**Analog Electronic Circuits**
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**Lecture – 51**
**Common Base and Common Gate Amplifiers (Contd.):**
**Numerical Examples (Part A)**

Welcome to this NPTEL online certification course of Analog Electronic Circuits. Myself Pradip Mandal from E & EC department of IIT Kharagpur. We are continuing this course for quite some time and today's topic of discussion it is Common Base Common Gate Amplifiers. In fact, this is continuation of our previous lecture. So, we already have discussed about the theoretical aspect, today we will go with more Numerical Examples.

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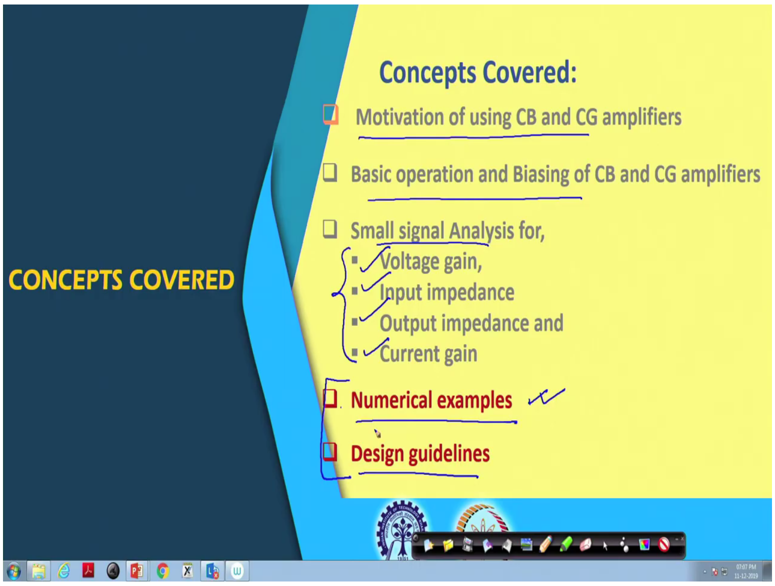

So, our plan is to cover the following items of this this topic. As I said that we already have discussed about the motivation of going for this common base and common gate configuration. We also have discussed about the basic operation and biasing of these two configurations and also we have talked about small signal analysis for different performance parameters, namely Voltage gain input impedance, output impedance and current gain.

Today we will be covering number of numerical examples associated with these 2 basic configurations and whatever the expression we have obtained in the previous class of different parameters that will be extensively used here and we will get numerical value of those parameters. And subsequently once you covered this numerical examples which are associated with analysis of design circuit.

Once we are comfortable on this numerical examples, then we will be in a position to discuss about what may be the design guidelines for a given requirement of the circuit performance. So, today's discussion here it is number of numerical examples and then design guidelines of common base and common gate amplifiers ah.

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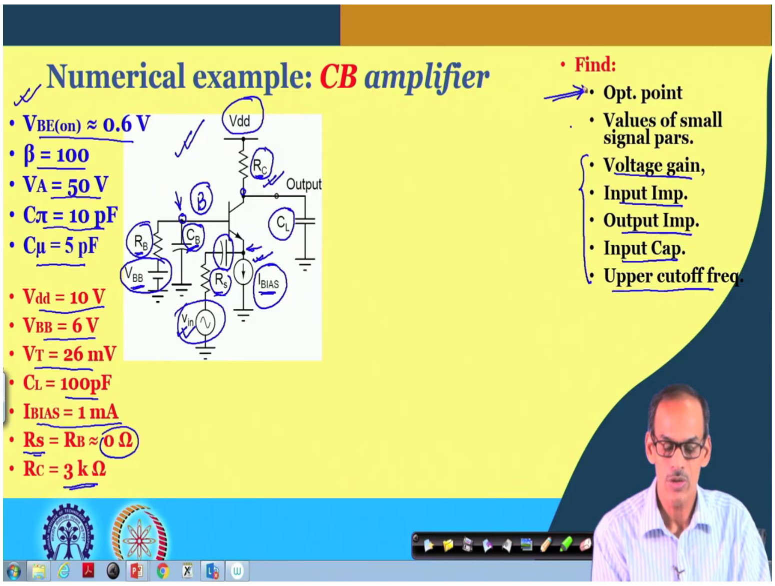


So, let us go to the numerical example of common base amplifier. What we do have here it is the basic circuit given here and you can see that we do have ideal bias as well as more practical bias of the collector terminal. And also at the base node of this circuit we do have a DC voltage along with Thevenin equivalent resistance of the DC source.

And since it is common base configuration and we want this base node should be AC ground, to ensure that we are also connecting CB large capacitor there. Input port is at the emitter and output port is at the collector terminal, input we are giving through a DC decoupling capacitor. In this case in this example we are showing input signal in the form of voltage and the signal source it is also having it is source resistance called RS.

And here we do have different parameter values namely VBE on of the BJT it is approximately 0.6, current gain beta of the transistor it is 100. Early voltage of the BJT it is taken 50 volt and then base to emitter small signal capacitance C pi it is 10 pico Farad and on the other hand base to collector capacitor C mu it is having a value of 5 pico Farad.

These are typical numbers and then also we do have the information about the supply voltage 10 volt and then base voltage DC voltage 6 volt, thermal equivalent voltage VT it is 26 milli volt and then also we do have the load capacitance connected at the output node which is 100 pico Farad. Now, in this bias circuit we do have IBIAS which is given as 1 milli ampere. So, for the time being in this numerical examples we are considering this emitter bias it is ideal. So, we do not have any associated conductance of this bias circuit, in later examples we will be replacing this ideal bias by resistive bias.

And in this numerical example let we consider that the source resistance RS is equal to 0 and also the Thevenin equivalent resistance for the base bias RB, let we consider this is very small. So, whether we do have CB or not we can consider that base terminal is AC ground. At the collector terminal on the other hand we do have practical circuit RC and let we consider it is value it is 3 kilo ohm. So, how do we find different performance matrices of this circuit which are in listed here? Namely voltage gain, input impedance, output impedance, input capacitance may be upper cutoff frequency of the amplifier. While we are driving the signal in the form of voltage.

So, how do we proceed? We can start with the operating point of the transistor, to get the operating point of the transistor we can do the DC analysis and then we will be going to the calculation of small signal parameter of the transistors. Namely gm and then r naught of the transistor. So, let us let we target at this point and try to find the operating point of the transistor. So, as I said let us try to find the operating point.

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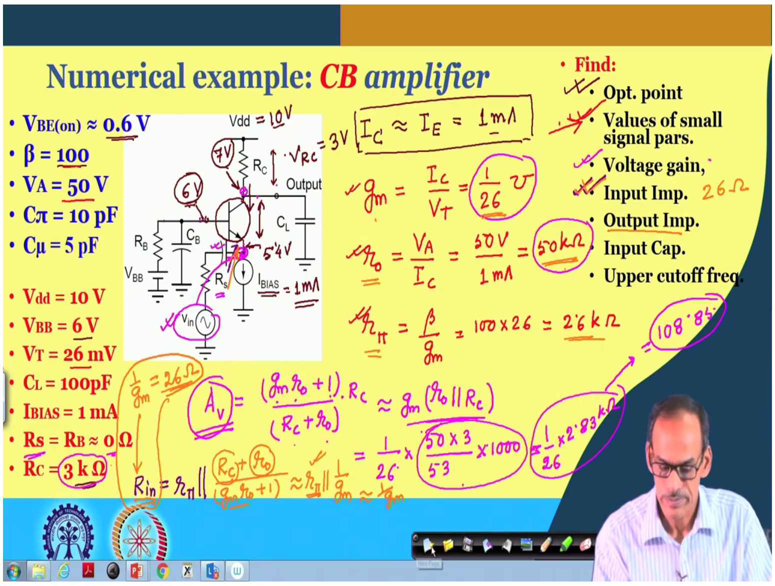


If we see that this IB it is given as 1 milli ampere and beta is 100. So, we may approximate that collector current IC is equal to I E and which is same as 1 milli ampere, so this is the DC current. And then the voltage at the base it is given as 6 volt and the emitter voltage here it can be obtained by considering 6 volt here and VBE all of 0.6 volt.

So, we can say at the emitter node we do have 6 minus 0.6 that is 5.4 volt. Now, if we have this 1 milli ampere of current at the emitter, approximately the collector current is also said by that, then the drop across this RC it is 3 k multiplied by 1 milli ampere. So, that gives us this voltage it is VRC equals to 3 volt, Vdd on the other hand it is 10 volt.

So, the voltage coming at the DC voltage coming at the collector terminal it is 10 minus 3 so that is 7 volt. So, if we have 7 volt here at the collector and at the base we do have 6 volt, the transistor it is in active region of operation. In fact, to consider this approximation it is very important to ensure that the transistor it is in active region of operation. So, that is how we obtained I C. So now, the operating point it is we obtained. In fact, we can find what is the corresponding VCE voltage which is 7 minus 5.4 here.

So, anyway then we come to the calculation of small signal parameters. So, let we consider small signal parameter calculation namely gm of the transistor which is IC divided by thermal equivalent voltage VT and it is given 26 milli volt. So, we can see this is 1 by 26 mho and then the other parameter it is r naught and it is expression is early voltage VA divided by I C and early voltage it is given here it is 50 volt and I C it is 1 milli ampere. So, that gives us r naught equals to 50 kilo ohms.

And then R pi which it can be obtained by considering this gm and the value of the beta given here. So, this is beta divided by gm can say this is 100 multiplied by 26. So, that gives us 2.6 kilo ohm. So, these are the small signal parameters we obtain. Now,3 using those parameters so we can find the corresponding voltage gain. So, let us see how we do get the voltage gain. So, the voltage gain starting from the emitter terminal to the collector terminal and if I call that voltage gain it is AV.

You may recall from our previous days discussion it was gm into r naught plus 1 divided by RC plus r naught into RC. In fact, if you do if you compare gm into r naught and 1 definitely, we can approximate this by gm into r naught only. So, we can drop this 1 and we can see that this is gm into r naught into RC divided by RC plus r naught, which is actually r naught and RC in parallel. So, the voltage gain now if I plug in this value of this gm and then r naught and then RC of 3 k. What we will get here? It is 1 by 26 multiplied by RC it is 50 k into 3 k divided by 53. So, this is k and this is 1 by 26.

So, I should see this is multiplied by 1000 that gives us a gain. So, this resistance if you see this resistance let me write that part also separately. So, gm it is 1 by 26 and this part it is 2.83 kilo ohms, in my previous calculation I already have done this one. So, that gives us the gain which is equal to 100 roughly 100 to be more precise 108.85.

So, that gives us a very decent gain of this circuit. In fact, this this gain it is very close to the gain of common emitter amplifier having the similar kind of bias level, so that is how we obtain the voltage gain. Note that in this example we are considering that RS is equal to 0. So, whatever the input voltage you are applying here, even though this circuit is having very low input resistance. This since this RS we are considering it is very very small, so we can say that almost entire signal it is reaching to the emitter.

Assuming of course, this capacitor it is successfully allowing the signal to be coming to the emitter. So, this gain it is the not only emitter to collector gain, but it is also representing primary input to the primary output gain. Now, next thing is the input impedance. So, let us look into the input impedance, let me use different color for that hopefully I will be able to manage to write that expression here R in, again you may utilize the previous derivation. So, if I look into the emitter terminal what we have here it is R pi that is the resistance from emitter to base and the base node it is AC ground.

So, that is coming in parallel with whatever the impedance we do have on out of this entire circuit, let me use different color yes. So, we do have input resistance looking into the emitter the input resistance it is expected to be RC plus r o divided by gm into r o plus 1. So, I should say that this is again gm into r o it is dominating and not only that if you if you see the value of this r naught which is 50 k and then this RC it is only 3 k. So, we can approximate this by R pi in parallel with 1 by gm.

And again the if I compare the value of this R pi and 1 by gm they are they are having a ratio of beta. So, further to that we can simplify or approximate the input resistance by 1 by gm 1. So, the summary is that the input resistance of this circuit it is 1 by gm and that is 26 ohm. So, naturally this input resistance is quite low. So, this input resistance as expected it is quite low 26 ohms.

In fact, if you consider this R pi and Rc also here, it may be slightly different but more or less it is value it is quite low as low as 26 or 25 ohm. Now, next thing is that we can try to find the output impedance. So, I think the board is really clumsy, so let me erase. But you please make a note that gm it is one by 26 ro equals to 25 kilo ohms R pi it is 2.6 kilo ohm.

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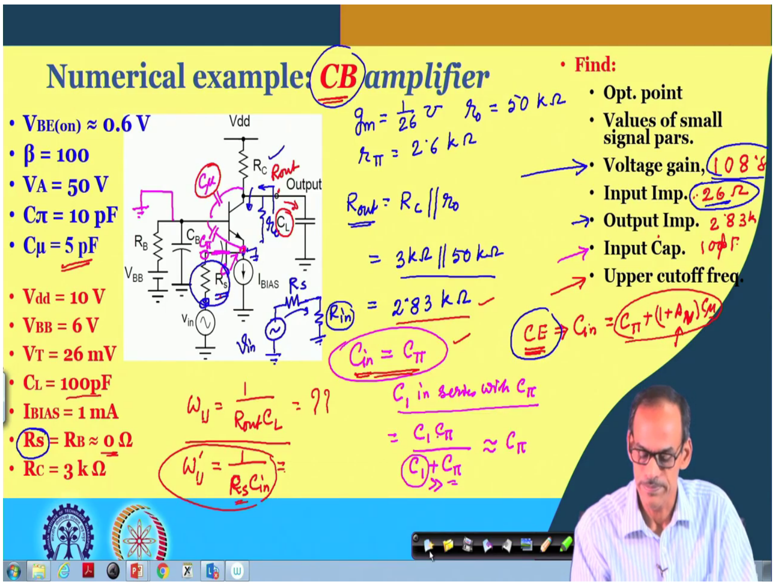


So, we need to calculate the output impedance and as I said that gm is equal to 1 by 26 mho ro equals to 50 kilo ohm and R pi is equal to 2.6 kilo ohm. Now, looking at the at this point if I want to know what will be the corresponding output resistance. So, that output resistance it is resistance of this RC this path and then the other resistance coming from the active device in parallel. So, that is in parallel with whatever the impedance will be seen.

Now, if I consider RS equals to 0 as we have discussed earlier. So, this emitter node it is getting grounded and the impedance will be seeing here it is only ro. So, the net output resistance it is RC coming in parallel with ro. Now, RC it is 3 k and ro it is 50 kilo ohms. So, earlier we already have calculated this resistance while we are calculating the voltage gain and that is two point 2.83 kilo ohm, so that is the output resistance.

Now, next thing is the Input capacitance. So, if we see the capacitance at this node for this signal, of course this coupling signal coupling capacitor it is quite large. So, whenever we are talking about input capacitance it is coming the emitter to whatever the ground node AC ground node will be considering that is the net capacitance. Now, emitter to base we do have C pi and then also base to collector we do have C mu coming out of the device.

So, if we look into emitter and since the base node it is AC ground, whatever the input capacitance we will see here it is only C mu C pi. In fact, to be more precise if I consider this is our primary input and if I call that this coupling capacitor signal coupling capacitor it is C1. So, then the input capacitance strictly speaking it should be C1 in series with this r C pi and whenever 2 capacitors in series their value it is C1 C pi C 1plus C pi.

Now, this C1 it is typically much higher than C pi, as a result you can say that since this is much higher than C pi. So, you can approximate this by C pi, so that gives us the input capacitance. Now next thing is the upper cut off frequency of the circuit and since we are dealing with the signal in the form of voltage. So, the upper cutoff frequency, of course it is coming from the output resistance here and the corresponding CL here. So, omega upper cutoff frequency it is 1 by R out into CL.

So, you can find what may be the value of this one CL it is given here it is 100 pico farad and R out we already have calculated 2.83 kilo ohms. So, we can find the corresponding value here. So, that is how whenever we do have the common base amplifier circuit, we can analyze the circuit and as I said that end of this analysis what we obtain that the voltage gain it was very good 108.8.

Input impedance it is low 26 ohms, output impedance it was it is different it is 2.83 kilo ohms and input capacitance on the other hand it is low. So, I should say it is 10 pico Farad only and C mu it is not having any effect on C in. In fact, that is say a good sign if you compare this common base and common emitter amplifier and if you recall for common emitter amplifiers input capacitance it was C pi plus miller affected C mu. So, which is 1 plus AV times C mu and if you have significant amount of C mu, since the voltage gain it is high for CE amplifier the input capacitance it was quite large.

On the other hand for common base amplifier that C mu it is not having any contribution. So, we can say that if I compare common emitter and common base in terms of input capacitance common base amplifier it is better. And as what will be the consequence of that the in case the upper cutoff frequency it is not only defined by the output node, if it is also defined by the input pole namely if C in and RS they are defining the upper cutoff frequency, then we can see this advantage.

So, in this example since we are considering RS is equal to 0 that is that is why the effect of the C in is not coming in the frequency response. But if we consider in general so the upper cutoff frequency defined by RS and C in, so that is the other candidate of the upper cutoff frequency that may using this expression. And if we are having RS it can be easily prominent that the common base circuit. Since it is input capacitance is low it is useful for some high bandwidth application.

So, now the next thing what we have to see that, even though we have seen that the voltage gain it is good, but input impedance is not so good. Now, if I compare again the CE amplifier and CB, then and if I consider practical value of the source resistance signal source resistance. Because of the input impedance is low we are expecting that primary input to emitter node there will be large attenuation. Namely if I consider say this is the input signal V in having a finite value of the source resistance followed by the input impedance of the amplifier and since this R in is small so we are expecting there will be big attenuation.

So, in the next example numerical example what we will consider that RS instead of considering 0 ohm, we will take some practical value rest of the things we will keep as it is. And then we can see what will be it is consequence particularly on the voltage gain.

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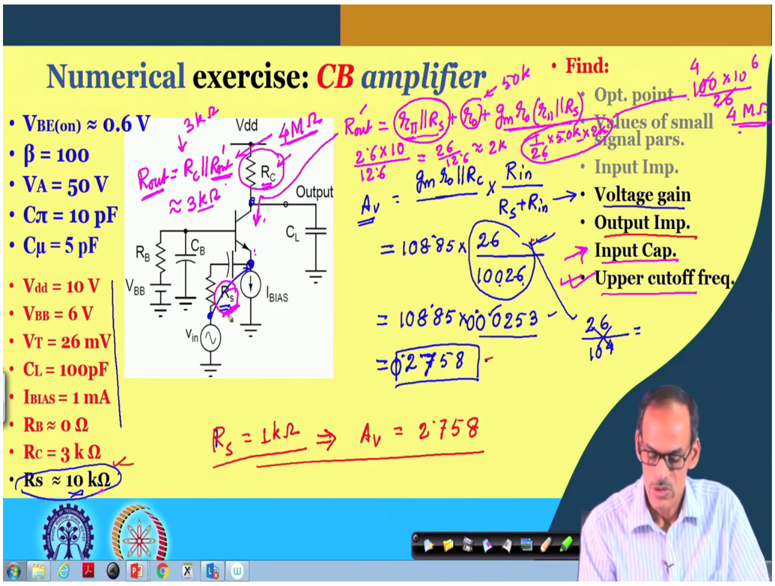


So yes, so this is the this is what exactly what I was telling, that all the parameters here we are taking same except the source resistance. So, we are considering the source resistance it is 10 kilo ohm. No,w let us see what will be the corresponding voltage gain. So, the voltage gain from this point to this point namely emitter to collector we already have seen that voltage gain it is gm into r o in parallel with RC.

And then if I consider from this point to this point primary input to the emitter node it is having an attenuation and that attenuation it is R in divided by RS plus R in. Now, this part we have calculated as 108.85 and then R in we obtained this R in it is only 26 ohms and then RS we are considering 10 k. So, RS plus R in it is 10026, so that gives a big attenuation.

So, the overall gain now with RS is equal to 10 k it is quite small, the I mean let me think I did some calculation on that yes. So, this attenuation factor 108.85 getting multiplied by;

multiplied by this attenuation factor which is 0.0253. I think I am correct and then that gives us the overall gain it is only 2.758 no surprise, there is a huge attenuation from here to here of 0.025.

So, the voltage gain in summary the voltage gain it is very bad particularly if I start considering practical value of the source impedance. Of course, it depends on the source impedance. But then even if you consider say 1 k which may be in the many of the application, then also the this attenuation will be quite big. So, we need to be a little careful here in I guess I am correct here 10 k. So, that is 26 yeah approximately you can say that this is 26 divide divided by 10 to the power 4. So, that gives us no sorry I will take it back.

In fact, the attenuation it is even more and that is what I was wondering that why the attenuation is only this much and that gives us very low gain. In fact, the gain it is less than 1 ok, so it is just 0.27. So, naturally if we consider practical value of this source resistance we can see the effect. In fact, if I consider RS it is a lower say RS is equal to 1 kilo ohm, then also this attenuation it will be quite significant and with this RS of 1 kilo ohm the overall voltage gain it is 2.758 yeah. I think I have done this calculation for 1 k and now if it is 10 k the situation is really bad.

Now, what is the effect on the output impedance on the other hand, since we are considering the finite resistance RS. So, I let me use different color to explain that, output resistance if I see it is having 2 components one is RC and the resistors coming from the active part. So, the resistance coming from this active part it is basically it is you may recall if I call this is R out dashed, so that is the impedance of the active device. So, that is R pi in parallel with RS plus r o plus gm into r o into R pi in parallel with RS.

And in this case if I consider this 10 k and R pi it was 2.6 k. So, these two in parallel, again I think I do have the calculation no I do not have that, but whatever it is this part this part it is 2.6 multiplied by 10 k. So, that is 10 divided by 12.6 k, so that is 26 divided by 12.6. So, roughly we can say that this is 2 k. And now if I consider r naught which is you may recall this is 50 k and the this part it is quite big and that is gm which is 1 by 26 and then we do have 50 k and then we do have roughly 2 k ok.

So, let me use this space here, this part is really becoming clumsy here. So, what we are getting here it is 100 into 5000 and then we do have this is kilo; this is also kilo; this is ohm, so into 10 to the power 6 divided by 26. So, roughly we can see this part and this part close to 4 which means that 4 mega ohms that is quite big; that is quite big. So, by having the source resistance we may get an advantage that this resistance is quite large. But then overall resistance output resistance it is RC coming in parallel with R out and R out dash rather. So, though this R out dash it is quite large of say four mega ohms of magnitude.

On the other hand RC it is only 3 kilo ohms. So, we can say that it is having hardly any influence on the overall output resistance, because this three k it is quite small it is I should say it is peanuts of the that the 4 mega ohm. So, the output resistance it is hardly getting affected by this RS, but we need to be careful that that is mainly because this RC it is small. In case if we have a have an implementation where this RC it also it is quite large, then only we can see that output resistance of this entire circuit it is highly dependent on this RS ok.

So, this is the other example, now also the other thing probably we can we can do the we can observe that output input capacitance and upper cut off frequency. Hardly it is in particularly input capacitance it is not getting changed, but then output I should not say output the overall upper cutoff frequency it depends on the RS. So, let me clear this board and then again rewrite with different color.

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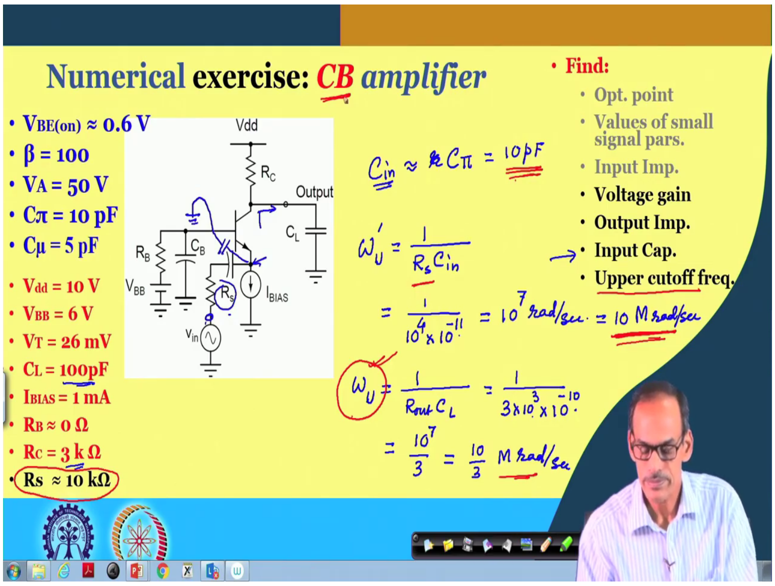


What we like to say that input capacitance C in it is C sorry C pi and this is 10 pico Farad and then this RS and whatever the capacitance we do have here the other end of this capacitance it is AC ground.

So, we can say that from primary input to this point we do have one RC circuit defined by C in and this RS. So, one candidate of the upper cutoff frequency coming from this RS, let me call this is omega u dashed is 1 by RS and C in and this is one divided by 10 to the power 4 and C in it is 10 to the power ah. So, this is pico Farad 10 pico Farad so this is minus 11. So, that gives us minus 7 here, so this is equal to 10 to the power 7 radian per second.

On the other hand, the upper cutoff frequency defined by the R out and CL and let me denote this by omega U which is equals to 1 by R out CL and R out it is dominated by RC. So, that is 3 kilo ohms 3 into 10 to the power 3 and then we do have the 100 pico Farad, so that is 10 to the power minus 10. So, that gives us here again 10 to the power minus 7. So, in the numerator it becomes 10 to the power 7 divided by 3, so yeah so I should say 10 by 3 mega radian per second and this is 10 mega radian per second.

Now, incidentally in this numerical example still this is higher than this one. So, I should say omega U will define the overall upper cutoff frequency, but we need to be careful that RS if it is higher and higher then this may also create the bandwidth limitation. So, the bottom line here it is rather I should say the information other way, even though RS it is say 10 kilo ohm.

Since the input capacitance it is remaining low unlike common emitter amplifier, where the input capacitance it is large. Since this input capacitance for this circuit it is remaining low, this upper cutoff frequency it is still going beyond the other candidate of the upper cutoff frequency here. So, I should say the common base amplifier it is helping to design relatively wideband amplifier.

So, later we will see that how this information can be utilized. Now, similar kind of analysis can be done for the most counterpart, namely the common gate amplifier. Before we go into that let we take a short break and then we will come back to analyze the common gate amplifier.