Analog Electronic Circuits

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Lecture – 73
Single- Ended vs. Differential Signaling and Basic Model of a Differential Amplifier (Contd.)

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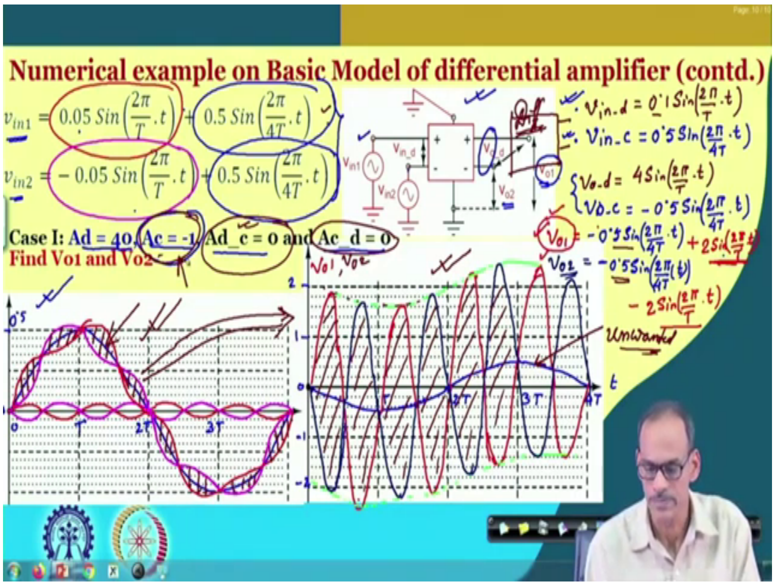

So, dear students, welcome back after the short break. And we are talking about the situation where we do have the model of differential amplifier and its parameters are given, namely differential mode gain it is 40, common mode gain is equal to minus 1 and then differential to common mode gain and common mode to differential gain we are assuming they are equal to 0. And, the signal we are feeding here at terminal 1 called V in 1.

It is having common mode component and half of the differential part. And likewise at the other terminal, we are feeding V in 2, that is also having common mode component and half of the differential signal. And this signal speak to really it is shown here. As we have discussed for the previous case; the signal remains the same at the input port. However, we like to see what may be the consequence in case if the common mode gain if it is having some significant value.

And from this information which is given here, we have the differential part of the input signal it is having an amplitude of 100 millivolt and the frequency is 1 by capital T and the common mode signal its amplitude its 500 millivolt and the frequency it is 1 by 4 T. So, now, let us see what will be the corresponding output. Output at probably in the form of differential and common mode and then we can see the individual signal.

So, as you know that this differential input it is producing the corresponding differential output. So, V o V o d equals to this signal multiplied by 40. So, that gives us 4 sin 2 pi by capital T into small t. And the common mode part it is we need to multiply with minus 1. So, we can see that V in, c it is producing V o c which is equal to minus 0.5 sin 2 pi divided by 4 t into small t.

Now if I combine this two, we can get the individual signal. Namely V o 1. So, let me sketch write the V o 1 part first. So, V o 1; it is having the common mode part namely, minus 0.5 sin 2 pi by 4 T into t plus half of the differential signal, namely 2 sin 2 pi by capital T into small t.

So, likewise the other signal; namely V o 2. So, this is equal to same common mode part minus 0.5 sin 2 pi by 4 capital T into t and then minus 2 sin 2 pi by capital T into small t. So, we do have 2 outputs here. So, let us try to sketch that. Now we can see that this red part which is the wanted part or desired part along with that we do have the unwanted part. So, what we are expecting that, let me use the same scale namely, we consider this scale it is a 2 1 this is 0 and so and so.

And so, let me sketch the blue part first having lower frequency. So, time axis it is 0 T, 2 T, 3 T and 4 T. So, same thing here also 0 T, 2 T, 3 T and 4 T here. However, this scale it was different, this was 0.5, this was 0 and so and so. Now, here the common mode part it is having a frequency which is 1 by 4 T, so that means; this is the time period. And its amplitude it is 0.5 and it is minus.

So, we can say that the blue part the common mode part it is having this kind of sinusoidal signal and then on top of that we do have the red colour part. So, if I plot the first output, I have to consider this signal which is riding over this common mode signal and its time period it is T and so, the signal what you will be seeing here it is something. So, it will not reach to 2 volt, it may be having slight smaller value compared to 2 volt, because it is having the common mode part it is existing. So, likewise here again this part it will not be really going to 2 volt, so it goes like this.

And here; however, it is exceeding 2 volt because you do have the common mode part right. And here it will be less than this minus 2 called rather it is having positive part. So, it is so, what we can imagine that this is having sinusoidal signal, but it is having slight change or wavy kind of nature and this wavy part if we see the if you connect the peak points it is similar to this blue line. Now if you consider the other signal so, this is the out 1. So, V o 1. So, this is the V o 1.

So, now if you plot the other output; namely, V o 2, it is complementary, but then common mode part it is remaining the same. Only the differential part it is complementary right and it goes like this. So, you can see now you can compare the first case namely case 0 and this case what you can see here, here also we are getting nice amplified signal. So, if I say that differential signal it is getting amplified, but of course, if I take the difference of this two, then only you can say that the signal got amplified.

If I on the other hand if I compare or if I consider only one of these two signals either V o 1 or V o 2, then will the signal it is really not pure sinusoidal, it is having some variation, particularly if you see this variation. And this variation it is due to the presence of the common mode signal. And why we do have this? Because at the input we do have significant part of the common mode signal and also in addition to that we do have the common mode gain Ac, it is also significant.

So, what may be the remedy or from this graph at least intuitively you can say that if we have Ac smaller, definitely it will be better. But in case, if you consider practical situation this may be the case and in case if you have to further suppress this unwanted part. So, this is the unwanted part. If you want to further suppress it probably you can put one more differential amplifier second differential amplifier.

So, based on the Ad and Ac of the second differential amplifier; this common mode part or the unwanted part it can be further suppressed and then you will we can get the individual signal coming out of the second differential amplifier probably hardly it will be having this unwanted signal. We can get the sinusoidal signal which is primarily out of the wanted signal or you can say the frequency of that signal it is 1 by capital T, only practically only that signal it will be available.

So, that is the basic characteristic what we are expecting out of the differential amplifier. Namely, this pair of input it is getting converted into this kind of output. Now let you consider a case where the other 2 parameters may be nonzero and then we can try to see what will be the corresponding consequences.

So, this plot will not be repeating, but we will try to make a sketch of the corresponding output. If I consider and see other parameters other performance parameters are nonzero and we can keep this part equals to 0.

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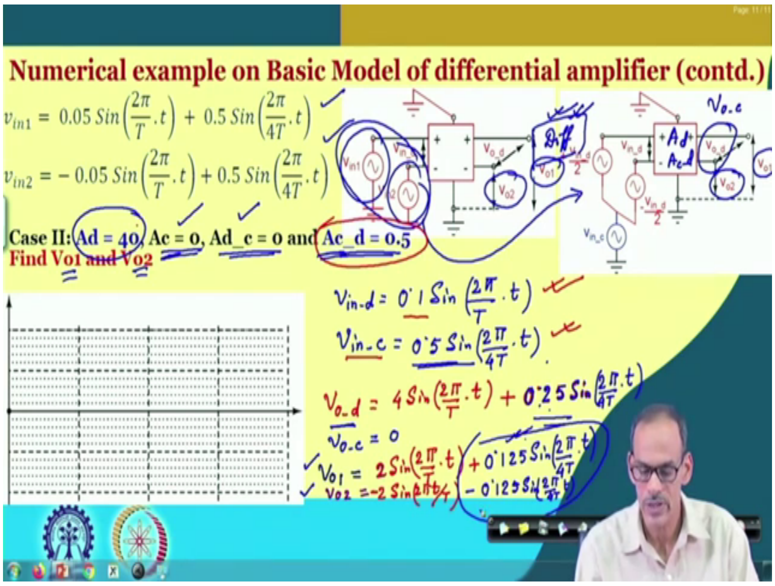

So, let we have that case 2 or you can say that third case where we do have Ad remaining 40 Ac, we are taking 0 and A d c, we are taking 0, but A c d we are taking 0.5. And again the signal we are giving here they are same. And we like to know what will be the individual signal.

So, again we can convert this signal pair in the form of differential part and common mode part and then we can make use of the value of A d and A c d to get the V o d and V o c and from that we can calculate the individual signal ok. So, probably we can say that V V in d equals to 0.1 sin 2 pi capital T into small t. V in c equals to 0.5 sin 2 pi by 4 capital T into small t. And from this we can calculate what will be the corresponding V o d.

So, first of all V o d; it is combination of the output coming from the differential input and also this common mode signal, it is getting converted into differential form because this parameter is nonzero. So, if I multiply this 0.1 sin so and so, with 40, we do get 4 sin 2 pi by T into t. And then also we do have this part 0.5 into this 0.5. So, that is giving us plus 0.25 sin. I should use different colour just to say that this is unwanted part and the common mode part essentially. So, sin 2 pi by capital T into t.

So, why do we have this one? That is because we do have the common mode input is non 0 and also the A c d this common mode signal it is getting converted into the form of differential. And since Ac and A d c equal to 0. So, we can say that V o c equals to 0. Now from this we can tell that the individual output V o 1 equals to half of this. So, that is 2 2 sin 2 pi by capital T into small t and then plus the unwanted part which is I need to consider this divided by 2. So, that is equal to 0.125 sin 2 pi by 4 T into t.

And then the other output V o 2 equals to this 2 sin 2 pi by capital T into t. And of course, this will be having a minus sign and this part is also having a minus sign. 0.125 sin 2 pi by 4 T into t. Unlike the previous case, where at the output whenever ac it was nonzero at the output the unwanted signal it was appearing as common mode signal.

So, as a result to suppress it further we could have placed one differential amplifier here and we could have eliminated that. But, unfortunately by placing one differential amplifier here, it will not help us to remove this unwanted part. That is because the signal this signal it is appearing at V o 1 and V o 2 in the form of differential. So, whatever the differential mode gain will be having for the second differential amplifier that again it will amplify this unwanted part. So, that is very dangerous thing. So, let me sketch this signal in the next graph and further try to illustrate that.

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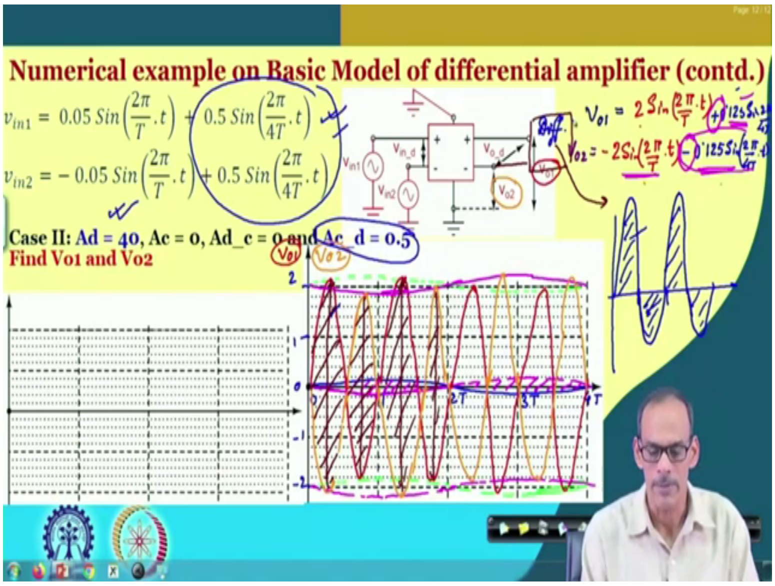

So, as I said that I am not going to sketch the input signal that we already have done, but let me write the V o 1 and V o 2. So, V o 1 as you may recall that it is having 2 sin 2 pi by capital T into small t plus 0.125 sin 2 pi by 4 T and so and so. Likewise, if we consider V o 2. So, that is having minus 2 sin 2 pi by capital T into small t. And also this part, unwanted part as I said that it is having a minus sign 0.125 sin 2 pi by 4 capital T into t. So, this is this is very important that this is having plus sign this is having minus sign.

So, this unwanted signal having a frequency of 1 by 4 T it is appearing as differential signal. So, if you sketch the signal here first of all let me sketch the unwanted part which is having a time period of 4 T. So, we do have we consider time scale it is 0 T, 2 T, 3 T and 4 T, its the voltage scale let you consider this is 2, 1 and 0, minus 1, minus 2. And its amplitude it is as I said that 0.125. So, that is really small, but let me try to emphasize that though it is small, but it is dangerous.

So, we do have very small amplitude here of this signal and then we do have the red color part. Now to represent this blue signal let me also try to put the image of that blue signal here all right and likewise here also and sorry, and then let me plot the red colour along with the blue. So, if I combine this blue part and this red part. So, what we have here it is V o 1 it will be like this right. And, then again here it is coming up, going to this green line and goes on like this all right. Now if I consider this part, this part having a minus sign.

So, which means that we do have similar to blue one, but it is having opposite phase right. So, we do have this is unwanted low frequency part or unwanted common mode signal. Now if I put image of this violet colour at the peak concern. So, along with this green we can see here they are in opposite phase right. And then if I if I sketch this part. So, let me use different colour for that, let me use a black one ok. This is also fine ok. So, here first of all both this part and this part is having opposite phase with respect to the V o 1.

So, we are expecting the V o 2, it will be going down like this and then it will be going here and then it will be here, it will go here and then it will go to the pink one. And sorry, this is this got exaggerated, but what I like to say here it is yeah so, yeah there you go. So, what we like to say that if you observe carefully that this signal, the orange signal which is V o 2 and the red one is V o 1. So, they are really not differ you know, they are getting affected by this unwanted signal, namely if you see that this part.

Now, if I take the difference of these two signals. So, you can see that the amplitude at this point and amplitude at this point, they are different. So, same thing here also amplitude here it is more like this and amplitude here it is different. So, if I put a differential amplifier now what this differential amplifier it will do. It will try to amplify the shaded part and as a result what we are expecting the differential signal nature of the differential signal it is like this.

This part it is having higher amplitude and then next part it is having smaller amplitude. But then time period it is if you see here and here they are same so; obviously, this is giving us some distorted signal and naturally, the signal what we are getting here it is it is not purely sinusoidal. It is having distortion coming due to this unwanted signal. Incidentally, here it is this unwanted signal it is having a frequency which is one fourth of the desired signal and that is why it looks like some harmonic distortion. But in general if the unwanted signal it is not really harmonics then you can see a lot of consequences.

And if this this this A c d, it is higher and higher the distortion here what we can see here it is it will be more and more prominent and most important thing is that by placing one more differential amplifier, we really cannot eliminate. In fact, whatever the number of differential amplifier you like to put you cannot really separate it out from the differential signal. Because the unwanted signal it is appearing as differential signal.

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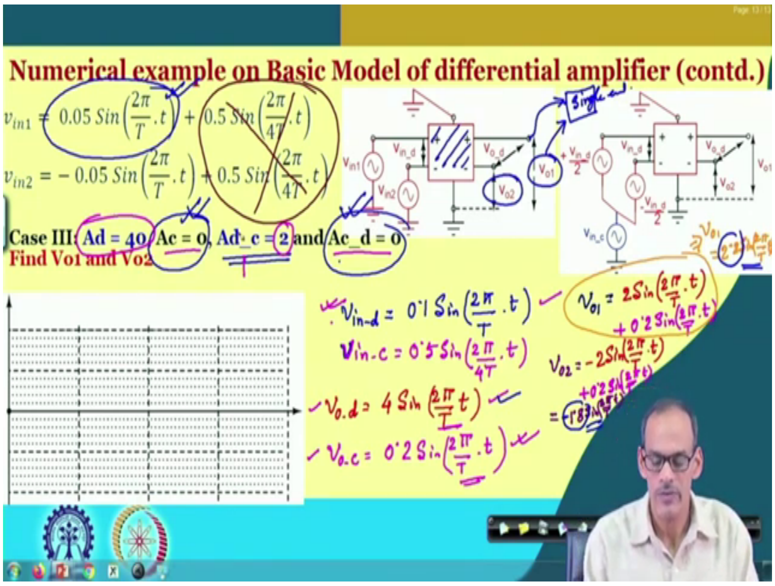

So, likewise you can probably work out on the other case namely, if I consider the other parameter it is nonzero. Say in this case, what we have considered it is A d c it is nonzero and Ac equals to 0 and A c d equals to 0 and then you can see what is the consequences.

So, in this case what we are expecting or let me let me at least give you a hint probably you can work it out. First of all V in d equals to 0.1 sin 2 pi divided by capital T into small t. And V, V in, V in c equals to 0.5 sin 2 pi 4 capital T into t. Now, this common mode sorry, this common mode signal it is really not having any role to play because both A cd and A c, they are 0, but then this differential signal one part of the differential signal it is also appearing as common mode output.

But of course, it will also produce significant amount of differential signal. So, what will be getting here it is V o d equals to 4 sin 2 pi by capital T into small t. And V V o c, it is 2 times, 2 times of this differential signal so; that means, this is 0.2 sin 2 pi by T into small t. Now here you can see that both differential part as well as common mode part, they are having the same frequency right. But then this is common mode and this is differential.

So, as a result, if you see the individual output say V o 1. So, V o 1; it is half of this differential 2 sin 2 pi by T into small t and then plus 0.2 sin 2 pi by capital T into small t. On the other hand the other output V o 2 equals to minus 2 sin 2 pi by capital T into small t. But then plus 0.2 sin 2 pi by T into small t. In fact, you can write since the signals are same, but the frequency is the same. So, you can simply say that this is minus 1.8 sin 2 pi by T into small t.

And the other one this one you can say this is equal to this gives us V o 1 equals to 2.2 sin 2 pi by capital T into small t. So, note that here the amplitude here and here they are different of course, it is a minus sign. But then both the signals are the wanted signal namely, whatever the wanted signal we do we are looking for that signal.

So, in summary, you can say that both this signal as well as this signal they are carrying only the wanted signal an unwanted signal it is it is completely absent. So, in fact, it is it is a good thing that both A cd and A c, if they are 0, then even if I consider individual signal that is good enough get the desired signal. And if you take a difference of these 2 of course, this will be nice. So, if you take a if you take the difference of that then you can get the entire signal.

So, what we like to say that in this situation without using any other differential circuit, we can as well you can extract the information from any one of them or you may say that if I put a single ended circuit from that you can get the desired signal. So, in summary, this circuit it is very nice, just by putting this one differential amplifier having this important property namely, Ac as well as A c d are 0 that completely suppress the unwanted part.

So, it completely remove in this part. Now in practical cases; however, all of these parameters may be present.

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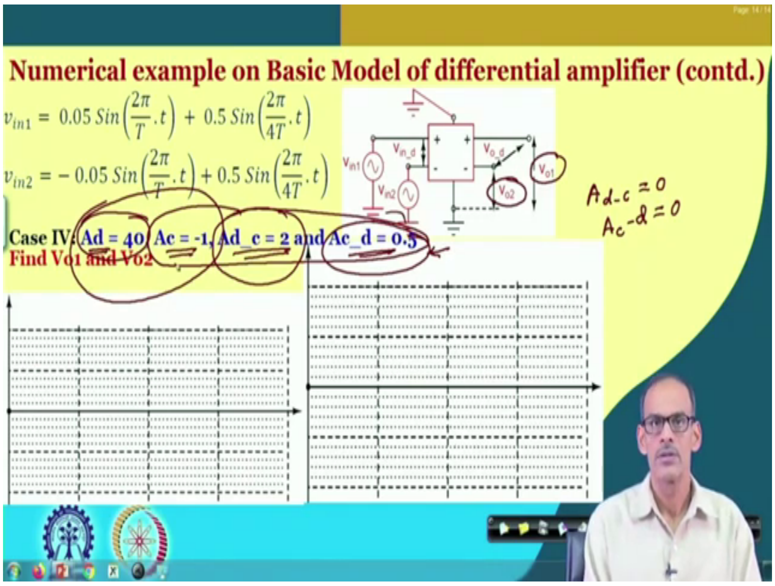

So, you can consider yeah you can consider a situation where both I should not say both, all of them are say non-zero, depending on their corresponding value, they are influences it will be there and then you can find the individual output and as I said that the this is very dangerous thing. So, that really creates the problem.

So, practically even though they are non-zero, but in this course of discussion, in this subject we will assume that these 2 parts; this part and this part they are absent. We consider A d c equals to 0 and A c d is also 0. And, we will try to characterize the circuit by considering the differential gain and common mode to common mode gain ok. I think, let me take a break here probably will come back we do have some more things to discuss. So, for the time being let me take a break.

Thank you.