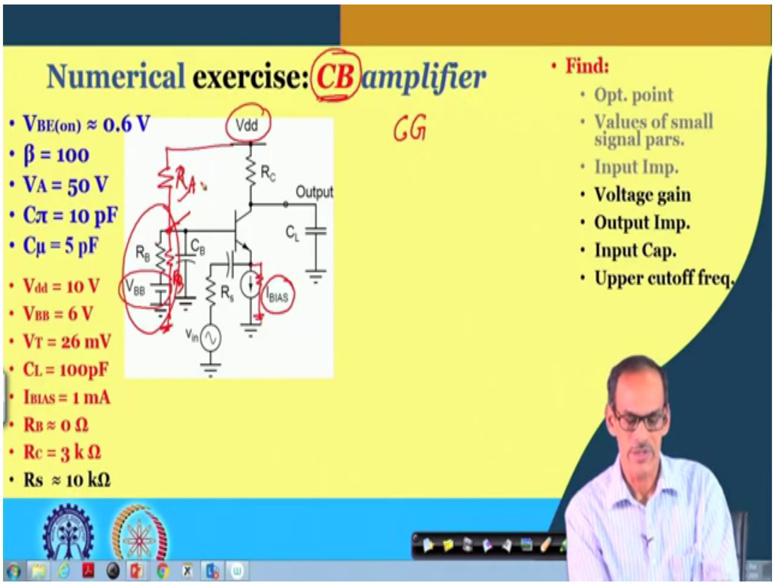
Analog Electronic Circuits
Prof. Pradip Mandal
Department of Electronics and Electrical Communication Engineering
Indian Institute of Technology, Kharagpur

Lecture – 52
Common Base and Common Gate
Amplifiers (Contd.): Numerical Examples (Part B)

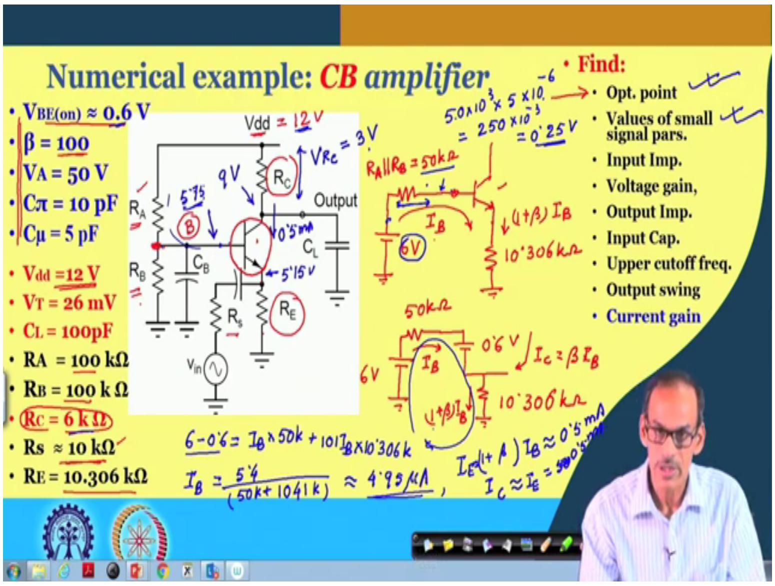
(Refer Slide Time: 00:27)



Yeah, welcome back after the short break. What we are discussing is Common Base Amplifier and we will be going for Common Gate amplifier, but before going to that I do have another example based on the common base where we are talking about practical circuit of this base bias. Instead of having you know ideal separate voltage source here along with the Thevenin equivalent resistance R B, practical circuit wise we may have only one supply voltage and from that we need to generate whatever the voltage we like to generate here.

So, we can have a potential divider constructed by say R A and R B connected to ground which generates the voltage here and also we may have a situation that instead of having this ideal current source, we may have some practical component either active device or passive bias circuit. So, in our next example what we will be concentrating on it is common base amplifier, but then with more practical bias arrangement.

(Refer Slide Time: 01:52)



So, in the next slide that is what we do have the example, here as I said that the voltage for the base we are generating in this base voltage by V dd and then the potential divider constructed by R A and R B and the value of R A and R B are given here. The other information about the b j t as well as the other parameters are remaining same which are enlisted here the R C intentionally we are making slightly different value or I should say we have made some change here and at the emitter instead of having ideal bias, we do have R E and its value it is given here close to 10 k. In fact, we are considering 10.3 kilo ohms so, that with a beta of 100, we can get the emitter current or rather collector current very very close to 0.5 milliampere.

So, and also we are considering the signal source resistance of 10 k. So, the effect of this resistance we already have discussed, in this numerical example primarily what you are focusing on as I said that we do have practical bias circuit and in case if we have practical bias circuit using that how do I find the operating point of the transistor.

So, let us try to see the operating point of the transistor by considering R A R B and so, and so, on. Now, in this case V dd also I have changed. So, instead of 10 volt it is 12 volt and R A and R B both are 100 k. So, we can say the voltage source coming to the base it is actually it is 6 volt. So, this 6 volt it is we can say it is Thevenin equivalent voltage in series with Thevenin equivalent resistance which is R A in parallel with R B incidentally that is 50 kilo ohm and then it is going to the base of the b j t.

And then at the emitter dc wise we do have r e here and it is 10.306 kilo ohm and the current flow. So, we are expecting that there will be a current flow and let me call this current is I B and if the transistor here it is in active region of operation this I B current it produces a current here which is 1 plus beta times I B right. Now ,base to emitter node we do have VB on off 0.6 volt. So, if I redraw the circuit considering base to emitter voltage.

Then what we have it is 6 volt Thevenin equivalent voltage source, 50 kilo ohm resistance coming from R A and R B in parallel and then we do have a drop of 0.6 base to emitter voltage and then we do have a this current flowing through R E which is 10 0.306 kilo ohm and the current flow here it is I B whereas, this current flow since we do have the collector current which is beta times I B.

So, we can say this current is 1 plus beta times I B. So, if I consider this loop if I consider this loop and if I see the potential dot drop. So, 6 minus 0.6 equals to I B into 50 k plus 101 plus beta is 101 I B into 10.306 k. So, that gives us I B equals to here we do have 5.4 divided by this 50 k plus 101 and multiplied by this one.

I think I do have some calculation on that. So, roughly you can say that this is 1041 k and that gives us close to 4.95 micro ampere of base current. Now, if I multiply this base current with beta I can get the collector current and the emitter current is of course, 1 plus beta into this I B.

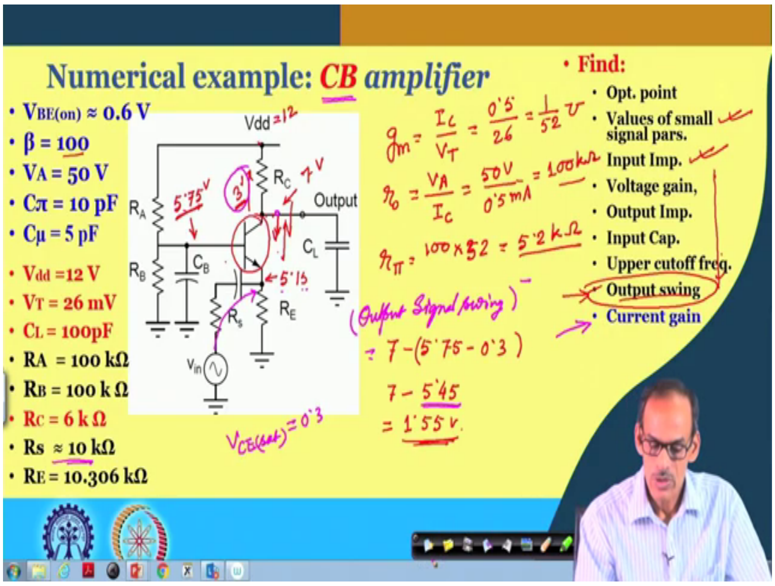
So, that gives us very close to 0.5 milli ampere. In fact, for simplicity collector current also we can consider this is same as the emitter current and that is 50 sorry 5 no 0.5; 0.5 milli ampere. So, we got 0.5 milli ampere current flowing here. So, the drop across this R C it is 6 kilo ohm and 0.5. So, that gives us voltage drop across this R C V R C it is 3 volt and then the collector voltage it is 12 minus 3 volt. So, that is we do have 9 volt.

And the voltage coming at the base of course there will be base current flowing here. So, it is not just entire 6 volt it is coming here. In fact, I should consider this drop also and this current it is as you have seen it is very small close to 5 micro ampere. So, 5 micro ampere multiplied by 50 kilo. So, that gives us this drop equals to. So, the drop across this resistance it is 50 k multiplied by 5 close to 4.95.

We can say approximately 5 micro ampere 10 to the power minus 6. So, that gives us minus 3 here and yeah. So, this is 250 into 10 to the power minus 3 or we can say that this voltage it is 0.25 volt. So, the voltage coming here it is 6 volt minus 0.25. So, the voltage dc voltage coming here it is 5.75.

That ensures that device it is in actively general of operation and of course the voltage coming here it is 5.75 minus 0.6. So, that is 5.15 that is how we can get the operating point of the transistor. Now, once you obtain the operating point of the transistor, then again we can go for calculating the value of the small signal parameters namely g m or not and so, and so, So, let me clear this board and then let me write those things.

(Refer Slide Time: 11:30)



So, small signal parameters g m equals to I C divided by V T. So, this is 0.5 divided by 26. So, I should say this is 1 by 52 more and then r o it is v t V A early voltage divided by I C. So, this is 50 volt divided by 0.5 milli ampere.

So, that gives us 100 k and r pi it is beta which is 100 divided by g m. So, that is two 52. So, that is 5.2 kilo ohms. Now, once we have to obtain these small signal parameters then rest of the things it is you yourself can do namely you can calculate what will be the input impedance and so, and so.

So, those things I will not be going to not I will not be repeating. Now, next thing it is that it is also important to see the output swing in this particularly in this practical circuit. So, what we said is that DC 5 voltage coming at this node at the base node it is 6 volt minus 0.25 if you recall correctly. So, that is 5.75 volt and the DC voltage on the other hand here it is 12 volt minus 3 volt. So, that is the 7 volt.

So, the possible signal swing at the output node it is lower side you can say that the collector node, it can go as low as this voltage. So, we do have negative side we do have a swing of 7 minus 5.75. So, we can say that 7 minus 5.75. In fact, you can go a little lower than this also by a an amount of 0.3.

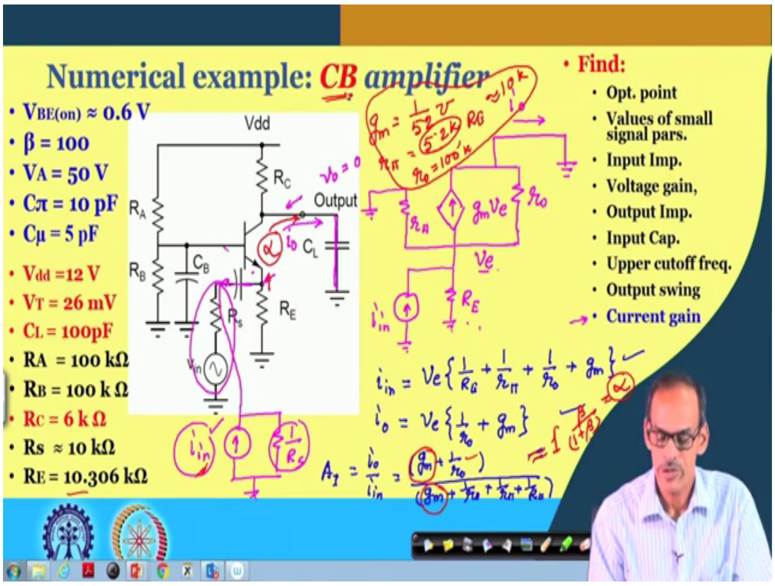
So, we can say that we can go even lower than that by 0.3. So, that gives you 7 minus 5.45. So, that is one point 1.55. So, we can say that lower side negative side the signal swing it will be this one positive side on the on the other hand it can go as high as 3 volt ok. So, you can say that the possible output range without really pushing the transistor into the saturation region.

We do have negative side we do have this much of current, positive side before the device it is entering into cut off we do have the swing as high as say 3 volt that is very good. So, that is the information about the output swing. In fact, output this swing it can be calculated other way also we do have 5.75 volt here, that gives us this voltage 5.75 minus 0.6.

So, that is 5.15 and then if I consider V CE sat; V CE sat of 0.3 volt. So, if I consider this is 0.3. So, which means that the collector voltage it can come as low as 5.45. So, in fact, this is same as whatever we have considered. So, this is we can say that output signal swing at the negative side and the positive side of course this 3 volt.

Now, the other aspect we so, far we are we have not covered, but at least we have given a hint that if we have R S it is sufficiently large, the signal it is failing to propagate in the voltage mode. So, this circuit it is many a times it is instead of using as a voltage amplifier it is preferred to be use as current amplifier. So, next item we need to observe that what is the current gain of this circuit we do have. So, let me clear the board again yeah and to took say what is the current gain.

(Refer Slide Time: 17:15)



First of all on the stimulus part here we need to replace by say current source, signal current source maybe we can consider this is i in and it may be having a finite conductance and this is conductance is 1 by R S. Now, this signal it is going here and again through this capacitor the signal it is arriving to the to the emitter node. Now, once we have this i in we are feeding at the emitter known and then we like to see how much the current we will be getting here particularly in unloaded condition.

And for unloaded condition what we mean is that, we have to basically sort it we have to sort it to the a c ground and while we do have this i in current what is the corresponding produced output short circuit current. So, for this current gain you may recall that the current gain it is very close to very close to 1. In fact, we do have the if I say that we are sorting this node here; that means, the corresponding v o equals to in fact, this is 0.

And if you recall the model here small signal model here, we do have this r o we do have the g m here and multiplied by v b and v b e it is minus v e and its minus sign can be taken out. So, the small signal model of this circuit it is it can be written like this and then the output node it is shorted and we are observing the corresponding output current there.

At this node we do have the signal here i in, assuming that this part it is zero conductance. So, we can say that i in it is entirely flowing through this producing a voltage of v e here [and/have] then we do have the R E part, also we do have the r pi part and r pi other terminal of the r pi it is connected to ground. So, the current flowing through this R E and r pi it can be directly obtained by considering this v e by r e or v e by r pi and so, and so.

So, I am just writing whatever we have done in the previous day's derivation that i in is v e divided by R E, v e divided by r pi and then this divided by r naught and also multiplied by g m. So, on the other hand i o it is v e divided by r o and g m. So, from that we obtain the current gain A I equals to i o divided by i in, if I consider these two equations what you are getting here it is 1. So, g m plus 1 by r o divided by in the denominator g m plus 1 by r o plus 1 by r pi and then 1 by r e.

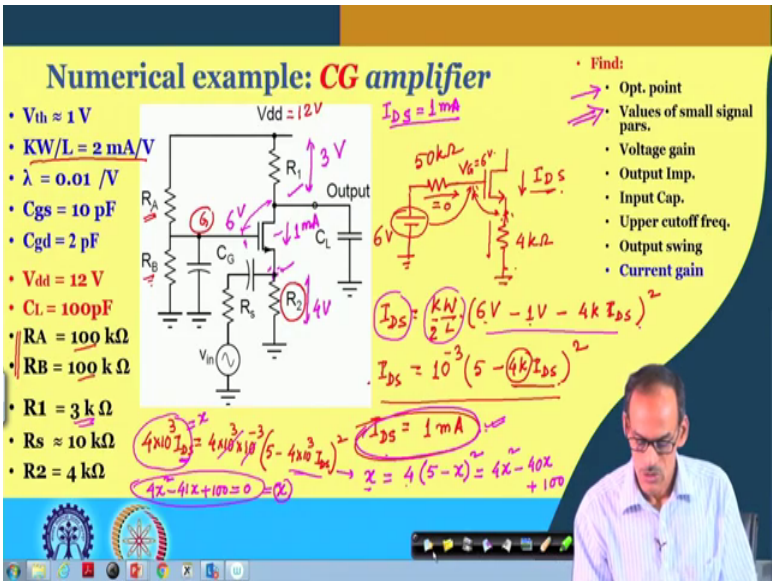
So, why I am writing here? It now we can compare each of these terms and you may recall the value of the g m; g m it is 1 by 52 more and the r pi it is 5.2 k and R E it is 10 k. So, 10 k and then we do have r naught which is 100 k. So, by considering all these practical values of different parameters naturally you may say that this g m it will be dominating over 1 by r naught in the denominator also this g m it will be dominating.

So, we can directly say that this current gain it is very close to 1. If you want the to get better approximation probably you can retain this part and then you can find what will be the value here and instead of 1 to be more precise, it will be then beta divided by 1 plus beta. In fact, this is alpha which means that if we have this i in it is entering here at the emitter, the corresponding available current at the collector it will be alpha times of this transistor.

So; obviously, this alpha it is very close to 1 depending on the value of the beta though mathematically it is less than 1, but as I said it is very close to 1. So, that completes the analysis of the common base amplifier, now similar kind of analysis can be done for common gate amplifier in the next slide we will be discussing that. And, but I must say that for common gate; for common gate circuit we can consider ideal bias and we already have done this exercise for common base.

So, instead of going with the ideal bias and then going for the practical circuit, I prefer directly go into a an numerical example where we will be having this kind of biasing arrangement.

(Refer Slide Time: 24:40)



So, in the next slide we do have common gate amplifier having be practical bias arrangement. Now; obviously, the finding the operating point of the mass transistor it is slightly different from b j t and that may be one important exercise we must try to do with this.

Now, we do have; we do have the different components values are given here namely R A and R B same as the previous case. So, we can say at the gate node we do have 6 volt getting generated by this R A and R B from this 12 volt supply V dd supply.

So, we do have 6 volt here and then that is coming in series with the Thevenin equivalent resistance of R A in parallel with R B which is 50 k. And then we do have the MOS transistor and then we do have the R E, I should not say R E I should say rather different resistance and it is its value it is 4 kilo ohm. Now, how do I find the value of this IDS from this circuit?

What we can do it is we can make use of the parameter of the device assuming the transistor it is in saturation region. So, if I say that I DS current is flowing and that is creating a drop here at the gate of course, the current is 0. So, we can say that the 6 volt it is directly coming here. So, VG it is 6 volt and source voltage it is such that VGS it is supporting the required current here which is exactly producing this ir drop.

So, we can say that this 6 volt minus this 4 k the into I DS that produces the VGS. So, if I say that I DS equals to K W by L by 2 into VGS and VGS is 6 volt minus V t h of 1 volt minus this i r drop which is 4 k into I DS and its square. So, here we do have I DS equals to 1. So, this part it is 2 milli ampere divided by 2. So, that is 10 to the power minus 3 into this is 5 volt 5 minus 4 k into I DS square.

Now, we do have this second order equation and if you solve this second order equation what we will be getting here it is I DS will be having two values one of them it is the actual one, other one it is hypothetical one and the correct one you will be getting it is 1 milli ampere. In fact, you can cross check it, I have done this derivation, but yourself can cross check it and how do you do this one how do you obtain this one? I am just giving a tips.

So, we do have this part it is 4 k multiplied by IDS. So, we can say this parameter if I multiply here what I will be getting here it is 4 k 4 into 10 to the power 3 into IDS equals to 4 into 10 to the power 3 into 10 to the power minus 3 into 5 minus 4 into 10 to the power 3 into IDS square. So, that gives us.

So, that gives us say this part and we like to calculate this IDS and let you consider this is equal to x. So, this is also x, so that gives us an equation x equals to 4. So, this part and this part is getting cancelled we would have four here multiplied by 5 minus x square.

So, what you are getting here it is 4 x square minus 10 and 4 basically 40 x plus 25 into 4 100. So, that is equal to x. So, from that you can get an equation which is 4 x square minus 41 x plus 100 equals to 0.

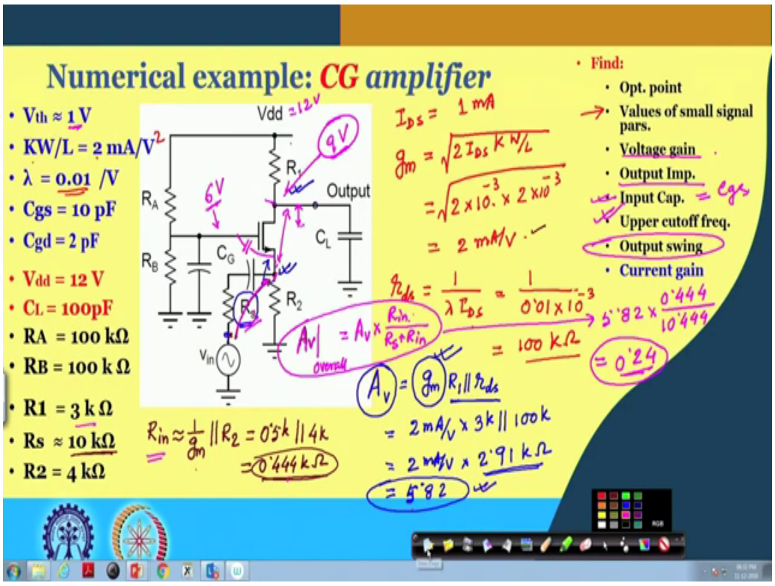
So, from that you can get the value of x and once you get this x you can find the corresponding value of I DS and one of them it is this I DS. In fact, you will be getting another I DS solution here which is in practical namely that will make this source voltage it is higher than the required voltage here pushing this transistor into cut off.

So, that the solution you can ignore and you can retain this 1 milli ampere of current. You can in fact, you can verify this one say if we have 1 milli ampere of current flowing here, the drop here it is 4 volt. So, if I am having 1 milli ampere of current the voltage coming at the source it is 4, here at the gate we do have 6 volt. So, the VGS it is 2 volt. So, VGS minus V t h is 1 volt. So, that gives say this part this entire part it is 1 and this part it is 1 milli.

So, that gives us IDS equal to 1 milli ampere. So, anyway, so that is how you can get the IDS and then the drop across this R 1 it is 3 kilo ohm multiplied by 1 milli ampere. So, that gives 3 volt here ensuring that this transistor it is in saturation region of operation and hence this circuit is in good condition to amplify the signal.

So, end of it what do you obtain? Here it is IDS equals to 5 milli ampere sorry 1 milli ampere and different V DS and the V GS you obtain. So, we obtain the operating point using that we let us calculate the small signal parameter. So, let me clear the board and then again calculator.

(Refer Slide Time: 33:19)



So, I DS as I said equals to 1 milliampere and hence gm of the transistor which is having an expression of 2 I DS into K W by L and this is 2 into 10 to the power minus 3 into K W by L is 2 milli ampere per volt square sorry this is this should be volt square.

So, this is 2 into 10 to the power minus 3 ampere per volt square we do have a appear here. So, that gives us g m equals to 2 milli ampere per volt. The other parameter we are looking for it is r ds small signal parameter r d s and this r ds it is 1 by lambda into I DS and lambda it is given here it is 0.01 per volt. So, this is 0.01 multiplied by this is 1 milli ampere. So, you can see 10 to the power minus 3. So, that gives us r ds is equal to 100 kilo ohms.

So, we obtain now the small signal parameters and then we can proceed for the voltage gain. So, what was the expression of the voltage gain we have for this circuit? A v let me use a different colour here. So, the voltage gain A v equals to g m into R 1 in parallel with r d s.

And g m it is 2 milli ampere per volt and R 1 it is 3 k in parallel with 100 k. So, again you may approximate or probably you can calculate more precisely I think I do have that calculation, this is to be more precise this gives us this is 2 milli per volt multiplied by 2.9 yeah 2.91 kilo ohm.

So, that gives us overall gain it is 2 8 4 you can no 5 yeah. So, you can see that the go gain here it is very small compared to compared to the common emitter amplifier that is expected mainly because value of the g m for mass transistor it is quite low. So, even though this R 1 and r d s in parallel it is having significant amount of resistance, but because of smaller value of this g m the voltage gain it is quite low.

So, even without considering this R S we do have this problem. Now, if I consider this R S. So, this gain this gain of course, it is from source node to drain node. Now, if I want to know what will be the voltage gain from the primary input to the primary output after considering this R S is equal to 10 k, then we need to calculate what will be the corresponding input impedance. So, the input impedance of this circuit of course, it is you may see that it is getting dominated by 1 by g m let me use different colour to derive that or calculate that.

So, R in. So, the R in it is you can well approximate by 1 by g m in parallel with R 2 all right and this g m we already have obtained here. So, that is 1 by g m it is 0.5 k in parallel with R 2 it is 4 k and yeah. So, that gives us 0.444 kilo ohm. So, the input resistance here of this circuit it is not as low as common base circuit where g m it was much higher, but still this resistance it is much lower and if I consider source resistance of say 10 kilo ohm that further degrades the signal from primary input to the source node.

So, the overall gain if I say overall gain I need to get the overall gain A v overall. So, let me use different colour yeah. So, A v overall. So, that is A v multiplied by this attenuation offered by R in and this R S; R S is 10 k. So, that is R S plus R in and this attenuation it is we can let me use this space here A v we already obtained it is 5.82 and then this attenuation it is 0.44 4 divided by 10.444.

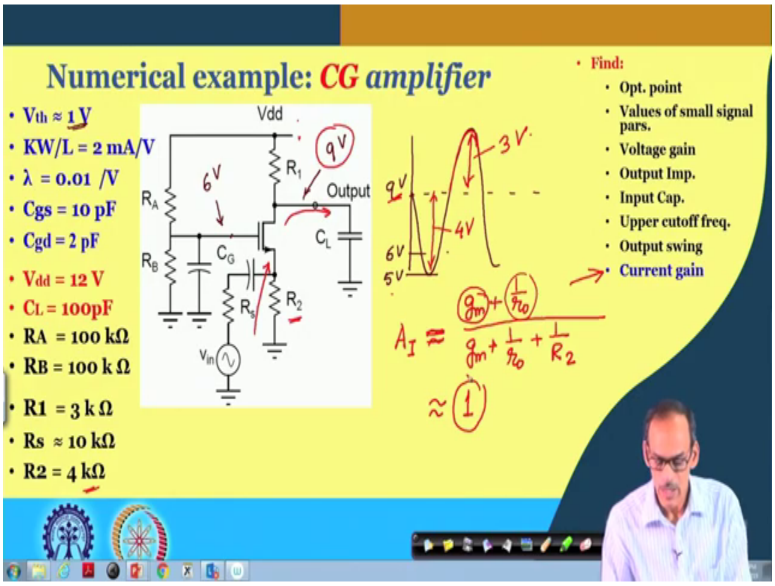
So, I do have the corresponding calculation of this gain and it becomes 0.24. So, what you can see here it is the gain it is much lower than 1. So, this is primarily because for this case this circuit itself it is having low gain from here to here in addition to that, the input resistance is low and we are considering a practical source resistance that further attenuates the signal before going to the source node.

So, I should say that the voltage gain it is slow the input resistance now we already have calculated, output impedance it can be calculated in the similar way we already have done. Input capacitance of this circuit it is similar to the common base namely input capacitance it is c gs and from that we can say that the we can calculate the input the upper cut off frequency define by R S and input capacitance.

So, those things I will not be repeating that but I must say about this output swing what we said here it is the gate voltage it is 6 volt and the voltage at the drain it is 12 minus these 3 volt drop here. So, that is 9 volt here. So, if the DC voltage at the at the drain node it is it is 9 volt, V t h it is 1 volt. So, this voltage it can go as low as 6 minus 1 so; that means, it can go to 5 volt as low as 5 volt. So, with respect to 0.9 voltage DC the corresponding swing towards the negative side it is 9 minus 5 volt that is the 4 volt.

So, we can say that the negative swing it is a 4 volt. Sorry the slide is becoming very clumsy let me clear it and then again rewrite this part.

(Refer Slide Time: 43:05)



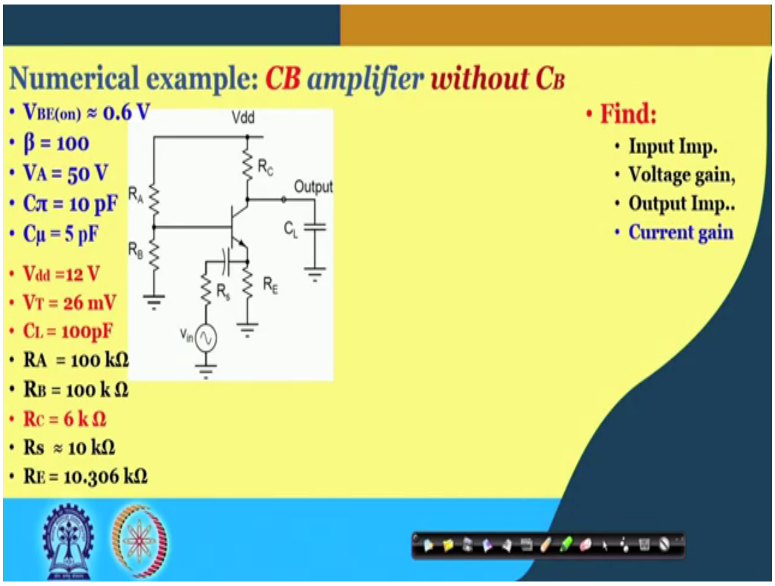
So, what we said here it is 9 volt DC, voltage here it is 6 volt. So, at the output node we do have the 9 volt here and the voltage here it is 6 volt. So, we can have the signal swing like this, if this is 6 volt it can go as low as up to 5 volt because threshold voltage is 1 volt. So, the swing here signal swing we can get here it is 9 volt minus 5 volt. So, that is the 4 volt negative side.

On the other hand positive side it can go as high as 12 volt theoretically, but of course, the corresponding signal may get distorted like this. So, the corresponding swing on the positive side; however, it is 3 volt. So, anyway for this design that is what the operating point and that is a corresponding signal swing this information it will be useful whenever we are going to design a circuit so, that we will be discussing later. Now, next item it is the current gain of this circuit.

Current gain for this circuit it will be it is you may recall on the previous discussion, this current gain it is very close to this g m or rather let me write the that explanation g m plus 1 by r o divided by g m plus 1 by r o plus 1 by R 2. And R 2 it is we already have discussed it is 4 k and this is definitely it is quite small compared to the g m. So, again here we can approximate this by this g m it is getting dominated.

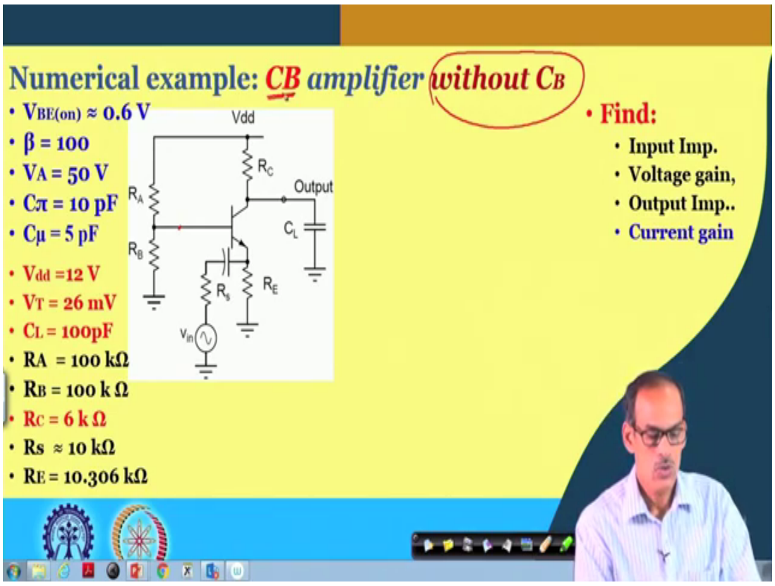
So, we can say that the corresponding current gain it is approximately 1. In fact, if you see if you ignored this resistance whatever the current it is entering signal current is entered into the source, the same current is flowing here approximately. So, that is an indication that the circuit current gain it is common gate amplifier current gain it is close to 1.

(Refer Slide Time: 45:57)



So, that completes the numerical examples whatever thing we have planned, based on this information you can probably I do have one more numerical example. Probably I will cover this one in the next class because if I start explaining it maybe it will take more time. So, let me break here and then of course, after this one we will be having a plan to cover design guidelines.

(Refer Slide Time: 46:18)



So, what we have to cover here this numerical example and in this numerical example it is yeah. So, in this numerical example what is the important point here it is in case if we are not using the CB what kind of effect it may come and this is important for common base amplifier. So, this numerical example it will take some time. So, let me come back on this example after break.