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**Lecture – 31**
**Common Emitter Amplifier (Contd.) Design Guidelines (Part B)**

Welcome back after this short break and let me continue the Design Guidelines for CE Amplifier.

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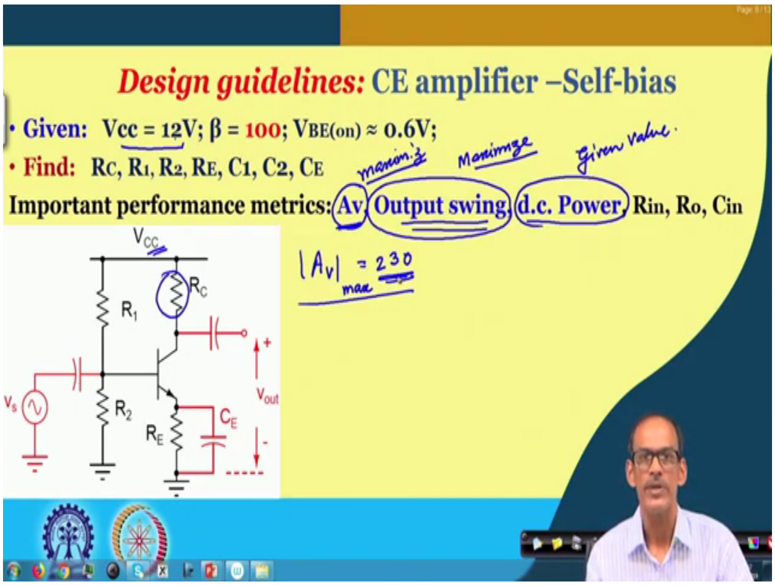


So, far we have discussed about the design guidelines where or mean objective there is to maximize the gain, voltage gain right. And, also the output swing we like to maximize and the power dissipation probably it is given value. And, this maximization of output swing of course, it is decided by the V CC predominantly.

So, likewise maximization of the gain is also it is decided by this V CC and thermal equivalent voltage and of course, the output swing. And, we have seen that the A v max it is to say 230 right. And, in case if we are looking for again higher than this one definitely we cannot achieve that by this circuit, unless otherwise we modify the circuit by some means.

Either we may have to in change this supply voltage or maybe we have to do something here, but then and we may require the other possibility that we may cascade or multiple amplifier together to get higher gain. On the other hand in case if we are looking for an amplifier having again, which is less than this limit, then how do you design? And, of course, having higher swing it is always better.

So, typically we like to keep the output swing towards it is maximum as much as possible, but definitely there may be a requirement where say we require only 20 gain, unnecessarily we will not be looking for say 230 gain. So, in case if this gain it is specified and if it is less than this limit, then what may be the design guidelines or design procedure to achieve that.

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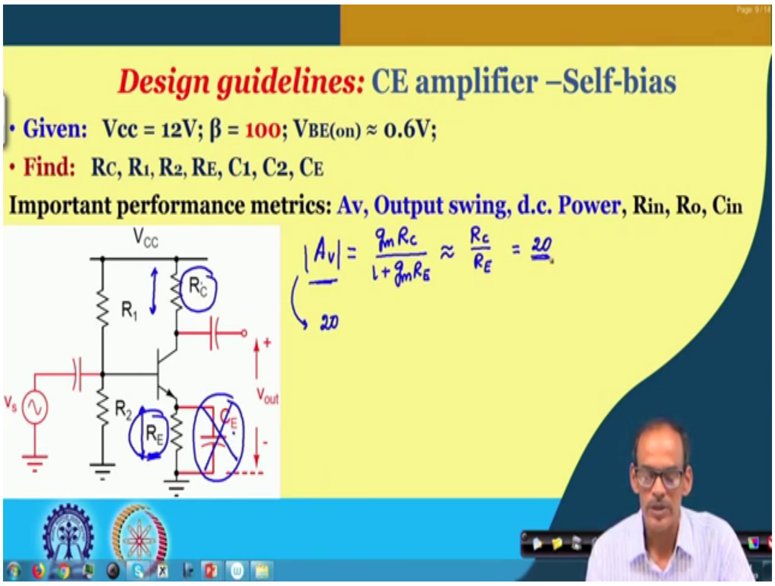


So, you may recall that we have discussed the gain of the circuit in case if this the C E part is not there, then the voltage gain A v it is expression it is g m into R C divided by 1 plus g m into R E, and that may be well approximated by R C divided by R E.

So, now in case if we are looking for low gain and then if we simply remove this C E and then try to achieve the required gain by this ratio of this two, that may not be giving a meaningful design. For example, if you are looking for say this ratio to be say or say this gain, it is given to us is a 20. And, if you are taking this ratio to be 20, which means that the drop across this resistance it will be 120 th of whatever the drop we do have.

And, if you pick up that value of R E, then R E may not be meaningful meaningfully large to get the operating point insensitive to beta. So, as I said that the drop across this resistance we take probably on may be one- fourth of this C E R C. So, this kind of value of this ratio, definitely it will affect the bias point stability against beta variation.

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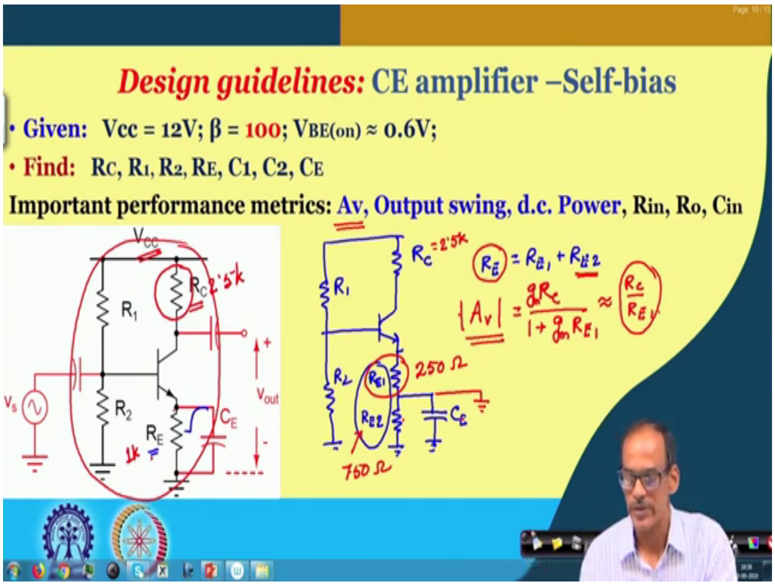


So, what may be the remedy for that instead of completely ignoring the C E or instead of completely bypassing this R E, what you can do we can partially bypass this register? So, what let me draw this circuit? The C R C part we can keep as is and then the R E part we can have 2 parts; one is the say R E 1 and R E 2 and only one of them it is getting bypassed by C E. And, then of course, at the base side we do have R 1 and R 2 and so, we do have R 1 and R 2.

Now, these two together it is giving us R E. So, R E 1 and R E 2 they are helping us to decide how to fix the voltage here to achieve whatever the operating point d sensitivity. Then on the other hand for gain since this part it is unbypassed and this is bypassed by the C E. So, we can say signal wise this is a C ground and this portion it is unbypassed.

So, the gain the voltage gain of the circuit now it will be R C. So, g m into rather let me write the complete expression g m into R C divided by 1 plus g m into un bypassed R E. This can be well approximated by R C divided by R E 1.

So, now we do have the flexibility to decide the value of R E and the R E 1 to achieve whatever the gain we are looking for. So, in case if we have this ratio it is the gain is given to be 20, let this ratio be 20, but by considering the other part of the R E, we can have different ratio of this R C and R E which is necessary for from bias point stability.

So, say for example, this may be 2.5 k, this we may require say 1 k and this register on the other hand we can make it say 250 ohms and then this part we can you say 750 ohms and this is as I said that 2.5 k. So, that is how we can and rest of the things it is remaining same?

So, the next thing is that in case if we are looking for a circuit having this gain, which is higher than the limit of the maximum gain we are achieving from single stage for a given value of V CC. So, there are two possibilities probably we can replace this register by active device, that it will be discussed later. The second possibility or the other possibility is that we can probably cascade to an amplifier to get total gain may be multiplication of the 2 individual stages gain. So, let us see how do we find the gain of that circuit?.

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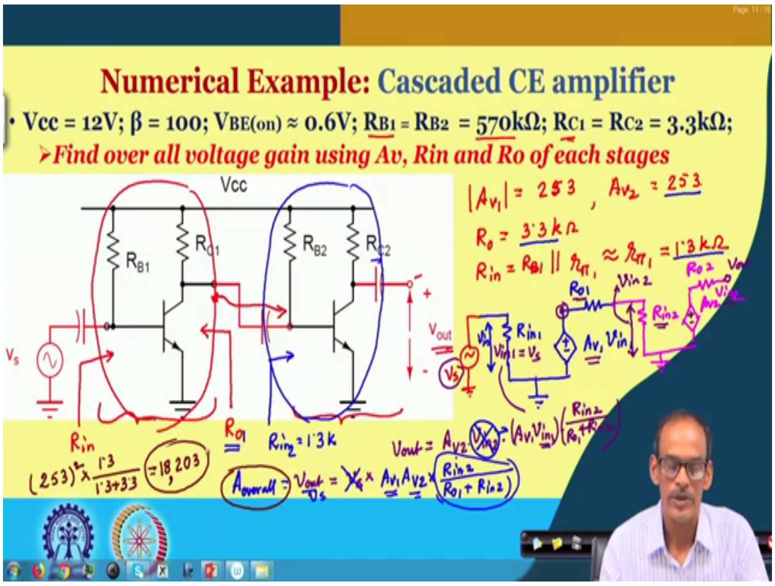


Again we are going back to the circuit analysis, but it is different kind. So, say we do have this C amplifier. So, this is fixed bias, also this is fixed bias and then as I say that individual circuit gained it is upper limit it is only 230 and this is also 230, but if we are looking for higher gain. We simply feed the signal on the output coming from this point and then we feed it to the input here.

So, that this will be getting further amplified and then we can get the final output. Now, this circuit gain if the sizes of different registers are given here, say R B 1 it is 270 kilo ohm and R C is a 3.3 k. Then earlier we have discussed that the gain of this stage and this stage they were let me check the value are us having around 200 no 200 it will be 200, but 253.

So, the A v 1 is 253 and likewise the A v 2 also this is identical A v 2 253. And, then also we have seen that the input resistance of this circuit and the output resistance R o and then R in.

So, the R o it is same as this R C which is 3.3 k. And, then R in it is R B 1 in parallel with r pi and this r pi it is dominating.

So, it is approximately r pi 1 and this is I guess it was 1 1.3 k 1.3 kilo ohms. So, likewise if I consider the second stage it is also having it is own input resistance R in equals to 1.3 k and likewise the output resistance. Now, if I replace this these 2 amplifiers by their corresponding model for signal, small signal model and so, the first stage it is having it is own input resistance call R in 1.

And, then it is having voltage gain defined by or modeled by voltage dependent voltage source which is a V 1 times it is input voltage V in 1 and then it is output resistance let me denote by R o 1 followed by the second stage. So, the second stage here we do have the input resistance which is R in 2 and then it is having it is gain it is defined by voltage dependent voltage source and then the output resistance R o 2

So, this is A V 2 multiplied by V in 2. Now, the of course, this is connected to a C ground or actual ground actually it is a C ground I should consider in the model wise. And, then at the input we do have the signal we are feeding here the V s. And, V s incidentally it is same as this V in whereas, the V out; V out coming from the first stage, let me use this color this color.

So, the voltage coming here it is the A v 1 multiplied by V in, this V in that voltage it is only here. The voltage coming here is the V in 2. So, the V in 2 here V in 2 it is not same as the voltage here. So, what we have to do to find the final voltage here, if I call this is the final V out. So, we can say that final v out equals to A v 2 multiplied by v in 2. And, then what is v in 2 that is the voltage here, which is A v 1 V in 1 multiplied by this attenuation offered by this R o 1 and R in 2 so, which means that R in 2 divided by R o 1 plus R in 2.

So, then we can say that overall gain, now this V in 1 V in 1 here, V in 1. So, this V in 1 it is incidentally same as the V s. So, this is equal to V s. So, we can say that V out equals to V s multiplied by A v 1, then A V sorry this V in 2 we are writing here. So, definitely I will be dropping this part. So, I do have V A V 1 and then A V 2 and then V in is same as V s we already have written multiplied by R in 2 divided by R o 1 plus R in 2.

So, if I take this and this ratio v out divided by V s. So, this part we are removing. So, that gives us the overall gain. So, overall gain it is the individual gain of the stages multiplied by this attenuation factor. This attenuation factor it is coming from the output resistance of the first stage and then input resistance of the second stage.

So, that is how we can probably calculate in and you can find what will be the gain. In fact, if you see in this circuit, if I consider R out is this and then R in is 1.3 k and then gain individual stage gain it is 253, then the overall gain what we are getting here it is something like, 253 each of this a V 1 and A v 2 are equal and so, that squared multiplied by 1.3 divided by 1.3 plus 3.3. So, that gives us the overall gain and I made some calculation here that is 18, 000 something 18, 203.

So, you can see that, how big this gain is it is quite large right. So, that is how we can get higher gain. So, at least we understand that how to increase the gain and how to decrease the gain by putting unbypassed R E? Now, similar kind of things it can be used for C amplifier having sale biased arrangement. So, let you consider the other example similar kind of example, where individual stages are the fixed bias sorry sale biased kind of arrangement.

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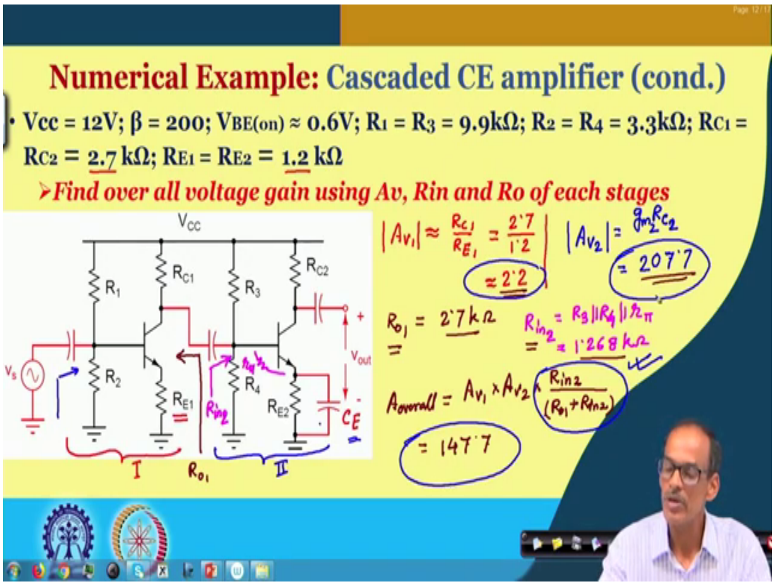


Now, in this case so, the second stage intentionally I have considered it is different from the first one. Particularly, here we do have the in the second stage we do have the C E emitter bypass capacitor whereas, this R E 1 which is remaining unbypass.

So, the first stage if I consider this one Ist, it is gain it is A v 1. So, A v 1 equals to R C divided by R E and the R C and R E are given here. So, that gives us 2.7 divided by 1.2. I am considering it is magnitude it is having minus sign of course, and then likewise if I consider the IInd stage, since it is emitter is bypassed by the C E. So, it is gain A v 2 equals to g m into R C 1 and I rather R C 2.

And this gain we have seen before it is I think 207 roughly 207 or 208 207.7. And, the gain of the first stage it is which is given here that is I think 2.2 around 2.2. And, then now, the resistances if you see the output resistance of the first stage R o 1. So, R o 1 it is R C 1. So, that is 2.7 k. And, on the other hand the input resistance of the second stage R in 1.

So, this R in 1 it is these 2 registers coming in parallel. So, that is R 3 and R 4 in parallel with the register here which is r pi. So, we can consider this r pi in parallel with the bias circuits. And, again it is resistance keeping all of them together 1.26. So, that gives us 1.268 kilo ohm. Now, this R o 1 and then R sorry this is sorry this is R in 2. So, this R in 2 and R o 1 they are making potential division and as a result that the overall gain.

Now, if I write the overall gain A overall the similar procedure will be following, which is A v 1 multiplied by A v 2 multiplied by this attenuation offered by this R o 1 and R in 2 which is R in 2 divided by R o 1 plus R in 2. So, if I plug in these numbers and the corresponding values of the resistances what we are getting here it is in fact, we are getting 147.7.

In fact, if you see here, this gain it is lower than this one is not it. And, why even though we do have gain of the first stage though it is low, but it is higher than 1 this attenuation part attenuation factor it is killing the gain which we obtain from the first stage. In fact, it is further reducing the gain.

So, while we are cascading we need to be little careful, that the if we are cascading in wrong way, then this attenuation factor it may decrease the overall gain even with respect to individual stage gain. So, on the other hand suppose if I put 2 circuits namely, one is having bypass capacitor another is not.

The other way probably the situation it will be better, that is because the input resistance of this circuit may be higher and it may not be very good, but at least still at least we can say that probably the gain maybe in this order.

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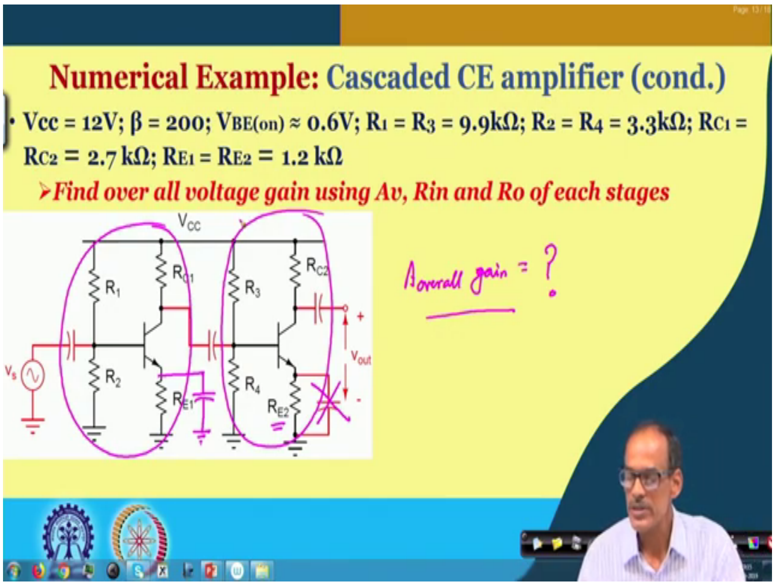


So, as an exercise what it can try. So, we can consider that if you remove this capacitor making this R E 2 unbypass. And, then if you put the bypass capacitor here. And, then you can calculate what will be the overall gain.

So, this you can do yourself and you can find this one. And, the also the procedure as I say that though we have discussed about the 2 stage cascading together what may be the gain. The procedure can be deployed for many stages and most important thing is that these 2 stages need not be of same type.

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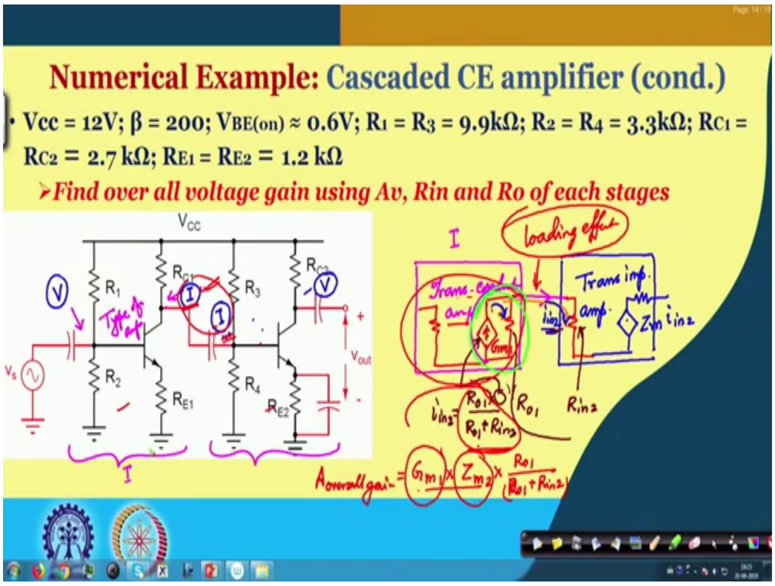


When it is the same type or does it mean is that, we are analyzing these 2 circuits as voltage amplifier. And, while you are cascading it is not mandatory to have both these 2 stages are having same nature. Say, for example, this stage may be transconductance amplifier and this may be transimpedance amplifier. So, based on the signal type here and signal type here we can define, what type of amplifier it is and accordingly you can have the macro model of the first stage.

So, we can take this first stage here. And, then if I consider say this circuit second circuit. Now, suppose this is at the input it is say voltage. And, you consider this is say transconductance amplifier so; that means, the signal here it is current right. So, if the signal you are considering this is current. So, the next stage it may be expecting the signal in the form of current.

So, then this may be since it is current either it may be current amplifier, where this the signal here it is current and the signal here also it is current or it may be this is current, but this may be voltage and in that case the type of the second stage it will be trans impedance amplifier.

So, likewise then we can draw the corresponding macro model of this one. So, let you consider this is current and then we are considering this is voltage. So, this is trans impedance trans impedance amplifier and we have discussed about it is corresponding model. And, the first one on the other hand based on it is input and output type this is transconductance.

And, then based on the signal here and here, you have to see that how much the signal it is really getting penetrated to the next circuit. So, that you can calculate accordingly you can calculate what may be the loading effect. So, earlier we have seen that this middle node it was the signal type it was voltage.

Now, in this case the signal here it is current. And, then the kind of analysis well be doing is that out of the internally generated current, how much the current it is actually going to the next circuit? Right. So, since it is transconductance the output port it will be not only equivalent and then whatever the internally generated current part of this internally, internally generated current it will be going through this and this. Then you can find that how much the current it is entering, that is where defining the next stage output voltage right.

So, here since the outputs it since it is Trans impedance output port it is termed an equivalent model. So, this voltage of course, it is current dependent voltage source we can say Z m into it is corresponding i in; i in 2 it is here right. So, this i in 2 it is not the entire current here it is rather it is having this current flowing here.

Now, based on the value of the resistance here R o 1 and the input resistance here R in 2 you can find what will be the current here. So, the total current whatever the current is flowing here out of that this current it will be; it will be getting divided. So, the R i in 2 I should say that i in 2 it will be R o 1 divided by R o 1 plus R in 2 multiplied by whatever the current we do have here right.

So, that is how will be getting some the loading effect and this loading effect it is I should say this is offering the loading effect. And, the this loading effect depending on the type of signal, you will be getting different way to analyze, but finally, you will be getting this loading effect it will be less than 1. So, if I say the first stage first stage this is transconductance.

So, maybe transconductance it is g m 1 and then the next stage Trans impedance is said m 2. So, the overall gain overall gain it is g m of first stage multiplied by Z m of the second stage multiplied by R o 1 divided by R o 1 plus R in 2. So, the this is also similar only difference here it is that, the now we understand that these 2 stages need not be of same type they can be of different types of amplifier right.

So, likewise we can consider other different combinations and you can probably can practice. And, in case say this models are given here. And, in case suppose the signal here and the signal expected signal here if they are not consistent. Say, for example, this is maybe transconductance amplifier which is producing output signal as current, but then if the second stage it is a voltage amplifier may be expecting here the signal to be voltage.

So, then how do you proceed? So, if this model is given to you then this part, this output port part, you can change; that means, different colored here. I guess I can use green color. So, this part you can change from not only equivalent to definite equivalent in that case. So, likewise you can you know proceed in case if you have multiple such stages and then you can find the overall gain. I think whatever the things we have planned mostly you have covered.

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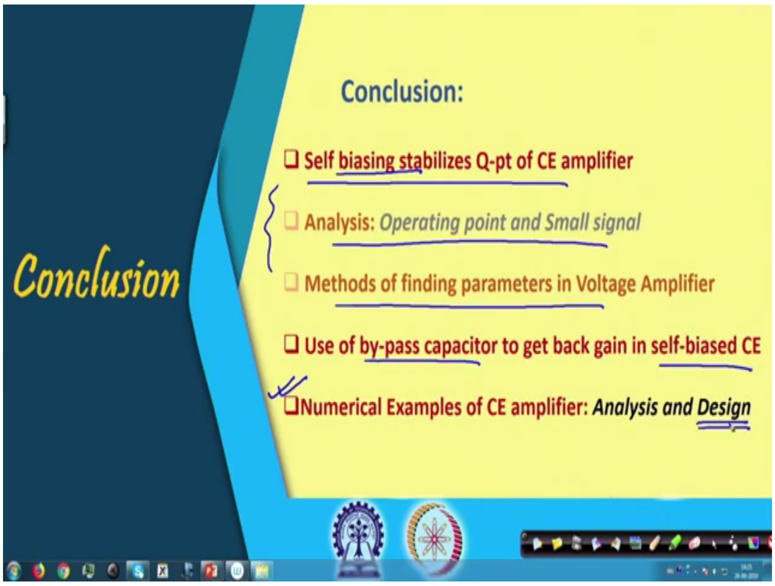


So, far in this module in last say, 3 lectures what we have covered let me summarize. And, the we have discussed the theoretical part before particularly the bias point stability of C amplifier and then how to find the gain of the circuit in through equation, as well as numerically. And, then also we have discussed about how to find the parameter of say, macro models either it may be voltage amplifier or current amplifier or transient variants or transconductance.

So, those numerical analysis we have done here as a theoretical analyst or a theoretical analysis we have done. And, then after that we have discussed about the how to get back the gain of self-bias circuit, which is having stable operating point namely by using bypass capacitor. And, then we have discussed lot of numerical problems starting from individual C amplifier having either self-biased or the fixed bias and then we have also given design guidelines, how to design a circuit?

And, also we have given some hint that how we extend the simple C amplifier into a bigger circuit namely, how do you cascade this circuit and then if you cascade it what may be the corresponding gain and how to find the gain of to cascade amplifiers. I guess that is all I do have.

Thank you for listening.