tools, download in the FPGA which is available on a board; then you can run it and test it for web design, if it is correct all the time. Finally, the concept is now evolving more and more like a system on a chip. That means the entire system is like a computer - a system were the memory, i/o, any peripheral like serial i/o, DMA or even systems such as digital camera.

Complete decoder this MP3 player. They talk so much of it but all these different devices today - all of them in a single chip on which it can be put. For example, a digital camera - it looks so small; one chip has everything in it. This is called system on a chip; it is also called embedded system. Embedded systems are nothing but systems on a single chip; a single chip on which the whole system is there. That is the evolution.

In this course, we will see how to design basically in an university course or any course or program for that matter, you cannot go all the way to a system on a chip; just as you cannot in a digital system course you cannot design a computer in a digital design class; we can tell you all about the fundamentals and the basics involved. Similarly, we will touch upon various aspects of the VLSI design and how intact individually things can be designed for that as you go into your workplace and with all the tools available to you; you can put them all together. Of course, no single person designs a microprocessor; it is a big a team of people working together on the microprocessor; you will have to contribute your share.

Likewise if you know everything about everything then you will be part of a team to put together or microprocessor or DSP or ASIC or a FPGA base system. That is the intent or objectivity course. You have a few things and I have more or less touched upon the need for this course and we will now talk about what we learned in this in detail. Before that a few things I would like to talk about are this IC itself. As I said IC has become a household word (Refer Slide Time: 23:50). I will tell you a few things about it, how it became (Refer Slide Time: 23:55).

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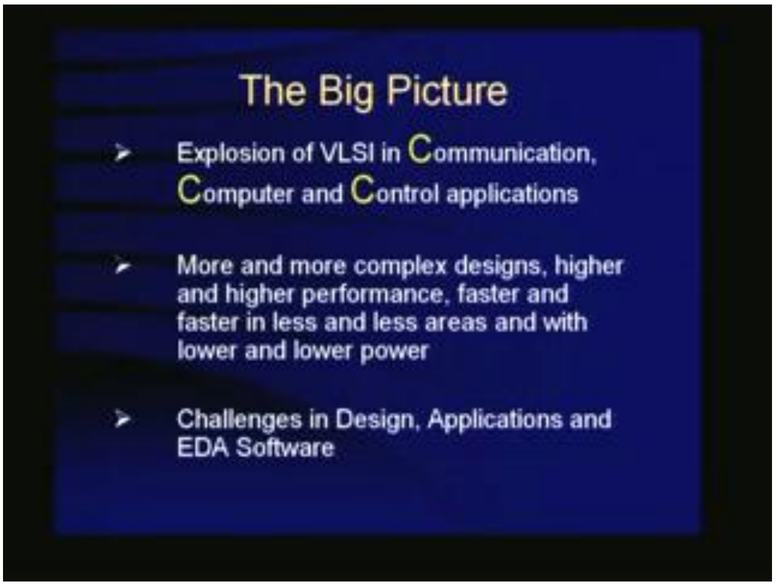

Now this VLSI technology fuelled the whole thing; because of the technology, there are advances of this VLSI used in communication computer control application. None of them is new. There were communication applications earlier but, people had to design huge equipment radio that links in transmitters and receivers were there; radio links in military applications were there, radar applications were there in the world war. They were all huge equipment, very big, very power consuming, expensive, sometimes unreliable.

Now, all these things are brought smaller and smaller and smaller. Along with that comes affordability, the reliability power dissipation, everything is improved. Today we have an explosion of information and communication. I already spoke about the internet application. All of you know cell phones; how many different things you do. Of course computers you know; the evolution of computers from 8085 and 8086. Today, we have Pentium processor that can control applications starting from simple control in the washing machine or a mixer at home to control aircraft, designs, we have applications.

As I said as you grow in this scale of either from 8085 to P3 or from the simple washing machine control to the missile control, it is an evolution which is complex in design, performance demand is higher. The higher you want to do it; faster, less area, less cost, less power, everything you want. We want to spend less money, we want to dissipate small amount of power; we want to make this tiny chip so that you can hold it in a small device or put in a pocket like a cell phone. People have hearing aid within, which is almost inside the ear; we do not even now that person having a hearing aid. That type of thing and the performance in terms of what it can do today; the amount of memory it has, type of processes it can do. All that complexity is increased. That means, we have challenges in design, challenges in applications; we have software. Designs have to be done before you can really put it into in chip. Once you make chip like a DSP or a micro processor you should find a use for it. You cannot sell a million pieces of a DSP if you do not tell people how to you use it, where to you use it; more important is the software. You cannot do hand design of all these things; you need electron design automation. In electron design automation software is required; without that software you cannot do these things today. Everything is done in a computer design VLSI chips. This is simple statistics. You do not have to be very serious about this. Of all the equipment today, about 30 percent of semiconductor components are application specification IC’s. And, application specification ICs are very much used.

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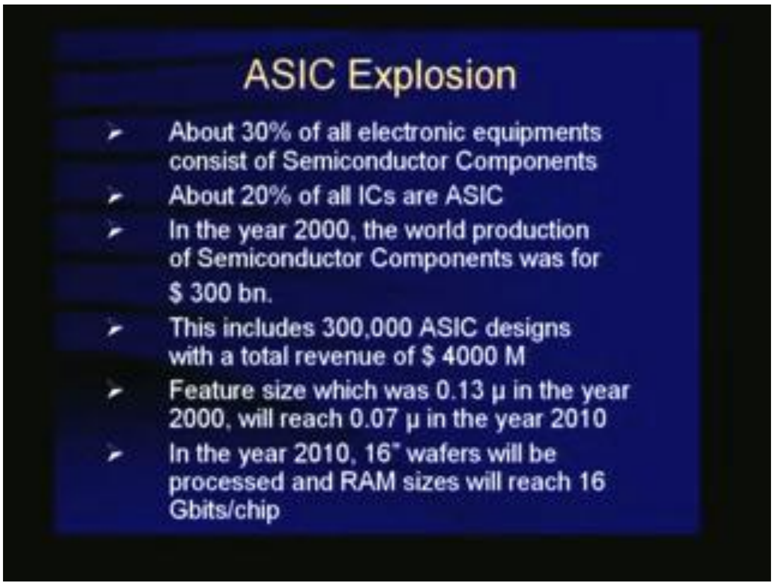

We are talking about 4000 million dollars of ASIC design, about 300,000 different ASICs. There is a feature size which I do not want to get into details here. How do you make it all small? How do you make a tiny piece and put it into a cell phone and put it into your pocket. There is a battery, a memory is there, your cell phone is there; everything is inside such a small device which looks like a snuff box. People take cameras into conferences, and photograph without your knowledge. How is it possible? It is tiny in nature; that is because the feature size as they call it, shrinks.

Connecting a device to another device using a wire or within a device design a transistor; for example, a base, collector and emitter or a MOSFET with a source, drain, gate channel substrate, the size has to be very, very, very, small. If I am going to accommodate a microprocessor which is equivalent of several 1000 transistors, each of the transistors would be very, very, very, tiny. Like a memory for example; if a have a memory of Giga bites in a small area each memory cell which contains several transistors has to be very, very small.

That is what we mean by feature size; we will not go into the actual definition of the feature size but you have an idea; that is 0.13 micron was in 2000. In the year 2007 feature size was 0.07 microns, we were talking about nanometres. 07 micron means 70 nanometres 17 into 10 power minus 9 meters is a type of link. This means, a technology which requires an electron beam technology, electron beam electrograph, so many things. So many advances but we are going to only design; we are not worried, but somebody is goes to fabricate it, that person is going to worry about this.

We are talking about 16 inch diameter wafer. Imagine the size of 16 inch diameter wafer. Put that huge plate like this (Refer Slide Time: 29:44), 16 inch plain wafer. On that wafer, I make a device which is very tiny, so I can make millions, at least thousands of these devices on this wafer; scribe them into individual things and package them. So this is gives you an idea; this is all, you do not even have to memorize the facts but this is an idea - common sense idea just know what we are into today. What is an application area? I said almost anything today there is nothing that is not VLSI application.

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Telecommunication - that is what we said about telephones, cell phones, radio; networking and internet. Internet is a lifeline today. Your computer network is down then you feel as if you have lost something. High performance computing, multimedia, everybody wants to make a presentation with Power Point and things like that. Industrial controls and Robotics we already talked about; very simple things – automatic robots, missile technology, automotive, your car has so much IC design and parts. Today's cars have so much electronics and if every electronics is made as a big system, then you would not have a place to sit and it would be a huge system projecting. Your radio for example, car radio - in that noisy environment we are able to listen to a radio perfectly without noise. What is the electronics involved? What will be the size? It will take a very small, tiny amount because VLSI. Emission control, brake control, everything is almost electronic. Energy management today is a major topic. Today we are energy starved globe; even advanced countries have power outages.

One technique is to improve the power generation which you are doing. The other technique is to manage it properly, like water and energy we are wasting. We do not have water you waste it; similarly, we do not have energy but, we waste it. How do you manage energy? We need a system which can monitor and efficiently use it. Medical electronics - we have implants today. Electronic implants are automatic; insulin dispensers which can be embedded into a body implant.

Defence and space electronics, you can imagine the type of missiles even India has. You can imagine the type of things advanced countries will have in defence electronics. Nobody goes to the field to wage a war; work is done electronically from a ship and the middle of the gulf; you bomb a target very precisely in a country to destroy it without coming in the way.

Consumer electronics is already told that you enough - television. Everything is consumer electronics today; MP3, DVD whatever it is called, there are so many youngsters who will know much more than me about these things, home appliances. That is the reason why you have to read this. I already told you about evolution starting from transistors from 50s to system on chip, 2000. That is why today VLSI has become suddenly a buzz word; it is not today it is invented. Electronics was there, applications were there, individual data was there, but putting together, making it affordable reachable by common man people start taking interest in it. TV advertisements come, news papers start talking about it when you want to know all about it and it becomes a part and parcel of of people's habit.

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All this has already been told to you. Three things we have to do; fabrication technology has advanced so much. We have delinked design and fabrication. We have the advanced CAD tools; without CAD tools you cannot do this. Imported design tools for design and fabrication which are delinked. I am not going to talk about design and fabrication in this course. We cannot do everything in this VSLI; it is such a complex vast field. You can be designer - analog designer, digital designer. You can in fact be a memory designer like that.

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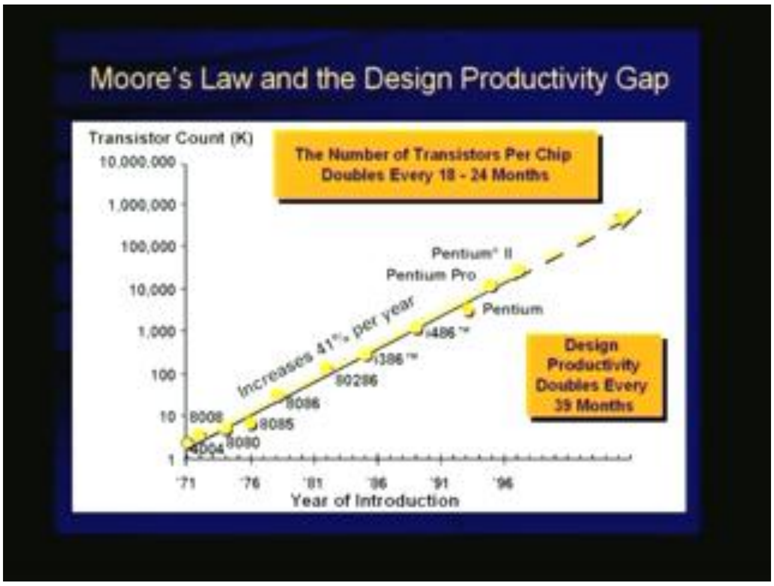

This is something, I already told to you. The number of transistors, the size is shrinking. This is the law, called Moore's law. As years grow, about 18 months, the number of transistors you can put in a same space doubles whereas the productivity does not increase. I am able to give a larger design but you cannot make those larger designs in terms of fabrication technology and in terms of productive use of that.

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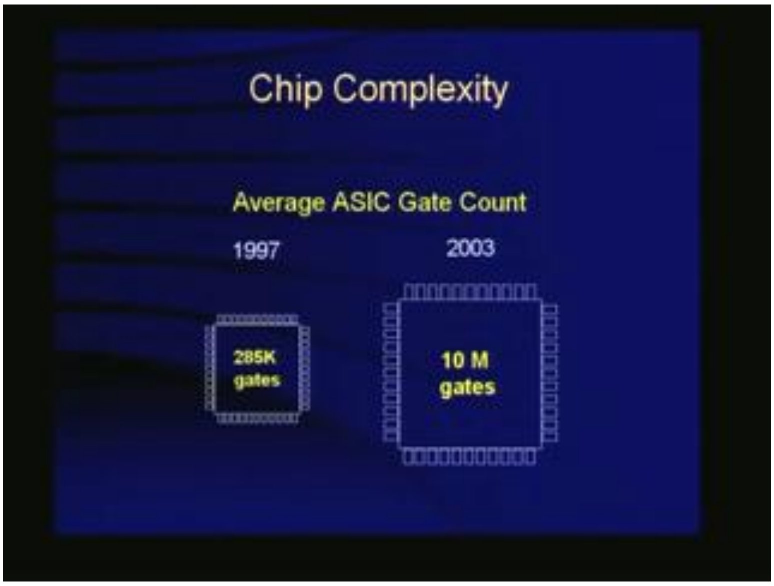

Gate Count as I said, since Moore's law applied 285000 gates a chip which ideally we had in 1997, the same chip can now fabricate 10 million gates in 2003. Gate is a few transistors all of you know that; the simple gate has about 10 transistors in it. You can imagine about 10 million into 10 million is 100 million transistors in a gate in a chip. We are now reaching 1 billion.

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Everything is an information revolution today. Most of the access to information will come through a VLSI system. Everything in this diagram is familiar to you (Refer Slide Time: 35:35) cell phone, copier, camera, simple aerospace controller, automatic robot, simple things like traffic control for air craft everything, almost everything.

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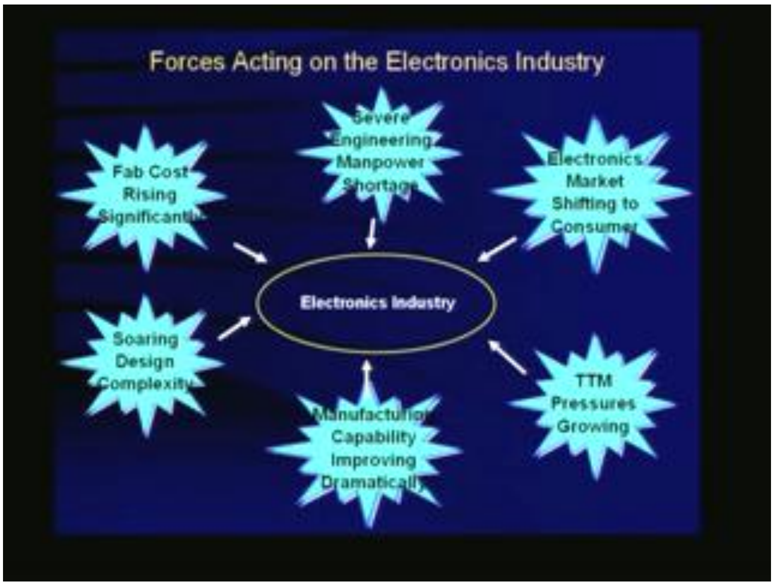

Lots of things you have to do. The fabrication cost is rising but you have to keep it low because people do not buy if they are expensive. Manpower shortage is there; we have to have very good engineers to design these things. Electronic market is shifting into consumer market. Consumer market is the only place where there is money. Why is every multinational interested in India and China?

We have people, the number of people in these two countries if they buy even a small percentage of these peoples' things, they will be much more profitable compared to what they can sell in entire United States and Europe. That is why market is shifting to consumers and they sell things which you do not need which you have to be careful. The complexity in design is soaring, at the same time, manufacturing capability is increasing. TTM means Time to Market; you have to beat your customer. Everybody thinks of the same thing at the same time but, you have to make your product well known, you have to beat your competitor at that.

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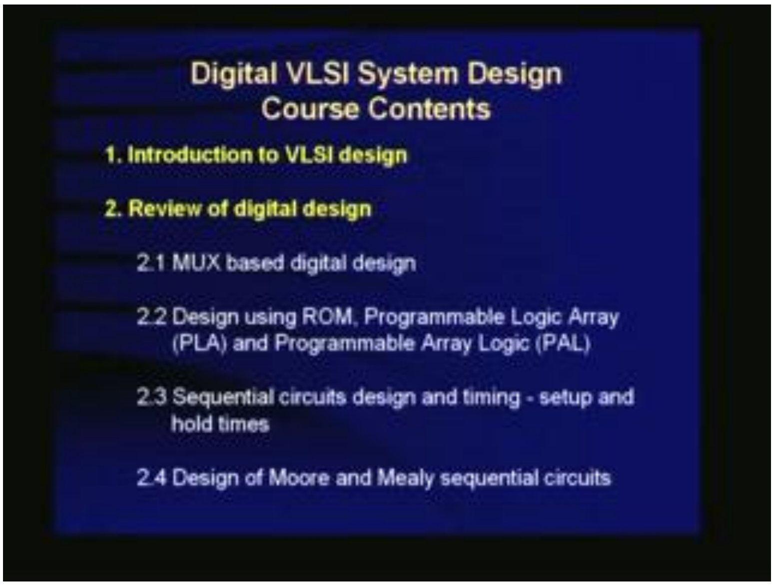

In this course, we will quickly go through the content in this course: introduction to VLSI design, that is what we did but then, we should know the design first. If you want to know VLSI system design, we have to know a digital system first and as I said this is a second course in this. This is not a first course. Do not expect us to teach you how to design a simple gate based structure or counter or an adder or something like that.

A first level digital knowledge is assumed. But will do system design in this course; multiple input multiple output systems in this course using multiplexers, using controlled programmable elements such as are ROM, PLA's, PIL's; we will do sequencing design and we will talk about setup time, hold time; these are important in the talk of design of VLSI. We will do sequential circuits of application for pattern generation function, pattern detection function, for example, Moore and Mealy circuits.

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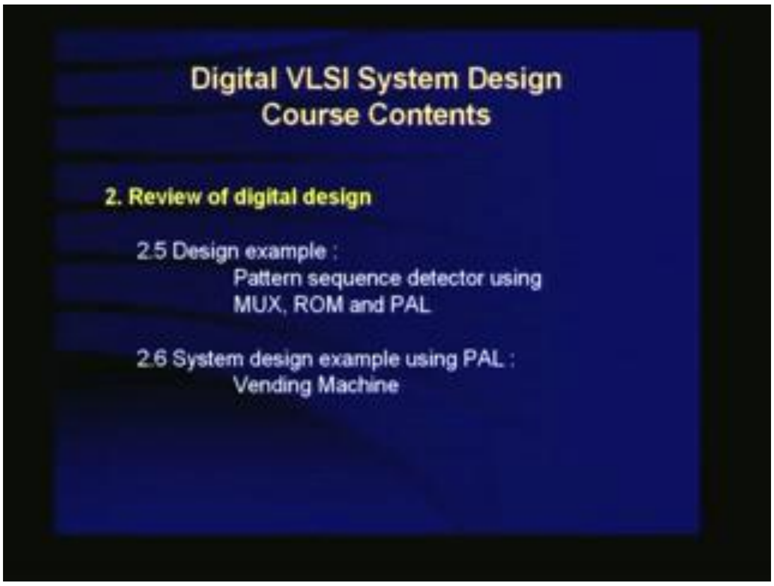

We can do any of these things using ROMs; we can do multiplexer, we can do PAL. We will also do full system designing. We will take a vending machine for example, we will take traffic light control, we can take dice game for example. How do you start from specifications? How do you break it down? Functional units and control units; functional unit - how do you break it into individual component? Control units – you have to find out the signals required to be given to the control unit. What are signals to give the control unit output? This will depend on the system; the system will give the status information back. How do you do that? Draw the ASM chart from there you do the individual design of the controller and implement it using a ROM and a multiplexer or a PAL; all that would be done in this course.

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How to design an ASM chart? What is an ASM chart? Algorithm State Machine is nothing but the flowchart in the hardware sense. How many clock cycles will it take to do this operation? What goes next? What are the inputs that have to be decided at this stage? If the input is this, what will happen to the circuit? If the input is that, what will happen to the circuit. Such detailed representation from the controller is called ASM (algorithmic state machine). In that we will give you several examples. As I said bus or biker traffic controller dice game.

You can also do the whole thing by micro programming; you can do two ways as I said MUXes, ROMs PALs, PILs; or you can do a micro programming approach. All that we will see in this, that means it is a revision of the digital course in one will sense; but in the second sense and more important sense, it is an advanced digital design course. That will be the first part of this course. First part of this lecture CD is about 50 lectures will be there totally in this. Out of this, first part will be covering all the basics.

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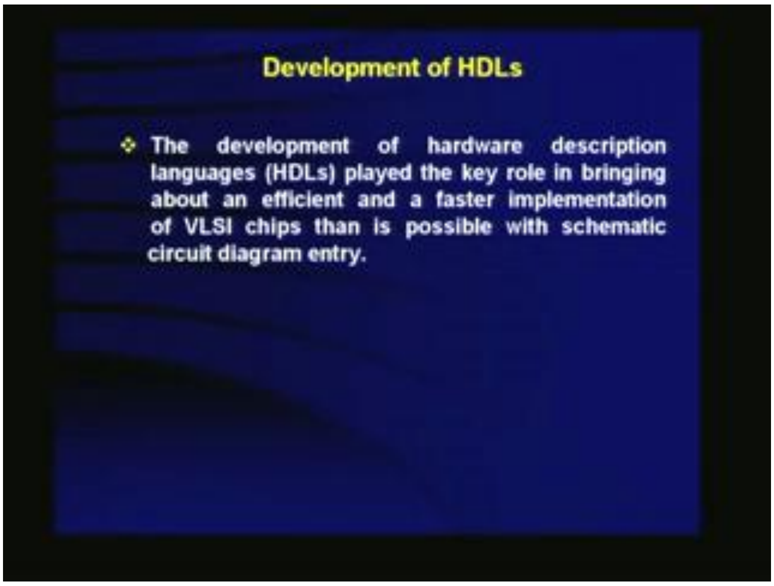

Then we will introduce how to start doing start design using the VLSI. How do I represent this? As I said, these are all computer aided design we do not do it by hand; that may it usual person to be design a computer. You need a computer language in which you can describe that design such as descriptions called Hardware Description Language (HDL), stands for hardware description. We have to develop the hardware description language; this is the key thing you design a paper brought into a program, which can be compiled and mapped on to as device which is available to you; this bridge is the hardware description language this is a very key component that made the design efficient and fast. HDLs play a key role in bringing about an efficient and faster implementation of VLSI chips than is a possible with schematic circuit diagram entry.

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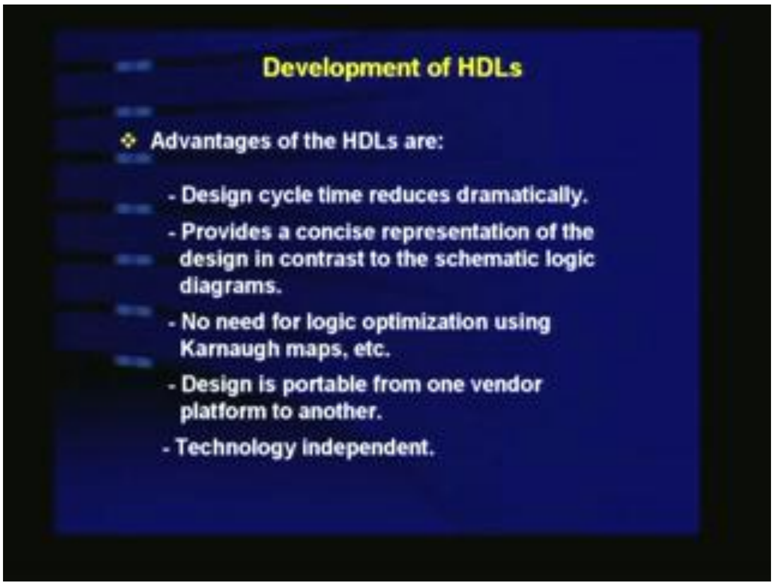

There are as I said many advantages; design cycle time reduces; it provides a concise representation of the design in contrast to the schematic logic diagram, no need for logic optimization, minimization, all this is taken care of. Design is portable, that means I can have a design description; I can use one particular FPGA and if I am not happy with that particular market vendor I can go to another vendor with the same description. Of course I may have to re-compile it for a device but, it is possible. It is technology independent; it can be point as I said 70 nanometres or can be 1 micrometer.

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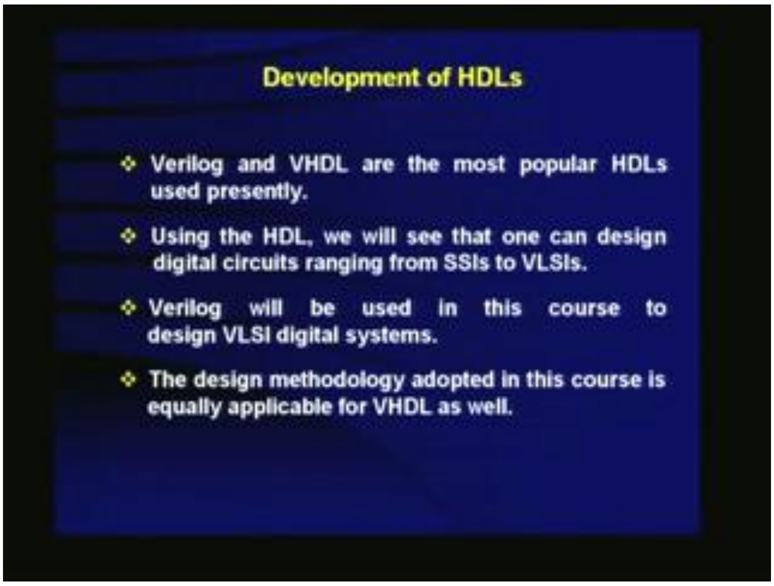

You can have two types of language. One is called Verilog (VHDL), we will use Verilog in this course. We will see that one can design the digital circuits all the way from SSI. SSI's (Small Scale Integration) gates and simple 1 bit full adder to VLSIs, ICs, like microprocessors, very large will be used. We use in this course both these. There is a subtle difference in the way in which we do things; one is Verilog is more industry friendly, be it in academics and some parts of the world they use Verilog. Other part is method. In design methodology in the course is equally applicable so do not worry that if we are going to Verilog, VHDL it is not that it is very, very easy.

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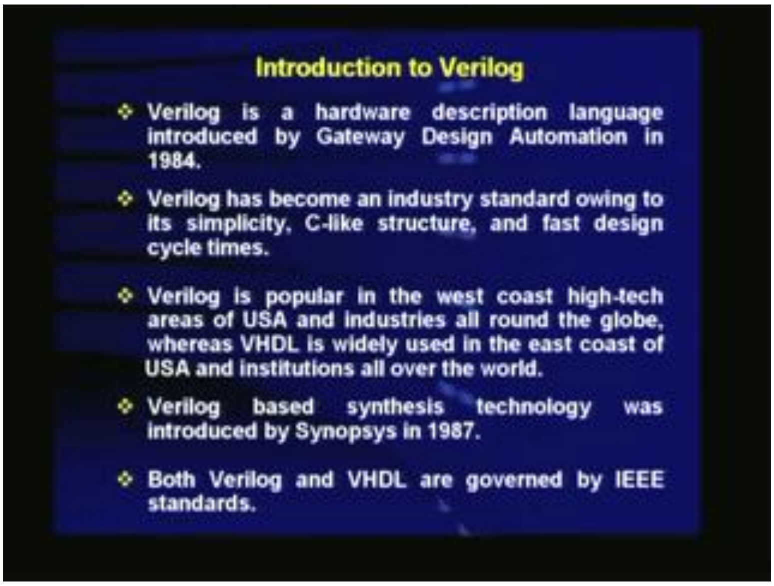

Verilog is used because it is structured like C language - shell-based structure. Verilog is a hardware description language. It was used by Gateway Design Automation in 1984, became an industry standard because of its simplicity in c-like structures and was popular in the West Coast of United States and Industries, whereas VHDL is widely used in the east coast of USA and institutions. Verilog based synthesis technology was introduced by Synopsis; there is a synthesis, will go to that. Both verilog and vhdl are governed by IEEE standards. We have to know synthesis. We will have to first describe and then go through a description and then we have to compile it, synthesise it and all that. So, synopsis is the synthesis tool which will be used.

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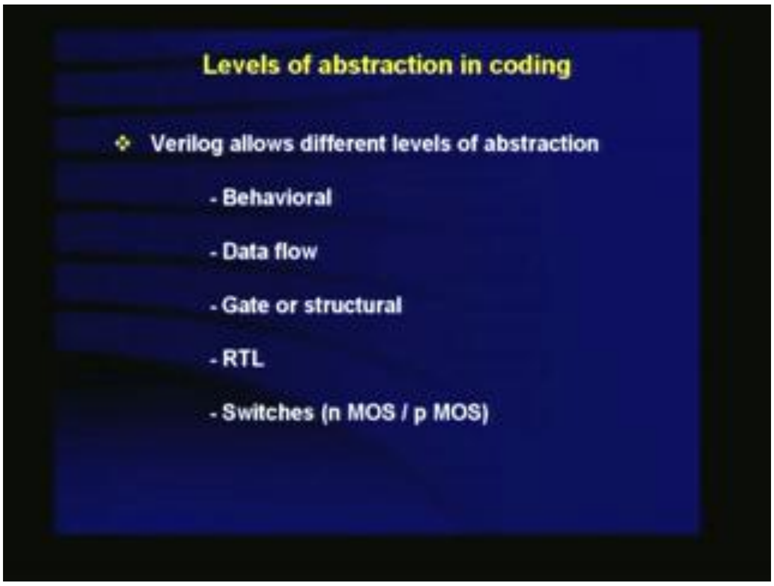

One of the various things - Verilog allows different levels. I can describe behavior circuit. I can give data flow of the circuit or I can give a gate of structural description, I can give an RTL. RTL means the Register Transfer Level. Register transfer what is it? How do you go about it? Or it can be switches – NMOS, PMOS, it can go to that level. Once you do Verilog, I will again introduce the Verilog properly and how to realize combinational circuits, how to realize sequential circuits, once you do that, how do you code it? Realizing is just simply writing but you have to organize the code properly for efficient design and you have to test it, writing a test page is important. How do you know the design is going to work? We cannot fabricate it every time.

You have to write what is in the test plan, what is the test plan? It will work with your design, finally the RTL coding guidelines will be given to you; only certain things are synthesizable. You can write a behaviour description, you can simulate it in the lab, can see in the oscilloscope but, when you try to build it will not work. What are guidelines you need to use in order to make it synthesizable?

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We should know the design flow. The methodology will be introduced to you. Design flow and then we will simulate.

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First of all you have to simulate it, before you can go into the fabrication. So, for simulation of Verilog, there is a tool called Modelsim which will be used along Verilog; it will tell you how to use it and then you have to synthesize it.

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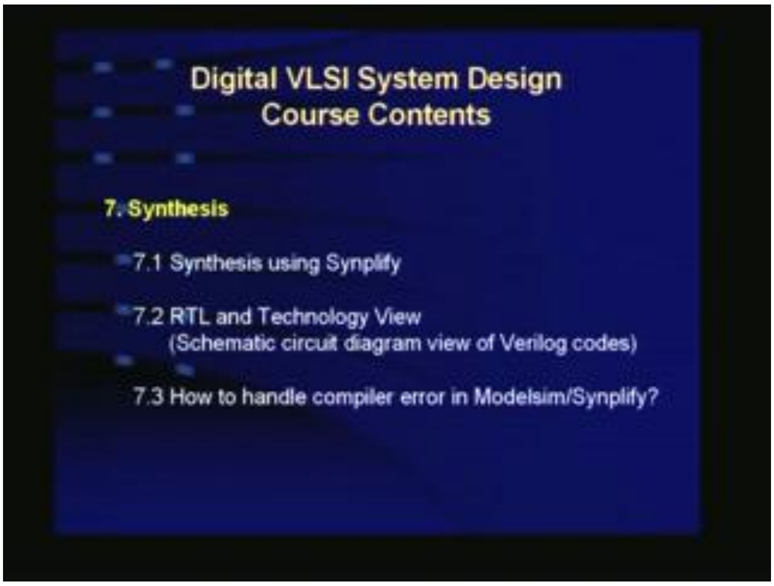

This is what I said synthesis is actually building the component by component. Component by component building is called synthesis; behavior description is translated. After the simulation of the behavior description for the verilog simulation, we have to synthesize it which is ready for implementation mapping on to the FPGA. This process called synthesis will use a tool called Simplify. We can see in this Simplify your RTL technology view that means you can see schematic circuit in Verilog codes.

When you see the code it looks like a computer language, C like structure. You should really know that finally it is what you want; an adder, you know how an adder looks like? When you look at this view, technology view, RTL view, you can see that in the circuit is similar to what you wanted. That way you are satisfied your designing is what you wanted. There will be errors and you should know how to....Modelsim may have errors, this synthesis processes also may have errors; when errors occurred, how do you handle it?

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Then after having synthesized it and you are ready to put it in a map, map it on a device - FPGA device; placing the various components within a field programming gate array and route it, place and route is what are the various functional blocks are. We are going to use within the FPGA for various relations, realizing various specifications of the required circuits, and how are you going to interconnect them, that is routing.

Once you do it you go back and see whether the back annotation, when you make that placing and routing we will make some minor changes and when you back annotate, you will go and verify whether your thing is still what you wanted. That is called back annotation and then you have what is known as floor plans - which are the units of the FPGA which will be corrected in what way.

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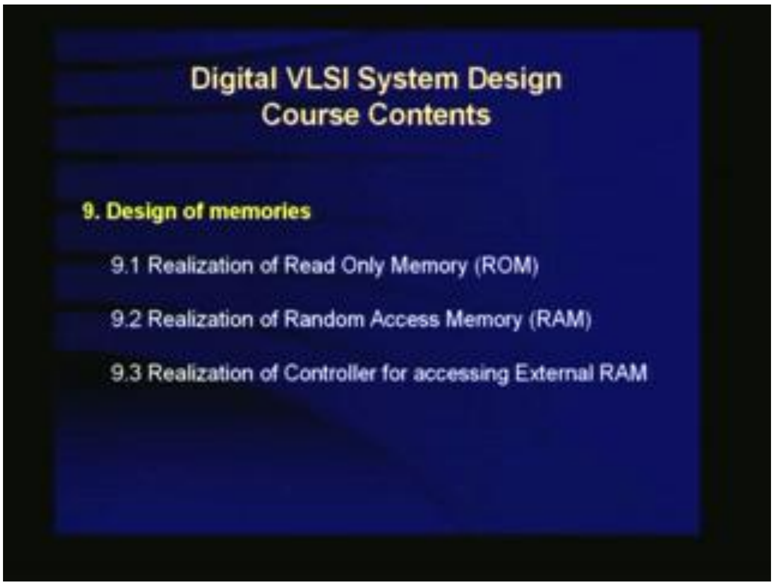

After doing that it will give you several examples; we will tell you how to design memories. This is not going to be a simple course; it is going to be an advanced course. You should know how to realize memories;. Read Only Memory, Random Access Memory, external controller, external memory, how do you control them?

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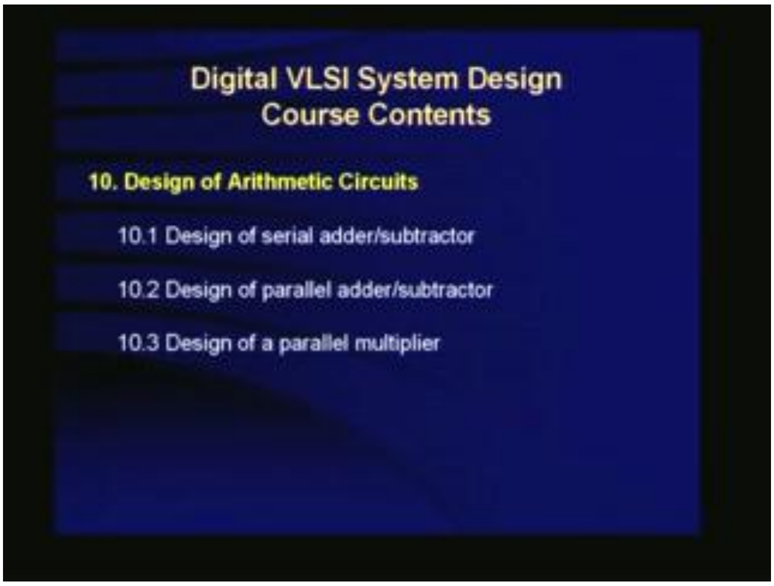

We will do arithmetic circuits for you. We will talk about serial adder, subtractors, parallel adder, subtractors. Multiplier is very common thing today in IC design. You need to know how to design multipliers. Parallel multipliers are a multiplier is very fast. Earlier they had Boots multiplier and all that. Even before that they had serial multiplier which is very slow when they had serial parallel multiplier something like Boot multiplier. Now we have array multiplier. How to design them? Design of parallel adder, subtractor, Boot multiplier and also design of array multipliers, all that have to be taught to you.

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Then using this FPGA you can design any application; many applications given as examples, design of PCI (Peripheral Controler Interface) arbiter, PCI control, we will do traffic light controller on FPGA, we will do Discrete Cosine Transform is used in compressing video. These are all some of the examples. It is not completely exhaustive there are lots of things you can do; we can only teach a few. Even these are about 50 lectures. Everything will be shown practically how to do it. Code will be developed and shown to you, how to synthesise it, simulate it, how to identify error, how to load it, everything will be shown to you in this course. Design and real time class will be very interesting and we will also give you several design applications which can be used further. Detailed Specification of Electrostatic Precipitator is an application which you will asked to do yourself, Electrostatic Precipitator Controller for FPGA implementation. Detailed Specification of Variable Length Coder is again used for video compression, building blocks functional units.

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So this is the type of things will learn in the course; it is an exhaustive course. I gave an introduction of what is VLSI? Why do we need to do VLSI? I also said why we are only doing digital because you cannot do everything and digital is most widely used and easy to implement and understand.

When you are doing the first time VLSI design, we start with digital then next part if interested we go to analog, then VLSI design; and then have to teach you lot of things about digital design itself. You may not be completely familiar with them; not only advanced level, systematically we are doing it.

Your design has been systematic keep on implementing, so not only it is in advanced design it is a systematic design and then once you have that you introduce the description language - hardware description language Verilog. How to translate your design into codes? How to simulate the code? How to synthesize the code? How to write test benches? How to synthesize it? How to map it? You back annotate and see whether your design is okay; how to find the errors and how to fix them?

You will be given complete information and knowledge and in the end of this course you will be very confident in designing digital system of any description. Given the size of that FPGA under our control, to fit into that size you can design anything of interest and as I said, we will give you several complete examples; several sub system design like traffic controller, several full control like vending machine. I will give you list of things to do there will be lots of exercise of problems. I hope you will enjoy this course and we have an exciting a syllabus for you.

My colleague Dr. Ramachandran will also share the lectures. Both of us will lecture in turns. You will see two faces doing these lectures. At the end of it you will become good VLSI - digital VLSI system designer. I look forward to teaching this course along with my colleague Dr. Ramachandran. The next fifty hours of lectures I hope you have patience to bear with us. I am sure the reward is well worth it. Good Day.