Analog Electronic Circuits

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Lecture – 54
Common Base and Common Gate Amplifiers (Contd.): Numerical Examples (Part D)

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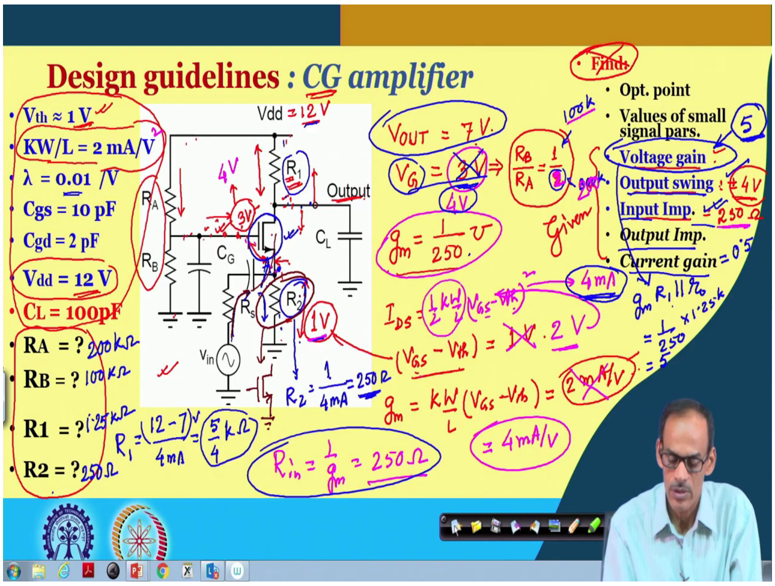

So, welcome back after the short break. So, we were here we do have the Common Gate Amplifier and let us assume that the performance requirements are given namely voltage gain it is given output swing it is given and input impedance is given to us and then, we need to find the values of different parameters. Now, you must be careful here in our circuit analysis we already have seen that out of this common gate amplifier, what are the achievable performance we do have?

So, if the specification the requirement if it is well within that the achievable performance of the circuit, then only a week this exercise is meaningful. So, for example, if we have say 12 volt supply and if we are looking for output swing plus minus 12 then this circuit will not be able to give. So, likewise if this common gate amplifier if you are expecting that voltage gain it is a 50 or so, it is not possible; whatever the practical value we do have of this parameter device parameter with that it is not possible, at least in this circuit configuration it is not possible.

Then we may have to adopt the circuit namely this resistance may be replaced by maybe by passive the active circuit and maybe this R 2 also need to be replaced by active circuit and so and so on. But let we assume that in this guidelines, we are not venturing into modifying the circuit topology; rather we are restricting our discussion on this topology and we are our task is to find meaningful value of different components passive components.

So, how do we proceed? First of all we are assuming that the supply voltage is given to us and then device parameter namely K into W by L it is given to us, threshold voltage it is also given to us, maybe C gs C gd they are also given to us, but for mid frequency performance they are not so important. And also we do have the requirement say voltage gain and then output swing. So, to start with let me consider that output swing it is see if this is 12 volt and the requirement maybe a plus minus see plus minus 4 volt; which means that the requirement is 8 volt peak to peak. So, how do you how do you utilize this information?

So, the first step it is that the voltage drop across this resistance, it should be more than 4 volt and the so that will ensure the positive swing of the output voltage it is at least it is 4 volt. On the other hand negative side if you see the gate voltage of this mos transistor should be sufficiently low. So, if the output voltage it is changing from it is quiescent voltage by an amount of say 4 volt towards the negative side then we have to ensure that the device it is in saturation region.

Which means that the DC voltage here at the output it should be such that DC voltage here and DC voltage at the gate it should be such that the V G d should be at least 3 volt. Why 3 volt, because the V th should have 1volt. So, the drain voltage it can go less than gate voltage by an amount of 1 volt before the device enters into the triad region. So, I should say that the gate voltage maybe decided after deciding the drain voltage drain DC voltage to accommodate plus minus 4 volt or 8 volt peak to peak. Let you consider V OUT DC voltage it is say we consider a drop of 5 volt so, 12 minus 5 so, that is 7 volt.

And so, likewise here also we can keep a margin of 1 volt. So, we can say that the gate voltage it can be the 7 volt minus 4 so that is a 3 volt. And once you have this voltages particularly the gate voltage is known to us and then 12 volt it is the primary supply that gives us the ratio of R B and R A. So, from this we can say that this R B by R A or R A by R B whatever it is. So, we can say that this drop it is ah. So, here we do have 3 volt remaining 9 volt here and there is no current flowing here. So, we can say drop across R A it is 3 and a drop across a R B it is 1 unit. So, R B by R A it is basically two- third.

And now so, we obtained this ratio relative value it is better to also get the absolute value and since we are not drawing any current here; typically to reduce this DC current flow here we may consider this is in the order of 10 kilo ohm so, at least say 10 kilo ohm. So, either you may take say a one of the possible value maybe you can say this is 100 k and this may be a 300 k this is one possible value there are of course, many other possible values we can consider 10 k 30 k and so and so but we obtain the required 3 voltage DC here.

And then next thing is that the you must be having the requirement of the input impedance and the input impedance we know that the it is expression it is 1 by gm and suppose this is given to us that this is a 250 ohm, which means that gm of the transistor it is we are looking for 1 by 250 more right. And then also we need to see what will be the corresponding current flow here and then we can get the value of this R 1. In fact, if we have a meaningful range so, we do have say gate voltage here it is 3 volt and if we are having some idea about the range of I DS. So, from that we can say then what maybe the value of V GS here then to achieve this gm.

In fact, if this is 3 volt and if we are looking for a meaningful operation we need at least some drop across this R 2 and the voltage here it will be left behind it is 3 volt minus whatever the drop we do have. Now, if I say that the drop here if we assign it is a 1 volt for simplicity. So, if this is 1 volt then corresponding V GS it is 2 volt and the corresponding the gm so, the gm it is. So, we can say that with this DC voltage the V GS is 2 volt and gains V GS minus V th is 1 volt. Now the expression of the gm we know that this is k W by L into V GS minus V th and then that gives us 2 milli ampere per volt.

So, if we have this gm the corresponding impedance of course, it is not achievable. So, I can see here with this value of the V GS minus V th it is not feasible ok. So, now, what will be the corresponding option, probably we kept 1 voltage margin here. So, we may increase this voltage by say 1 volt and then we can get the V GS minus V th 2 volt. So, let me modify let me modify this gate voltage to 4 volt and the corresponding ratio here it is 1 is to 2 and then if it is a 100 k this would be a 200 k.

Now with this modification let us see whether is it achievable to get this gm and hence the input impedance of 250. So, to get the gm of course, here if we have 4 volt and if we are still keeping this voltage 1 volt then V GS is 3 volt and V GS minus V th it got changed to 2 volt. And with that this gm it becomes 4 milli volt per milli ampere per volt. In fact, that gives us input impedance R in equals to 1 by gm it is just exactly 250 ohm.

So, it is possible to get this input impedance of 250 ohm, but at the cost of the probably the higher current. So, if we are having V GS minus V th of 2 volt the corresponding I DS it is higher. In fact, from here you can calculate what will be the I DS, I DS it is half of k W by l V GS minus V th squared. So, here we do have 1 milli ampere per whole square and then we do have V GS minus V th is 2 so, that gives us 4 milli ampere.

So, what we have obtained here it is let me summarize, output DC voltage is 7, V G we are converging to 4 volt instead of 3 volt we are converging to 4 volt, I DS it is 4 milli ampere and so, that is helping us to get the R in equals to 250 and then of course, we are getting a both output swing as well as the input resistance.

Now, how about the voltage gain? So, probably the voltage gain may not be having much option, but let us see. So, if we have this current of 4 milli ampere and if this drop it is a 5 volt.

So, we do have 12 volt here, we do have 7 volt here so, R 1 R 1 equals to 5 volt, basically 12 minus 7 divided by 4 milli ampere. So, that is 5 by 4. So, this is volt 5 by 4 kilo ohm yeah. So, likewise the since the I DS it is known here and the target drop here it is 1 volt. So, that gives us R 2 equals to 1 volt drop divided by 4 milli ampere.

So, that gives us the corresponding resistance here it is 250 ohm. So, what we obtain here it is end of this analysis what you obtain here it is the R A equals to say 200 k and then R B it is 100 k, then R 1 it is it is 5 by 4. So, it means 1.25 kilo ohm and then R 2 it is 250 ohms, And then if you want to know what will be the corresponding gain. So, if you consider the corresponding are not probably that are not it will be much higher than this R 1. So, the voltage gain if I consider this voltage gain now it is gm into R 1 in parallel with R naught and the gm we already have 1 by 250. So, that is 1 by 250 and R 1 maybe you can say it is dominating so, that is 1.25 k.

So, that gives us the corresponding gain equals to 5. So, the achievable gain here it is 5. So, as I said that if you are if you are having a target arbitrary or you know flexible target it may not be possible to provide the performance by this circuit. So, this if you are considering this output swing an input impedance of this circuit is more important, then whatever the voltage you are getting here you should be happy with that. In fact, some extent it is possible to further improve the gain, but of course, the gain of this voltage gain here it is not so great and that is of course, obvious it is because of the ah the gm of the mos transistor it is a not so good.

The output impedance you can calculate and the current the current it is of course, we do have 250 ohm here and the input resistance here it is 250. So, whatever the current you are putting here half of the current actually it is flowing here and remaining half it is going to the device. So, the while the current gain of the main amplifier from it is source to the drain node it is 1, but because of the bifurcation of this current here and here we do have only a current gain of 0.5. So, I should say in this design the current gain it is 0.5 and that is mainly because the R 2 it is it is comparable with a 1 by gm.

In case if you are looking for better current gain then you may have to replace this one in fact, you should replace this transistor by active device. So, we may replace the transistor by active device, we still discuss that in our later classes that if we replace this passive element by active device the corresponding resistance here it will be much higher as a result the input current most of the input current ah should be entering into the source of the mos transistor and then the overall current gain it would be approximately 1. So, that is about the common gate amplifier.

So, let us see the similar kind of exercise for the common base amplifier namely the design guidelines of the common base amplifier.

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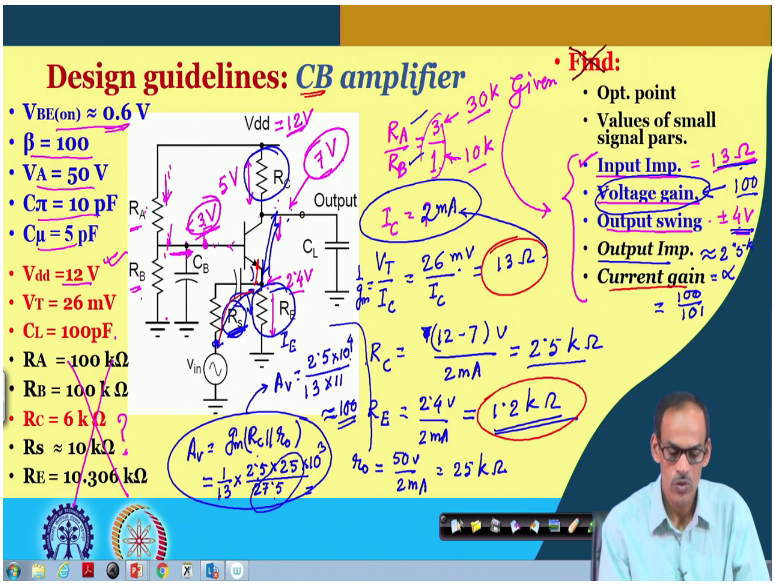

So, again here we do have the same circuit configuration which we have discussed in our analysis part and what we are looking for here it is, instead of find we should say it is given.

So, probably what are the things are given, probably this part it is given at least the voltage swing and the either the voltage gain or most important thing is the input impedance. So, and we need to find the value of different components here. In fact, all of these components it will not be there we need to find rather this components.

We do have this the other information device related information so given to us and also the supply voltage is given to us then maybe the load capacitance also. And let to start with we do have the supply voltage of 12 volt and then let you consider again the output swing it is a plus minus 4 volt which means the peak to peak it is 8 volt.

So, the drop across this resistance it will be it should be at least 4 volt and let we keep this voltage 5 volt. So, that gives us this DC voltage again 7 volt and then to gate the so this gives us the positive swing positive side it is ensured negative side to get the negative side swing the voltage at the base node of the transistor should be sufficiently low namely the base voltage here it should be less than 5 volt minus 4 volt here. So, I should say this voltage should be less than 3 volt. In fact, it is not necessary that it should be less than 3 volt if I consider the base to collector junction maybe weakly forwarded, but the valuate is only 0.3 so, it hardly matters.

So, if we say that this voltage the voltage here it is even if it is a 3 volt that may be considered is good enough to get the negative swing of say 4 volt. So, we do let you let you proceed with 7 volt here and 3 volt here and we do have 12 volt supply here. So, the requirement of 3 volt here demands that this voltage it should be you know divided by these 2. So, if I ignore the base current compared to this current, then we may say that the R A and R B this ratio can be obtained by considering this drop and this drop without considering the IB, which means that drop here it is 9 volt and drop across this R B it is 3 volt. So, we can say this is 3 is to 1 right.

So, I hope in my previous exercise I have done correctly namely the R A and R B for common base I have done the correct calculation; maybe you can check that, but anyway let us proceed with this example. So, what we have it is R A divided by R B it is 3 is to 1 ratio. And in case if we want to ignore the effect of IB the current flowing through this circuit we can consider it is almost say 10 times higher than IB at least 10 times higher than IB and typically you may consider this is a 30 k and this may be 10 k is a meaningful option.

We can have any other combination only thing is that as a if you are increasing the value of this R A and R B towards higher value maintaining this ratio. Then the moment that you draw the base current the voltage here it will not remain at 3 volt it may drop, but in any way if this voltage is dropping the output showing it is not getting affected it may affect something else.

So, let we assume that 3 volt it is written by the selection of R A and R B and then the voltage coming to the emitter after the dirtying of 0.6 V BE from 3 volt we do have here it is 2.4 volt right. So, we do have 2.4 volt here. So, now, we do have the drop here known to us next thing is that we need to find the corresponding collector current or emitter current.

Now, how do we find? We can make use of particularly this one the input impedance. So, if the input impedance is given to us then from that we can say that what may be the corresponding current. So, let you assume that input impedance required input impedance it is say 13 ohm suppose, which means that 1 by gm 1 by gm it should be it is 13. So, V T by I C which is 1 by gm and that is we can approximate ah to this input impedance and this is 26 milli volt divided by I C and this is say 13 ohm which means that the I C equals to so, that gives us I C equals to 2 milli ampere.

So, once we obtain this I C to achieve the input impedance now we obtain I E also and then I C we are already obtained. So, from that we can calculate R C equals to 7 volt not 7 volt 12 minus 7 rather 5 volt, 12 minus 7 volt divided by 2 milli ampere. So, that gives us a 2.5 kilo ohm. So, likewise R E it is drop across this one is 2.4 volt divided by 2 milli ampere. So, that gives us 1.2 kilo ohm. So, we obtain R A, R B and then R C and R E and then probably you can find, what is the corresponding gain.

And you may recall the gain it is equal to gm multiplied by R C in parallel with r o. And if you consider 2 milli ampere of current value of r o equals to V A 50 volt divided by 2 milli ampere so, that is 25 kilo ohm. On the other hand R C it is 22.5 kilo ohm so, we do have gm here it is 1 by 13 and R C in parallel with R naught which it is which is equal to 2.5 minus multiplied by

25 divided by 27.5 right. In fact, if you see here it is this part it is it is 10 by 11. So, it is coming. In fact, this is a 25 k should multiply by 10 to the power 3 and this calculation it is giving us A V equals to 2.5 divided by 13 into 10 by 11 into 1000.

So, I should say 10 power 4. So, whatever the value it is coming roughly this may be giving close to a 100 yeah close to 100 approximately. So, in this case as expected that voltage gain of this amplifier it is expected to be high. So, we can have a 100 gain roughly, but in case if we have the source impedance and the input impedance it is a 23 ohm. And if this R S it is much higher than this input impedance then again it will be having attenuation as we have discussed earlier.

So, the voltage gain maybe from here to here it is a 100, but then here to here we have to see how much the attenuation coming due to the potential division happening by R S and input resistance. So, that gives you an idea that to get a meaningful input impedance and output swing how we select the value of different passive components. Again note that the in case if you want to further improve the circuit you may have to replace this register by active device maybe another NPN transistor. Similarly if you want to improve the output impedance in this case the output impedance it is dominated by R C show it is approximately R C so, that is 2.5 k.

Current gain from here to here it is close to 1 in fact, this is alpha and alpha it is this is 100 divided by 100 and 1 coming from the device, but then if you consider the potential division it is happening here and here there will be a certain loss fortunately this R E if we see this R E it is much higher than. So, this R E it is much higher than input resistance of the circuit so, most of the current it is entering to this circuit. So, I should say this current gain for the common base amplifier without replacing this register by active device current gain it is still approximately 1. So, that is the that is the difference compared to this common gate and this common base. What I was telling in the previous example now let me just since we do have maybe 2 minutes of time.

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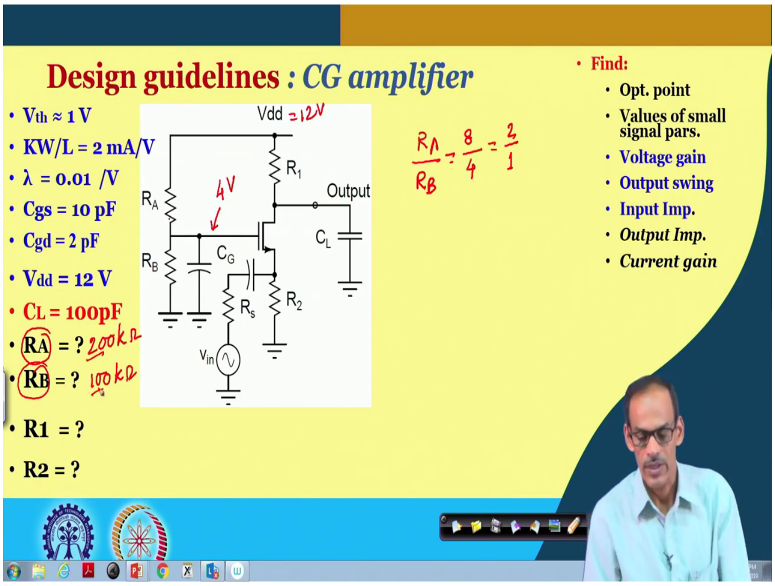

So, if we recall in this circuit what we said is that, the voltage we are targeting here it is 4 volt. So, the ratio of R A and R B so, this is 12 volt. So, that is 8 divided by 4, 2 by 1. So, this resistance you may consider this is 200 say 200 K and this resistance it may be a 100 k or maybe 20 k and 10 k is fine. Now, let us see what we have, I think most of the things I have discussed whatever we have planned.

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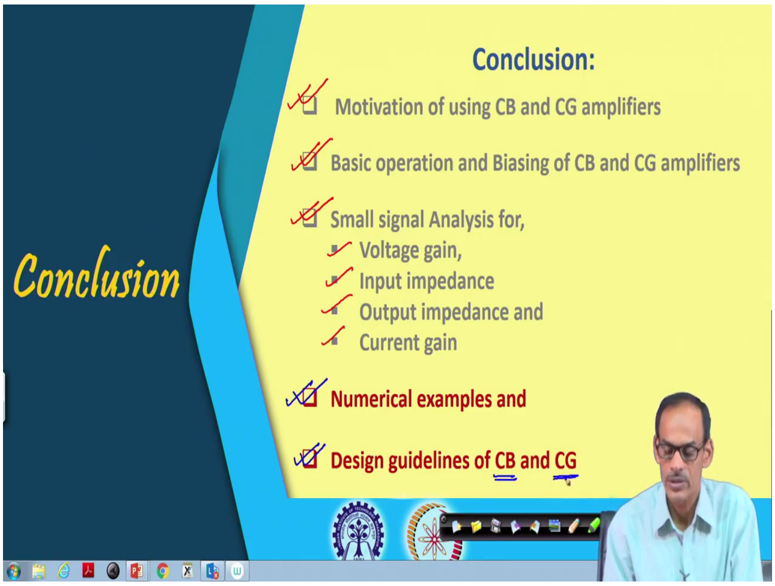

So, in this module what we have done it is we started with motivation of going for this third configuration namely; common base, common gate configuration. We have discussed about the basic operation and biasing of this configuration. We have done the detailed small signal analysis to find voltage gain, input impedance, output impedance and the current gain and also the cutoff frequency.

And then we have seen a number of numerical examples where we obtain the performance of designed circuit both common base and common gate. And then we have discussed about the design guidelines; namely how do we select the value of different registers in the common base and common gate configuration. I think that is all I do have.

Thank you for listening.