Analog Electronic Circuits
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Lecture – 65
Multi-Transistor Amplifiers: Cascode Amplifier (Contd.)-Numerical Examples (Part C)

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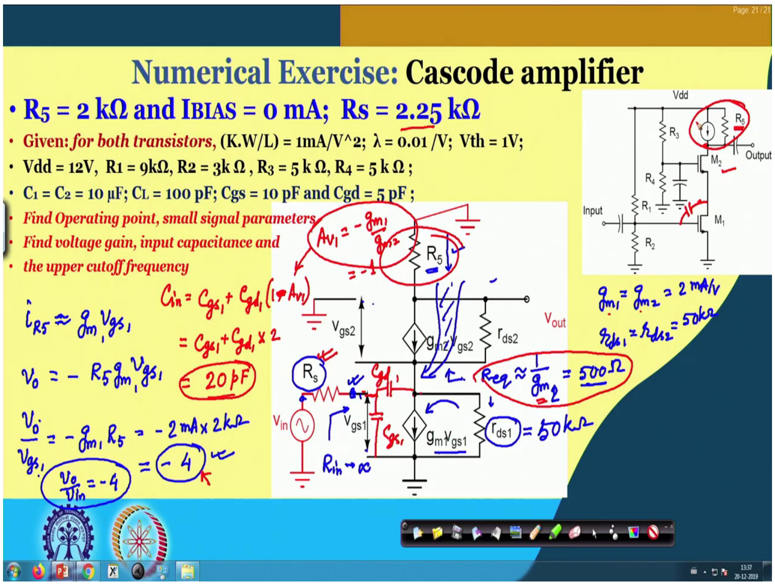

Welcome back after the short break. So, we are talking about the Cascode Amplifier using BJT sorry MOSFET. BJT part we already have completed now come here so, far we are talking about the passive load namely R 5 it was 2 k now we are going to change this load to active kind of load, where our basic motivation is to for higher gain.

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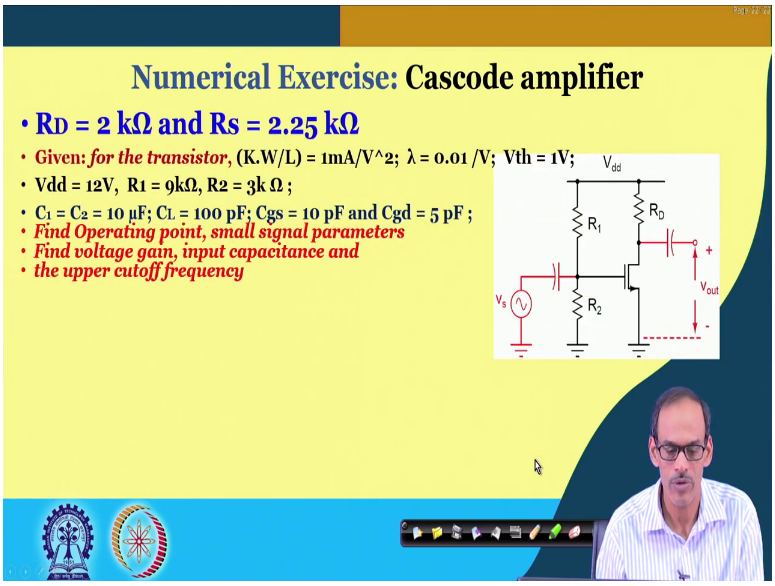

So, in the next slide we do have the formulation of the problem ok. This is the standard common source amplifier for performance comprising, I am not I am just skipping this part.

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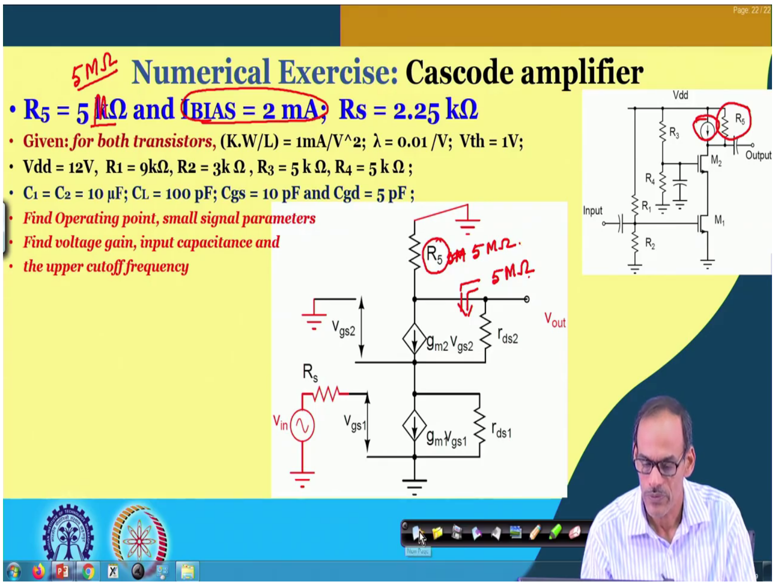

So, we do have; so, we do have the cascode amplifier here with active load namely the I BIAS here it is 2 milli amplifier current and this R 5 it is 5 I should say 5 mega ohm sorry it should not be kilo ohm it will be 5 mega ohm please read as this R 5 as 5 mega ohm.

So, why did I take this 5 mega ohm? It is whatever the parameter we have calculated small signal parameter based on that the equivalent resistance coming here it is 5 mega ohm and for that I have taken this is also 5 mega ohm, this is also 5 mega ohm.

So, any way let we go with this 5 mega ohm and let see what kind of situation we are arriving into. So, first of all based on the bias conditions the current I DS 1 equals to I DS 2 equals to 2 milli amplifier.

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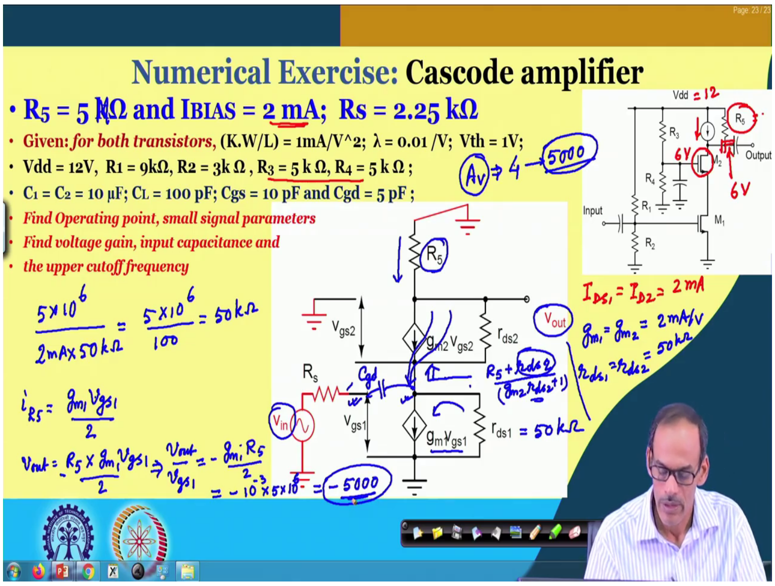

So, the main current it is getting supported by these 2 milli amplifier of I BIAS and then we do have the R equivalent resistance which is matching with this R 5 similar to the bjp BJTs circuit configuration, this 12 volt with this is 5 meg and the equivalent small signal resistance 5 meg, it is giving us a DC voltage here it is half of that. So, that is also 6 volt.

So, this 6 volt of course, we do have 6 volt here also based on these R 3 and R 4 we do have 6 volt. So, this transistor it is still it is in saturation region. So, then there is no problem the value of small signal parameters namely gm 1 equals to gm 2 is equal to 2 milli amplifier per volt and rds 1 equals to rds 2 they are equal to 50 kilo ohm.

Now, with this we need to find what will be the voltage gain. V out divided by this V in or may be this voltage. Now for that we need to know what will be the equivalent resistance coming here and this equivalent resistance it is equal to R 5 plus rds 4 sorry rds 2 divided by gm 2 multiplied by rds 2 plus 1. So, this resistance if you put the value here what will be getting here it is R 5 is 5 meg. So, this is 5 mega ohm.

So, 5 into 10 to the power 6 probably you can drop this part and then divided by gm, it is 2 milli amplifier multiplied by we do have 50 kilo ohm. So, that gives us 5 into 10 to the power 6 divided by 100 that is 50 kilo ohm. So, this is 50 kilo ohm and this is also 50 kilo ohm. So, this half of this gm into V gs 1 it is coming from rds 1 and remaining half it is coming from this circuit.

So, that gives us the current flowing though R 5 namely i R 5 equals to half of this gm 1 into V gs 1 and hence we are getting the output voltage V out equals to R 5 multiplied by this gm 1 into V gs 1 by 2 and hence V out by V gs 1 equals to of course, it is minus sign.

So, minus gm 1 into R 5 by 2 and if we see the value of this R 5 it is 5 meg and gm 1 it is 2 million amplifier. So, that gives us this is 10 to the power minus 3 and here we do have 5 into 10 to the power 6 that gives us minus 5000. So, this big number big jump compare to when were we have consider passive load and then there we got the gain of only 4.

So, I should say this voltage gain Av got increase from 4 magnitude wise to should say it got increase to 500. In fact, this is I should say it is a big jump and as I said that for most transistor this cascode structure it is frequently use to enhance the gains and also similar to BJTs version since we have increase this resistance to increase the gain and it is also affecting the input capacitance is particularly Miller factor for this C gd it is getting increased and that is done by because we do have the R equivalent resistance is high and gain from gate to drain of transistor 1 it is large.

So, what is the gain here? Let me again erase this part, but then keep in mind that the gain of the overall circuit it is 5000 all right. So, the input capacitors before we go for a calculation let me clear the board and then input capacitance yes.

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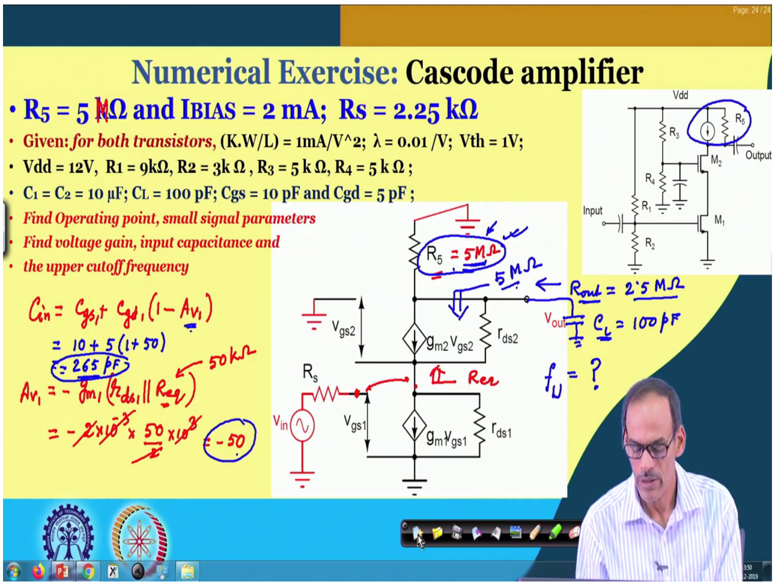

So, to get the input capacitance C in which is C gs plus C gd multiplied by 1 minus whatever the gain we do have from here to here which is let you call this is Av 1 and what is the Av 1? Av 1 equals to minus gm 1 multiplied by rds 1 in parallel with the equivalent resistance coming from this circuit.

And we made the calculation if this is 5 mega ohm, if this is 5 mega ohm then the this resistance it is 50 kilo ohm. So, that gives us these gain of minus gn is 2 into 10 to the power minus 3 and then we do have 50 k and 50 k. So, that is 50 by 2 k and so, these 2 are getting cancel, this is also getting cancel that is the giving us minus 50 gain.

So, the gain from this point to this point it is minus 50 and hence the input capacitance with this value of this v 1 Av 1 it is V gs is v C gs 1 it is 10 C gd it is 5 and then we do have 1 plus 50 here and that gives us 2 6 5 pico Farad yes. So, it is increasing the input capacitance, but probably still it is not so, alarmingly high, maintain this factor it is so, high, but yes depending on the situation we may or may not be able to accept that.

So, the somebody here it is that by using active device here, we can get higher value of this R 5 and this value of this resistance in this case critically we have taken the resistance coming from the lower part. So, here it was 5 mega ohm and hence we have taken this resistance.

So, to get the maximum advantage what about the resistance we got from this circuit lower part, if we take the same resistance then we can get the maximum benefit for both the gain as well as bandwidth consideration.

If you are putting see relativity smaller resistance then of course, that resistance it will be defining the output resistance while this gain got increased from 4 to 5000 the output resistance R out in this circuit is of course, 5 meg ohm 5 meg in parallel. So, that gives us 2.5 mega ohm and with the CL here with the CL of say I mean 100 pico Farad the upper cutoff frequency may be the quite look. So, that again we have to see what is the corresponding upper cutoff frequency define by this R and this C time constant.

So, in summary if I compared this cascode amplifier to boost to the gain and if I compare the performance of the standard common source amplifier.

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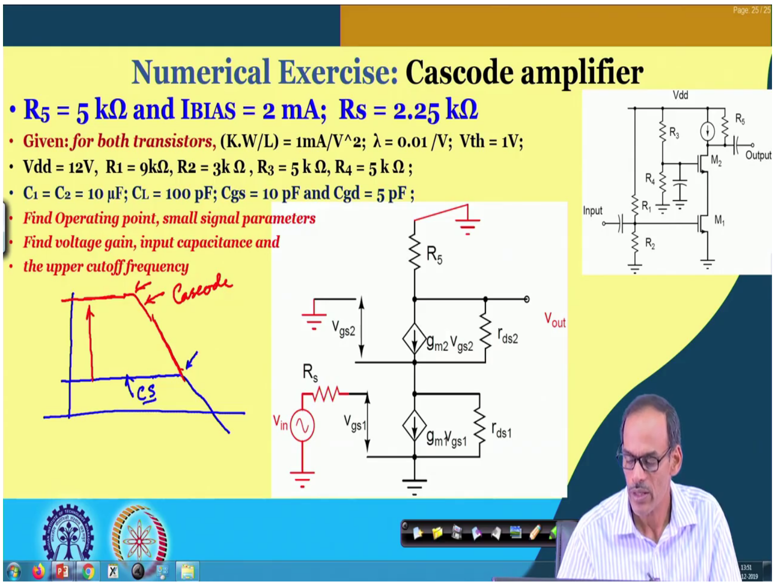

Here the common source amplifier may be having very low gain, but then it may be having very high bandwidth mainly because the output resistance and the CL it is defining that. But then by the virtual of the cascode structure we can increase the gain by a big factor, but then the corresponding bandwidth it is getting affected. So, the gain bandwidth product for both the cascode and the simple common source both may be having the same gain bandwidth product.

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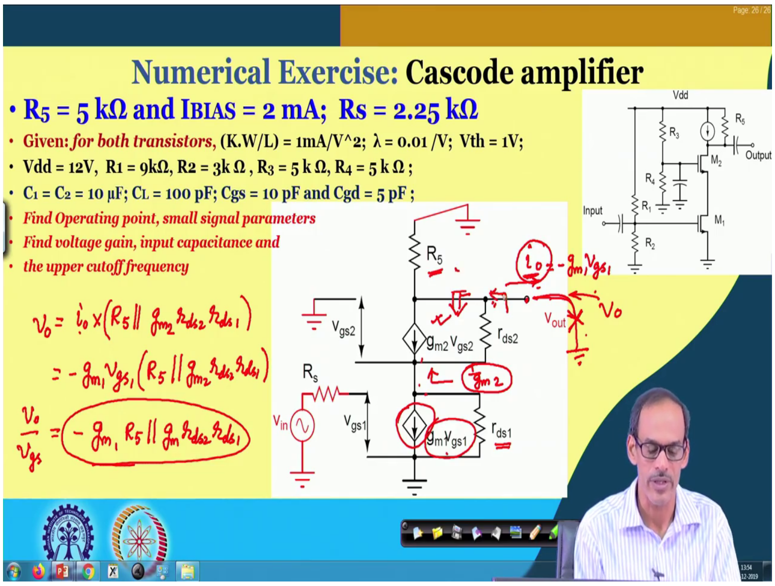

It may be it may be important to take a note that the gain calculation can be obtained by some other means also namely you can say sort this you can sort this output note to and ac ground and then you can calculate what is the corresponding current is flowing here. The moment you sort it the resistance looking into this circuit it is just 1 by gm 2. So, compare to rds 1 this resistance it is quite low. So, you can say that this short circuit current it is primarily it is this current only. So, we can directly see that this equal to minus gm 1 into V gs 1.

Now, to get the voltage here once we release this connection, then we need to find what will be the corresponding equivalent resistance and this resistance it is R 5 in parallel with whatever the resistance we do have here.

So, once we release this and then to get the corresponding output voltage coming here, what we have to do that this output voltage equals to this current i o multiplied by this R 5 in parallel with whatever the resistance we do have and that resistance it is gm 2 rds 2 and then rds 1. And that gives us the and this part as I say that it is already as having an expression of gm 1 multiplied by V gs 1 and then R 5 in parallel with gm 2 rds 2 rds 1 all right.

And hence the voltage gain V o divided by V gs equals to minus gm into R 5 in parallel with gm rds 2 into rds 1 right. So, this the this is alternative way of finding the expression of the gain earlier we are calculating based on the current bifurcation, this may be a simpler method what is the what are the steps it involve, first of all you make a sort here and then you find what is the expression of this current, primarily this stage the common base what are the common gets stage it is convening this current to the output which is gm 1 into V gs is coming to the output with the minus sign.

And then once you release this connection and then we can find the voltage here just by multiplying this current with equivalent resistance there. I think we have covered what are the things we have planned.

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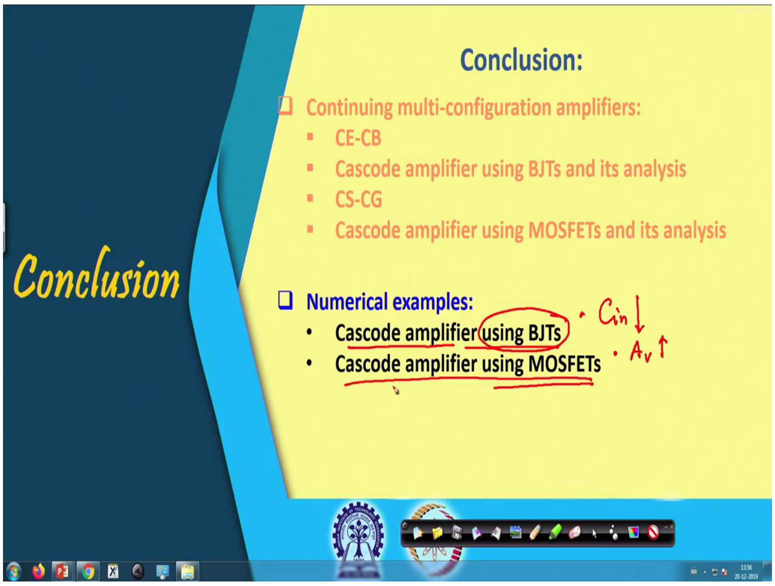

So, today we have in fact, cover only two numerical example, but I guess they are very extensive example to demonstrate the potential of cascode amplifier. First one it is using BJT and we have seen that, it is having both the capabilities. Of course, not simultaneously. So, two capabilities one is it is having the capability to reduce the input capacitance and may be the gain we can maintain same.

On the other hand the other case is that we can make the voltage gain very high may be the input capacitance it may be in the same order or unchanged. And this is valid for not only for the cascode amplifier using BJT this is valid for MOSFET. I should say that the standard CE amplifier namely the simple amplifier using BJT since its gain it is it gain of it CE amplifier it is significant and it is quite high cascode amplifier may or may not be require.

However, if we consider common source amplifier, this simple amplifier voltage amplifier using MOSFET. Since its intrinsic gain it is not so, high particularly because of the gm. So, it is better to go for the cascode amplifier to enhance the gain of the circuit. So, in VLSI circuit whenever we will be implementing some analog circuit in may be using MOSFET, then this cascode amplifier it will be frequently used.

I think that is all see.

Thank you for listening.