Analog Electronic Circuits
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Lecture - 02
Introduction to Constituent Topics of the Course and the Layout

So, welcome to this 2nd module of Analog Electronic Circuits. So, today what we are planning to do it is we will browse through what are the topics we will be covering in this course and how each of those topics are related and how do they address the new topic called analog electronic circuits. And we will also see that how those subtopics are related to each other and then also what will be the weekly layouts of the content. So, primarily we will be covering different subtopics of this course and their corresponding weekly plan.

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So, let us move to the main topic. So, the content of like the today's discussion it will be, what are the tasks are performed by a one analog circuit or typically the analog circuits. So, that is the first thing we will see and that probably it will help us to understand that what are the importance of different subtopics are there. And then we will also see that what are the constituent blocks are there within analog system typical analog system, and how the analog system can be architecturally constructed.

So, this will help us to understand why a specific flow it has been followed here in this course and how it is; how each of these subtopics are useful to construct say analog circuits or analog systems or analog subsystems. So, these are the main two I should say sub topics to be covered today. And then those sub topics are; however, they plan as I said; however, they planned over the different weeks that we will be discussed.

So, let us move to the what are the tasks it will be performed by analog circuit; but before that, let me recapitulate the last slide of our previous discussion.

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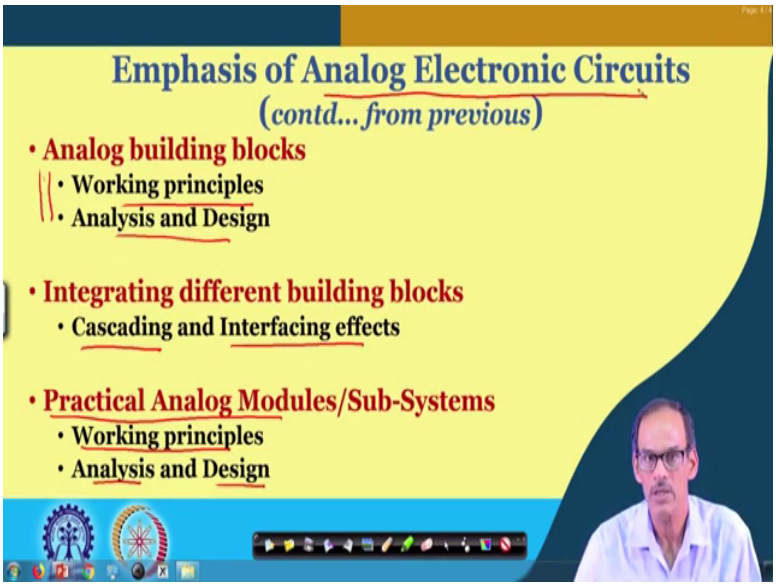

So, what are the emphasis we say that will be given in this course namely the building blocks of analog circuits and their working principle and analysis and design of those building blocks and then while we are integrating different building blocks to construct relatively bigger circuits. Namely if we cascade and cascode and so and so; what are the interface effects it will be coming there so, that also we will be covering.

And then of course, will be looking into some of the practical analog circuits and their of course, working principle, analysis and design. So, this is what the overall emphasis it will be there for this course and now let us look into the what are the basic performance it is done by a typical analog circuit.

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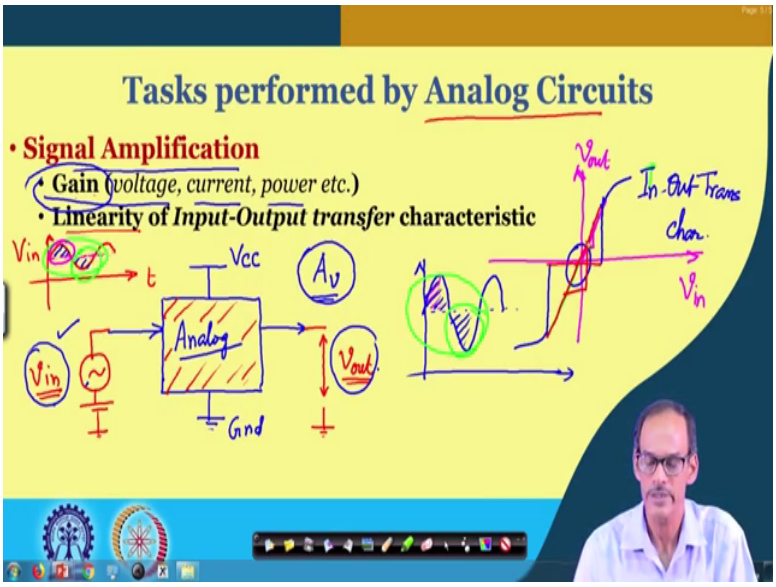

Now, if I see the typical analog circuit and if I say that what are the topmost objective it is performed by a typical analog circuit is, basically it amplifies signal. Whenever we say same amplify a signal what we mean it is we like to say that it may be voltage domain signal and its nature it may be retained and then the at the output what we are expecting it is same input signal, but of course, its strength it is expected to be higher.

So, if I say that this is the typical analog circuit, which is powered by say a DC voltage here let me call this is V cc and this is ground. And the analog signal we are applying here say it may be having its meaningful DC bias and at the output what whatever the output you are observing may be with respect to the main same ground or it may be with respect to a DC voltage whatever the signal will be observing that you call it is signal in the form of voltage and if we observe the signal at the input.

So, what we are expecting is that, this V out and V in they are highly correlated and what we are expecting is that suppose we apply a signal with respect to say time. So, this is the V in, it may be having its own DC level on top of that suppose we do have some signal. So, what we are expecting at the output which is the effect of the signal we are applying at the input.

So, the V out is we are expecting it may be having its own DC level, it may be different from whatever the DC voltage you do have here and we do expect that corresponding output it will be amplified version. So, if I say that this is the signal part this is the signal part so, that same signal it is coming here, but it is coming in amplified form.

So, the ratio of this V in signal wise of course, V in and V out they are defined by a parameter called gain of the circuit. In this case you may say it is voltage gain of the circuit. So, whenever we are looking for this analog circuit, the first and foremost objective we try to perform by this circuit is getting a good gain which is referred here in this case.

So, this gain in this case we have given an example saying this voltage gain need not be always voltage gain, it may be current gain in that case input signal it will be current output signal it will be current. It may be power. So, input may be power output may be power or it may be different combination; for example, input may be voltage and output may be current.

So, in that case of course, the definition of the gain instead of saying voltage or current gain, it may be input as voltage output as current so, we may say it is transconductance gain. So, likewise, if the input is current output is voltage it may be trans impedance gain. So, whatever it is the first task performed by analog circuit is amplifying the signal with a predefined or well defined gain. Now the second task or a while it is rather amplifying this signal, it is assumed that the shape of the input signal whatever the shape we do have its supposed to be retained in the output signal.

So, in other words you may say that linearity of the input to output transfer characteristic must be retained. So, if I draw the input to output transfer characteristic say along the x axis we are plotting input in this case V in and along the y axis we are say plotting V out note that we are

talking here it is only signal part. So, if the signal may be with respect to ground it may be positive or negative and as we see here this portion, if the signal it is positive with respect to its DC level we are expecting that the output signal it is also positive in this case and, but then it is amplified version.

So, if I say that input to output transfer characteristic and if say the x axis and y axis they are having the same scale, the slope of this line if we are expecting it is having again, it will be much higher than 1. So, likewise, whenever the signal it is negative which means that we are concentrating say this part and the corresponding output it is here and the in the input to output transfer characteristic, the characteristic curve it will be like this.

So, ideally we want this input to output transfer characteristics. So, this is called input to output transfer characteristic. So, input to output transfer characteristic. So, this characteristic should be as linear as possible, but of course, practically the this characteristic may be retained fairly linear around this operating point, it may be maintained linear beyond some point, but later on it may get it may get saturated. But whatever it is you may say that over this range of this transfer characteristic, the characteristic you may say it is fairly linear.

So, ideally we want this portion it should be as linear as possible with a constant slope which means with a constant gain. So, whenever we are looking for analog circuit, basically we must be looking for what is again, what is the linearity of the circuit it is maintained or at least you can say over what range of input the linearity of input to output transfer characteristic it is maintained. So, these two important aspect we will be expecting from analog circuit and of course, within this one so, that is the expectation.

So, within this one we must be having some meaningful circuit and in this course we will be discussing about what are the circuits are there within this block, how they will be maintained or how they may be biased in technical terms so, that this input to output transfer characteristic it will be maintained to be as expected as linear and having a decent or meaningful gain.

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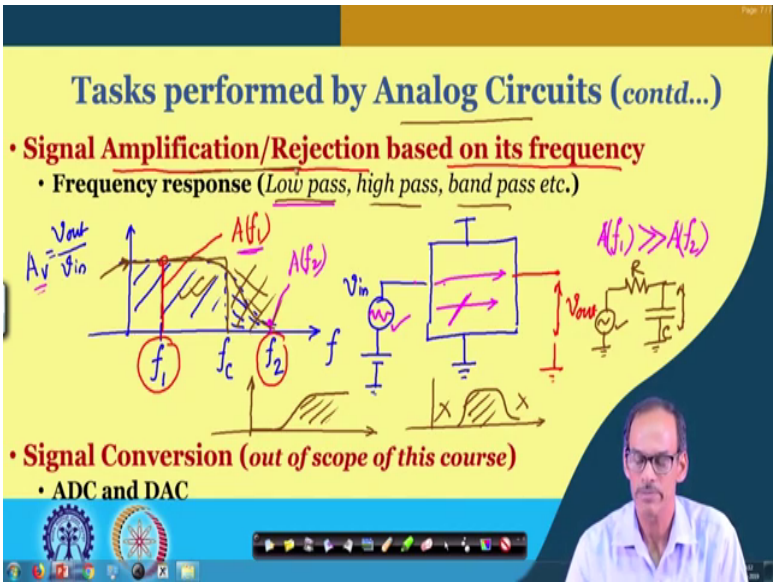

So, this is the first task and then second task; the second task of this analog circuit is, it is very important it is equally important rather.

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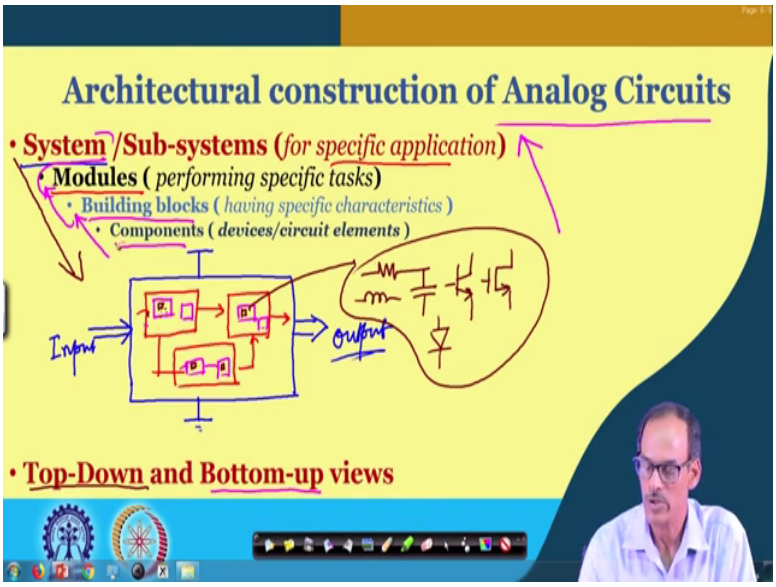

The when we say amplification we are also expecting that how this characteristic may be changing with frequency. So, what you are talking about the second task need to be performed by analog circuit is the amplification of the signal or maybe even attenuation of the signal or rejection of the signal based on the frequency of the signal, which means that it does some intelligent tasks based on the signal frequency the circuit gain it may be much higher than maybe one while in other frequency signal in other frequency the corresponding gain it may be lower.

Which means that if we sketch say circuit gain namely say V out by V in whatever we have discussed which is a voltage gain defined as V out by V in and if we observe this gain as function of frequency. So, it may be expected that the gain may be remaining high in certain frequency range and then if you go beyond some point, it may drop towards 0. So, this kind of

characteristics namely based on the frequency of the signal, it provides a decent amount of gain or very good gain.

On the other hand, if you go beyond some frequency called say cutoff frequency, then beyond this point the corresponding gain it is dropping or you may say that the signal at the output it will be much weaker than whatever the signal we are obtaining having this frequency component. So, if I say that suppose you do have one frequency component say f 1 here and then you do have another frequency component of f 2 in the input signal.

So, which means that suppose we do have one analog circuit which is having a good gain in low frequency region; that means, it is having very good gain, but then suppose we do we are feeding signal may be with respect to a DC voltage and we call this is V in. Having this V in two frequency component say f 1 and f 2; now whenever you are observing the signal at the output with respect to ground and if you are observing the corresponding V out, this component it may be having very good gain like this.

So, we may call this gain it is A at frequency f 1; however, on the other hand if the if we consider say this frequency component it is having very poor gain. So, we may say that this gain it is A at frequency f 2. So, this f A at f 1 in this case in this illustration it is much higher than A at f 2 or what I mean is voltage gain A v basically the A v. So, if you do have a signal it may be having different signal it may not be purely sinusoidal, it may be combination of these two signals or it may be having different frequency components.

Now, depending on the frequency component, this circuit it appreciates say low frequency signals, but then it rejects the high frequency components. So, you may say that this circuit is having some special feature called a low pass which means that it allows low frequency signal from the input to the output not only it is allowing, maybe it is having a very good gain it may be much higher than 1. While in the frequency component in the higher frequency region that may be getting attenuated or removed.

So, this is again for signal processing purpose, this kind of circuit is commonly used which means that based on the frequency of our interest, we may put some filtering circuit here

within this so, that you can remove this unwanted part. So, we can simply say that this unwanted part may be rejected, this part will be rejected and this part it will be appreciated ok.

So, this is the; this is the second task it is performed and of course, based on the application the requirement need not be always low pass, it may be high pass in nature and for high pass characteristic as you may guess that in the low frequency region it may attenuate the signals and in high frequency region it may appreciate the signal or it may be having band pass which means that over certain frequency band it may allows the signal while it may reject this part and this part.

So, there may be different classes of you know frequency characterizing circuit namely low pass, high pass and band pass. And this kind of characteristic it may be obtained by a simple passive circuit. So, say for example, if you are having say simple RC circuit you may be aware of this circuit from electrical technology.

So, if I say that this is input and if I observe the corresponding output here then of course, this circuit depending on the value of this R and C you will be getting a this kind of low pass characteristic then you may say that what may be the task of this analog circuit is doing. Well, if it is RC circuit the corresponding gain here low frequency gain here it is theoretically less than 1 it may be very close to 1.

But if you are using analog circuit in combination with maybe this RC circuit, then this gain you can make it much higher than 1. So, in case if you want to amplify low frequency signal and reject the signal in the high frequency component, you may use combination of active circuit along with the passive circuit. So, whenever we will be talking about analog circuit it is primarily it will perform signal amplification and also it modulates the signal based on the signal frequency component namely it amplifies and reject based on the signal frequency component.

The other important task it is performed by a analog circuit is converting signal from analog domain or analog nature to digital nature and it may be vice versa. However, because of the

restriction of the time, will not be able to cover this kind of circuit base namely, analog to digital converter and digital to analog converter in this course.

So, whatever the circuit we will be covering primarily we will be covering the first two features, but of course, there will be depending on the application there will be wide ranges of the circuit and we will see that what are the different circuits we do have particularly different circuit components. Now, let us look into how a how a one analog system how a an analog system looks like.

So, whenever we are seeing some analog system we may say that at top level this may be say analog system, it maybe is supposed to be performing some task. Namely if we do have input signal, it is supposed to be giving some what you say processed output signal and it may be doing some of course, intelligent tasks namely amplifying rejecting all these stuffs.

Now, within this circuit, if I want to see what are the different blocks are there, based on the system you know requirement for some specific application it may be having different modules performing very specific tasks. So, you may say that the blue color it is say system or subsystem within that there may be different modules interconnected modules. Now they are having their own tasks whatever the task it is there and finally, if they are helping to produce the and the primary output of the system.

Now, within this circuit within each of this module again they are there are different building blocks. So, these are the building blocks. So, these are modules different modules and now each of these modules there are different you know building blocks. They are again they are constructed there they are interconnected and they are constructing each of these modules.

Now, within this module within this each of this modules if I zoom in to this one, what we will be seeing there it is different circuit components and those components may be passive, those components may be active devices and so and so. So, it may be MOS, it may be BJT, it may be diodes and so and so, it may be inductor and whatever it is. So, if you see the system essentially it consists of different circuit components.

So, for a given task if you try to see one realized circuit. So, what you can see architecturally, you will see that from the system we go to the module, from module we can go to the building blocks and within that there are different components. So, this decomposition of the system you may say that looking into the system in top down approach. So, we are starting from system or subsystem and moving towards the components.

But then if the circuit is already constructed or if somebody is already aware of what are the constituent blocks are there, this may be the way it can be visualized. So, that is called top down views of the system. The other view it is that, say whenever you have to construct this circuit you need to go say bottom to up. So, we have to construct individual building blocks and then you have to interconnect them in meaningful way so, that you can go from components to building blocks and building blocks to modules and then finally, you can construct the system.

So, if you see this analog circuits or analog systems if you see and whatever the topics we will be discussing, it is better to have this fair understanding of this architectural construction of the system. So, that you can correlate whenever any discussions are happening either related to components or building blocks, you should be able to correlate that how those blocks are important to achieve something at the system level.

So, whatever the topics it will be discussed here definitely they are aligned with this building blocks components and so and so and since here we are trying to make system definitely we will be starting from component and then we will be moving towards the building blocks and then building blocks to modules, modules to subsystem and then system. Of course, the boundary of subsystem and system it may vary depending on the context.

But of course, there are a distinct boundary from component to building blocks, building blocks to modules and so and so. So, whatever the different subtopics we will be discussing in this course, we will be starting from here and let us see how what are the things it will be there within this components and how they will be planned.

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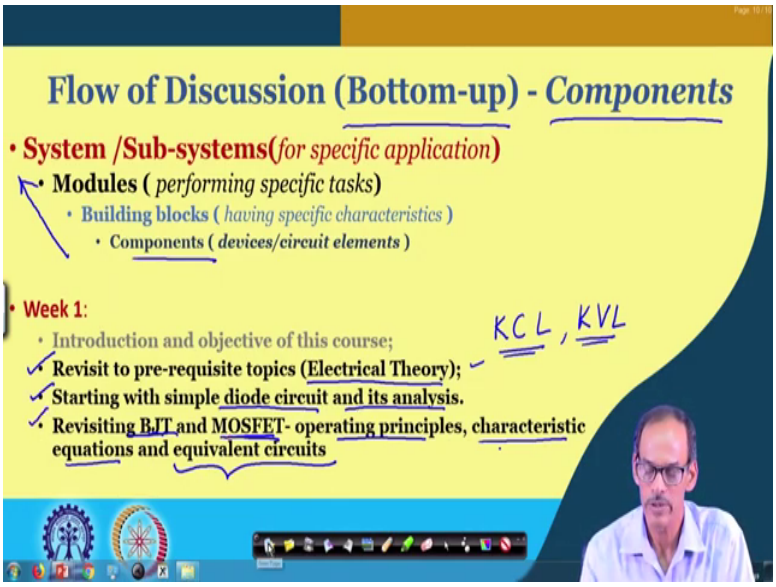

What will be the flow of this content or namely what will be the overall weekly plan namely we will be discussing with this flow namely it is bottom up flow. So, the bottom up flow it will be followed. So, we will start from components; in the first week we will be starting with the components.

First of all while we will be connecting different components, we need to revisit this electrical technology and while we will be discussing about this electrical technology, primarily we will be focusing on say KCL KVL and so on. So, those are frequently those topics it will be frequently used. So, after this introduction namely the previous discussion and today's discussion we will be moving towards the prerequisite topics related to electrical technology and KCL KVL.

And then we will be moving towards the different components particularly the non-linear circuit components starting with diode and how do we analyze the circuit and how this non-linear circuit it will be converted into quote and unquote linearized with respect to some operating point and so and so. And then after the diode then we will also cover the other non-linear device to be more precise the active devices namely bipolar junction transistor and MOSFET transistors.

There are different other transistors, but of course, these two transistors are quite dominant in present context. So, our focus it will be only to these devices we may touch a little bit about their operating principle, and then we will be going towards the characteristic equation of each of these devices and then those characteristic equation how do we represent in the form of equivalent linearized circuit called equivalent circuit of those BJT and MOS transistors.

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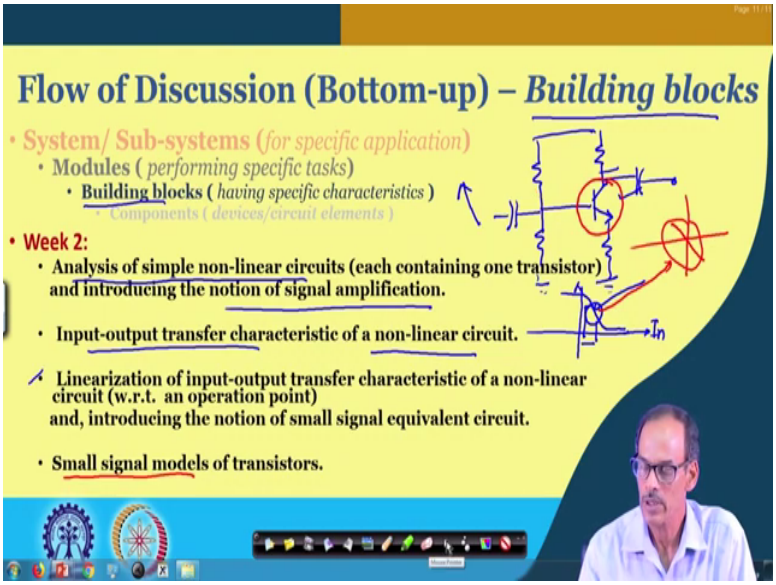

So, that is the plan for the first week. So, then in the second week what we are planning it is again it will be as I said that it will be the bottom up approach and after the components now we will be moving to the building blocks. So, in the building blocks before we will be directly going to the building blocks, how do we analyze a typical building blocks namely simple non-linear circuit?

When we say a simple non-linear circuit what we mean is that, it consists of a transistor say and surrounding that there may be different biasing components and so and so. So, then we will be analyzing this kind of circuit and then of course, we have to put appropriate bias. So, in second week we will start with that and then we will try to introduce what do you mean by signal amplification considering this circuit may be one example ok. And of course, then the once we are comfortable of understanding the amplification of the signal so, that is the input and this is the output.

So, then next thing is that how do you achieve the linearity, what may be the linearity of their circuit or limit of the linearity and so and so, namely input to output transfer characteristic of this circuit as an example or in general for non-linear circuit, how do we get input to output transfer characteristic and then how do you get the corresponding linearized part of it. So, something like this around the operating point how do you get a linearized circuit. So, that is what it will be discussed here.

And then if I restrict this input and output within this linear range, we call the small signal. So, if you restrict the input within this small signal range, then how do we translate this small signal this portion as a notion of something called small signal equivalent circuit or small signal characteristic so, that thing we will be discussing. So, basically this part it is getting translated here. Anyway I will be discussing the detail, but what is important thing to understand that there will be some notion something called small signal models of analog building blocks.

Now, along that of course, we like to draw small signal equivalent of the transistor as well which may be frequently used for analyzing bigger circuit. So, in the next week then what we will be covering it is.

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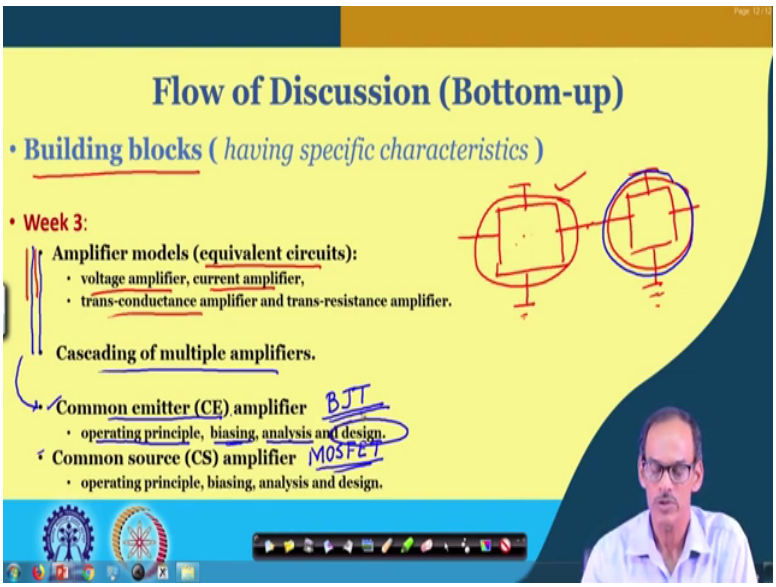

So, the building blocks we will continue the building blocks and so, we will continue this building block in the second week. So, we will start with how do we model one amplifier namely if I want to consider analog building block as a simple black box for its extension of this black box for bigger system.

Keeping in mind that this black this building block it will be stitched together to construct bigger circuit. So, we need to understand what may be equivalent circuit of this part, equivalent circuit of this part so, that constructing bigger system will not be going little I mean detail nitty gritty of within this circuit instead we may be considering simplified circuit

of this one and this one together. So, those simplified circuit it will it will be called equivalent circuit.

Now based on the signal here and signal here or the nature of the signal their, we may call this is their voltage amplifier, current amplifier and so and so, or transconductance amplifier and so and so. And then once we are comfortable of representing one building block in the form of simplified model, then we can stitch them together as I said that we can cascade with another circuit and then we can construct multistage amplifier.

So, basically it need not be only two, it may be having multiple stages and then with this overall understanding or understanding at abstract level, then we will be moving towards more practical circuit called common emitter amplifier, which is I should say a very fundamental building block for analog circuit. So, this is in BJTs realization likewise we do have the MOSFET realization. And as I said that in this course we like to continue BJT and MOS together side by side so, that we can understand that which is better and in what context what are the similarities are there so and so.

So, while we discussing each of this amplifier, what are the emphasis will be giving is that operating principle of those circuits and then biasing, how do we give the active device in appropriate region of operation so, that it is successfully amplifying the circuit and then what may be the analysis approach and then we will see that what are the design procedure it will be followed ok.

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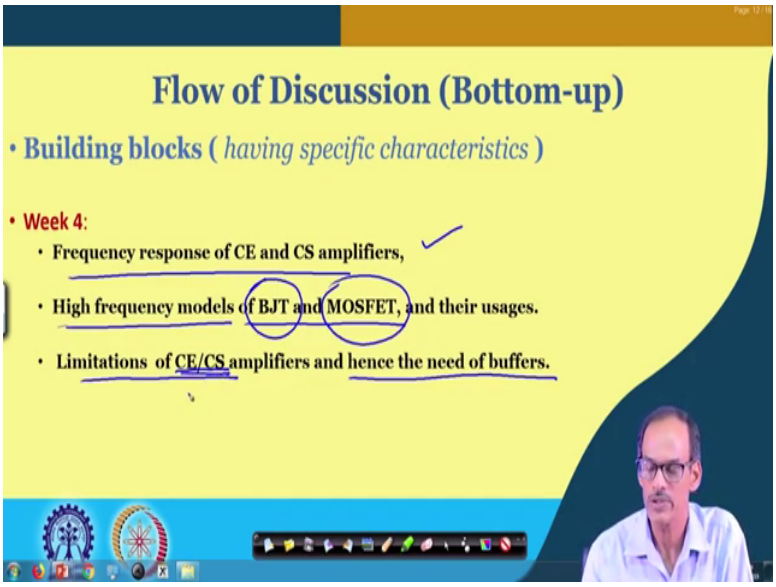

So, now in the next week, week 4 we will continue this building blocks, but then and next thing is the apart from the gain, what we are looking for it is the frequency characteristic of those amplifiers. So, then this is where we will be discussing how this circuit is performing in terms of frequency response whether it is band pass or high pass or low pass those things it will be discussed, and then we will be moving to the transistor model.

Keeping in mind that individual transistor they have their own limitation in terms of the frequency of operation. Namely each of these transistors they are having their own parasitics restricting their performance over certain range, and hence each of those transistor they will be having their own model representing the parasitic components, which are called high frequency models of those transistors.

And then after that we will visit or we will look into what are the limitations are there for common emitter and common source amplifier, which implies that to overcome those limitations we need to move for some other configuration. So, these two as I said that these two are very vital configuration, but they cannot do everything. So, we need to look out for other different configurations.

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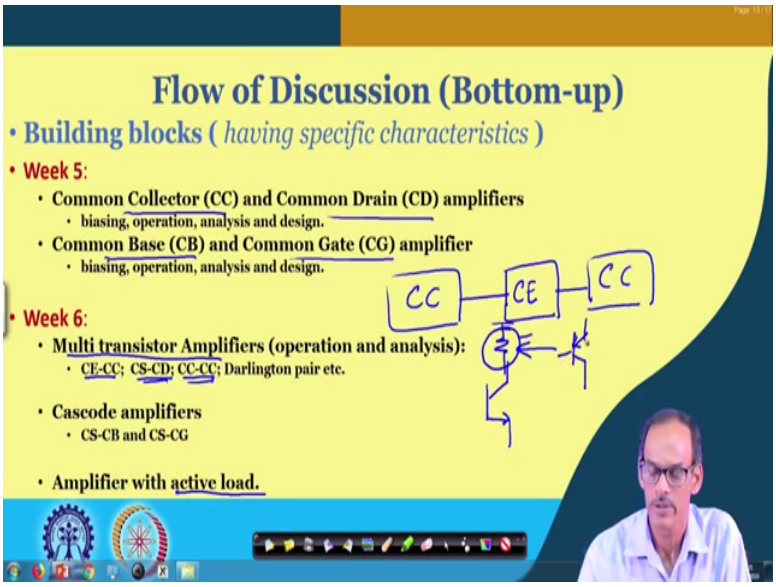

So, in week 5, week 5 we will be looking for some other configurations; namely common collector, common train likewise common base, common gate and so and so. So then we will see that how each of those different building blocks are judiciously getting you know connected together to get multi stage amplifiers.

And so, basically it need not be just only CE we may be having CE followed by CC and so, and so, or it may be preceded by another CC and so and so. So, those are the things it will be

discussed in week 6 and then the here so, far we will be discussing the connections around one transistor. And the biasing arrangements are performed by passive components, but then we will see that if we use a passive components as biasing component always, there will be its own limitation which invites that can we make a better connection or better biasing arrangement namely what is called active load.

So, instead of having passive circuit there, can we have some load or can you have some biasing arrangement performed by BJT or MOS and so and so? So, in the subsequent week so, that is what will be here will be discussing up to the building blocks and then in the subsequent week will be moving towards the modules.

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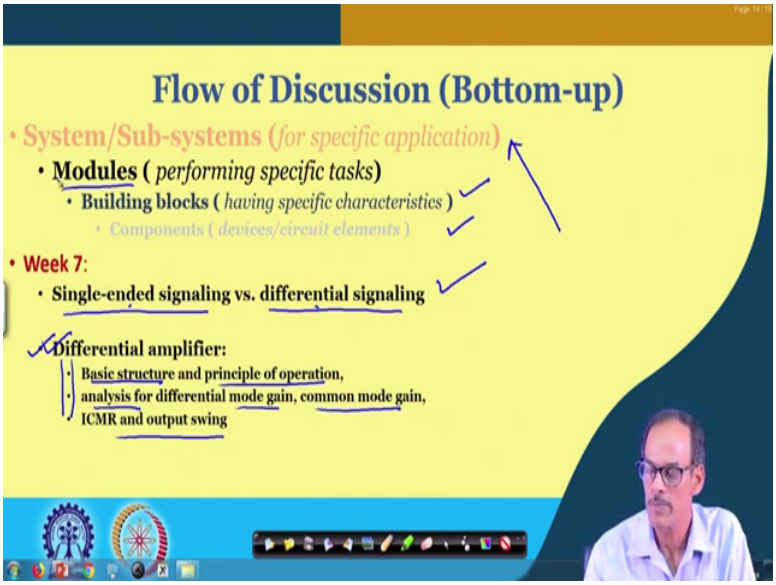

So, you may recall that our flow our flow it is basically bottom up. So, we are expecting the by this time we are done here, we are almost done here and then we are at the module level.

So, before we go into the module level circuit, it is very important to understand that two different types of signaling namely called single ended signaling and differential signaling.

So, some theoretical aspects and advantages and disadvantages of these two kinds of signaling it will be discussed and then we will be moving to another special kind of circuit called differential amplifier. When you are talking we will be talking about differential amplifier definitely we need to understand the differential signaling and to appreciate that what is the need of this differential signaling.

So, that is why we first compared single ended signaling with differential signaling and then we move to this differential amplifier. Then within the differential amplifier which again consists of different multiple transistors. We will see there the basic structure, working principle, analysis to get their gain namely differential mode gain and common mode gain and so and so output suing input common mode range and so, those things we will see. Then we will be continuing this module in week 8 ok.

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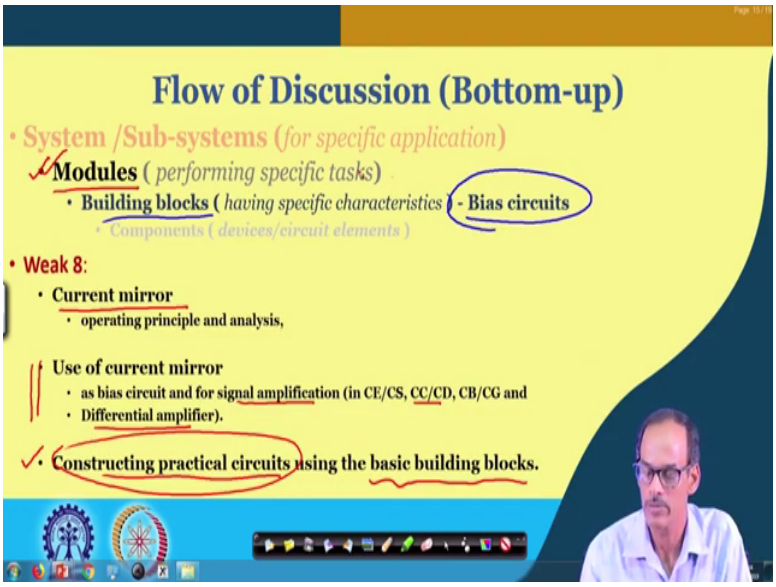

So, we will be definitely in we will be moving towards the module, but then there is a special kind of circuit again they are block level, but specifically not amplifier some bias circuits.

So, in week 8 we will be going on discussing about the current mirror week 8 this special kind of biasing circuit will be current mirror it will be discussed and then subsequently how those current mirror it will be used can be used for biasing or the main amplifiers they do to amplify the basic signals in better way, particularly for differential amplifier and then the common collector stages how those current mirror it will be used. And then will be actually into a situation to discuss about circuit module and to discuss about a practical circuit.

So, the basic building blocks will be used there to construct this practical circuit. So, at this point of time now we are already here maybe some more thing could can discuss at module level and then we can move to the system or subsystem level.

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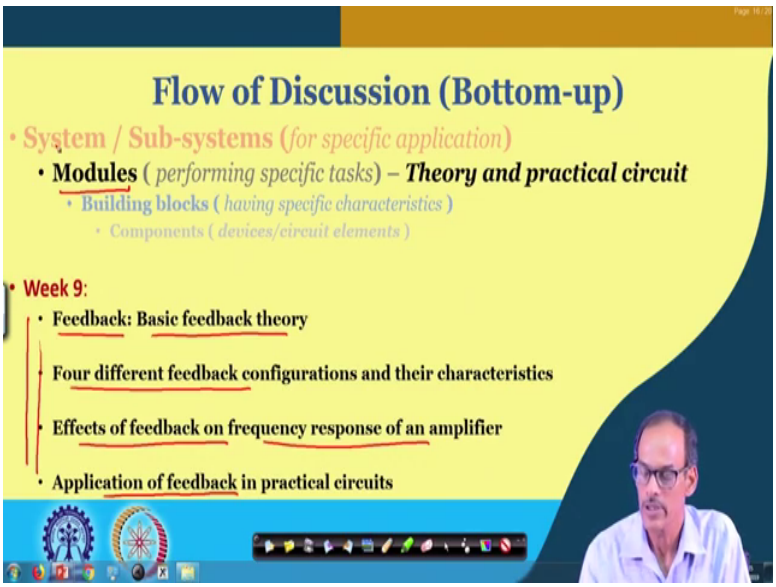

So, before we go into the system or subsystem level, we need to understand another basic concept called feedback which is very vital for analog circuit particularly analog circuit for amplifier as well as oscillator.

So, basic feedback theory it will be discussed, different configurations it will be discussed and what will be the effect of feedback configuration on frequency response of a typical amplifier those things it will be discussed and then of course, how those feedback circuits are

deployed in practical circuit. So, these concepts particularly these theoretical concepts it may be applicable for module level as well as it may be applicable for the subsystem level.

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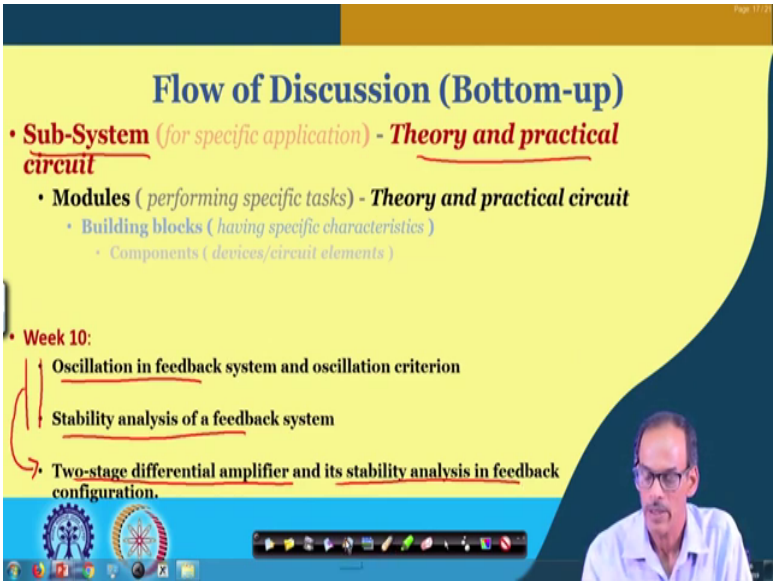

So, then we are getting ready to move towards the sub-system or system level. So, in week 10 we will be; will be moving to the sub-system circuit. So, there a little bit about theory and then we will be moving towards the practical circuit. So, there what will do it is that we will see that the oscillator circuit and what will be the oscillation criteria those things we will discuss it will be discussed.

And for amplifier in presence of feedback system in feedback connection, how do you ensure the stability of the circuit that will be discussed. So, these two are of course, more towards the theory and then it will be discussed towards how those theories are getting deployed for a

practical circuit namely two stage differential amplifier and its stability aspect it will be discussed there.

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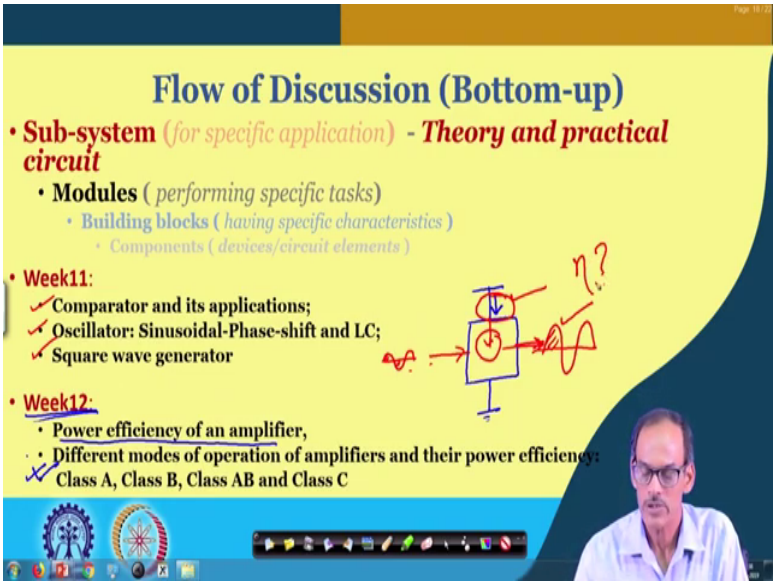

Now, in week 11 we will continue this subsystem. So, in week 11 we will continue with different subsystems namely, the comparator and then its application, then oscillator and then square wave generator and so and so. And then week 12 we will be discussing different kinds of sub circuit namely power amplifier and before going into the power amplifier we must discuss about the power efficiency of a typical amplifier.

And then we will be discussing different configurations and how the power efficiency of those circuits are there. It may be noted that for this topic particularly for power amplifier instead of power gain what is important is that, power efficiency is important which means that whenever we are drawing some power from the DC source and so, we are drawing the

power from DC source and those sources those energy it is getting utilized to amplify the weak signal into the to convert the weak signal into the form of strong signal at the output node.

So, how this input signal it is getting stronger and stronger by this power. And in this case of course, gain may be important, but whether I should say gain may not be so, crucial, but what is important thing is that how much the DC power is getting converted into the output power that is what it is important. So, we will be discussing about something called power efficiency which means that, how much the power we are drawing from the DC getting actually to the signal. So, that power efficiency it will be discussed there. So, that is the overall plan of this course.

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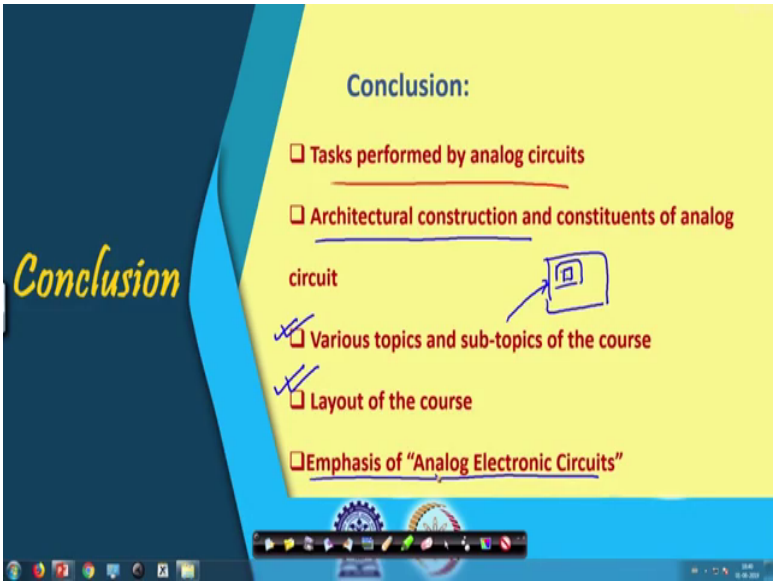

So, what we have discussed in today's module it is what are the tasks are performed what are the tasks are performed by typical analog circuits then what are the different building blocks are there within analog circuit namely how do we split a system into different modules, building blocks and then components those things it has been discussed. And then we have discussed about what are the topics it will be there in this course namely topics and subtopics.

How are they related to those that architecture and then of course, those things we have discussed about how they have been planned in this course basically how weakly they will be covered to move from component towards the system level. We also have discussed little bit about what are the emphasis it will be given in this course, namely the working principle of the circuit and then the analysis of the circuit and then design approaches and some of the practical circuits it will be discussed. I think that is all we need to cover in this module.