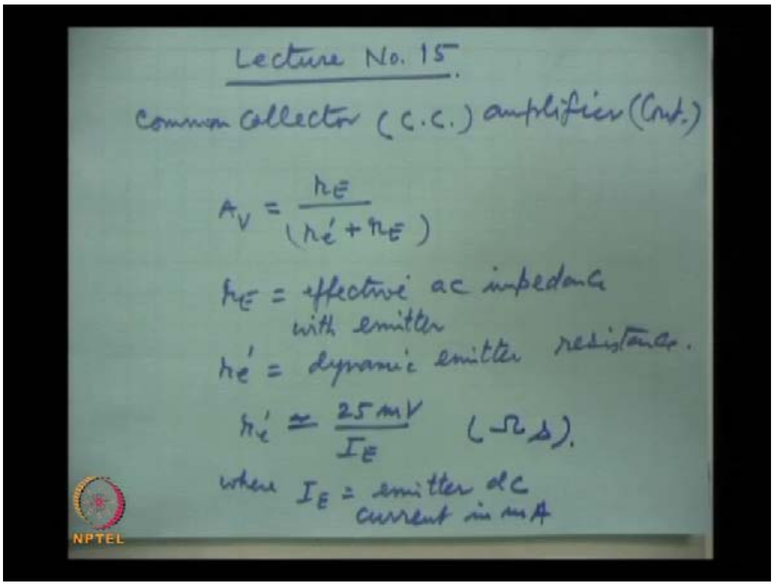
Video Course on Electronics

Prof. D.C. Dube
Department of Physics
Indian Institute of Technology, Delhi

Module No. #03
Small Signal BJT Amplifiers
Lecture No. #05
Common Collector (c.c) Amplifier (Contd.)

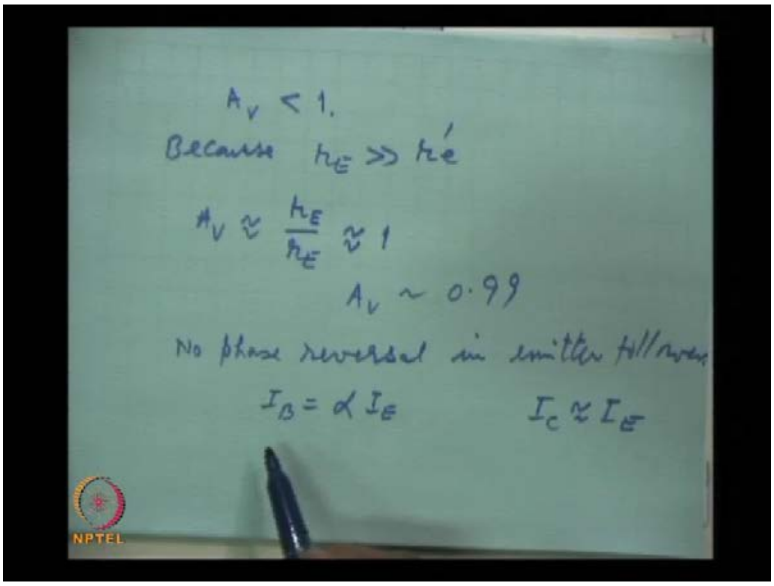
(Refer Slide Time: 00:48)



We will continue our analysis of common collector amplifier. I I explain, and now we will see that why this common collector is called emitter follower. We were doing the r parameter analysis, that is resistance parameters, unless is of the small signal amplifiers. And we arrived at the expression for the voltage gain of this emitter follower as A v r E r e prime plus r E and we are, let me recollect that r E is the effective r E is effective ac impedance or resistance with emitter r E prime is a dynamic emitter resistance, and this was this we can calculate this is one of the parameters in r analysis, and this r e prime is given by approximately as 25 milli volts, and to be exact 26 milli volts divided by I E. Where, I E is emitter current - emitter dc current, dc current in milli amperes, when this is already milli volts, if this in milli amperes then this resistance will be in ohms.

And this is very small resistance. Just it normally varies from say 10 to 40, 50 ohms. Now, there is and this value of gain, obviously it is less than one.

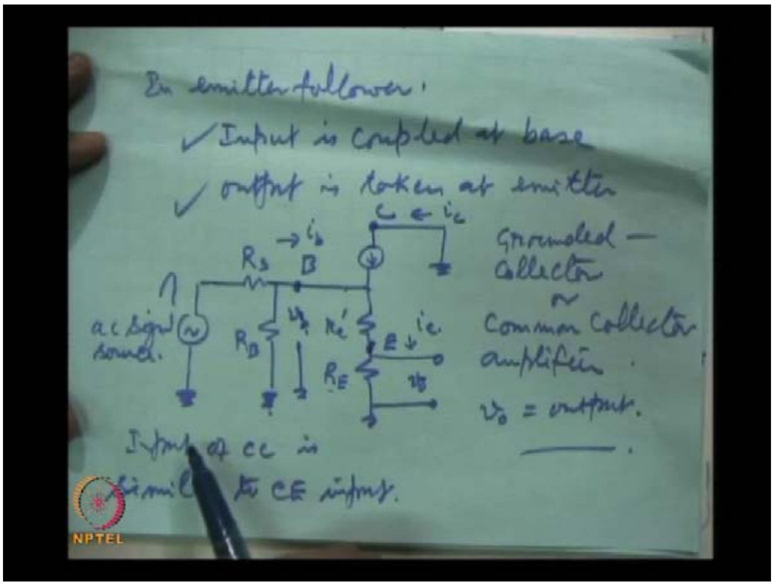
(Refer Slide Time: 03:05)



And so, A V is less than one, but because because this r e is very high is compare to r e prime. Then then you will see that A V turns out to be very close to when we neglect r e prime the denominator then this is r E by r E which is close to one and for well designed emitter follower amplifiers this gain is for example, practical value is A V 0.99 or 0.998 or so on. Now now we will talk about the phase relationship between the output and input that means whether there is a phase reversal or not in this amplifier by we have seen that in common emitter amplifier there is a phase reversal that means the output has a phase difference of pi with the input. We mean when input signal because it is all varying time varying this is ac signal and for simplicity we are taking our signals as sinusoidal ac signal.

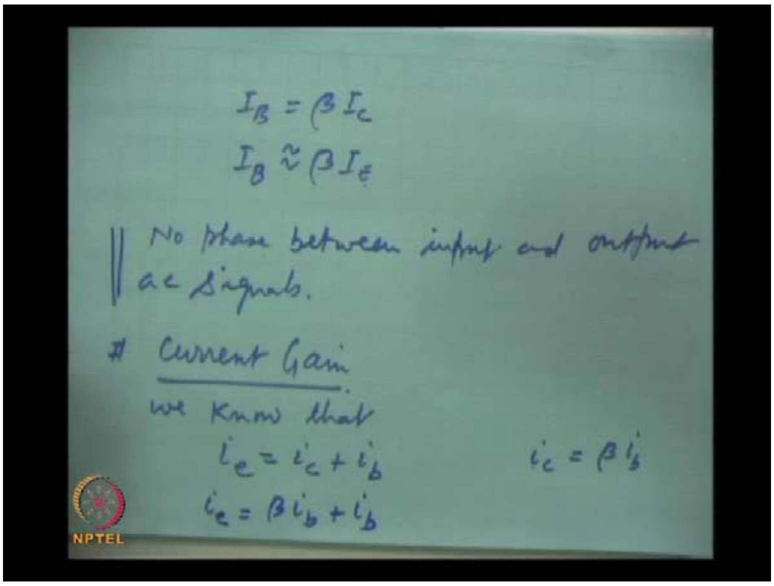
So, when the input is at the peak positive then the output will be peak negative and so on. So, there is a phase reversal in this amplifier in emitter follower the common collector amplifier there is no phase reversal that means that and remember that this is the only circuit among the three common base, common emitter, common collector is the only one in which we give the input to the base and we take the output from the emitter. The load is put at the emitter this is the only circuit in other two the load is with the collector. Now gain a voltage gain is very close to one and as I said there is no phase reversal no phase reversal in emitter follower in emitter follower. There is no phase phase reversal.

(Refer Slide Time: 05:59)



Now, let us see this from the figure which I have drawn earlier that this is this was this was the figure which we have drawn earlier where in the N common emitter common collector circuit emitter follower circuit. We have replaced the transistor by it is a small signal simplified model and this is that model. Now this is the ac signal and when the signal is positive it goes up then because there is a ac and dc simultaneously. So, this will be this will add up with the with dc signal and hence when the input signal is at peak positive then there will be the i b the base current is varying, but it will be maximum at this time. When base current is maximum since that base current base current as you remember this is alpha times I C or I E because I remind that in all a small signal amplifiers the I C is very close to into equal to the emitter current this two are equal ac or dc this is true for both.

(Refer Slide Time: 07:44)

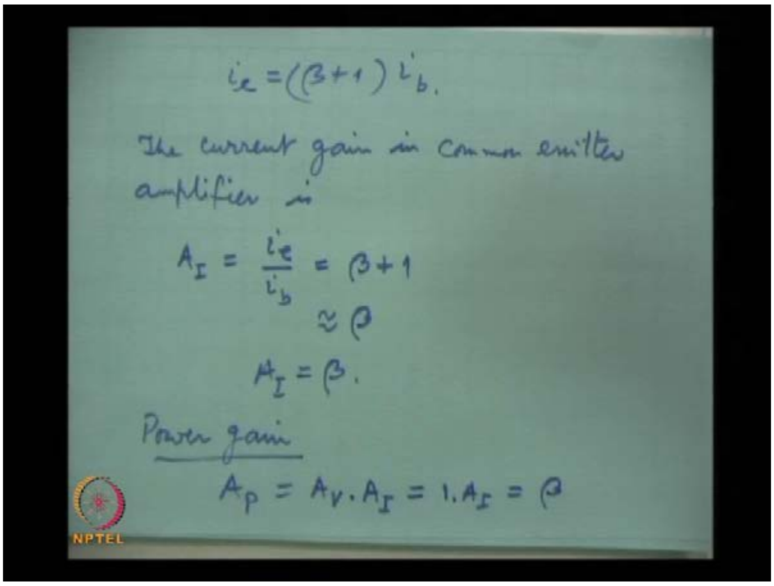


So, this is that so, if I B if I B increases then I C will also increases. I B is beta times I C which is very close to beta times I E. So, if beta being constant if I B impresses I E also has to increase and once I E increases then this voltage will also be high. I repeat this ac signal is super imposed on the q point the dc current and voltages. So, the net base current will be highest when the ac signal is here and it will be least when it is here. Now we are talking at the point when the base current is highest then this positive half of the signal at the peak value will be large value of I B and since beta is constant I B increases I E will also increases. When i e increases then the drop across this that is the ac voltage which is varying across this will also be high.

What I have said, i have said when this is maximum positive the output which we take from the emitter the load we put at emitter this is also highest positive. Similarly, when it is negative then base current will be least accordingly i e will also decrease and this will be least. Meaning as I said no phase reversal no phase between input and output ac signals. Now there is no phase reversal that means the output follows the phase of the input and also the gain in this is close to one gain is one so, magnitude is also high. Magnitude of output is also the same as the input that is is the reason that means amplitude and phase of output is same as the amplitude and phase of the input signal.

That is the reason from here the name comes emitter follower the emitter follows the input signal and phase and magnitude and hence there is no phase reversal. Now, let us talk other parameters of the emitter follower and this is current gain current gain. We know that we know that i e emitter current you remember from where we started the physics of the transistor that i e is splits into two i b and i e. So, i e is equal to i c plus i b or and also as seen here that i c is equal to beta times i b from where the fundamental definition of beta comes beta is the current gain which is the ratio of i c by i b and so, this equation becomes i e equal to beta i b plus i b.

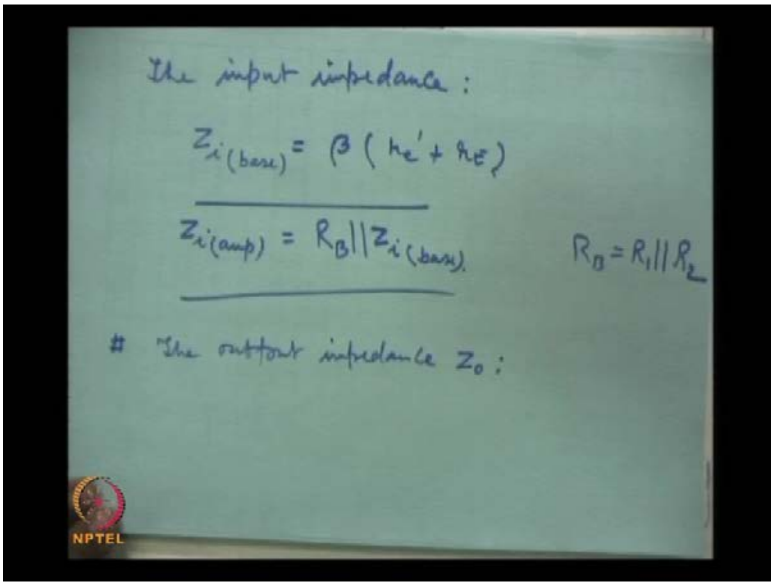
(Refer Slide Time: 12:11)



This becomes i e is equal to beta plus 1 into i b. So, the current gain the current gain in common emitter amplifier common emitter amplifier is A I output current by input current an output current is i e input current is i b and from this equation this comes out to be beta plus 1. Which is because beta is high? So, 1 can be neglected and this is beta current gain is high. Now voltage gain is unity that means there is no voltage gain, but power gain is the product of current gain and voltage gain. That is A P the power gain is voltage gain into current gain and voltage gain for common collector is one almost 1. So, 1 into current gain and current gain is beta so, this is simply beta and beta is very high 100, 200, 300 that means there is a power gain.

Now, in in emitter follower the level of the signal goes up it it raises the power level though it does not there is no voltage gain, but because of the current gain being strength of the signal goes up beta times in this amplifier. Now, let us talk about

(Refer Slide Time: 14:31)

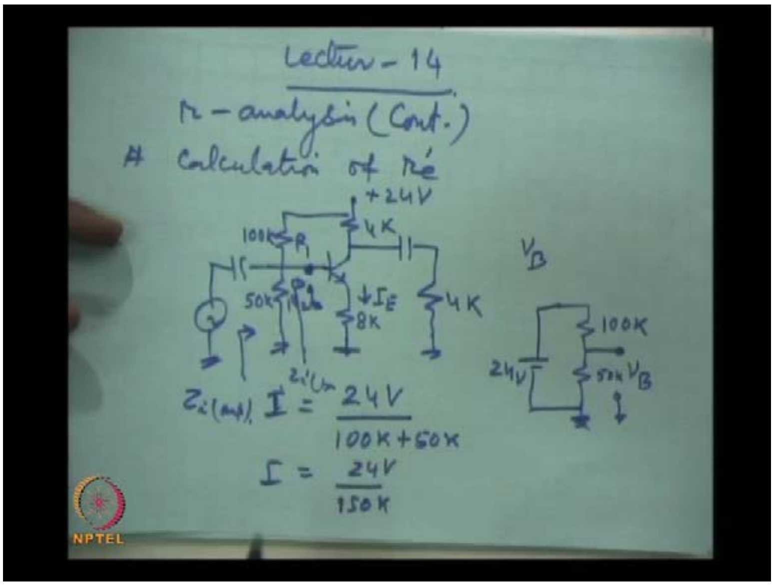


the input impedance the input impedance. If you look this circuit which the ac equivalent circuit of the emitter follower here the difference between this circuit and common emitter circuit was simply that we take the output from the collector, but R E was still there.

So, the circuit between base and emitter is the same as in the case of common emitter and you will recall that if I explained it also very clearly which I am sure you all followed that the input impedance looked into the base of the circuit is beta times the impedance available or connected with the or the total impedance assumed by the emitter lead. Now, so, in this case we can use the same and Z in the input impedance into base this is beta times the impedance and the impedances are the two impedances are in series this is ac dynamic emitter resistance and this is R E which we have connected.

So, this is r e prime plus r E and you remember that here this is the impedance which we see here here. This is Z in base and for the amplifier it is here that means R B the biasing resistances have also to be considered when we talk of the input impedance of the aim of the common emitter or any amplifier in general. This point we discussed in details in in the common emitter circuit also.

(Refer Slide Time: 17:08)



For example, we remember that this was the common emitter circuit and when we see here this is Z in i base z in i base and when we take the biasing resistance into account.

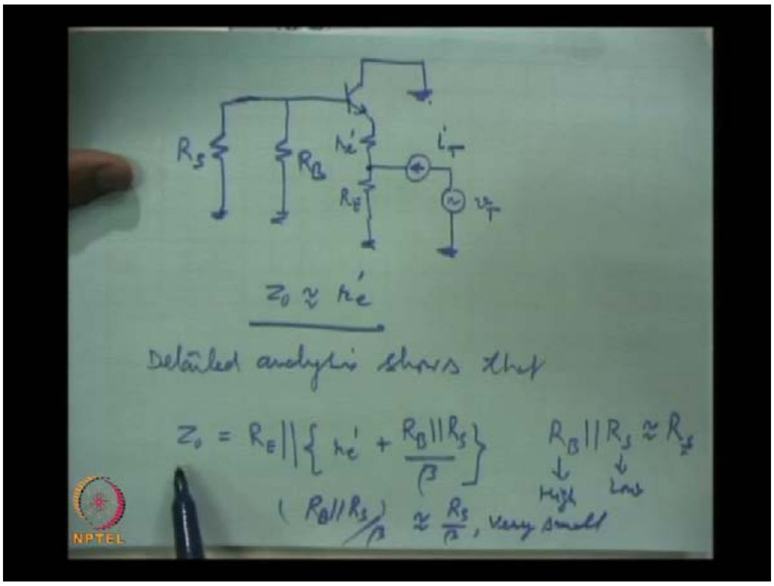
This is the input impedance of the amplifier same here. So, the input impedance of the amplifier will be Z i input impedance of amplifier this will be R B effective value of load resistance and if it is the two resistances R 1 and R 2 then R B is simply R 1 in parallel with R 2. So, R B in parallel with this Z in base. This is the input impedance and this is quite high, because r E will say 1 kilo hertz 1 1 1 kilo ohm and this is if we neglecting and this is hundred then you know it becomes hundred kilo ohms and whatever is R B.

Through one example we will find out these values. So, this is about the input impedance of the amplifier and now the output impedance. You will remember that we talked about the four basic parameters which are essential for a small signal amplifier one was the current gain, the voltage gain and then the two impedances the input impedance and output impedance these are most important four parameters which characterize an amplifier. Now the output impedance (Refer Slide Time: 19:00) output impedance Z o output impedance.

Let us draw the circuit the equivalent circuit how do determine impedance for example, if we are given a circuit and do not know anything about the circuit just the input terminals are available and output terminal are available. Now you have to find out the input impedance if it is input impedance you apply a small voltage at the input and what is the current which flows in the circuit the ratio of the two by ohms law will be the input impedance similarly, we have to apply.

Now we are talking about the output impedance so, we have to find out we have to apply a small test signal a text test voltage at the output and find out the current i T and that will give the output impedance.

(Refer Slide Time: 20:18)



Let we draw the circuit first this is the effective biasing resistance and when we have finding the input impedance then we apply here ac test signal v T which will send a current i T and the ratio of the two will give the input impedance and here the input input signal wears has to be reduce to 0, but still it will be in the circuit therefore, its resistance will be in the circuit. You may be little surprised that once we are saying that the input signal has to be reduce to 0 then why we should put this R s this is like that suppose you are talking from a mike whether and it is connected to the amplifier whether you are speaking or not speaking that means whether the microphone is in actual use or not, but the resistance of the coil will be in the circuit. So, when we have we have signal is reduce to 0, but is still source resistance has to be considered. So, this is the circuit and this resistance is R E and this is r e prime.

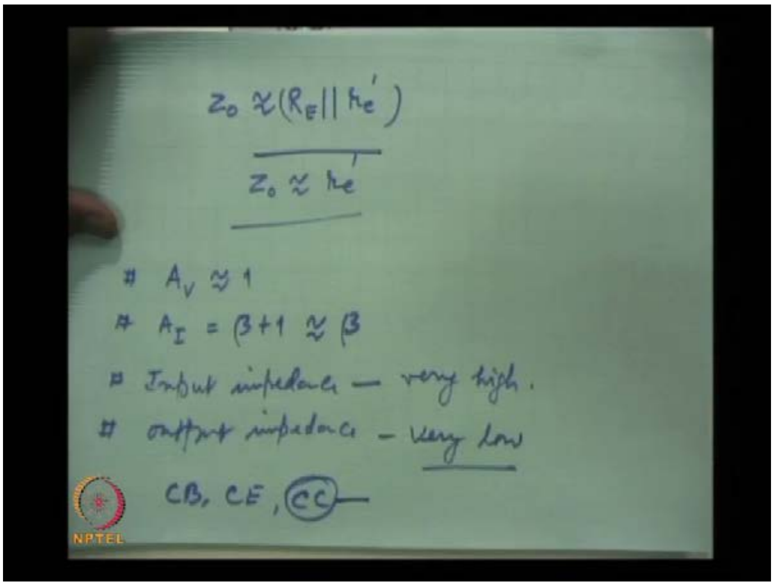
Now you remember it was said that input side and output side of the transistor they are not completely isolated what we do at the input it does reflect at the output what we do at the output is reflected at the input what we do at the input is reflected at the output. Now same is here, but broadly speaking for the time being even if we neglect this part and we look how much will be the impedance. So, you can see here that this is almost at a ground potential and x as seen at this point this is ground if this is ground then two impedances will be in parallel.

This is high resistance, this is low resistance and I remind that when two resistances one high resistance and one low resistance they are in parallel then the effective resistance equivalent resistance of this combination will be closer to the smaller resistance and actually it will be a smaller than the small resistance, but it will be close at the value will be closer to the smaller one. So, that way into intuitively we can see that output impedance of emitter follower will be equal to this resistance. Because these two resistances are almost in they are in parallel this is high resistance so, the effective value will be Z 0 will be equal to r e prime.

Which is very low which is very low this is important and in fact that is one of the biggest application of emitter follower input impedance very high output impedance very low. We will talk about it little later. Now detailed analysis also comes to this conclusion I am not taking the detailed analysis, but this can be shown that detailed analysis shows that output impedance is R E in parallel with r e prime plus R B and parallel with R S by beta. This is the effect feedback effect we will say the effect of these resistance is connected at the input of the amplifier on the output impedance.

Now, here this expression in this expression as I said just now R B is several so, many times at several hundred kilo ohms, but normally 10, 20, 40 kilo ohm and this R S will be much less than 1 kilo ohm. So, the parallel combination will give you a value smaller than R S so, closely equal to R S. So, R B prime R B in parallel with R S is equal to R S because this is high and this is low resistance and when divided by beta, beta is 100, 200. So, this becomes almost negligible. So, R B parallel with R S divided by beta is equal to R S by beta and this is very small very small. So, we can neglect it so, then we are left with R E so the output impedance becomes equal to Z 0.

(Refer Slide Time: 26:35)

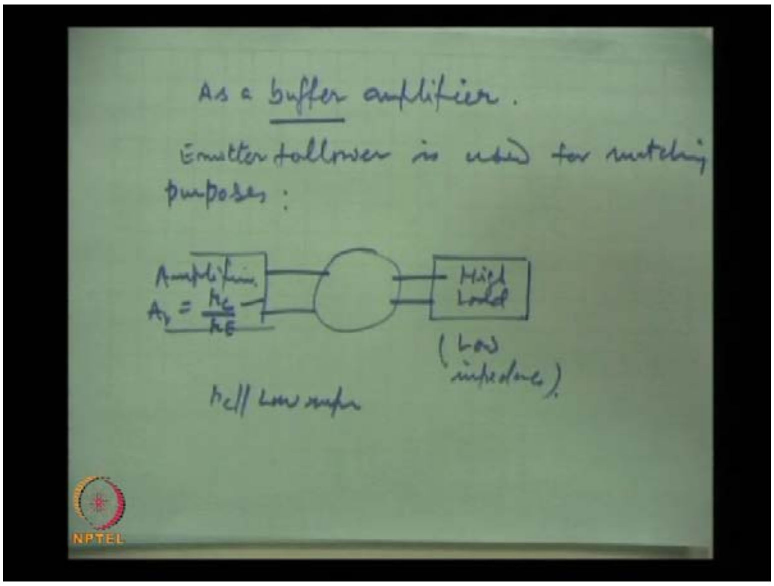


Then is very close to R E in parallel with r e prime because the other term which was with this we found two small and negligible we can neglected. Now again this is impedance in kilo ohms this is ohms. So, this parallel combination will give you a value very close to r e prime. This is from were started logically that the output impedance is equal to r e prime and r e prime is very small. So, we have found out all the parameters of the emitter follower. To summarize the emitter follower the voltage gain A V is very close to 1 and current gain this is voltage gain current gain is actually beta plus 1 which we can take as beta because beta is high 1 can be neglected.

So, this is high input impedance input impedance is also very high and output impedance output impedance is very low very low in fact out of the three configuration common base common emitter and common collector which is under discussion at the moment emitter follower has the lowest impedance.

Now as far as the application of emitter follower is concern then remember that there is a power gain and input impedance is very high output impedance is low,

(Refer Slide Time: 29:06)



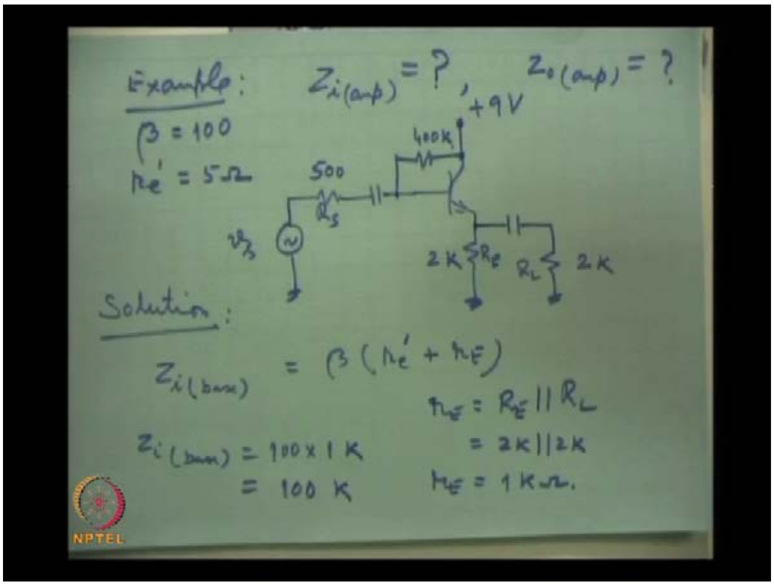
very low. So, the biggest application for this amplifier is as a buffer buffer amplifier by buffer we mean a intermediate between two states. So, it is used for matching purposes this emitter follower emitter follower is used for matching purposes what is to be matched I will just call for matching purposes. So, it is used as a buffer amplifier we have suppose because in the actual system there are several stages.

So, it suppose this is the previous stage and this is the next stage and this is high load high load that means low impedance remember this this is also one feels high load means high resistance load again this I said earlier also high load means this takes high power and which will draw high power or will give you high power when the impedance is very low. So, high load means low impedance and this is the normal amplifier the voltage amplifier. For example, c stage and the voltage gain for this is r c r c is the effective value of the collector impedance impedance is by the collector and this is the effective value of the resistance with the emitter emitter. Now here we connect these two high load cannot to this because this will going parallel with the output that will reduce r c r c in in parallel with very low impedance low impedance.

So, the gain will fall that means the performance of this stage amplifier and all previous stages will be effective this will go down. So, we cannot connect a a high load to an amplifier directly amplifier which has a high output impedance, but common emitter amplifier has a very low impedance as we have seen so, this can be connected the input will match with the high impedance here and the output of very low impedance low output impedance of the common emitter will match with the high load that means low impedance of the mast stage may be load as so, that is this is one of the major application of the c E amplifier.

Now let us quickly take a example because unless you can calculate some parameter of the amplifier our knowledge is incomplete we cannot handle circuit when it come to it comes to it comes to practical solutions. So, taking practical examples is a way of getting acutance with the in developing the handling capability in our selves.

(Refer Slide Time: 32:50)

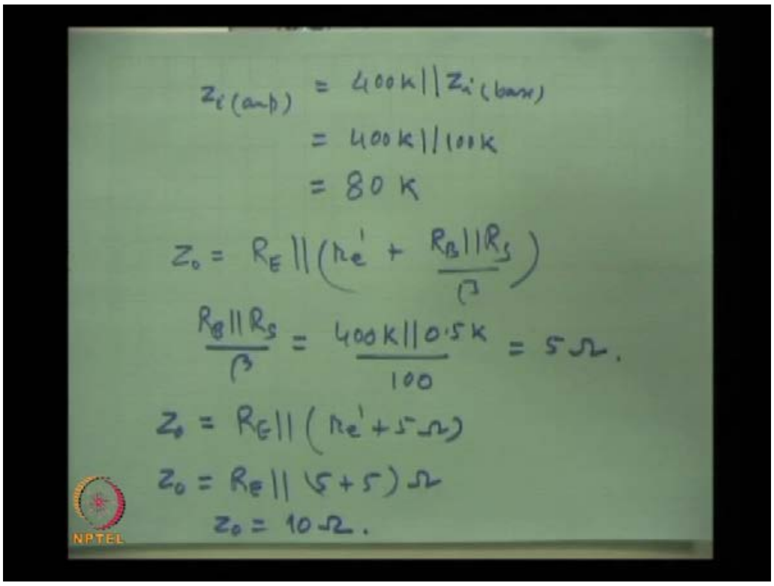


So, let us take one example, let us consider this circuit this is at the input or at the output the source and the load they are always connected with the capacitor capacitor coupling. We use this point also we have discussed and we will discuss more latter. So, let us consider that this is the source resistance and this is the signal v s which we have through this capacitor to a emitter follower and this is our load R L which is say 2 K and this is R E which is also 2 kilo ohms 2 kilo ohm and this is 400 kilo ohms. This is the circuit and it is given for this amplifier with the transistor the beta is given as 100 and r e prime is given as 5 ohms and we have to find out the input impedance Z i amplifiers this is to be calculated and also Z o out amplifier this is to be calculated.

So, we have to find out this two impedances and the circuit. Now see this is the solution the above we derived an expression for Z in base and this was equal to beta r e prime plus r E. So, r e prime what is r r e prime is given that is the dynamic emitter resistance which is given as 5 ohms and r E R E is the effective impedance as seen by the emitter of the transistor. Now you remember that in ac analysis all capacitors are taken as shorten. So, this is shorted then these two resistance will will come in parallel and this is what emitter is seen therefore, this is equal to R E in parallel R L that means 2 k in parallel with 2 k , use the formula for parallel combination of resistances 1 by R is equal to 1 by R 1 plus 1 by R 2 and find out the value of R.

So, this comes out to be r E comes out to be 1 kilo ohm therefore, this is and this is very small. Whether we consider we do not consider it it hardly matters few percent 2, 4, 5 up to 5 % variations in electronics in most of the situations they are acceptable. So, Z i base is 100 beta into r E which is 1 kilo that means 100 k this is the impedance as looked at the base and amplifier the amplifier I said this has not here taken into account the biasing resistance when it is given and the circuit which here R v is 400 k.

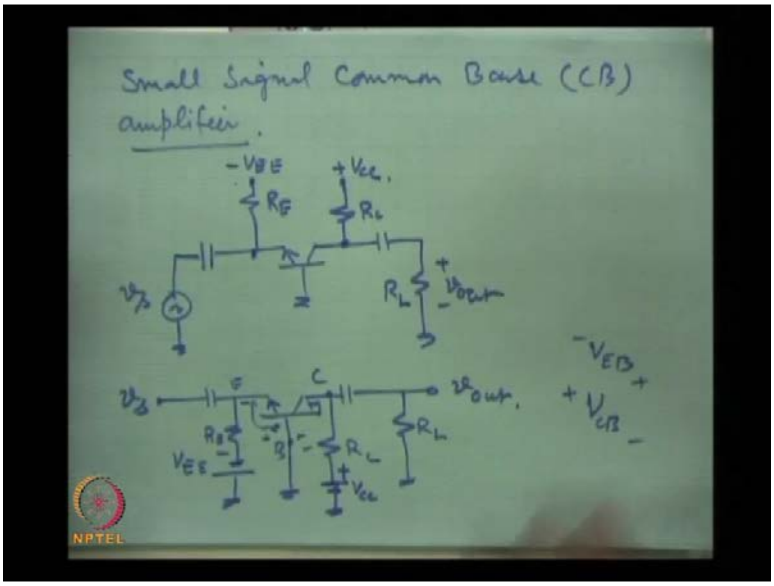
(Refer Slide Time: 37:23)



So, Z i amplifier is equal to 400 k and parallel with Z in base this is 400 k in parallel with 100 k and when you again solve it it will come out to 80 k. So, the input impedance of the amplifier is quite high. Now the output impedance Z 0 we arrived at the expression R E in parallel with r e prime plus R B in parallel with R S by beta this is what we arrived at. We talked about this and now R B in parallel with R S beta this is 400 k into 0.5 k divided by 100. So, it comes out to be 5 ohms substitute here Z 0 is R E in parallel with r e prime plus 5 ohms this is also given 5 ohms here.

Therefore this is R E this is in kilo ohms. So, the effective value will be all this much output impedance is is 10 ohms. So, this is the way how we can calculate the impedances for an amplifier. So, this was all about common emitter call common collector amplifier the emitter follower. The last thing in this amplifier is

(Refer Slide Time: 40:00)

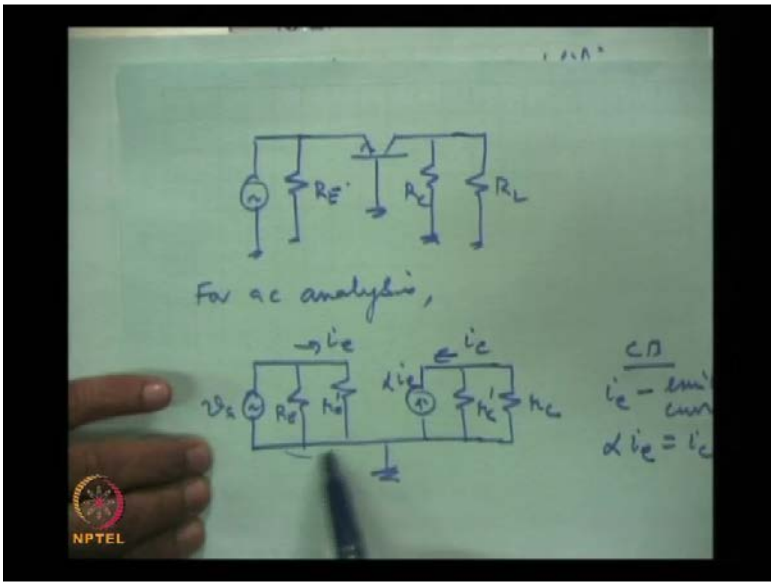


a small signal common base amplifier. In this circuit the input is connected input signal, signal to be amplified is connected to the emitter and it is connected through a capacitor.

Normally, the output we derived from the collector and the load is connected to the collector. So, the circuit becomes this this is R L and output we take from R L, V o V out this is the circuit and this can be redrawn like this this is the circuit. Here we connect the input signal to be amplified and we take output from here with respect to ground. Now here notice one point that in the earlier two circuits. We could draw we could forward biased and reverse bias the junctions by using a single battery this is not possible in the common base common base needs two batteries with opposite polarity plus V c c minus V E E.

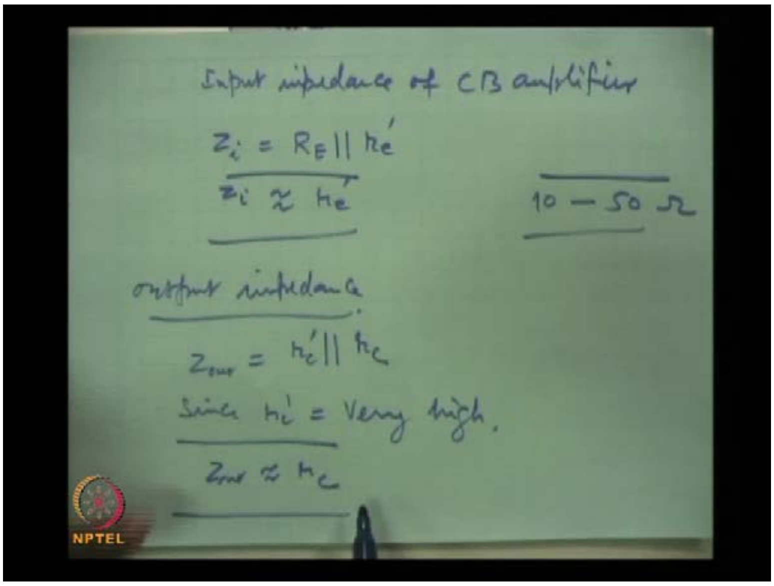
So, this circuit needs two batteries which is again it goes against the about this common base, but anyway this is not the reason for it is a very few applications we will come to that. So, this is the the circuit which can be either draw in this fashion or it can be draw drawn in this fashion these here this between a emitter this is emitter lead E this is base and this is collector. So, between emitter and base this voltage is a V E B with this polarity and here the collector has the base with this polarity plus minus this is with minus plus and the error one is V C B this is with this polarity. We can draw it is ac equivalent ac equivalent these capacitors to be shorted and dc sources have to be dc voltage sources have to be grounded.

(Refer Slide Time: 44:44)



So, it is ac equivalence circuit simply will be this. Now to do the any ac analysis for ac analysis we replace this transistor with the small signal model which we have been using in earlier amplifiers also when we do that then we get this here earlier. we we have seen that this this is the the the current which goes in this common base circuit to the collector. If i e is the emitter current emitter current then to the collector what is available is alpha i e this is equal to i c and alpha is close to one, but less than one. Now look here what will be the input impedance input impedance simply simply this two resistance in parallel.

(Refer Slide Time: 47:14)



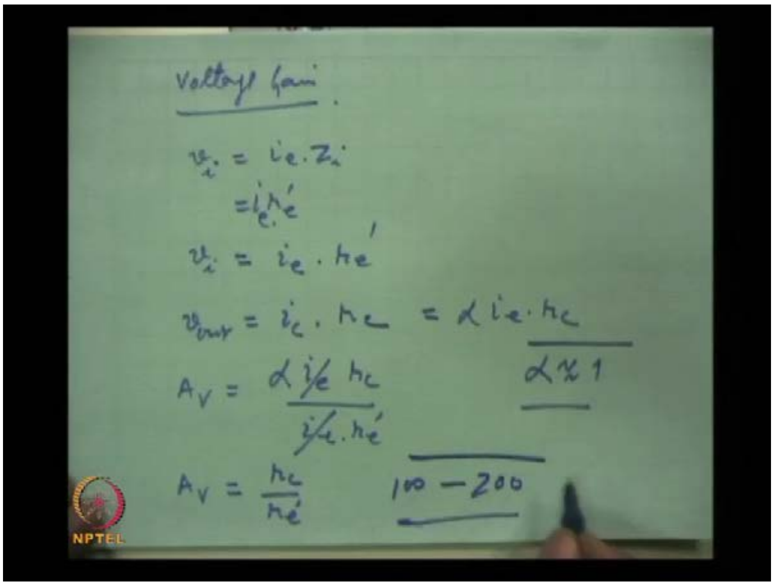
So, the input impedance input impedance of common base amplifier is Z i this is of the amplifier itself. When we take the biasing i into this into consideration otherwise it is r e prime, but two are coming in parallel. So, Z in Z i is simply equal to R E and parallel to r e prime and again the two resistances has in parallel smaller one will be a real the value which were very close to this. Hence, Z i is is equal to r e prime, r e prime very small this we have been telling this is normally 10 to 15 ohms. Little variable can this side and this side, but basically this is the value. Now, input impedance of the amplifier is very low. This is one big reason that why common base circuit is not used, if this amplifier is connected to battery because of the small impedance it will draw lot of current.

Hence, battery life will be very short if it is connected to the other amplifier stages as we have talking as that is very shortly. When we are talking about the the applications of common collector that is emitter follower we were talking that this will load that if this connected to the other amplifier having high impedance then it will load that is the effective gain will be reduced drastically and hence the performance of the amplifier will be very poor. So, we cannot earlier do that and that is one reason of that it is very rarely used.

Now, the output impedance output impedance is look here the output impedance this two resistances in parallel. So, Z o is r c prime in parallel with r c this is the effective impedance has seen by the collector and this is the resistance of the collector and this is the resistance of the collector. Now collector and the amplifier is a reverse bias junction so, this impedance is very high. So, since r c prime is very high and why it is very high because it is a reverse bias junction reverse bias junction has very high impedance from few hundred kilo ohms to mega ohms.

So, the effective value will be r c effective value of output impedance is equal to r c. This is high input impedance for common base very low output impedance very high.

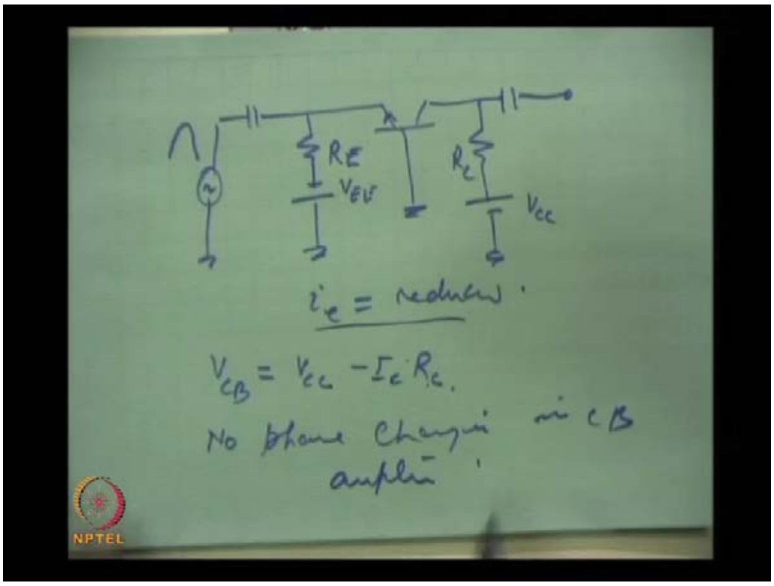
(Refer Slide Time: 51:13)



Then the voltage gain voltage gain voltage gain we will see from here from here the voltage gain is v i that is v here if we neglect the source resistance then v i and v s will be the same otherwise there will send drop across the s and that they are neglecting. So, this will be equal to i e into Z i and Z i is equal to r e prime. So, this is equal to this into i e this is the input input is I will write again input signal input voltage you see input voltage will be i e into r e prime and v out v out will be i c and the collector current which is flowing through the effective resistance r c the output resistance and output resistance effective will be this the current is flowing through this is i c and the two resistances. We have seen output resistance is two is equal to this.

So, output voltage is i c into r c into r c therefore, therefore, the voltage gain is the and this is equal to the i c and the module this is alpha i e they are the same. So, this is alpha i e into r c so alpha i e into r c divided by i e i that is i e into r e prime alpha the current gain is very close to one this we have been talking right from beginning. So, this is one then i e cancel’s with this i so, the voltage gain is equal to r c r e prime which is quite high because r c quite high one or two with 4 kilo ohms and this is few terms of ohm only so gains of 100, 200, 300 are quite possible in this common base circuit there is no phase reversal.

(Refer Slide Time: 54:21)



Because, very quickly I can draw the circuit and show you that why they are would not be a phase reversal very quickly I go through it. Here this circuit this contains ac and dc both. So, both currents will be there. Now then this is positive plus this will reduce this and so, the i e will be reduced i e reduced. Now, if we collect the output voltage V C B here V C B is V C C minus I C R C if this is reduced. So, I C is also reduced this factor will be reduced and this will increase that means the output voltage will also be high at the same point when input is high hence there is no phase change no phase change in input and output in C B amplifier.

To summarize in this amplifier current gain close to one, that means no current gain, voltage gain high, input impedance very low, and output impedance is quite high. The input impedance is low, and that is one single reason that it it finds very few applications; one of the applications is of for matching. If you have to match low impedance at the input, and high impedance of a load; very few situations particularly in high power electronics sometimes you face. Then this C B amplifier can be used - C B amplifier is very useful to understand the fundamentals of transistors, and and the working of the amplifier this we have done earlier, but as far as the practical applications are concern common emitter amplifier is most widely used, and common collector that is emitter follower is also used as a buffer amplifier. The another reason for common emitter is common emitter can be cascaded without any any buffer stages required.