Analog Electronic Circuits

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Lecture - 71
Single - Ended Vs. Differential Signaling and Basic Model of a Differential Amplifier (Contd.)

So, welcome back after the short break.

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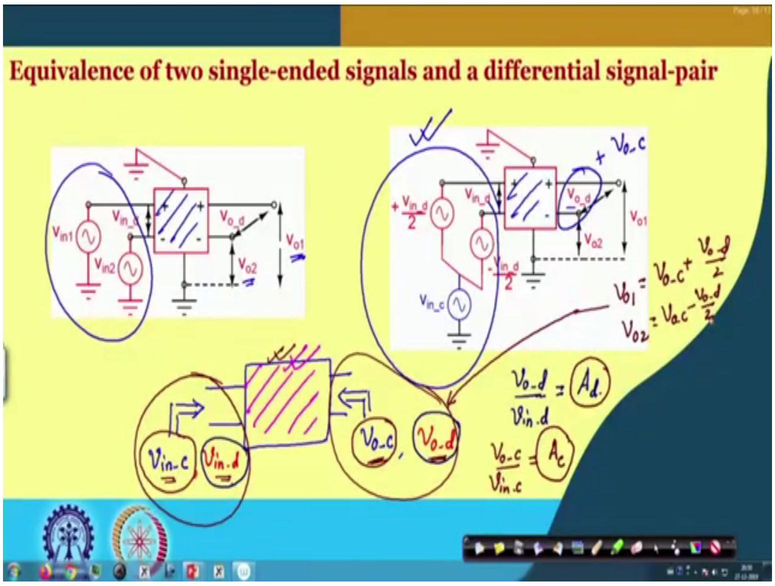

So, we are discussing about the equivalence of the 2 single ended signal and differential signal pair. Now let me give you some example of that maybe pictorial example of representing individual signal versus common mode and differential part.

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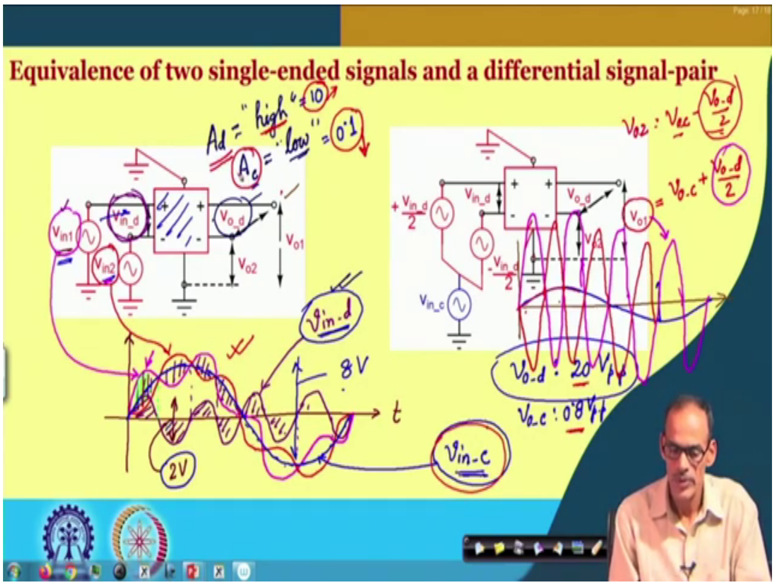

Suppose we do have say one signal something like this. See V in 1 let me sketch that V in 1.

So, we do have one sinusoidal part and on top of that with respect to that we do have see V in 1, it is sinusoidal with respect to that bigger sinusoidal part right. So, we may say that this pink colour is V in V in 1 and then if I consider say V in 2. So, that is also with respect to this dotted blue line and that is also sinusoidal, but it is in opposite phase.

So, the pink one you may say it is true signal and the red one it is the complimentary signal and inside that whatever you see this is the signal and difference of these two it is basically the differential V in d. So, V in 2 is the as I said it is the red colour one and the then, if you try to represent say these two signal namely the pink colour and red colour in terms of say differential and the common mode component. So, let me draw the differential part, let me use a colour say green. So, here you can see that the signal here it is large up to this point let me use different colour otherwise you may get confused.

So, here you do have large signal and then here you do have signal going negative, again here to here we do have positive and then negative and so on right. So, what would this violet colour signal? I have drawn namely this signal it is the difference of the 2 signals V in 1 minus V in 2, which means that this is the differential signal right. So, this signal it is V in d and then if you observe carefully that if I take average of these 2 signals namely the common mode signal is this blue line. So, this is a common part or the common mode signal. So, this blue signal is V in c .

So in case in case if you have a situation like this. Suppose your main signal is this one the violet colour one, but then you do have a lot of disturbance getting represented by this blue signal and in case if you want to really find the find out this signal and if you extract this remove the noise part, the blue part then you can take help from this differential amplifier, how will you tell while you are feeding the signal it is having different response to the differential component and the common mode component.

So, if I say that it is a differential mode gain ad it is say high. So, if this is say high quote and unquote high and the common mode gain ac if I say it is having low value then at the output whatever the Vo d you will get Vo d it will be amplified. The amplified version of this signal and then if it is low common mode gain, it is low then this blue colour part it will be also coming here as common mode, but its strength it will be less.

Say for example, if I am having say amplitude of say this signal it is say 1. So, which means that peak to peak it is say 2 volt, whereas, a the blue one that you consider blue one it is having large amplitude say 8 volt. So, naturally if I try to amplify this signal both V in 1 and V in 2 by single ended amplifier then I cannot remove this component, but in case if I am having a differential amplifier which is having say gain a differential gain of say this gain it is 10 and say this common mode gain it is a only 0.1 right.

So then at the output what we will get Vo d Vo d will be having 2 volt multiplied by 10 that means, 20 volt peak to peak. On the other hand the common mode part Vo c at the output port the common mode signal, it will be 8 volt multiplied by this 0.1. So, that is only 0.8 volt peak to peak right. So, as a result whatever the output voltage will be getting, it is primarily this signal it will be dominating. In fact, pictorially if I try to draw it let me make an attempt to draw the signal whatever the signal we will be expecting here.

We do have the blue one which is having very small amplitude only 0.8 volt peak to peak and then we do have this 20, we do have 20 volt peak to peak differential and individually if I see. So, this signal it will be the signal plus half of this Vo d by 2. So, this is equal to Vo c plus Vo d by 2. So, that means, over this signal we do have this part which is which is in volt peak to peak. In fact, it goes like this right something like this and keep on going like this which means that this pink colour it got amplified like this and that gives us the Vo 1 part.

On the other hand if I consider the red part which is a Vo 2 Vo 2 which is Vo c minus Vo d by 2 which means that it is also having this blue part, but then its um peak to peak value it is only 0.8 volt and then also it is having a differential part half of the differential part which is having 10 volt peak to peak. So, that signal it is coming like this right. So, what we have here it is you can say that if I compare the input situation at the input, where the signal strength it was almost or I should say it is very small compared to the that disturbance part or noise part and that noise part if I consider output wise even individual signal if I see that almost they are giving the good quality signal.

Now, you can imagine that if this am a differential gain it is higher and higher, which means that this signal the differential output it will be more and if I if I can make the circuit is smaller and smaller; obviously, then the blue part it will be getting suppressed. So, qualitatively I can say that whenever we will be designing one differential amplifier, we like to have a differential amplifier having differential gain as high as possible and the common mode gain. On the other hand it should be as small as possible or it should be having high attenuation and this is the main purpose this is the main objective of going for differential amplifier.

We will be discussing that some more, but intuitively at least you understand that why these 2 parameters are important for this differential amplifier. In fact, they are the vital parameters of characterizing the differential amplifier.

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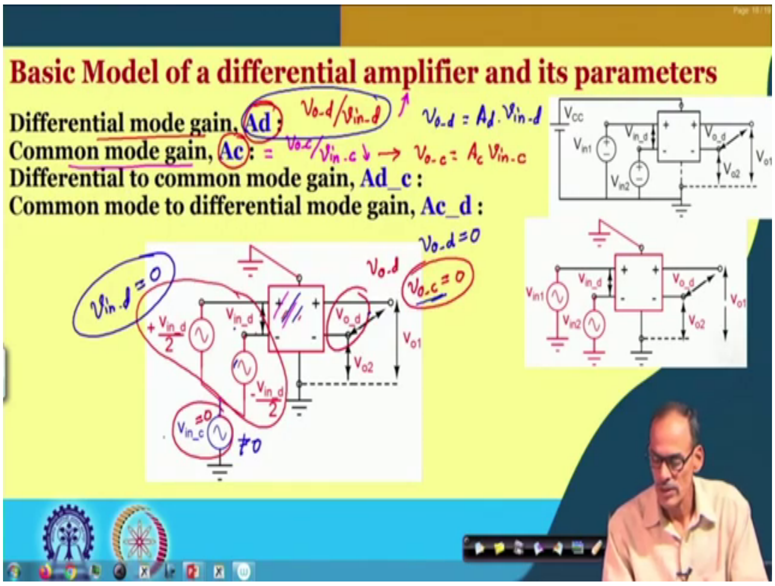

So, whenever we do have a differential amplifier we like to have a basic model and the basic model it is as I said that it should be having 2 important parameters the differential mode gain which is defined by Vo d by V in d and then it is also having another important parameter called common mode gain which is defined by Vo c divided by V in c and as I said that this should be as high as possible, this should be as small as possible and that makes the circuit more towards the ideal one and then only we can say that this circuit can remove the average part or the common mode part and it appreciates the differential part.

Now if I write this equation say this equation what we can say that Vo d equals to A d multiplied by V in d.

So, likewise if I see this equation, we can see that Vo c equals to a c multiplied by V in c which means that if the circuit it is linearized and if I stimulate the circuit only with this part keeping this is equal to 0 then at the output we will be getting only Vo d and so, on the other hand the corresponding Vo c it is expected to be 0. So, if I make this is equal to 0. So, we are expecting this should be 0 on the other hand if I if I consider say this is non zero. So, if this is this is non zero and then if I make say the V in d equals to 0.

Then what we are expecting is that Vo d should be equal to 0 and then Vo c maybe not 0, but that is the idealistic situation which means that the circuit it is only allowing differential signal in the form of differential signal at the output port and common mode signal at the input port 2 common mode signal at the output port practically; however, there is a chance of having a having a cross propagation namely the let me clear the board, yeah namely this differential part, this differential part it may be appearing at the output in the form of some part of the common mode signal.

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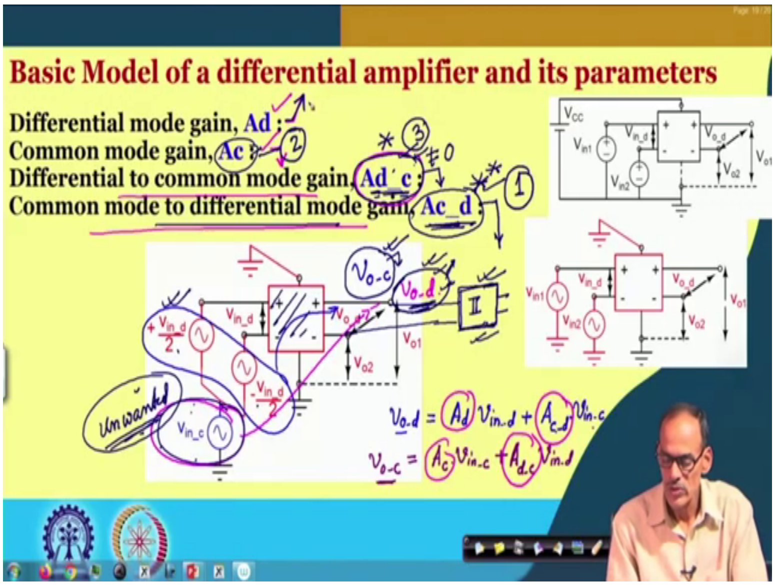

So, likewise if I consider a say a common mode signal part that may come here in the form of some part of the differential. So, we can say that individually then Vo c if I am stimulating the circuits with both differential and common mode. So, we can see that Vo d it is a d times V in d plus some parameter multiplied by um, some parameter multiplied by V in c and this parameter seems it is converting common mode signal in the form of differential. So, we can see that V c d. So, we do have one more parameter.

So, likewise if I consider differential part, sorry the common mode part. Let me use this colour. So, Vo c ideally we want it should be is a c times V in c, but then practically some part of the differential signal it may get converted may get converted in the form of common mode signal and since the differential part it is getting converted into common mode part. So, the corresponding parameter we can call it is A d c. So, apart from apart from Ad and Ac which we already have defined here we may have 2 more parameters. So, we do have differential to common mode gain and then common mode to differential mode gain.

So, yeah. So, ideally as I said that we want this should be as high as possible and this should be as low as possible. So, likewise here also we like to have both this parameters should be as small as possible and it need to be observed that the we want both these parameters should be as small as possible, but making this parameter smaller is definitely, it is more desirable because it converts the common mode signal in the form of differential. So, if I say that our main purpose of using this differential amplifier is to eliminate the common mode signal which means that this is the unwanted part correct and we want this part should be as low as possible and at particularly at the output port they should not propagate.

So, in case if this part it is say non zero which means that this unwanted part it is getting converted here in the form of differential signal and once this unwanted part it is sneaks into the differential signal in the form of differential signal at the output port then we cannot do anything. On the other hand in case in case say Vo c output common mode signal if it is still significant then probably this signal we can put it into to the input port of second differential amplifier, where we can further suppress this unwanted part and then we can appreciate this part. So, we can try to suppress this part and we can appreciate this part by putting the signal to another differential amplifier.

But then once we have this unwanted part namely the common mode part if it is getting converted into the form of differential then by using the second differential amplifier, there is no use because this differential amplifier it cannot really you know suppress the unwanted part which already got converted into differential form. So, this circuit will not be able to really distinguish whether unwanted signal it is getting converted in the form of differential or the original differential signal it is coming here correct.

So, the summary is that this is most dangerous thing. So, definitely we want both A c d and A c should be low. So, priority wise; however, this is having highest priority to make it as small as possible and then probably this one and then the third one is this A c d in A c d in case, sorry I will take it back the what I like to say that this part should be as small as possible which converts common mode signal in the form of a differential. So, highest priority is this one.

So, we do have highest priority to reduce this signal to as small as possible and um. So, this parameters should be as small as possible and then the A c and then A d c. So, in case A d c it is non zero which means that we do have some differential signal that may be getting converted into common mode part, but anyway by the time we already have significant amount of differential signal coming out of the differential input. So, probably that is not so important. So, main thing what I like to say that the A c d should be as small as possible. So, this is the highest priority.

And then this is the second highest priority and probably this is the third highest priority to make all of them low and of course, this A d should be as high as possible right. So, let us try to do some numerical example yeah.

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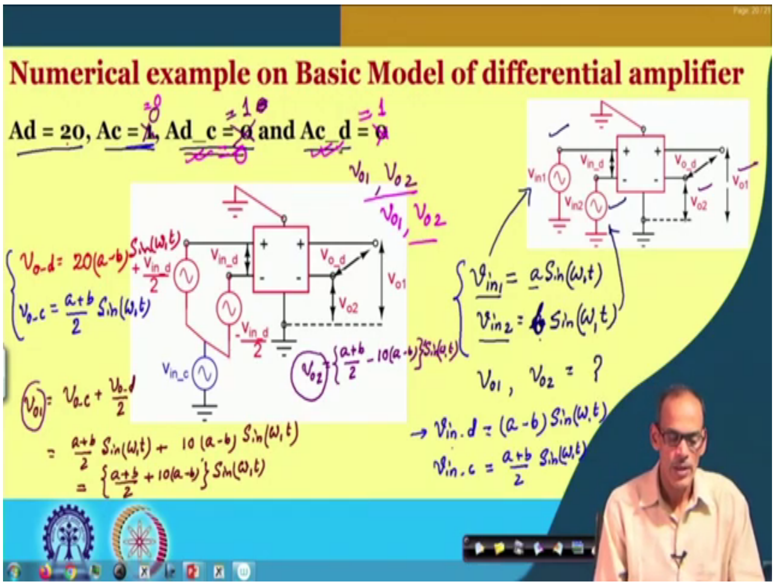

So, we do have some numerical example of which we already have discussed probably with a different quantity and mathematically probably you can try it out differential mode gain. It is say 20 common mode gain, it is say 1 and both differential to common mode gain and common mode to differential mode gain they are say 0.

And this is the corresponding circuit and if I say that V in 1 equals 2 say a sin omega 1 t and V in 2 equals to say a rather b let me put b b sin omega 1 t and then you can find what will be the corresponding V o one and V o two. So, how do you proceed? First of all the circuit is already linearized. So, though we are giving the information in the form of single ended and both of the signals are having the same frequency, but having different amplitude now if you directly approach using single ended a signal I it is not possible rather it will get complicated.

So, the better option is that let we convert the signal in the form of V in d and V in c. So, what is V in d here and the difference of these 2 signals, So, that is a minus b sin omega 1 t right and then common mode signal it is a plus b by 2 sin omega 1 t right. Now this differential part of course, it will be producing differential output and the corresponding output we can get by multiplying with A d. So, we can say that V o d equals to 10 rather 20 yeah.

So, that is 20 20- multiplied by a minus b sin omega 1 t and then V o c equals to we do have one common mode gain it is 1. So, that is a plus b by 2 sin omega 1 t. Now by combining this 2 we can get the individual signal. So, namely Vo 1 equals to Vo c plus Vo d by 2 which means this is a plus b by 2 into sin omega 1 t plus 10 a minus b sin omega 1 t right and um. So, if you consider further simplify what you are getting is um yeah. So, a plus b by 2 plus 10 a minus b sin omega 1 t correct.

So, likewise you can get the Vo 2. So, that is equal to a plus b by 2 that is the common mode part and then minus 10 a minus b into sin omega right. So, that is how we can get the individual signal at the output alright probably we can work out on some more numerical problems, but I think it will be more interesting if you consider say one of these 2 entities nonzero and. So, let you consider say this is equal to 0 this c equal to 0, but this is equal to 1.

So, instead of 0 if we consider this as 1 and if I consider on the other hand this is equal to 0 then you can find what will be the corresponding V o 1 and V o 2 and then the next part. What you can do? You can consider this is 0 you can consider probably this equal to 0, but then you may consider this is equal to 1 and this is also equal to 0 and then you can see what is the corresponding V o 1 and V o 2 and then from that you can get an idea that what is the significance and importance of this parameter if they are non-zero what will what kind of problem we will encounter right.

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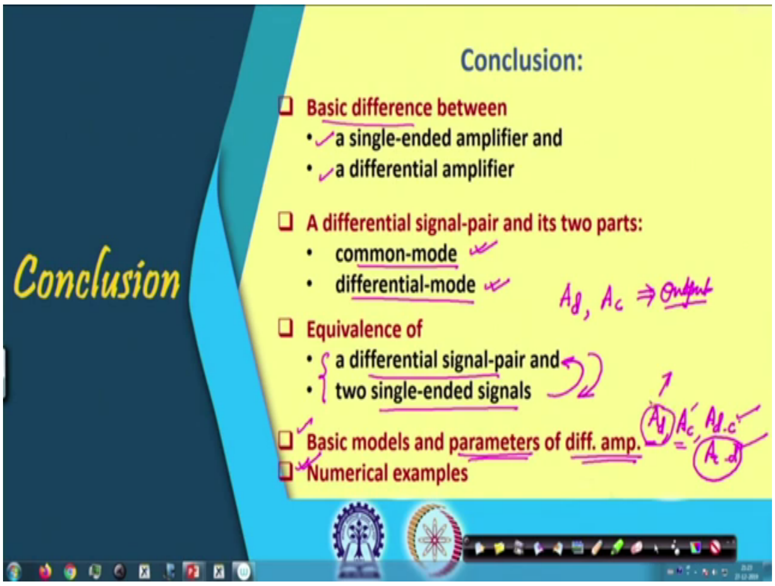

I think that is all we have to cover then we need to conclude here what we have discussed it is basically the single ended amplifier and differential amplifier. We have compare in terms of their basic operation and then while we are talking about differential amplifier, we do have a notion of something called a differential signalling. So, then once it is coming differential signalling it is essentially a pair of 2 individual signal, but it is really not a pair of individual signal.

We need to represent that a pair of signal in the form of common mode part and then differential part. So, that while we will be dealing with a differential amplifier then we can basically we can simplify the analysis and once we convert the signal in the form of a differential part and common mode part then only we can make use of whatever the parameter or the amplifier it has given namely differential mode gain common mode gain to get the corresponding output whether it is in the form of differential or single ended and. So, to do that of course, we need to make equivalence basically converting say two single ended signal in the form of differential signal pair and vice versa once you want to convert back into the single ended.

We also have discussed about the basic model of a differential amplifier and what are the basic parameters of the differential amplifier. It is there namely a differential mode gain common mode gain and then differential to common mode gain and then common mode to differential gain and also we have considered 1 numerical simple numerical example to understand the importance of a differential mode gain and common mode gain, namely this need to be a high and this need to be low. In fact, both are the other non-ideal parameters should be low.

In fact, we have said that this part particularly common mode to differential mode gain should be as small as possible otherwise it may create a problem and of course, the differential mode gain it should be as high as possible. I think that is all to share.

Thank you for listening.