Digital System Design

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Lecture - 01
Introduction

The subject that we will read in this class is Digital System Design, today is the first class, so first I want to give a Introduction of the course. Mainly what do we mean by digital system, how we can design or what will be the efficient design of a digital system, so what we have to learn, if we want to design a digital system.

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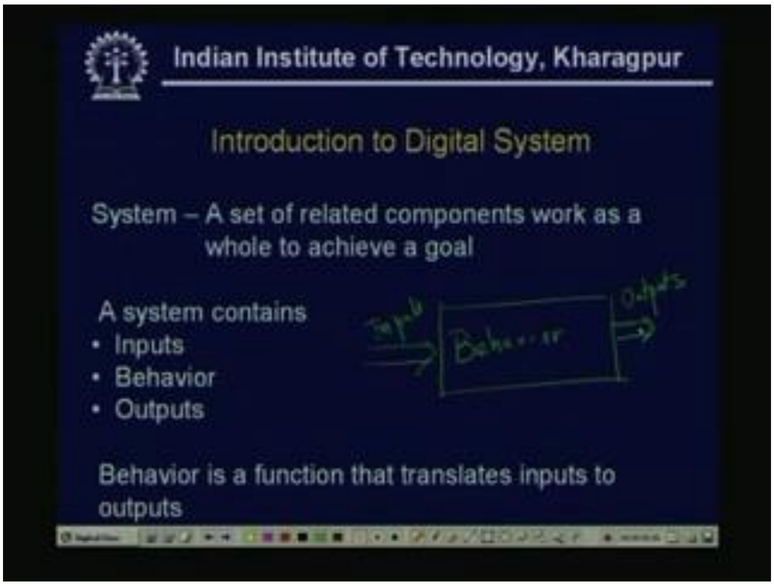

So, first we see what do you mean by a system? A system can be defined as a set of related components that work as a whole to achieve a goal. Means, that is a relative components means say some part that system has a different part, but when they actuate as a whole, then it will be actuate as a whole to achieve a goal. So, system contains our inputs, our behavior and outputs, you can let us elaborate this thing.

See if we draw a picture we see that, since a initially the system we are as if thinking as a black box, now we are feeding some inputs and this is the behavior. Means, how this black box works or what just know we have define this related components are the part of the systems as a whole how they works to produce some output. So, these three together these inputs behavior and outputs we are defining as a system, so what it is this behavior, behavior is a function that translates inputs to outputs.

That means, we are giving these inputs and then, what will be the outputs. That means given a problem that if we give this as the inputs, then what will be output or how it solves the problem means what will be output, so in this way we are defining a system.

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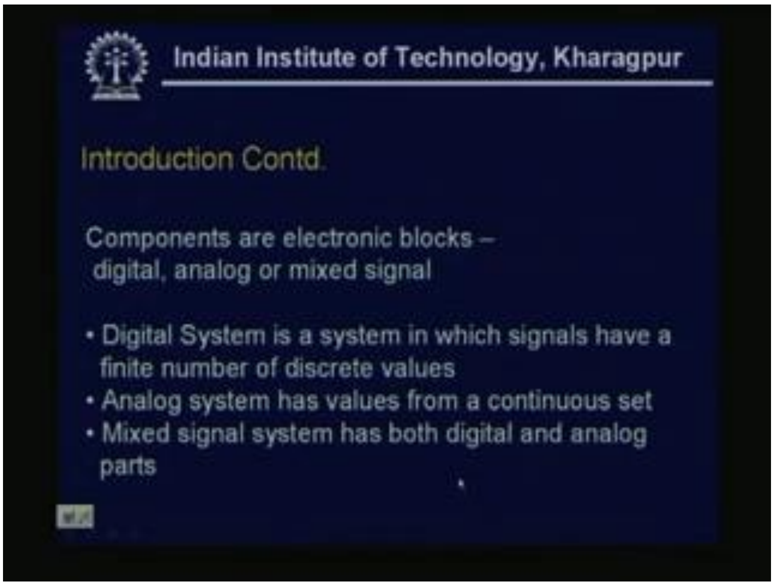

Now, see these components are that related parts or related components of a system that can be digital, analog or mixed signal. Now, what do we mean by this digital, analog or mixed signal components, first we see that the digital system is a system in which signals have a finite number of discrete values, whereas this analog system have values from a continuous set. So, first we elaborate these two thing, because digital system is the main concern of our class, so we understand what do we mean by digital system.

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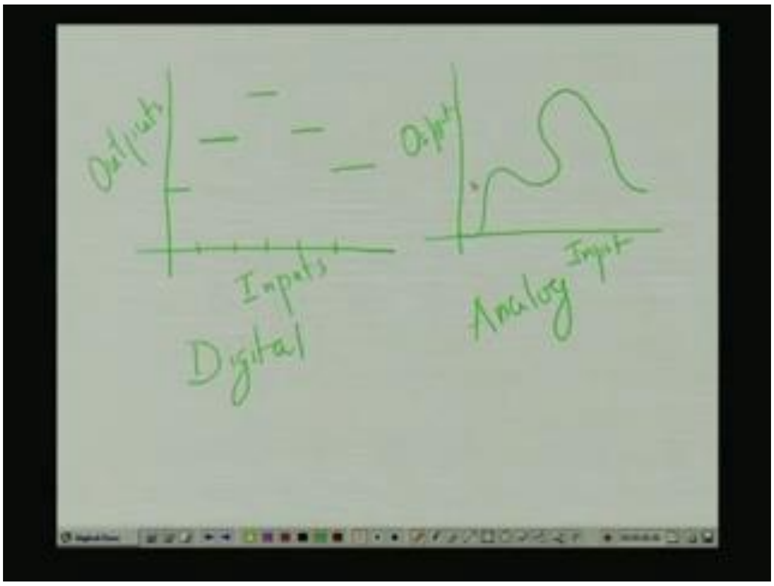

Say now if I draw this thing that means, so this is my some inputs, because already we have define that inputs behavior and outputs, so these are the inputs and these are the outputs. Now, say again inputs can take some discrete values not all the values here, say these are the some values it can take, now for these input see output can be this one. So for this input the output it can take say this is output can be this values.

Similarly, for this input the output can be this one, again for this input say it is taking that same output, that means see here only 1, 2, 3 these 3 finite values it can take, these we are calling that discrete values. So, this is my digital, this we can take that these are my digital system, whereas that analog how we are defined, that analog means we told that the signal can take this is a system. How that signal can take the continuous values, that means a infinite set, here it is a finite set, here it is an infinite set.

So, just if we draw this can be a, so continuous function, see that first the input can take again the input can take any value, any value here. See for each value of input the output can also take any value, so this is some infinite set. So, now how we define the mixed signal, so mixed signal actually this is a mixed of both digital and analog parts. Now, one thing normally that see this a mixed signal values though we are telling that it is that components can be digital and analog.

But, normally the inputs and outputs that are either inputs can be either digital or analog, output also can be digital or analog, that means again if we draw some pictorially if I can say.

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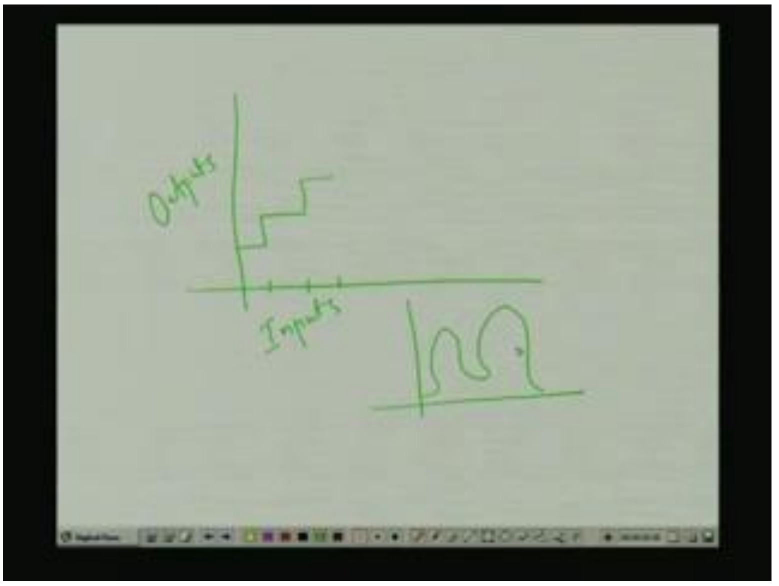

So, again these inputs can be say the inputs that can take some fixed values, say for here some of the components it can take this type of digital values, but for some of the components that output can be that continuous values. So, if a system consists of both the digital as well as the analog signals or analog components, that means here that inputs can take finite or infinite, as well as the output can be also finite or infinite, then we are thinking we are telling that these are the mixed signal system.

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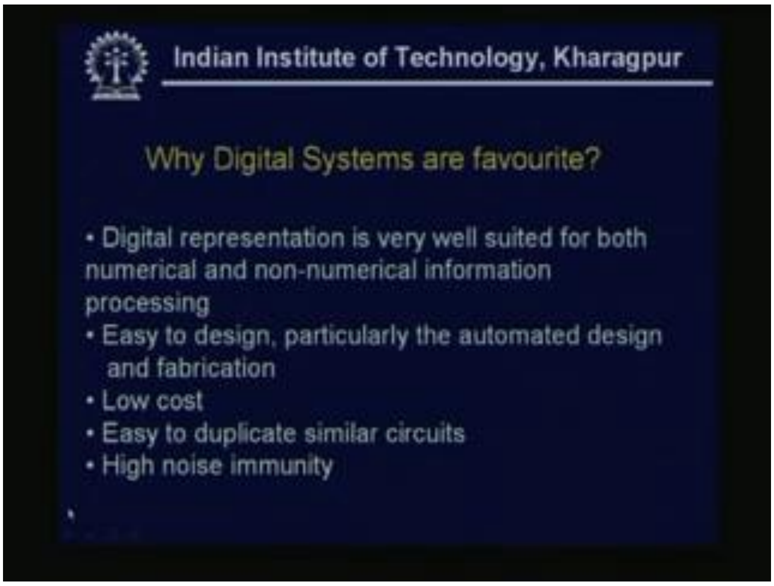

Now, why digital system are favorite, why we will read the digital systems or why we are eager to know that how we can design a digital system, that what is the advantages of digital system. First thing is the digital representation is very well suited for both numerical and non-numerical information processing.

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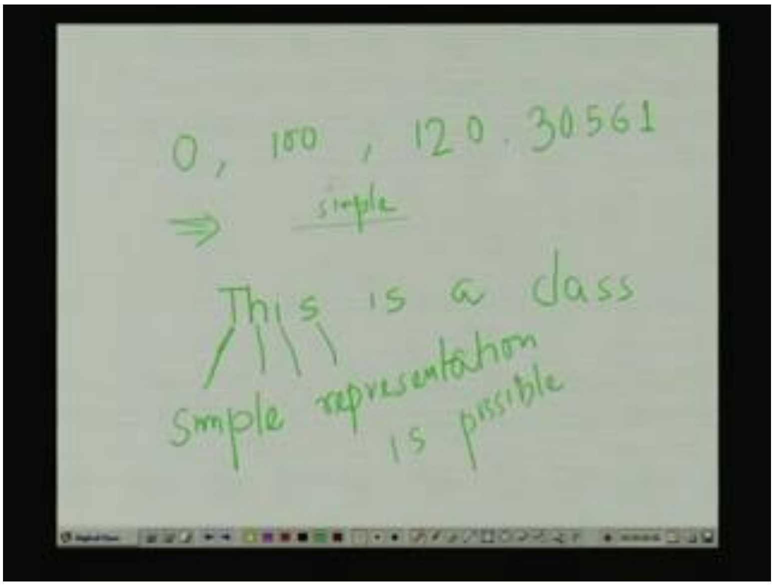

Say non-numerical information processing means, again if we tell say numerical means that 0, 100 or say 120, again some big numbers if we take some 30561. So, what we will see in this class what will read, that all these numerical values whether it is a small number or whether it is a very big number large number. Then very efficiently we can represent that thing or the digital system concerns that the digital representation of these numerical numbers will be very simple, that will be very simple representation.

Now, see non-numerical, non-numerical means say our language, say our English language I am telling that this is a class, now see this English language all are this characters say here T is character, h is character, i is s and similarly. So, now this character can be easily digitized, that means the digit even T characters first we can represent simple representation again simple representation of these characters are possible, so that is why this is simple representation is possible.

((Refer Time: 10:47)) So that we are telling that this is one of the biggest advantage, now another is easy to design particularly the automated design and fabrication. So, as digital system already we have seen just now I mention that it is the representation of numerical as well non-numerical data or the information that we can easily represent, and only for that reason some simple circuits are available for the design.

Say if for this information processing, first how we input this thing or the behavior when we are actually that is the main system design part, that how we can represent it is behavior that means, how we can process this numerical or non-numerical data to produce my output. And as it is a very easy to design and it is to automate that thing that means, automated design or that automation of the system that is a very advantageous for digital designs.

And again fabrication part also, because nowadays all of we know that mainly that digital design means whether why it is so popular, because for the digital chips, it is within very small area that a small chips that we can implement a system. Now, it is very low cost, because the representation is simple, because the design is easy to implement and the automation is possible and that is why it is very low cost.

Now, easy to duplicate similar circuits, normally this we call that VLSI circuits, where that it has a very regular type of structure these digital systems. So, within a small area we can fit a number of, actually this number varies from thousands to millions, millions of small circuits in a very small area, so this is a easy to duplicate similar circuits.

Another is the high noise immunity, so what do we means by high noise immunity means that, that is small variations of the components cannot change the outputs very fast or even in very large scale. So, actually that means, it is a noise immune, so what we I am telling that variations, so their variations can be done by using by applying some noise or by introducing some noise; so even if it is a small noise is incorporated or some somehow it is noise affected, so then also our digital circuits performs correctly. So, this is a very big advantage that this is a high noise immunity power.

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Now, easily controllable by computer this is the main advantage of the digital systems, so the finite number of values in a digital system can be represented by a vector of signals with just two values, what we call the binary signals. Let us discuss this point, because this is the main backbone of the digital systems, so already we have defined that a digital system that it is the system where it can take only some finite values.

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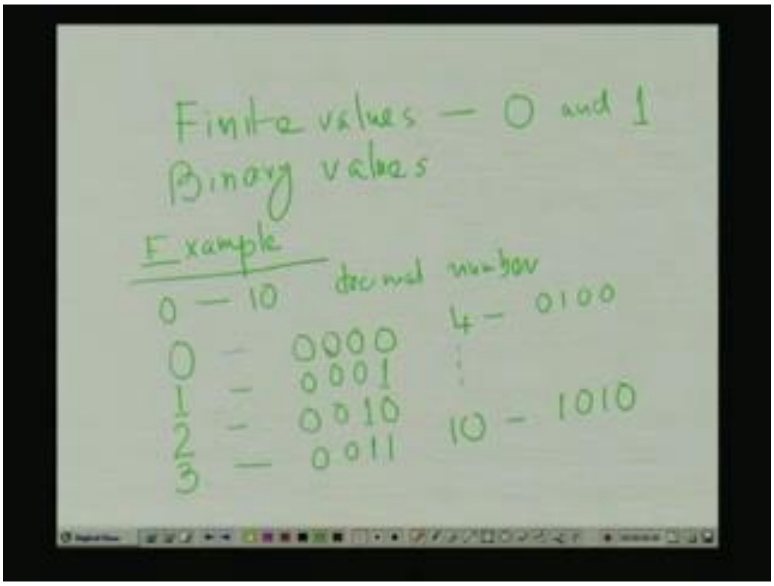

Now, say this finite values I am taking only two, the two values, so these values I am telling 0 and 1, just two values that is why normally we call this is a binary values. Now, any number say I am taking one example, so some example if we take since first taking some numeric numbers say 0 to 10. Now, if I want to represent, because these are my decimal numbers normally 0 to 9, this 10 values are used to represent decimal a numbers.

So, this 0 to 10 decimal numbers I want the representation of the binary, now this is if I want that I will use some 4 digits, means that using only these two values and that 4 numbers. Say that means 0 means, so I am telling all 0, 4 this I am telling that our digital bits, so digits means that 4 digital bits I am using, one means this is say 0 0 0 1. Now, 2 mean say I am telling 0 0 1 0, actually how we are getting these numbers we will read in the next class.

So, 3 means 0 0 1 1, this is very easy to in that similar way I can represent 4 which is nothing but, 0 1 0 0 and say my 10 is 1 0 1 0. So, see that if by 4 bit I am representing see here all the values can be I only 0 or 1, 4 digits I have taken, but every digit is either 0 or 1, so very easily I can represent that thing. So, the computer can easily control, because this is a machine, computer is a machine, so it can recognize only two values say 0 or 1.

That means, if we think that computer is nothing but, ((Refer Time: 17:53)) a combination of switches a millions of switch, then every switch can recognize the it has two step either one switch on means it is a 1, if it is a switch off then it is a 0. So, that we can logically we can tell that switch of means this is our 0 and switch on means this is 1. So, only by taking a thousands of switches or millions of switches I can easily define or I can easily construct or design a digital systems.

So, the device which process this signal is very simple say switch or open or closed, so this is the biggest or the main advantage of the digital system. Another thing is the adjustable precision, see I am given one example again if I draw.

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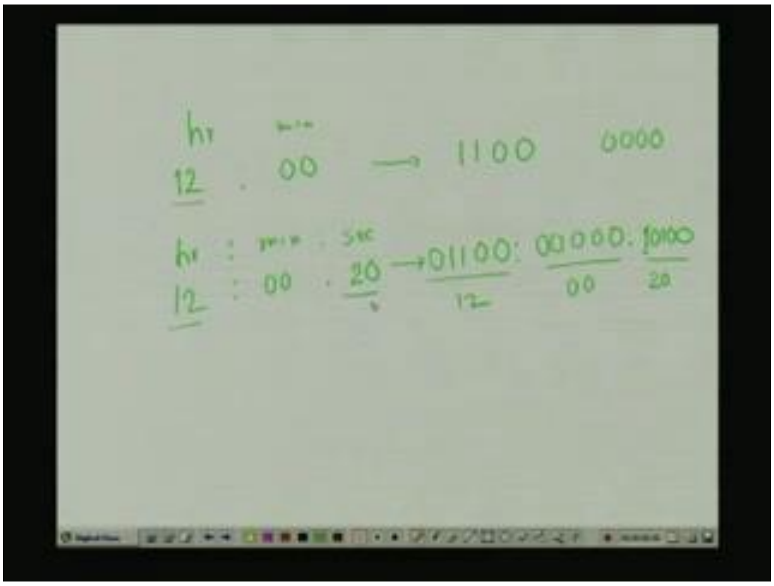

Say, I am telling that I have some digital clock, see my clock is giving some hour and minutes, say now it is 12 o'clock, so 12 hours and 0 0 minutes, so I can all as it is a numerical numbers, so 12 hour, so I can take some digital values. See this is 1 1 0 0 again the previous example if we take it is represented by a 4 bit, and this 0 0 again if we take that this is all 4 numbers.

Now, see if one person wants the second also, then it is another second is also there, so it is 12 hours and then, 0 0 minutes and say 20 seconds, then it is 20 seconds. Then again what I can do that, see I can do that 12 is again 1 1 0 0 again this is 0 0 0 0, now here I have to represent this thing by a, so 20. Then I have to take another value that means by 4 bit numbers I cannot represent 20.

So, then what just I am telling taking see as here from 20, I need 5 digits, so this should be 1 0, so 1 0 0, so I am taking 1 0 1 0 0 say 16 and for 20. So, how I can change see easily I can change if I put another 0 here, if I put another 0 here it remains same that means, this means my 12, this is my minute representation 0 0, this is my second representation say 20 second. See that means, that precision if I want to this is nothing but, precision that it was earlier hour and minute, now I want to change that thing by a second.

So, I am introducing another field and again it is another field means this is earlier if it is second means I want 5 digits, so only I need another bit that is left hand side that easily it can be included, so that is why it is a adjustable precision. Now, complex digital ICs are manufactured with advent of microelectronics technology, already I mention this that VLSI, this is a reason because now normally we call that this the world, the current word is digital world.

So, that means that wherever all the systems, where the digital is possible to design a digital design and the main advantage is that, I can. The thousands of circuits or digit even large systems that I can put in a very small area. And that we are call that integrated circuit or that normally we call that IC chip or even you can tell the VLSI chips.

So, we know that our starting from our digital calculator, our digital watch, the digital computer or say if we see that number of applications mainly that number of all the personal digital assistance, say your mobile phone, your pump top or any type of electronic goods that we are using now a days. That everywhere that mainly, why that it is a the size is very miniaturized and that is possible, because it is implemented or it is designed by or constructed by that digital design. So, that is the that complex, any complex digital circuits that we can implement or we can design by a digital design.

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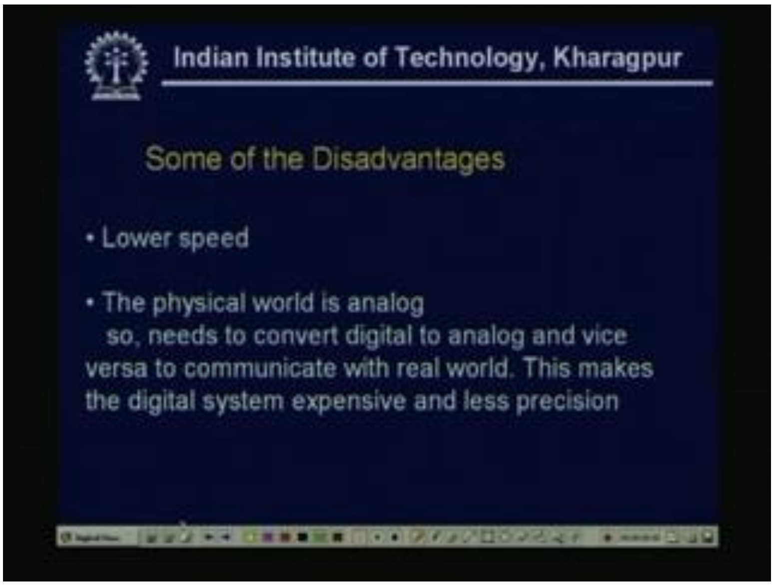

Now, not all are the advantages some of the disadvantages are there, one thing is that lower speed, so if we use that analog though analog has many other disadvantages, but we will not discuss that thing, because our main concern is digital system. Then one advantage is that it is very fast, whereas the digital is that speed is lower, another we should tell this is not a disadvantage, but we have to it is a costly or some complexities are involved, because that our physical word is analog.

Means say this I am talking, this is a analog signal, so a someone is singing that is a analog thing mainly the signal we are producing that is a analog signal. So, if one system is analog, then directly it can catch our analog signal and it can process whatever it wants, see I am taking one example again, see I am taking one analog signal.

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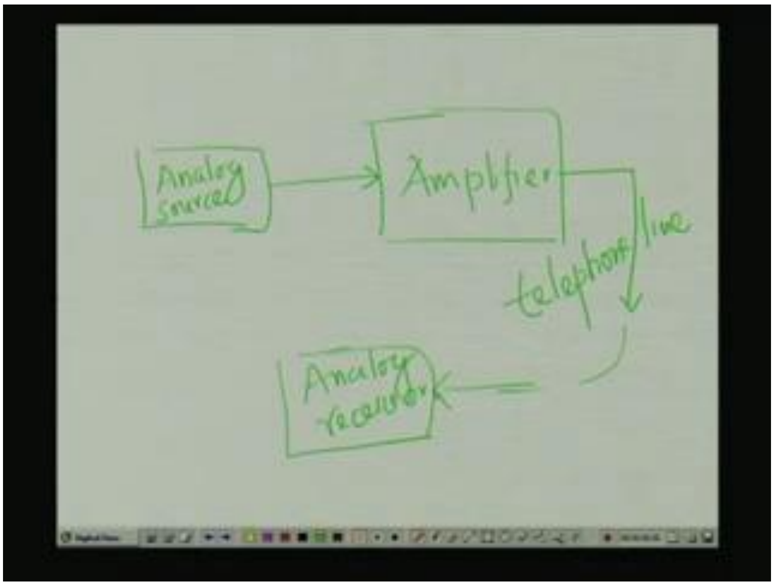

Say, this is one source, I am telling this is one analog source, means that it is generating some analog signal values, that can be a song, that can be a some words. Now, directly I want to amplify simple one, simple system I am thinking that this is I want to amplify, this is a amplifier. So, these are the inputs, I can directly feed these inputs, I can directly put that thing say my telephone line, say this is my telephone line.

So, it is going through the telephone lines and via telephone again it is some sender, again some this is a analog receiver say the it is going. Now, see here there is no conversion is needed, the analog signal is generating this is being processed. Say amplifier is one example, then it is via telephone line it is communicated, again if it is a telephone line; that means, it carries the analog signal and then some analog receiver is taking that thing.

Now, say I want this, if this is digital I want to incorporate the digital; that means, so for it is a digital design. So, needs to digital design means our word is analog means, I am talking or someone is singing that is the analog signal, so what we need? I need to convert that analog data to the digital one, because my information processing should be done in digital way because we are discussing about the digital system design.

So, now first we complete this thing that to analog and vice versa; that means, one analog to digital and digital analog to communicate with real world. Now, this makes the digital system expensive and less precision, so what we need.

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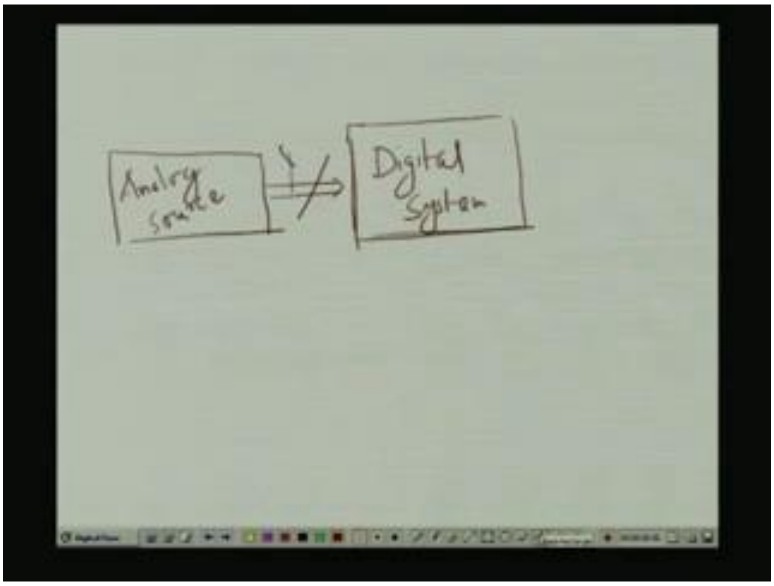

Again if we draw that thing say again one analog sender or analog source what we call the analog source means some, say some song is produced, some music this analog signal. Now, instead of this amplifier see I have some digital systems, now see I cannot feed this analog source directly what I want, then I cannot because this is a analog signal.

And this is a digital system means my inputs should be digital input output should be digital output, this processing or this behavior implementation of this behavior that how it translates or how it converts the input to that is also digitally process. So, I want to one converter here, so if I want to change this thing, I want one say delete that whole thing.

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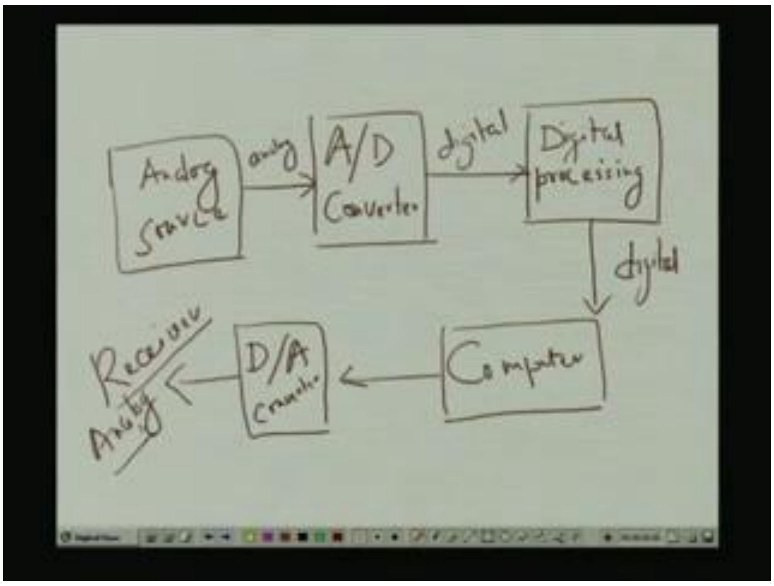

And I again I do that this is my that one analog of source, now I want one converted this is called analog to digital converter we normally called a 2 D converter. And then, so here it is a analog signal here output is digital. So, now, can easily attach one digital system, so some digital amplifier I am telling, I earlier it was analog amplifier, so better I call some digital processing, so this is an digital processing.

So, again these output it is digital, now think that, see actually it was a song, so when I again I want to listen this should be analog. Say now, I fed it into a computer, so digital processing then it is a digital computer, now either within this computer or outside I need a digital to analog converter. So, for all these things are this is processed the digital, so I need one digital to analog converter, so that I can the receiver can listen that receiver can hear the sound.

So, this is again a analog receiver, so see I need this to this conversion and this is the conversion, so this is somewhere that is why it is called that, this is expensive. So, to communicate with the real world, that digital system is expensive, and this is and less precision.

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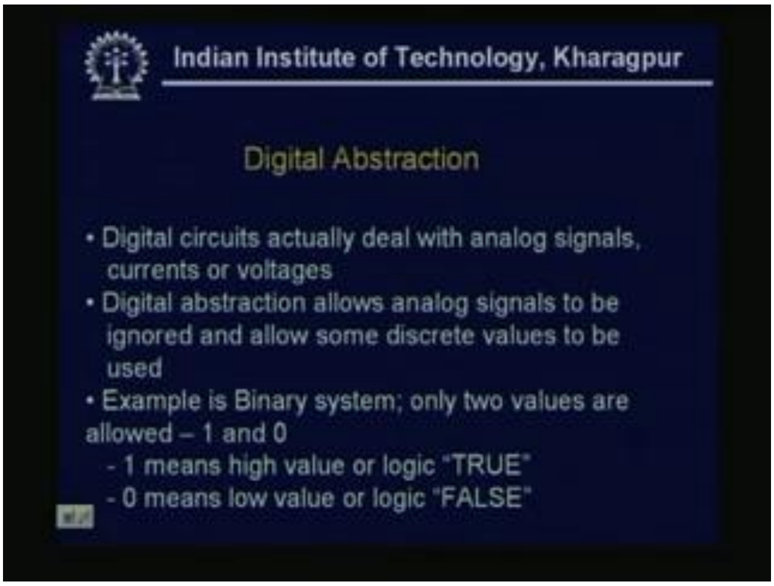

Now, another thing is very important, we are telling our physical world is analog, that means what we are generating, what we are listening, all are analog. And then it is processed or that normally say some information processing or data processing, that we are doing by digital. Because so, far what I mentioned that digital implementation very easy, data representation, whether it is numerical, whether it is non-numerical that is very simple.

So, actually some digital abstraction is there, because the real world is analog, so digital circuits actually deal with analog signals, say here signal means currents or voltages. See I have one voltage source that is generating say 10 volt, this is a 10 volt supply, so where it can generate 0 to 10 volts say if I can vary that thing. So, 0 was, 0.5, 1, 1.2, 2, 1.3, so it can take any values actually it depends on that the accuracy of the supplier.

Now, how I can tell that, when it is attached because one power supply will be needed, so when it is attached with a digital system, how can you tell that either it is a one or it is a zero, so these we are calling they one abstraction. So, digital abstraction allows analog signals to the ignored and allow some discrete values to be used, what does it means

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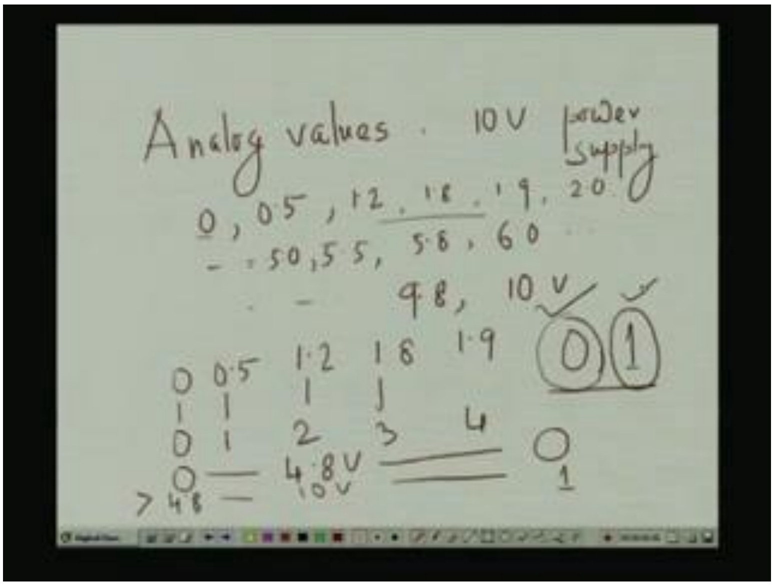

See, I have some analog, again if we take the same example of that power supply that is a one the analog values can be 0 if it is a say 10 volt power, it can take 0 or 0.5 volts then 1.2 volts it can be, then it can be 1.8 volts, 1.9 volts, 2.0 volts like that, like it can be 5.5. So, it can be 5.0, 5.5, 5.8 like 6.0 in that way in that way it will be say 9.8, then 10 volts.

See. So, many values it can take, see now you can tell this the again these are some finite values, then I need some discrete values to represent if I want to convert or to represent rather not converted. If I want to represent these whole set of values digitally, then what I want say for 0 I want because these are all separate values, so far 0 I want one discrete value say zero.

Say for 0 point say if the precision is 0.5. So, I am taking 0.5, then I want say for this is 1 then say for 1.2, I want another value 2, 1.8, I want another values 3, 1.9, I want another value 4. So, many values will be there, but just now I we mention that everything we can represent by binary by only taking 2 digital values 0 and 1. So, we are what we are telling all these analog values that we are actually we are ignoring.

What we are doing say actually some a range of values logically we represent that thing by a 0 and another range of values we are representing by 1, see this is 0 to 10 volt. So, I am thinking that if it is or just we are maintaining this that if it is 0 to say 4.8 volt then we are telling this would be a zero, this will be treated as a zero.

If it is greater than 4.8 volt; that means, 4.8 to 10 volts, then it will be 1. So, now see actually all these this is a range one range is replaced by 1 value, another range is replaced by another value 1. So, this is these we are calling that one digital abstraction.

So, example I have just now what I mention this is a binary system only 2 values are allowed 1 and 0, 1 means high value, say our high value means this high value is range, say if it is 5 volt to 10 volt I am telling this is a high value or logic true. Sometime this is called a true means this is on or switch on, Zero means low value; that means, if it 0 to 4.8 volt, if we take that some example and this we call that logic false.

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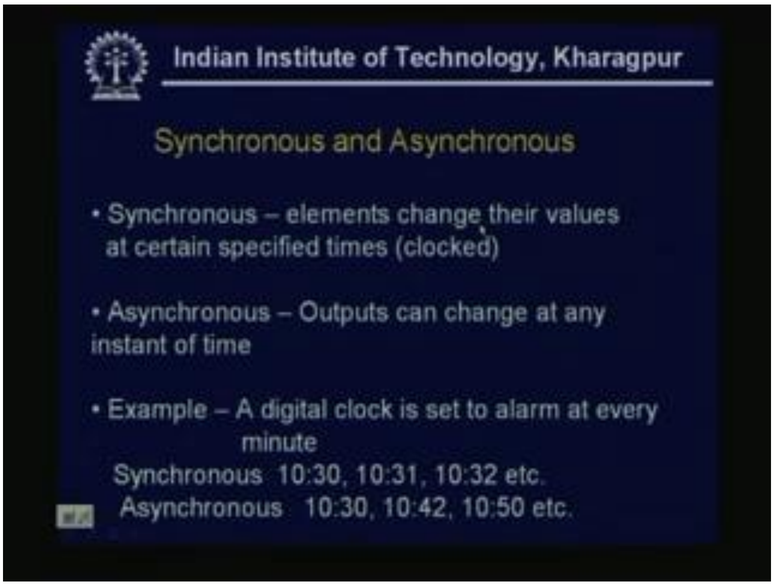

Now, another two terms are very important, when we read that digital systems, one is called synchronous another is called asynchronous. So, what do you mean by synchronous system? A synchronous system has the is the elements, if the elements change their values at certain specified times. Certain specified times means some specific times only they can changed and it is normally we call that clocked, we will discuss that thing later.

Now, only we can think that the input we can apply the output that the system produce or even the processing or what we have represented by our behavior. When it is processed that everything is being done at some specific time instant, then we are calling that this is a synchronous system and asynchronous means that outputs can change at any instant of time.

So, there is no fixed or instants that the inputs can change inputs can apply outputs can produced at any instant of time that can be done One simple example we can see that again we take the same example of digital clock it is set to alarm at every minutes every minute it will make a sound.

So, synchronous means 10 30 it will may then it is 10 31, 10 32 at every minute it will give a it will make a sound. Asynchronous means no it is not in every minute say 10 30, then 10 42 say 12 difference is 12. Now, it is around 10 50 means 8; that means, there is no fixed instant there the fixed instant was the period was at 1 minute when we consider the synchronous. If it is asynchronous again that it can be 12, it can be then 8, again it can be 1, so there is no fixed instant of time that it can change.

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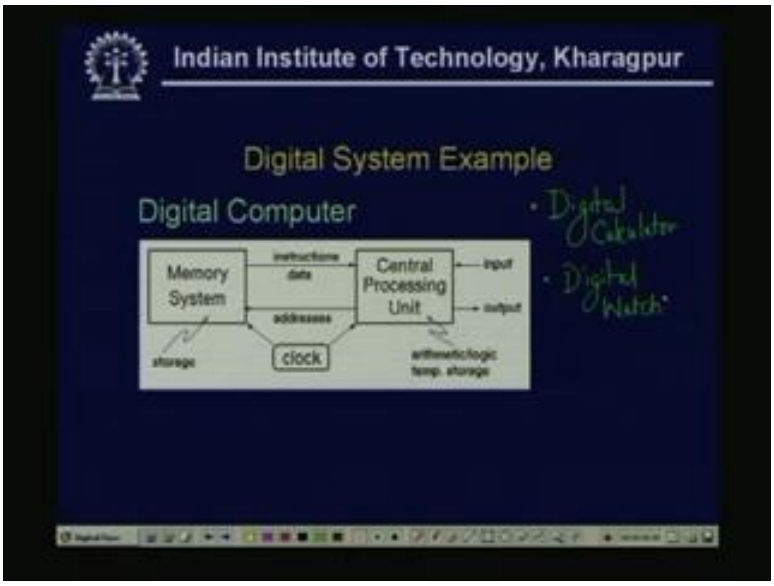

The most common example or actually if we already I have given, I mentioned many digital system examples or digital calculator is one example. So, if we think that our examples are digital system examples, I can tell that our digital, just a minute our digital calculator is one example, another is our digital watch, so very simple examples. Now, these class mainly we will consider our digital computer is the digital system.

If we learn the all the parts the way we have defined the digital system is a, one system is a related components and if here the components are digital block, then we are telling that this is a digital system. So, our digital computer is the example which if we see the design of a computer, then actually the all the concerns of the digital systems how we can design an efficient or easily understandable digitals systems, then that computer is the ideal example. See, in very abstract way, very simple module I can tell that computer has, the very basic that it is memory and it has some central chip processing unit the CP.

See as if memory from memory that instructions and data are going these are digital data again instructions that we can represent by digitally. Because I give that example that if it is a English language or English type language mainly consist of characters only or some other characters, always we can represent that thing by a by 0 1 bits.

Then again these addresses this is a nothing but, digital addresses means these are 0 1 and the this CPU again that inputs, which are that nothing but, the digital inputs means against that 0 1 that are fed to the central processing unit and the outputs are also digital. Now, here some arithmetic logic unit means I want that the thing should be processed this is CPU, say that input I fed to the CPU, then I want that this the 2 inputs should be multiplied or the 3 input should be added; that means I need some arithmetic to be done.

So, these arithmetic logic or again some temporary storage that also that can be the other parts, actually there can be many other attachments I have given only a simple example. Now, see again this CPU I can think that this is a digital subsystem again my memory system, again this is a digital sub system and the two things together and not only the two actually that ALU that other temporary storage that was all the things together I can tell that this is a full digital system.

So, in this class we will read that first how I can represent these numerical data on non-numerical data means instructions is how we can represent that thing digitally, then how we can process this thing digitally. That means how my arithmetic's my multiplication, addition, subtraction, division, exponentiation, what I know that, how we can digitally we can compute that thing, how digitally we can perform these all these arithmetic's.

Similarly, input I can generate the digital outputs, how we can store that memory, in the memory or it is a permanent storage or whether it is a temporary storage and all the things we are doing digitally means only two values we are using say 0 and 1. Another big thing is a clock, because already I mentioned the synchronous and asynchronous; that means, that at only some specific instant of time all these things can be done.

So, this clock is also concern; that means, out synchronous system or asynchronous system that also come into picture. So, we will mainly the this course concentrates on the design of a digital computer and if we learn the a digital computer, then this is a digital system design the full course will be covered, so mainly these we have to learn.

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Now, some more things are, some related things are there when we discuss about the digital systems or digital system design, one is called the specification and implementation of digital designs. See when a system I want to develop I want to design that what do you mean by specification of the system is the description that, what I want by designing this system what problem actually I want to solve, what will be the function of this system.

So, what we can tell simply specification means the description of it is function and other characteristics required for it is use say speed, cost, power. So, what should be the speed of one system, say once a system is, so slow that the speed is very less. So, actually it is of no use, so I have to tell that this should be the speed, so this is some specification of the system.

Say cost say it is very costly, so people cannot afford then even I can design a very good system, but the cost is huge cost it is very expensive then it is of no use. Similarly, power, so that is again main concerns say in now a days that one very good example is our mobile our cell phone. All of we know that it is now it is everyone is using that cell phone, but the main drawback still today, the drawback is the power, because we have to charge the everyday we have to charge the our systems.

So, this speed, cost and power these are the mains, we can tell these are the specification, so this performance cost power and everyone is related to all the other characteristics. S this three are the mainly the main three concern, main three characteristics that concern to digital systems.

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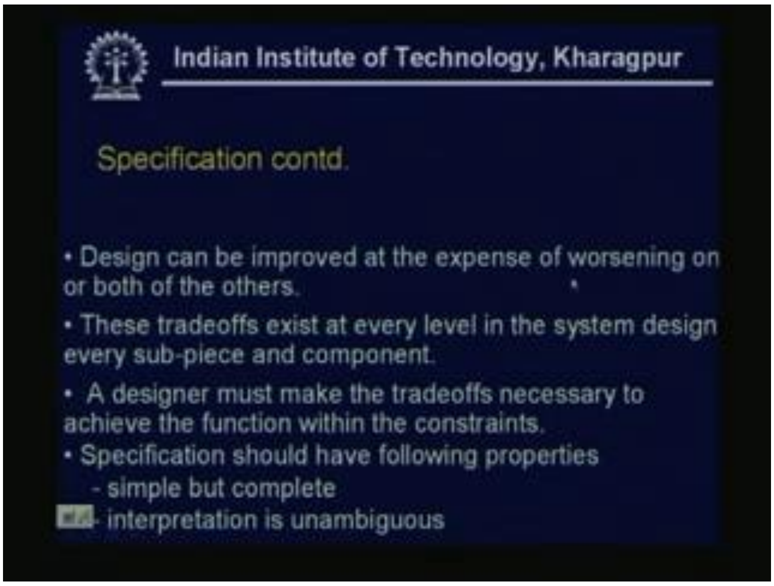

So, design can be improved at the expenses of worsening on or both of the others, that means say speed can be, I can made my system very fast, but the cost increases as well as that it takes huge power. So, that is the worsening the here, worsening the cost and power I can improve my speed or the vice versa, I can do always. So, these tradeoff exist at every level in the system design and every sub-piece and component.

So, this is one very important thing when we design a digital systems that what is our specification; that means, what is our requirement, that which characteristics means that power cost or speed, which one I want to emphasize, which what is the users choice based on that that system the design of the digital system can vary. So, a design almost make the tradeoffs necessary to achiever the function within the constants that everything should be that the tradeoffs can be there, specification should have following properties.

Now, specification means that is the function of the system how this system behaves, so this should be simple, but complete that because our main aim is to automate the design. So, if it is simple then the representation will also be simple and it should be complete that specification should be complete, so that your system should be the complete one. The interpretation is unambiguous, that means there must be when you are giving the specification this should be a unique specification, because this is a machine that some circuit which are doing this thing. So, this interpretation should be unambiguous, it cannot have double meanings, then it will be a problem.

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We can another very important thing is implementation, so in the next class we will discuss that thing we end here.

Thank you.

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Lecture - 02
Introduction (Contd.)

In the last class the digital system design was introduced, we are discussing about the specification and the implementation of digital systems.

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Today, we will see that, what do we mean by implementation of digital system, now, implementation means how the system is constructed from smaller and simpler components called modules. The modules can vary from simple gates to complex processes; that means, that one system has a related components, we have defined digital system like that.

Now, these components again a set of components or more than one components that is clustered together and we are calling that is as a module and this module can be a set of gates, a combination of simple gates or it can be a complex processor. Now, digital systems follow some hierarchical implementation, so today we will see that what do was mean this hierarchy and how that one last digital same digital system can be designed.

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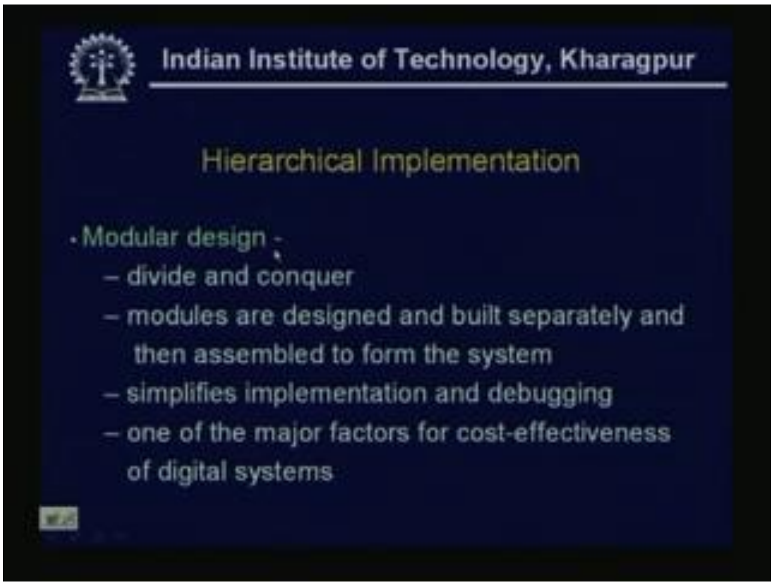

First we see that what do we means by modular design, we see first we take one page and see that.

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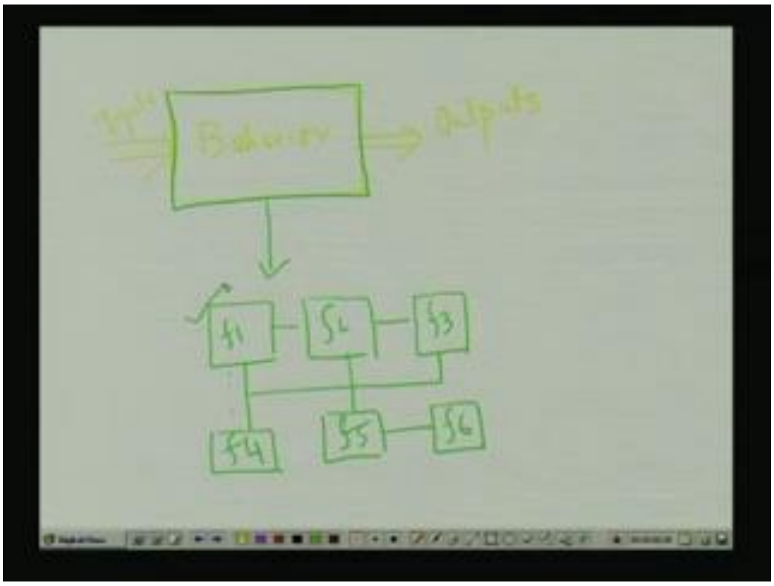

Rather where we have discussed that as if this some function or behavior of the system and some inputs are fade and outputs are taken. Now, if this a large system what we can do we can break this thing as a some smaller blocks, say this behavior as if this is some smaller blocks again it has a each of the blocks has it is own function.

So, this is f 1, f 2 functional behavior means the it is normally it is used the same definition, say f 5, f 6. So, if these are the some blocks; that means, these as if this large system is broken into some smaller blocks, there must be some interconnection between these blocks. So, this each smaller blocks we are calling this is a module, so mainly this is divide and conquers, means the last system is divided and then the smaller module is designed first. Modules are designed and built separately and then assembled to form the sub system, why we are doing thing because it simplifies.