Analog Electronic Circuits
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Lecture - 01
Introduction to the Course

So, welcome to this NPTEL online course, titled Analog Electronic Circuit. Myself Pradip Mandal, from Electronics and Electrical Communication Engineering department of IIT Kharagpur. Today we are going to start with the Introduction to this Course and before I go into the introduction just I like to highlight that, I am teaching this course for almost more than 10 years.

So, most of the materials it will be covered from for this course, it is not only from textbook, but also whatever the experience we have gathered throughout this program. And prior to that I will must say that, before joining here I was in industry for nearly 7 and a half years. So, there I learned some of the practical aspects. So, I am trying to mix with theory and practical aspects together to give you maybe slightly different flavor than normally available in textbook ok.

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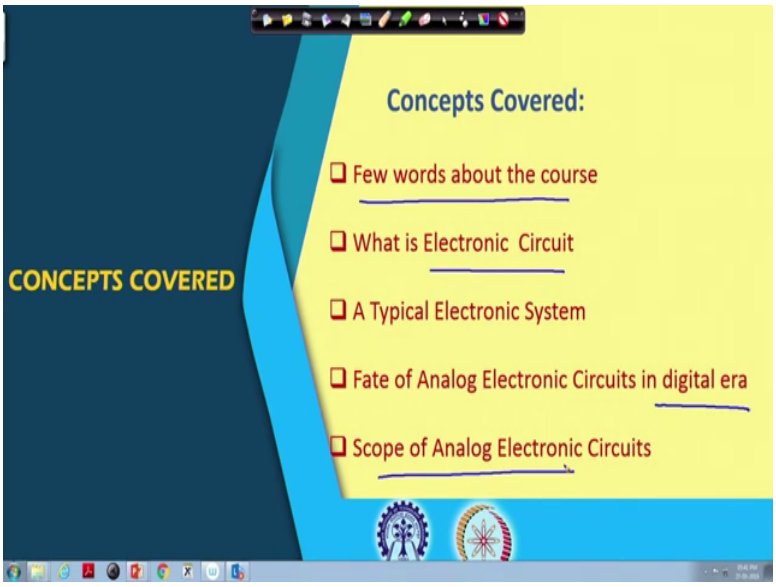

So, let us go into the, whatever the topic will be covering. I will start with few words about the course and then we will be going more towards the introduction of analog electronics. So, to start with we will be discussing about the electronic circuits, then electronic systems and then in the present scenario what we call it is digital era.

In this era what is the significance and importance of analog electronics or to be more precise what is the fate of analog electronics in digital era. And then we will be talking about how whatever the things we are planning in analog electronic circuits, basically the scope of analog electronic circuits in this course.

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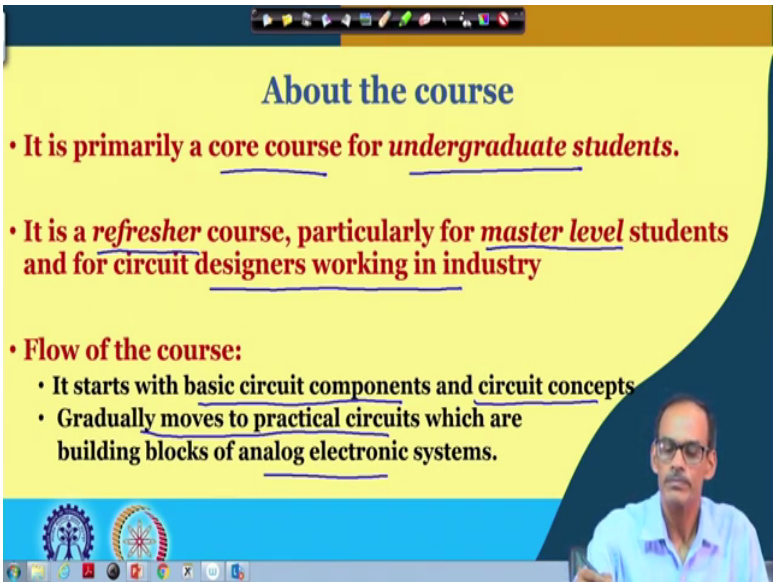

So, let us move to next. So, about the course this course it has been primarily designed as core course, and explicitly for UG level students. However, this course can also be used as refresher course, particularly for those students who has gone through the UG level before and now in mastered levels or the designer who were working in industry and they like to look back the theory and correlate whatever their day to days performance or day to days circuits they do design.

So, this may be looked into as both aspects; core course for UG and refresher course for master level students or maybe 2 to 3 years experienced designers. So, the flow of this course we shall start with basic components, circuit components and course circuit concepts. And gradually we will be moving to practical circuits, which are essential parts of analog electronic systems.

So, that will be the flow. So, we will start with components, it may requires a little bit prerequisite of devices, may be prerequisites from electrical theory and so and so and then we will be moving towards the main topic analog electronic circuits and systems.

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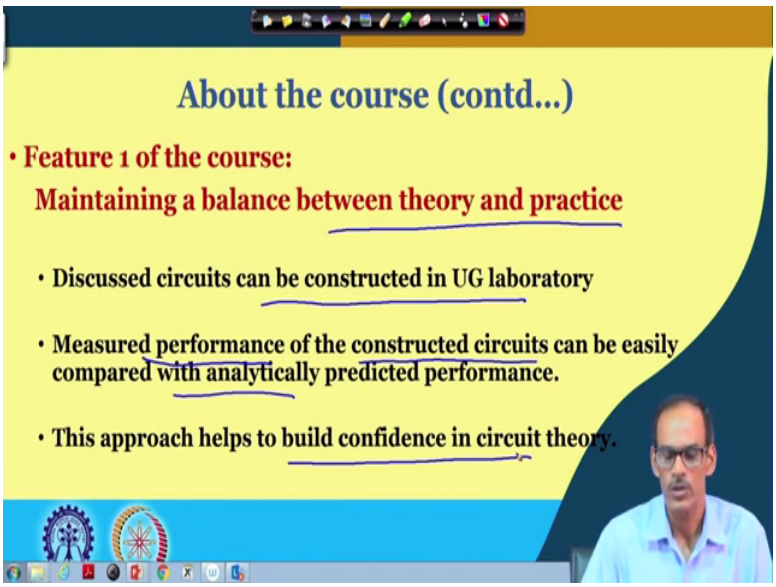

Now, few more words to say; so, to continue with whatever we like to say about the under course namely, while we have planned this course intentionally we made some emphasis, so that we can make a good balance between theory and theory and practices. And also while we will be going through this course materials, we will see that the circuit examples we will be discussing; they are whatever the examples will be covering, we will try to make a balance between theory and practice.

And the example circuit they can be easily constructed in a UG level instruction lab and those circuits, the constructed circuits can be characterized or their performance can be measured

and the measured performance can be compared with analytically predicted performance of the circuits.

So, the examples if you practice those examples along with this theory in lab classes; what it helps is that, it will build up your confidence level about the circuit theory and not only that probably you can get advantage of whatever the theory will be gathered here to add to your practical experiences. So, this is the first feature or characteristic I should say of this course content.

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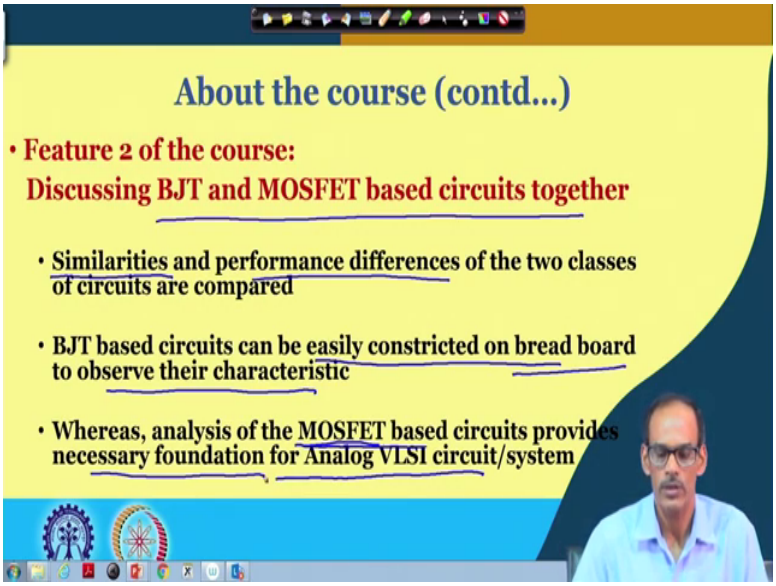

The second feature of this course it is, we are going to discuss the both BJT and MOS based circuit simultaneously; so that you can get a similarities of those circuits as well as you can find the differences, particularly the they are not only their operation, but the performance differences of BJT based circuit and then MOS based circuits. And not only that, based on

this simultaneous study you yourself can gradually understand that in what context we should go for BJT based circuit and in what context you can go for the other one

So, while we are simultaneously covering this BJT and MOS based circuit obviously, there is a reason; first of all there will be a lot of commonalities of the these two classes of circuits, namely say common emitter amplifier and common source amplifier they do have good similarities. But then the basic important thing is that, why we like to cover both BJT and MOS together; the reason is that BJT's this components are easily available.

So, you can easily construct circuits different building blocks in your lab laboratory on bread board and you can observe their characteristic, you can measure their performances; which may be little difficult for MOS base MOSFET based circuit. So, to correlate the theory with the practical measurement, I think the BJT based circuit is need to be covered.

But then at the same time we like to also cover MOS phase MOSFET based circuit; that is because whenever we go down the line and in the present scenario where instead of analog circuit alone in a typical system, electronic system we will see that both digital and analog counterpart, they are mixed together to get something called mixed signal customized design.

Where instead of BJT, MOSFET based analog circuit is quite popular, mainly because this MOSFET it is it helps to integrate the analog circuit along with the digital counterpart on the same IC. So, if you look into the present scenario where instead of standalone analog electronics circuits, analog VLSI circuits are more popular where most of the circuits are getting implemented using MOSFET base.

So, here whatever the circuit analysis will be covering about the MOSFET's MOSFET based circuit that gives you the foundation for the next level course analog VLSI circuits and systems. So, that is the main two features we will be having this in this course.

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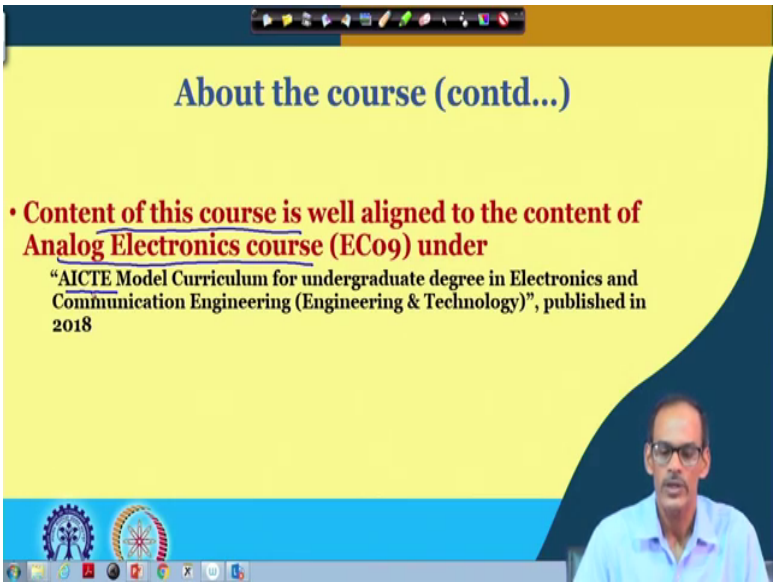

So, these two features namely this feature 1 and feature 2, these two features are helping to make this program or this course quite distinct and different from normally available courses. Apart from those two features, the content of this course we have tried to make it aligned with the content of analog electronics course under AICTE model curriculum.

So, that those students who are having this program they are coming under this program, AICTE program they can easily attend this course and make them prepared, well prepared for maybe the get preparation or their own on engineer their college courses. So, the this is how this course it is different from maybe the other online course available on this topic at present. Now let us move towards what are the things we like to cover in analog electronics, particularly let us move to whatever the electronics or analog electronics mean.

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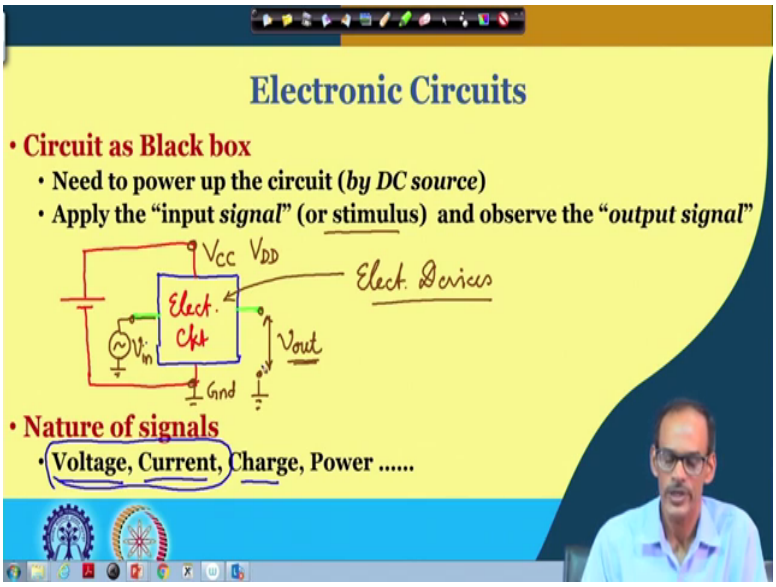

So, let me start with electronic circuits. So, whenever we say electronic circuit what we are looking for it is that, if I look into the circuit as a black box. So, if I say that this is my electronic circuit, to make this circuit working what I need to do it is we need to put the power on. So, we can give a DC supply to activate the circuit.

So, let you think of that, this is a power supply by which we are energizing the circuit. So, we are having this electronic circuit here and then once it is getting energized then you can apply the signal at the input port. And then you can consider the corresponding effect at the output, namely you would like to see what will be the corresponding output coming to this circuit.

So, whenever we are giving the signal, we will be giving the signal at this input port; it may be with respect to the same ground of this or it may be having it is own DC. And suppose this is the output port, we like to observe the corresponding signal at the output port and let you

consider that the output signal it is voltage. So, we like to observe the voltage here with respect to the ground.

So, let you call this is output signal maybe in terms of voltage V out and this is the corresponding V in. So, whenever we are talking about say electronic circuit what we mean it is, of course we do have a lot of activities within the circuit; but that will be getting activated only when we turn on this power. And then we apply the input, namely what we call input signal or stimulus and then we can observe the corresponding output.

So, unless otherwise it is stated we assume that, this DC power supply it is well connected. And instead of showing this DC supply every time, we may say that this is the DC supply; either we call this is VCC or sometimes you call VDD depending on the kind of circuit we will be using and then this is the ground and so and so. The both input and output may be with respect to the same ground or it may be with respect to the some DC level, that we will see it later.

But what we like to say that electronic circuit, whenever we are talking about electronic circuit; it is basically it consists of different electronic devices. So, within this one we do have electronic devices and those devices are getting activated by this DC and they should be in proper region of operation and so and so. So, those details we will be seeing later, but whenever you are talking about see signal, what we mean by signal?

So, in this case as an example, we are saying the signal can be voltage. So, both input as well as output signal here it is shown as voltage and, but then need not be always voltage it may be current also. In fact, it may be the other likes charges or powers and so on; but unless otherwise it is stated in our in this course, in our context primarily we will be thinking that the signals are in voltage or in current form.

So, whenever we are feeding some stimulus, we will assume that non electrical signals are getting somehow converted into electrical signal either in voltage or current. And likewise whenever we will be observing the signal we will be expecting that the signal it will be observed either in voltage or in current form, ok. So, whenever we say that nature of the

signals, we will keep our focus either in voltage or current; but in general it can be power or charges, ok.

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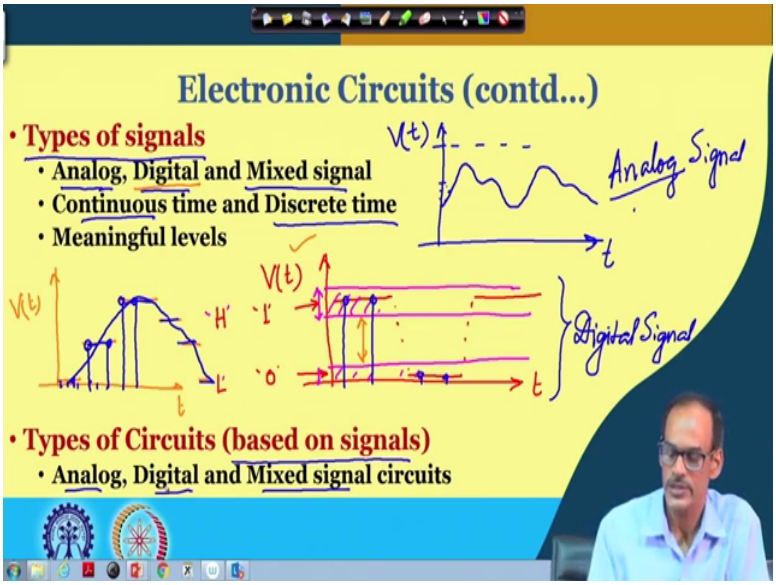

So, let us move into little detail of what are the things are there inside this electronic circuits. So, we said that signals, now let us look into what kind of signals it is possible, types of signals. So, whenever we say a types of signals, it is we are assuming signal means it is voltage changing with time. So, the x axis is t and then y axis it is voltage, for the time being let you consider it is capital V and then this is time axis t, it may be seconds, milliseconds, microseconds and so and so, so this is in the scale of voltage.

And then, it may be changing with respect to time like this. And we are expecting that the signal of course it is having it is own limit, it may be some higher limit and the lower limit may be 0; but we are expecting the signal, it will be within this range. Now depending on the

emphasis and the allowable levels of the signal, the signal can be different types; namely analog and digital kind of signal.

And if you see this analog or digital kind of signals it is basically indicates that, what are the possible levels acceptable levels or meaningful levels of the signals the circuit can recognize or we recognize. Say for instance, here this signal at any level, it may be recognized as signal. So, we can say if the signal it is having so many possible acceptable levels, then or you can say the resolution it is continuous, so we can say that the signal it is analog in nature.

In contrast to that, in case if we are having a special situation where the signal, it is having distinct levels; may be here also we may say that say V t, but it may be having say two distinct levels, may be either high or low and so and so. In between if there is any transition we may ignore, we may ignore this transition levels and the acceptable or meaningful levels are only say this one or say whatever the level we do have.

So, we may say that this is level 1 and this is say level 0 or we can say this is high level or low level. By the way it is not mandatory that these two levels it will be expected to be 1 volt or 0 volt; it may have a range of voltage, which may be accepted as meaningful logic 1. Say for example, we may have a meaningful voltage range, over which we may say that signal it is level 1.

So, likewise we may have another acceptable level for 0 levels. So, this 1 and 0 does not mean that the voltage it will be 1 volt or 0 volt. And of course, it is having some acceptable range, so whatever you say high level and low level. In between whatever the levels we do have, in case if the signal it is falling within that; we may say that this is undefined level. So, if it is within this range we call it is undefined level; for such scenario, since the signal it is having only two levels we call it is binary signals.

In case if you are having such kind of distinct levels, need not be only two, but it is having finite levels then we call it is digital signal. Which means that, in case if we have a scenario like this, the signal maybe having say distinct levels need not be only two; but it is having

only some acceptable finite levels, then we call it is digital signal. So, both this case as well as this case, these kind of scenarios are called a digital signal. So, these are digital signal.

Whereas for this case, the signal it is it can continuously vary in the voltage level voltage scale and this is called analog signal. So, we call analog signal here and these signals whatever the signals we have discussed here, here as well as here they are digital signal. Now for both cases whether in this case or this case, you see that the voltages they are there continuously along the time axis; which means that at every time instances the voltages are available, either here or here at every time instances the corresponding voltages are available.

In contrast to that, in case if we have a situation where the voltages are available only at distinct time point; namely say at this point time point we do have the signal available. And then in between we do not have any information about the signal, but then at other instances say here we do have the signal information available and so and so. This may be the case for here as well, if the signals are available here at some distinct points; then such kind of signals we call it is of course, digital signal, but we call it is discrete time digital signal.

In contrast to that whatever just now we have discussed, earlier we have discussed where if the signal it is available for every time instances, it is called continuous time signal. So, based on the availability of the signal along the time axis we do have one category; basically one types of classification called continuous time versus discrete time signals. On the other hand whenever we see the signal voltage range, there again we do have two types of signal; one is analog signal and digital signals.

So, whenever we are dealing with electronic circuit, it is expected that the circuit the intended circuit should recognize at least one of these kind of signals and based on that we may classify the circuit type also. In fact, in the recent scenario I should not say very recent, but of course, in recent scenario there is the other kind of signals called mixed signal; where the signal may be in digital form, but the information may be continuous.

Say for example, here we do have digital signal, but if you say that actual signal it is something like this which we are knowing that the information is like this; but the signals are

captured by this different digital levels they are called mixed signal kind of in a circuits. So, we will be going detail into that; but for the time being let me move on to classify the circuit analog versus digital.

And so, based on as I said that, based on the kinds of signal they do recognize the circuit recognized, those circuits will be classified as analog circuits, digital circuits or you know mixed signal circuits.

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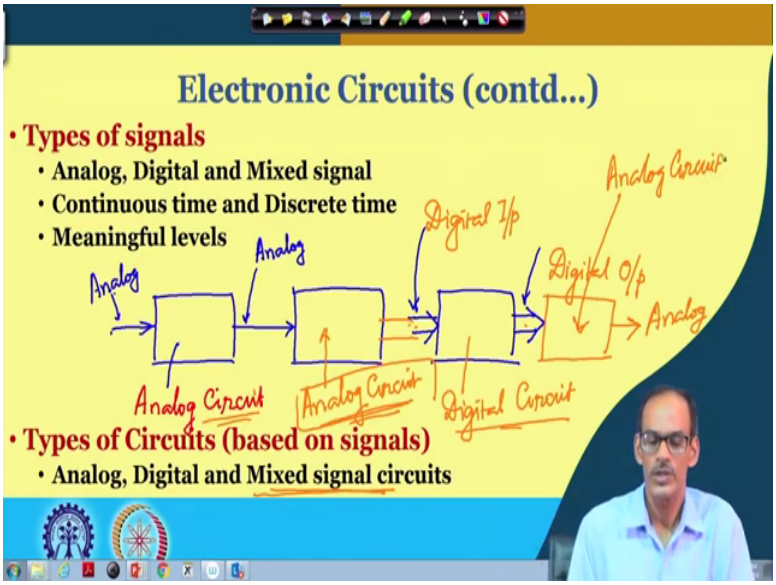

So, we may have a scenario where we may have one circuit here, another circuit here and so and so. Now each of these circuits, they may have their own functionalities to perform. And let me assume that the signal it is propagating from left hand towards the right.

And suppose say this signal, signal here it is analog and here also the signal it is analog. So, these signals are analog. So, we called then this circuit, so we call this circuit it is analog circuit. And so, likewise whenever let us consider say this last block, say we do have different digital signals coming here and we are expecting the outputs are also digital; which may be single or multiple signals and if I say that these are digital signals.

So, likewise this is also collection of say digital output signal. So, this digital outputs are basically output of this block. Since it is input and output. So, this is of course, it is a corresponding input signals. Since the input and output signals are digital in nature, we call this circuit as digital circuit. Now you may say that if I want to cascade say this in between, so if we want to cascade say analog circuit to digital. So, we need to place in between a special kind of circuit, we suppose to convert analog circuit into digital.

Now, the question is that, then how do you name this circuit; shall you call it is mixed signal, analog or digital. Normally this is referred as analog only, because this signal whatever the signal it is received by this block it is analog in nature. So, without going into any ambiguity, we call this is analog circuit; mainly because the digital signals it may be treated as a special kind of output of analog signals so on.

So, that is how we classify different circuits as different circuits either in analog, digital. And then the next type or whatever I was telling that mixed signal, it is kind of a special kind of signals, a circuits; which involves the information in analog form, but it may be having digitization within that. So, that will be another the third class or third types of a circuits called mixed signal.

Now, whenever we consider the next block and we may similar to or complementary to this, we may convert this digital signal into the form of analog. So, again similar to this circuit, this circuit we will also be called analog; that is how the classification goes, ok.

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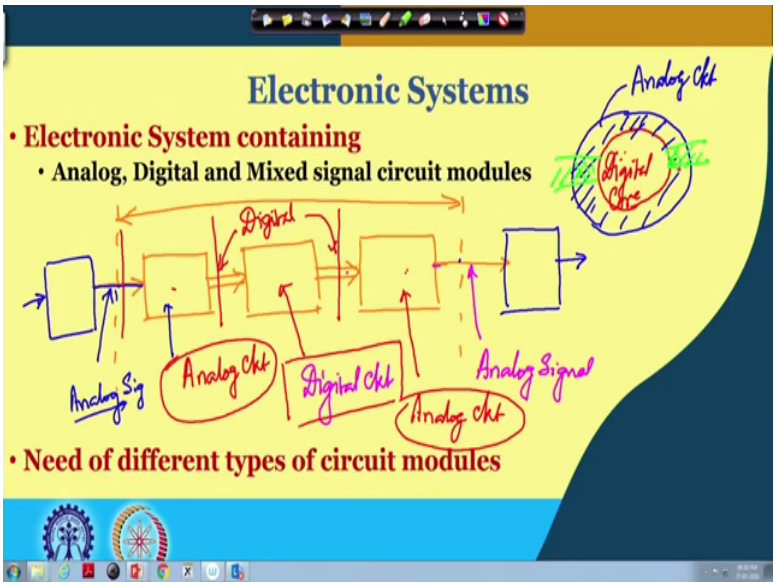

Whenever we look into the electronic system and that involves different modules; namely analog circuits and then we do have digital circuits and maybe mixed signal also. And so, how do we, how do you classify them? Of course, circuit wise we can definitely classify; but main thing is how do we integrate them and what is the present scenario and so on so.

So, let you consider we do have different modules and this is we call say boundary of the electronic systems and then we are interfacing the real world. So, we can say that this is the scope of analog system, inside whatever the things we are doing end of it we like to give the output to the real world. And whenever we are talking about say real world, we may be having some device, special kind of device which may convert non electrical signal in the form of electrical signal.

So, this block which is called say typically it is called sensor. So, likewise at the other end, we may be having a special kind of circuit which converts a maybe electrical signal in the form of non electrical signal; say for example, this may be speaker, this may be a sensor. So, here we do have maybe some sensing circuit which senses, may be pressure or temperature or whatever it is; likewise the output device it may give the signal in the form of acoustic signal and so and so.

So, in this electronic system we are expecting that there will be a meaningful conversion of a real world signal into the form of electronic signal; likewise at the output side, there will be a meaningful device which supposed to be converting electrical signal in the form of non electrical signal. So, the first block since it is interfacing the real world, and the signal here it is analog in nature; typically this is what it is analog in nature, this first block it is analog circuit. So, this first block it is analog circuit.

And then we do have digital signal here. So, likewise here also do you have digital signal here. So, as you can guess that this block it will be digital. So, once this digital signal it is coming to another circuit which is, so it is supposed to be interfacing with the device here to convert electrical signal into non-electrical signal; it may be speaker, it may be display or whatever it is and we may require to change this digital signal into the form of analog.

So, this is analog signal and this circuit maybe I will use this color. So, this is again analog circuit. So, if you see here a typical system, it is mix of a analog circuit and digital circuit. And if you see that it looks like within the electronics we do have a digital core, so we can say that this is digital core. And these two circuits, particularly this part and this part which are interfacing with the real world, you may say that they are peripheral devices.

So, you may feel that this is a digital core, digital core circuits and surrounding to that we do have interface circuits. So, this portion, this shell you can say it is analog. Now of course, then the natural question is that what may be the boundary of this digital core or digital circuit and what may be the thickness of this analog shell to interface with the real world, is it changing or is it evolving?

So, if you see a typical evolution of electronic system, this core circuit it is growing; it is growing of course, it is having it is own reason. And then of course, also I know I miss the another important thing is that, this whenever we say this analog circuit which is interfacing with real world; then it is also it is another provision. In fact, if you see here I should I must mention that, you may be having some alternate means to interface with the external world; either through RF for through opticals.

But again there you may require some additional circuitry which is very similar in nature of analog circuit. We may call it is optical circuit, optical sensor, optical driver or you may say RF receiver or RF driver; but their nature it is similar to a analog circuit rather than digital circuit. So, the knowledge you will be gathering here in this course related to this analog circuit, that will help you to understand that how this interface circuit it is working.

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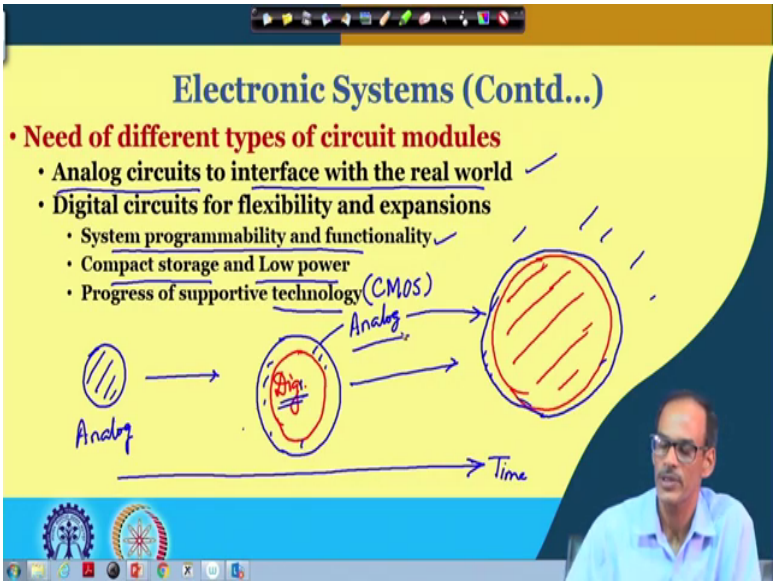

Now so, we require different types of modules; namely analog circuits and digital circuit. Now to summarize that why do we require and when do we require this analog and digital; so analog circuit it is essential to interface with real world that is very very much needed. So, we required this analog shell. So, it interface with the real world.

On the other hand whenever you look into the core, digital core, so it provides it is having it is own advantage. So, this is digital and this is a analog and I should say it is kind of a shell outside of this core, digital core. So, if you see the advantage of this digital core it is, it provides flexibility and the programmability of the whole system. If I say that this is the electronics system, this is a very much flexible.

Even user can define the behavior of the digital core or maybe you can load the software and you can change the behavior of the whole system and that is how this digital core it is getting more and more popular. So, that is the first advantage of having digital code.

And of course, the it also easy to store information, it is easy to store in compact devices. And of course, they are not only the storage part but also the implementation of the circuit it is; we can say that they requires a lot of this they require less amount of power compared to the analog counterpart. And with progress of time, the implementation technology it is very supportive for the digital kind of circuit, particularly if you say that CMOS technology. It is very suitable for digital circuit.

So, with progress of time if you see the evolution of this analog electronics, originally maybe it was having only analog circuits. So, that was self sufficient. But then with progress of time this digital core it has been added and with progress of time this digital core it is in fact getting more and more fatter, probably the analog shell it is getting thinner and thinner. So, the natural question is that whether this shell it will be completely getting vanished; the obvious answer is no; because the outside world, this external world is analog in nature.

So, definitely for digital to interact with the real world, you require this analog shell; so this analog shell it will be remaining there. And with progress of time, it is expected that this

digital core it will be further improving with more and more application, more and more you know implementation and probably more and more development of the technology. And as it is progressing the need of this shell definitely it will remain there.

The interesting part is that, as this core portion it is increasing; it is design and it is implementation it is more, it is getting automated by computer. Whereas, this analog portion of course, it is if we do use computer to design this analog portion; but it requires very customized skill to design this analog circuit, that may be one of the reason why this analog circuit is it remains very hard to implement. But at the same time you may say that, the knowledge expert knowledge of analog circuit it the circuit design, it is value it will remain there.

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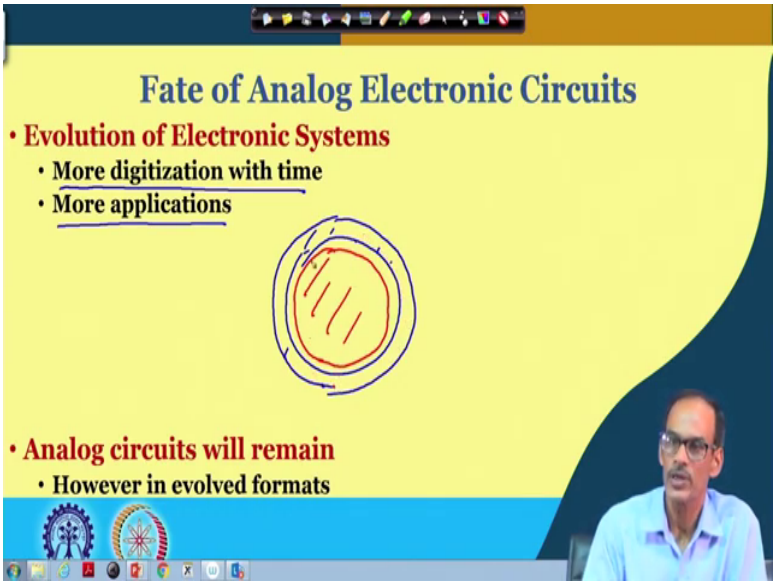

So, the need of analog designer of course, it will be there. So, if you see the fate of the fate of this analog electronics it is if it is in particularly in digital era. So, whenever we say the digital era, basically we are saying we do have more and more digitization with progress of time; but then it also have more and more application. But then as I said that along with the digital core the requirement of this analog shell it will be remaining there; and hence the and requirement of analog circuit it will be remaining.

But of course, you need to be careful, while this core portion it is; core portion it is dominating in terms of volume. The nature or the format of this analog shell it may evolve while it need to be integrated.

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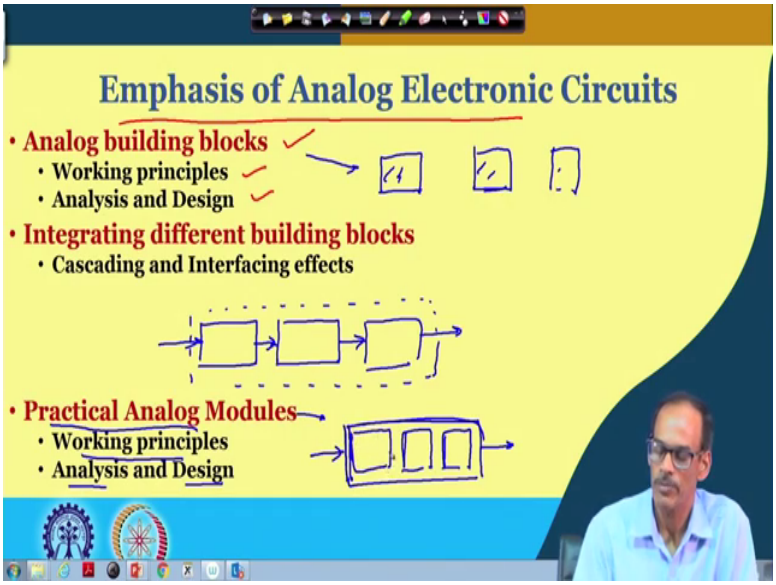

So, to summarize, so before we summarize; so in this context I must say that, what are the; what are the things we are going to covered in this analog electronics, to be more precise what

may be the emphasis of this course. We will start with analog building blocks, their working principle, analysis and design and those building blocks.

So, here we will start with building blocks, different building blocks individually and then we will move to whatever the challenges we will face while we will be interfacing different blocks together to make a bigger system. So, we may make bigger analog system or I should say analog module to be more precise by stitching individual analog building blocks.

And then we will see that how this interface effects are making it more and more challenging. And then we will make this circuit more towards practical analog modules. So, when we will be covering these practical analog modules, we will be definitely, will be discussing about their own on working principle. So, suppose this is the analog modules, it may be having it is own building blocks.

But before we go into the building blocks, holistically we can look into this entire module and we can see what is the input output behavior; based on this required input output behavior how the circuit can be analyzed and designed. So, I should say we will start from this block level, namely bottom and then we will try to see what will be the interface effects. And then we will see that how we can make bigger system and then we will go from top to bottom; we will start from system level and then we will go to the implementation of the smaller level.

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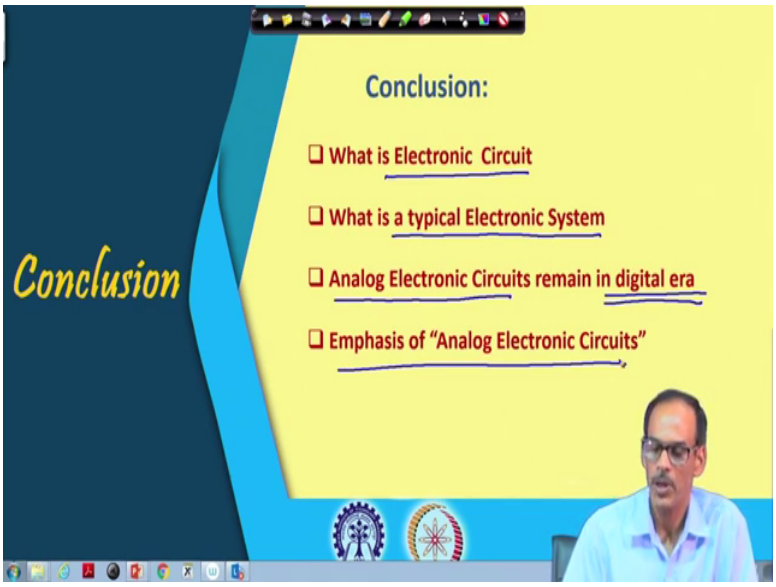

Now, moving to the conclusion; so what we have done is that, at least we got some idea about what is electronic circuits and what is the typical electronic system consists of and then also we have we got a sense of what may be the fate of analog electronic circuits, particularly in the digital era which is more and more getting dominated. And then a little bit about what may be the emphasis of this course, analog electronic circuit course that we have covered.

Subsequently we will be making a plan, the whole course plan and the break up per week what may be the topic it will be discussed. So, that is all I need to cover here.

Thank you.