Analog Electronic Circuits
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Lecture no 13
Module no 01
Midband Analysis of CB and CC Amplifiers

We are going to talk about common base and common collector amplifier mid band analysis as usual. The common bass amplifier has the base common to both input and output and the circuit looks like this.

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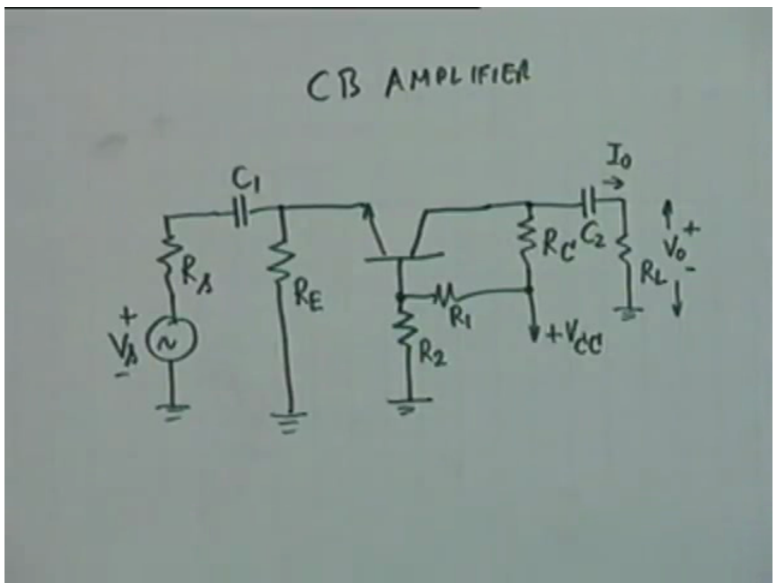

We have the transistor, now you draw in this fashion because the base has to be common alright, the input has to be applied between the emitter and the base in the output is to be taken from the collector to the base but then the collector must be biased so we attach a resistance R sub C intake it to + V CC as usual, this is an NPN transistor. Then the base also has to be biased, the base current has to be supplied so what you do is from the base to ground we connect a resistance R sub 2 and from this junction to V CC we connect a resistance R 1, it is exactly the same way just orientation has been made different. And output has to be taken from the collector so output goes via coupling capacitor C 2 to R sub L and this is my V 0 root mean square voltage the phasor voltage and this is the current I 0 the load current.

Now at the input obviously I have to connect between emitter and base a source I cannot make it short I have to use resistance okay and this resistance cannot be bypassed, why because if it is bypassed then the source the AC signal cannot be applied so you must have a coupling capacitor C 1 and the source the usual story R s and the source is V s, this is my common bass amplifier okay the total circuit. You understand the connection, once you know how to argue what is to be applied where the circuit can be drawn from logical arguments we do not have to commit to memory alright.

Now the biasing as you can see is in the same manner as in the common emitter amplifier except for the fact that if the base is like this, this will cause a feedback and therefore the base now has to be bypassed. You connect a capacitor C sub B so that it does not cause a feedback, if the base is not bypassed then there will be problems with regards to feedback okay, it will affect the gain it will affect the input resistance and everything okay, this is the circuit. Yes...

"Professor–student conversation starts"

Student: I could not get the importance of C B.

Professor: Importance of C B, you see what I want is that the AC signal should be applied between emitter and the base okay and this cannot be done unless R 2 is bypassed, if R 2 is not bypassed then obviously input signal V sub I appears between emitter, base + R 2 which causes a feedback because there is some amount of output which also shall flow through R 2 some amount of output okay, so we have to bypass R 2 now that is why we call this a capacitor C B base bypass capacitor.

"Professor–student conversation ends"

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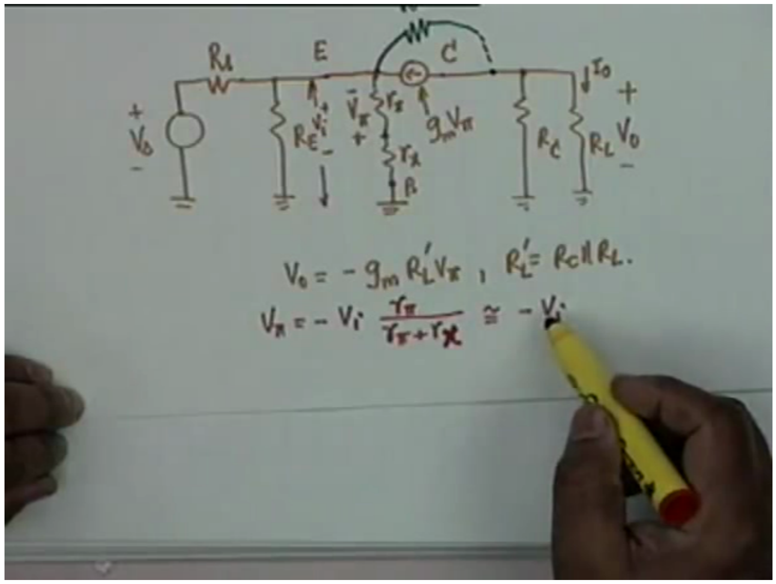

Now to draw the equivalent circuit if you follow the sequence, we have V s, R s, C 1 is a short for midband and therefore I have R E then I have the emitter terminal, the base is grounded here and this is the collector okay. Between the base and emitter you shall have the r x and r Pi and the voltage across r Pi is V Pi with polarity this positive here and negative here, the usual hybrid Pi equivalent circuit we must do it carefully and then this is the internal base and this is the emitter between emitter and internal base is r Pi, this voltage is v Pi. Between the collector and emitter we shall have the current source g m V Pi, from the collector to emitter you must keep the directions the same.

In addition we have this innovative r 0 which I shall show as a dotted connection r 0 and we will assume that r 0 goes to infinity in order that it does not complicate matters. R 0 is of the order of for the example that we have been considering it is 139K and mostly it can be neglected from the collector , then you have the what do you have? You have R C going to ground and the C 2 the coupling capacitor act as a shot and therefore you have R L, this is V 0 and this is I 0 okay, this is the equivalent circuit.

“Professor–student conversation starts”

Student: R 1?

Professor: What happen to R 1? R 1 is connected from V CC which is ground to a point which is ground so R 1 does not affect, neither R 1 nor R 2 affects the AC operation, is that clear we have killed R B the parallel combination of R 1 and R 2 which shows its stick in the common emitter amplifier so prominently okay we have killed it.

"Professor–student conversation ends"

Now this circuit is now to be analysed, as you can see if you ignore r 0 that green part of the circuit then g m V Pi this current source this current lose to the parallel combination of R C and R L and therefore V0 can be immediately written as – g m R L prime, where R L prime = R C parallel R L multiplied by V Pi that must of course be there. But then we have to find out what is V Pi, if you look at the circuit this voltage is V i the input voltage so V Pi can be very simply written as V Pi is the result of potential division of V i between r Pi and R L but we take negative sign because the polarity of V Pi opposes that of v i so V Pi is – V i times r Pi divided by r Pi + r x, and as you know... r x that is correct r x.

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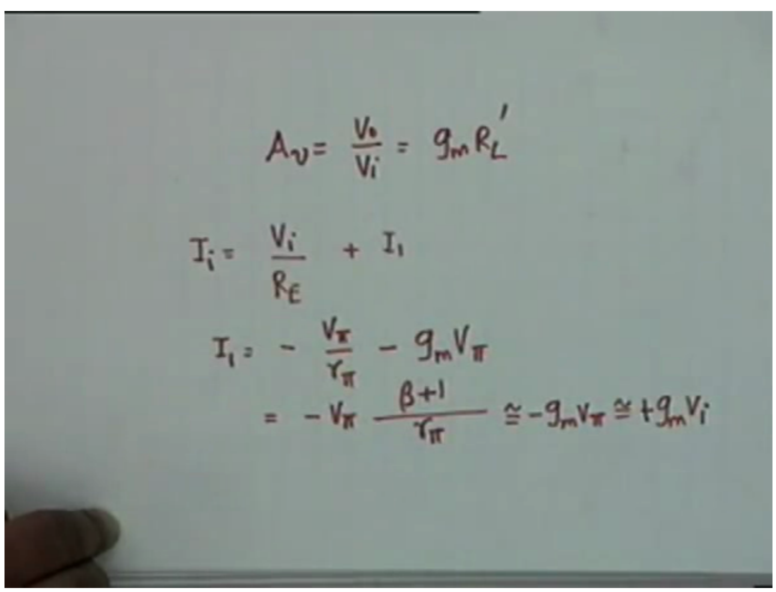

And as you know r x is negligible compared to r Pi so this is approximately = – V i and therefore the voltage gain A v, V Pi if you substitute – V i the voltage gain simply becomes g m times R L prime therefore our expression was simplified to A v which is V 0 by V i = g m R L prime, notice that there is no negative sign here, in the common emitter circuit again the gain was prime of g m

R L prime there is negative sign and therefore V 0 and V i are in phase, this is one of the distinct differences between common emitter and common base amplifier that the output is in phase with the input, this is A v.

Now we want to calculate the input resistance that is the resistance that is faced by the source R sub i, obviously the input resistance shall be the parallel combination of R E, and whatever V i faces alright so if I call this current as I sub i then I sub i and this current as I 1 then I sub i shall be V i by R E + I 1, is that right? I sub i the current fed by the source = V i by R E + I 1, let us see what I 1 is. I did not refer to this circuit, what is the current through this resistance this current, we have taken the polarity as this so this current is V Pi by r Pi this current is V Pi by r Pi alright and r 0 has been ignored.

This current is g m V Pi therefore I 1 is simply = - V Pi by r Pi if I write KCL at the node at this node V Pi by r Pi – g m V Pi, all these 3 currents go towards the node, the sum of them = 0 so I want is this and you can see that this = – V Pi Beta + 1 divided by r Pi right, and since Beta is much larger compared to 1 we can ignore 1 and then Beta by r Pi simply becomes g m so this is approximately = – g m V Pi and since V Pi is approximately = V i, we get this as approximately = + g m V i. Where did you lose the negative sign? V Pi is approximately – V i okay.

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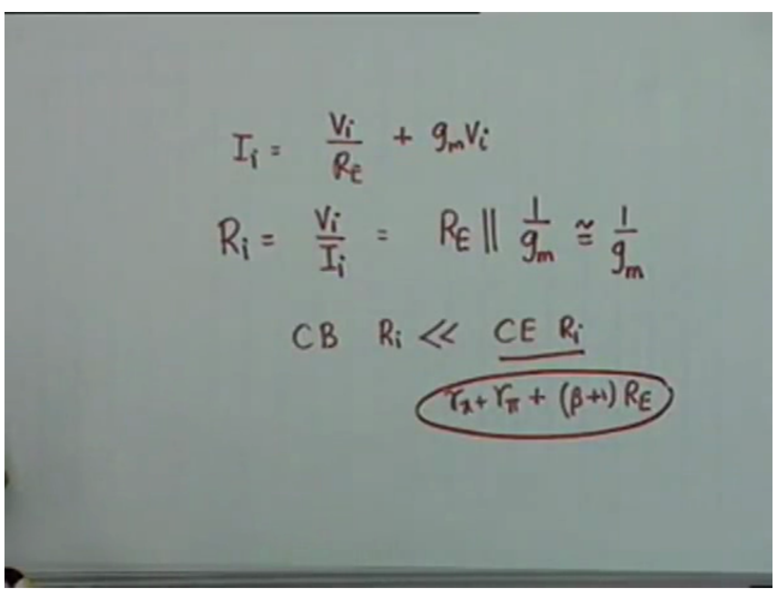

Therefore, my I sub i this equation if I substitute this in this equation I get I sub i as = V i by R i + g m V i alright and therefore R i which is the ratio of V i to I i is simply = the parallel combination of R E and 1 by g m and as you shall see R E is of the order of K or more Whereas 1 by g m is several tens of Ohms for example, if g m is 40 millimhos 39 as we have taken because we took Q by k T as 6 millimho instead of 25. If g m is 40 millimhos then what is 1 by g m, it is only 25 Ohms is not that right? And what is 25 Ohms compared to 1K or what is 1K compared to 25 Ohms, shunting effect so this input resistances is of the order of 1 by g m agreed, because the shunting effect of R E is negligible.

This shows a 2nd difference between a common emitter and common base, in the common emitter amplifier the input impedance is of the order of r Pi alright which is of the order of K. On the other hand in a common base if it is of the order of 1 by g m which is a small resistance so C B input resistance is much less compared to C E input resistance alright, and you know that C E input resistance drastically increases if the emitter resistance is unbypassed if the emitter resistance is unbypassed then CE input impedance becomes r Pi + Beta + 1 times R E, of course you can add r x if you so desire, this is for unbypassed emitter resistance.

Common base circuit has the lowest input impedance of all the 3 configurations, not only CE also CC as you shall see in the common collector circuit this is the order of input impedance, a common collector circuit we shall show this is the order of input impedance and therefore common base circuit has the lowest input impedance. Now if the input impedance is low, what kind of source would be most appropriate; Voltage source or current source? Current source, if it is voltage source then there will be potential division between a low resistance and a lower resistance right, whereas in a current source high input impedance all the current will go into the common base agreed, so CB is more appropriate for a current source drive whereas CE is appropriate for voltage source drive.

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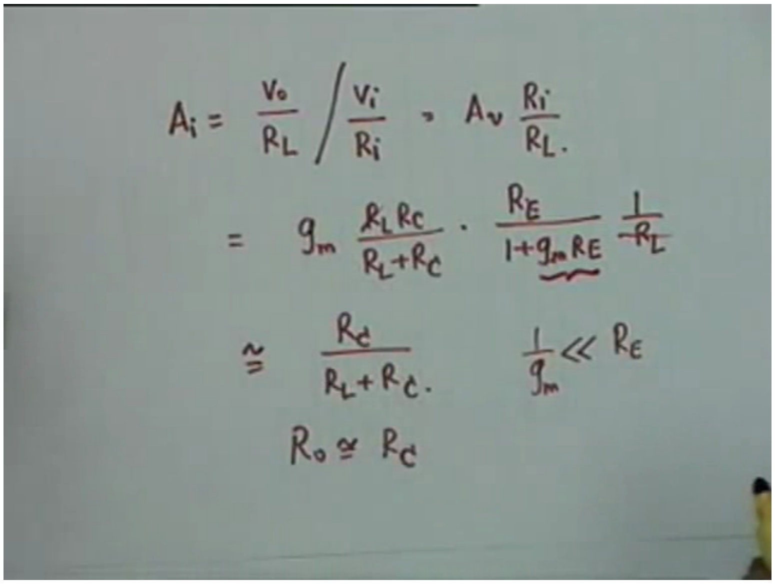

Okay that is the story with regards to input impedance then of course our current gain A sub i as we have already shown V 0 by R L divided by yes V i by R i this is the output current, input current and this = A v because V 0 by V i is the voltage gain multiplied by R i divided by R L. And you can see by substituting, let us substitute A v is g m R L prime, R L prime is R L R C divided by R L + R C, and R i is R E parallel 1 by g m which = R E divided by 1 + g m R E agreed, R i input resistance we have just shown is the parallel combination of R E and 1 by g m.

This is the expression R E into 1 by g m + R E divided by R E + 1 by g m, this is the simplification and you have to divide by R L, so R L and R L cancels, g m R E is usually much greater than 1 and therefore what is left here is 1 by g m agreed. g m R E is much greater than 1 because 1 by g m is much less compared to R E okay, this we have already demonstrated this is much less than R E so g m R E is much greater than 1 and therefore what will be left is approximately R E divided by g m R E. R E, R E cancel g m and g m cancels so this is approximately = R sub C divided by R L + R C that is the current gain is determined by the load and the collector biasing resistance only, it is approximately independent of what the input conditions are okay.

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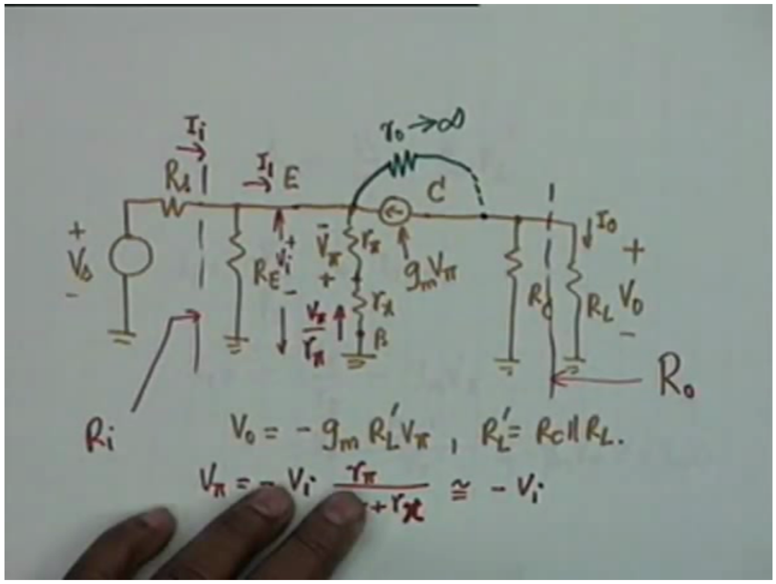

This is I sub i and what would be the output resistance? What is the resistance that is seen by by the load? Does it require any calculation? What I want is this resistance r 0 R C because it is shunted by current source whatever be the value of the current source the impedance internal resistance is infinity and therefore r 0 is approximately R C, why I am saying approximately because of r 0, if r 0 is there then be sure this is not the calculation it will affect the output impedance. So we say output impedance output impedance r 0 is approximately = R C, r 0 is approximately = R C.

"Professor–student conversation starts"

Student: Sir this question (())(19:39) why is the input impedance of a dependent current source also infinity?

Professor: Any current source the input impedance is infinity, the internal resistance is infinity any current source. Any voltage source weather dependent or independent...

Student: Sir physically it is not a current source (())(19:58) and it is proportional to some current which flows in some other part of the circuit.

Professor: No but this current is independent of what we connect across it, the current g m V Pi is not dependent on what you connect across it so it is a current source. Similarly a voltage source delivers its voltage irrespective of what you connect to it that is the definition.

“Professor–student conversation ends”

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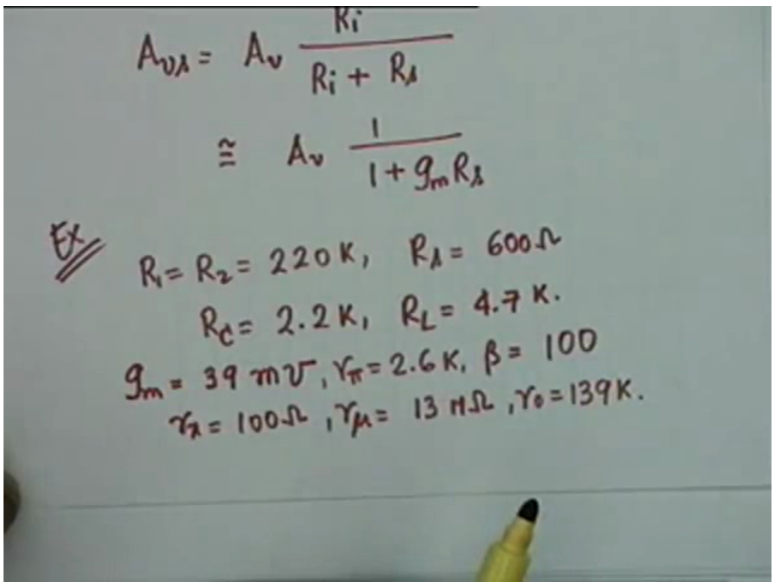

And the other quantity, a quantity which we often find is A vs which is simply A v multiplied by R i B have found that out divided by R i + R s, and naturally this would be approximately since R i is approximately what 1 by g m, this should be A v multiplied by 1 by 1 + g m R s, is that clear? And g m R s normally may be comparable to 1 effect is much larger than 1 then you can ignore the 1 okay. R s has not been specified, R s could be low it could be a good voltage source, if R s is 0 for example, A vs = A v so you cannot make this approximation blindly, R s depends on what your source is, if it is a microphone source then the impedance is usually high, where as if it is a signal taken for a loudspeaker, the internal impedance is only 8 ohms agreed so that completes the that completes the analyses of the CB amplifier.

Now if we use this for calculating the performance of a CB amplifier whose parameters are same as that of the CE that we considered earlier what were the values? We had considered R 1 and R 2, we shall continue the same example again and again, R 1 and R 2 were 220 K, R s was taken as 600 ohms the source resistance, R C the collector biasing resistance was taken as 2.2 k and the load was taken as 4.7 K, the transistor parameters were g m = 39 millimho because I sub C is 1 milliampere and this is 1 milliampere divided by 26 millivolts, then Beta was given so you could calculate r Pi as 2.6 k, Beta the product of the 2 is 100, r x was given as 100 ohms, we did not consider this we could there was no problem in considering r x but it affects very slightly, r Mu we have ignored because it is 30 megh that was the resistance and r 0 was = 130 9K, we have ignored the effect of this also.

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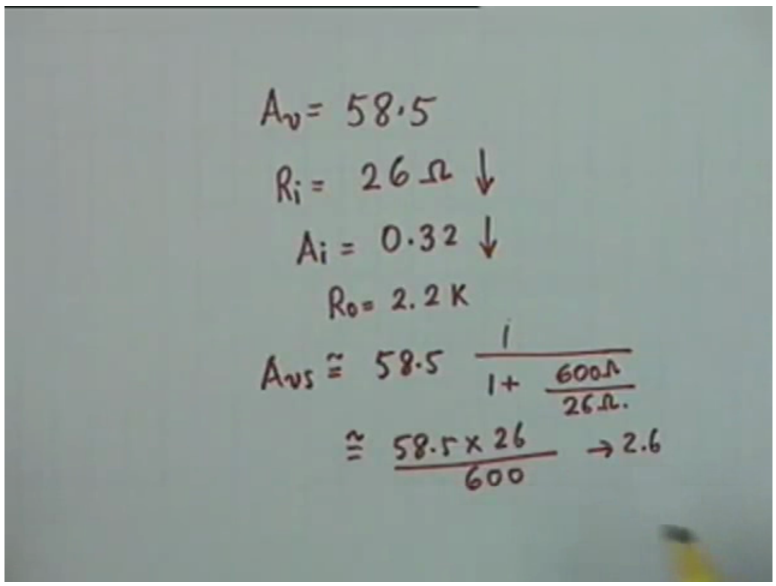

If we substitute these parameters in this calculation then our results are A v is 58.5 which is the same as that of the CE amplifier same no change, R sub i approximately 1 by 39 million ohms and this becomes how much would it be 1 by 39? 26 we have already calculated this, how did you calculate g m.

Student: What is R E?

Professor: Oh we did not specify R E, R E was 1k that is right R E is 1K.

So R i is 26 ohms which is way down, it is much lower as compared to CE amplifier, A sub i the current gain is only 0.32 it is much less than CE case. CE case it was less than Beta but it was in the order of tens; 30 or 31 I do not remember what it was but here it is less than 1 and it can be it can be same it is logical because whatever we are feeding to the emitter the collector current cannot be more than that of the emitter so the current gain shall be less than 1 but it is it is much less than 1 it is 0.32 only and R 0 is 2.2 K, you can calculate what is A vs would be 58.5 multiplied 1 by 1 approximately 1 + R s is 600 ohms and 1 by g m is 26 ohms okay so this is indeed greater than much greater than 1 and you can approximate this as 58.5 into 26 divided by 600, the gain is approximately 2.6 right tends to 2.6 because this is approximately 10. Any questions on this?

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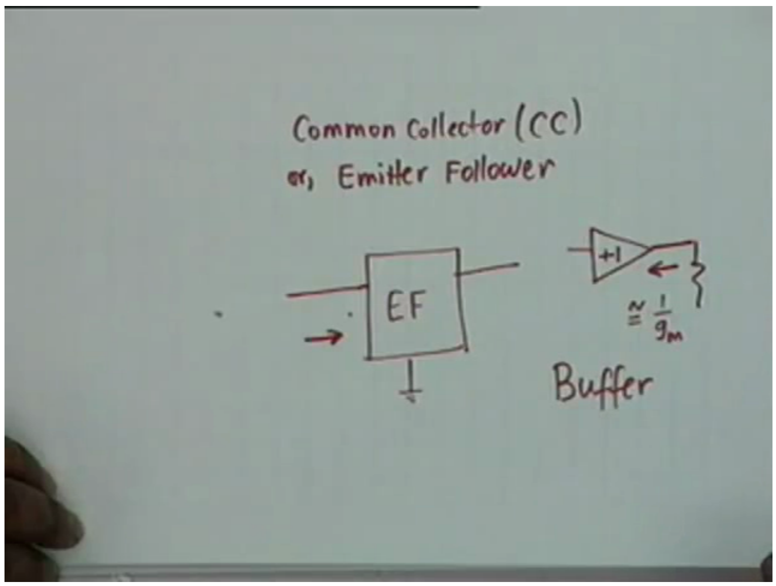

That leads us to the common collector amplifier the 3rd configuration that is possible common collector amplifier CC, it is also called the emitter follower and this terminology emitter follower arises because the output if it is a common collector, collector is common between input and output so where do you fit the input, obviously the base alright and where do you take the output? The emitter. It turns out that the emitter voltage closely follows the base voltage and therefore it is called emitter follower, the voltage at the emitter closely follows the voltage at the base, which immediately says qualitatively that the voltage gain of the circuit shall be approximately 1 okay, it is however always less than 1 it is always less than 1 as we shall show. Now the biasing of the circuit... Yes...

Student: (())(26:55)

Professor: Less than 1 yes because it can be current gain, from base to emitter there is a current gain, it can give power gain, if the current gain is greater than 1 voltage gain is less than 1, the product can be greater than 1 so it can give power gain alright and therefore the circuit is...

But the major use of the circuit let me let me point out write here, if I call this as emitter follower, this is the input and this is the output, the emitter follower has the property that the input impedance is very large and therefore if you connect a voltage source here, the output shall be virtually decoupled from the source okay that is suppose you have an amplifier of gain + 1 agreed , which the emitter follower is and if you apply a source here the output does not interact with the input because the source feeds into high impedance, the output impedance usually is small, in an emitter follower the output impedance is of the order of 1 by g m alright. So what it does is, it converts a no, it isolates the source from the load, you can connect any load here which is much greater than 1 by g m alright.

So the source is isolated from the load and in that sense it is also called a Buffer it is also called a Buffer alright, let me explain why this term Buffer, we shall be using this term again and again in throughout electrical engineering, let see why is it called a Buffer.

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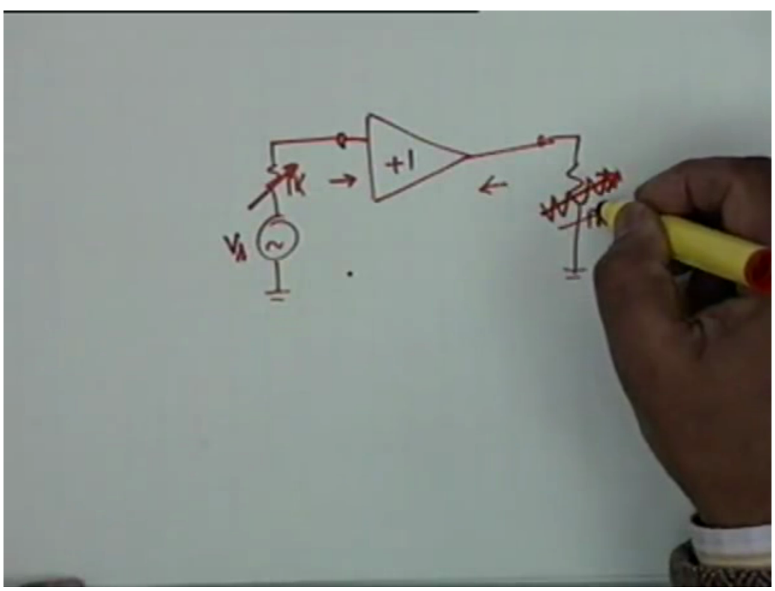

Suppose you have a source of resistance 1K and the load which is also 1K and the load varies no, let the load be constant it does not matter let the load be constant okay. Now if you connect this directly, only half of the voltage will appear here alright and any change that occurs in the source due to any reason will affect the load voltage also. On the other hand, if you apply it to an emitter follower which has a gain of + 1 approximately then the input impedance let us say is 100K, the total voltage here can be transferred over here alright not only that, the load variation will not affect the source, the source variation will not affect the load so this is a buffer circuit, it isolates the load from the source exactly like a transformer.

“Professor–student conversation starts”

Student: Please repeat that.

Professor: It isolates the source from the load that is load changes will not affect the source, source changes do not affect the load.

Student: (())(30:25)

Professor: Suppose the source internal impedance changes from 1K to 990 ohms, because the input impedance is large the voltage that appears here is still the same okay. On the other hand if the load changes here the input impedance because the input voltage does not change, the output voltage also does not change why not if the load changes because the output impedance of this is low of the order of let us say 25 ohms okay. So even if the load changes, the load voltage will remain constant, this would not have happened if this was not there so it is called a buffer, we shall see examples of applications of buffer later.

“Professor–student conversation ends”

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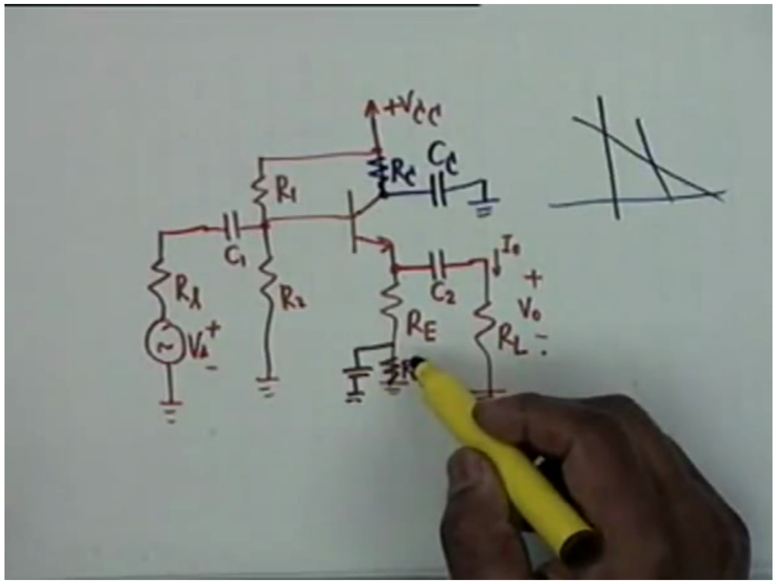

Alright now the circuit, the circuit as same as of the common emitter same as that of the common emitter except that the collector is virtually grounded okay. So what I should have done is I take the V CC directly to the transistor directly to the transistor, I have R E which I can no longer bypass because this is the load and therefore from R E I take the coupling capacitor C 2 and connect to R L, this is my V 0 and this is my I 0. Now the base biasing I do exactly the same manner that is I use 2 resistances R 1 and R 2 connected to ground and the source is applied through a coupling capacitor, source resistance R s and V s, this is my common collector circuit.

I have not reoriented it, I shall have bought this down, turned it upside down, I have not done yet I have drawn it in the same manner that we are used to. I must also mention...

Student: R 1 is connected to V CC.

Professor: R 1 is connected to V CC.

However, in order to get a correct biasing you see now the DC load is simply R E is not that right, DC load is simply R E there is no R sub C, DC load formally was R C + R E, now there is no R E. Suppose in order to bias a transistor at the appropriate Q point you have to use a large R E okay which you do not want to okay because of reasons that you know later you do not want to use because large R E will also affect the AC load, AC load is the parallel combination of R E and R L right AC load is the parallel combination of R E and R L.

Now you do not want to increase R E then what you do is, you do use a resistance R sub C here but in order that it does not behave like a common emitter amplifier, we have also used this as a common emitter amplifier we took 2 voltages; one from here and one from here and this was called paraphase amplifier, 2 voltages of opposite phase. Now in order that R sub C does not develop yes...

“Professor–student conversation starts”

Student: You said I do not want to increase R E because in the AC analysis I do not want R E to be large.

Professor: No, AC load is determined by R E and R L parallel combination and therefore the voltage swing, this is the DC load line and this is the AC load line, voltage swing will be determined by a parallel combination of R E and R L right so I do not want to change R E.

Student: If I change R E then R L might approximate to the AC load.

Professor: See R L is fixed R L is fixed, I may want to decrease the effective AC load because I want a particular voltage swing alright, so if needed I should get hesitate to use R sub C, but we know that R sub C does not affect the AC operation I bypass, where they connect a capacitor? Across R C or from collector to ground, I shall call this C sub c it is collector bypass.

Student: (())(35:23).

Professor: Yes I can do that I can do that but if I have a ground I will connect it to ground, why keep one of the terminals of capacitor charged, make it uncharge.

Student: Sir we can use resistance in the emitter and bypass that.

Professor: We can as well use another resistance in emitter and bypass yes we can do correct. What it says is suppose you use another resistance here and bypass this, if we can do it we can do that also okay that is a good idea. So this is the circuit, as far as AC is concerned this point is at 0 potential.

Student: (())(36:11) in R E.

Professor: Oh instead of R C instead of R C suppose we use a resistance here okay and bypass here alright let me use let may show you. Suppose we use an R sub e prime here and bypass it then the DC load is still R E + R E prime, whereas the AC load is R E parallel R L so this is an alternative.

Student: Effectively we are reducing the value R E for the AC load.

Professor: That is right.

"Professor–student conversation ends"

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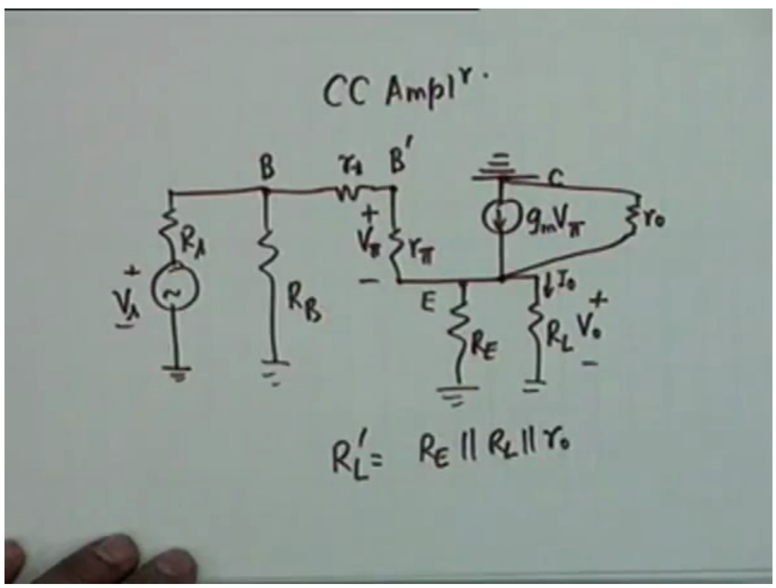

Okay now let us see now let us look at the AC equivalent circuit of the common collector amplifier. We have the R s, V s this you should be able to do by looking at the circuit without any further calculation any further talk, just looking at the circuit it should become a part of your daily life routine. C 1 is a short, R 1 and R 2 come in parallel so that becomes R sub B, R 1 and R 2 in parallel then this goes to r x and r Pi, this r Pi does not go to ground, it goes to R E and also to R L, this is V 0 and this is I 0. This is the internal base B prime, this is the external base B, this is the emitter E, from the collector from the collector we shall have a g m V Pi, a V Pi is this voltage g m V Pi and where does this go? It goes to ground.

In addition we shall have and r 0, let us include this r 0 now because it is easy to do so, do you see how how it is easy? It comes in parallel with R E and R L it can be absorbed. Now my R L prime let me call this as R E parallel R L parallel r 0 okay then by looking at the circuit can we simplify, let me simplify this circuit a little bit.

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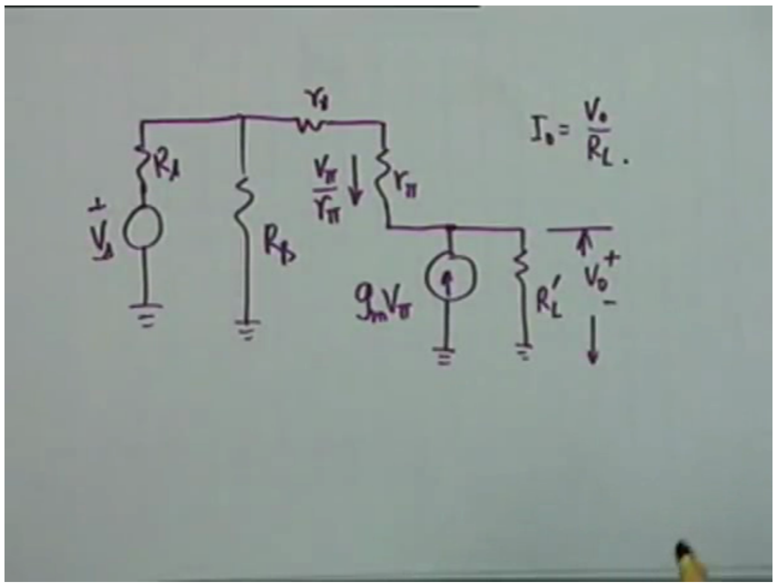

V s this things would be obvious if I do the simplification, the calculation will almost be done by inspection, this is R b then you have r x r Pi, what is the current through this? I b but this is in terms of V Pi it is V Pi by r Pi agreed. Once you recognise this current then there is another current here coming from ground, I have proved that where I am taking ground, this is g m times V Pi, and the effective resistance here is R L prime and this is V 0, I have lost I L though is not it? The load current because I observed R L but no problem, load current is simply V 0 by R L, so I have not lost it I have lost it only in the Picture, I must keep those in my mind V 0 by R L. Now therefore in this simplified Picture one can very easily write the value of V 0, as you see V 0 is the effect of 2 currents coming over here; V Pi by r Pi and g m V Pi these 2 currents can flow through R L prime.

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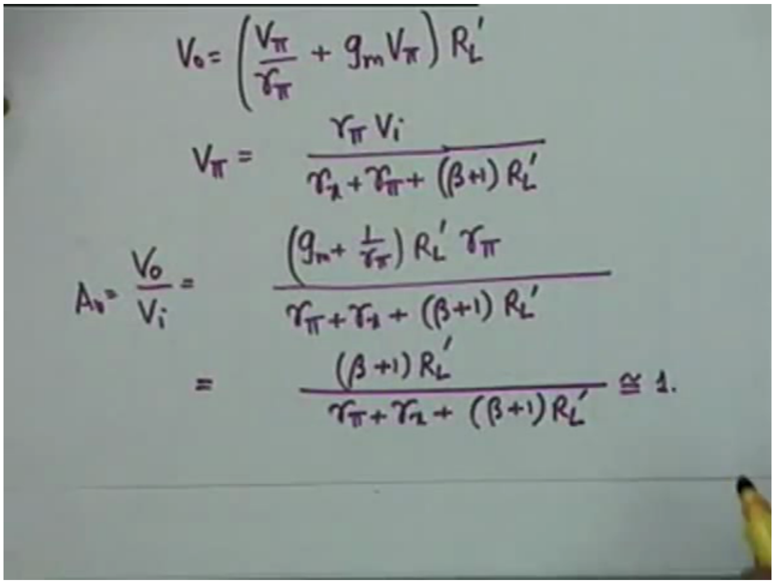

And therefore V 0 is simply V Pi by r Pi + g m... r 0 is included in R L prime… This multiplied by R L prime. Now also require the value of V Pi alright, what is V Pi? V Pi is the voltage across r Pi, this voltage is V Pi, how do you find V Pi. V Pi this is V i, V Pi is the result of the potential division of V i between r x, r Pi and Beta + 1 R L prime, effective voltage here is Beta + 1 times that current multiplied by R L prime is that clear because the current flowing in this is not I B, it is I B + Beta I B so the effective V Pi shall be r Pi V i divided by r x + r Pi + Beta + 1 R L prime, is the point clear? Therefore, V 0 by V i which is A v the voltage gain I can write this as g m + 1 by r Pi which comes from here times R L prime into r Pi divided by r Pi + r x + Beta + 1 R L prime.

And if you notice the numerator when you multiply by r Pi, it simply becomes Beta + 1 so they conspire to make it very nice expression Beta +1 R L prime divided by r Pi + r x + Beta + 1 R L prime. Now Beta + 1 R L prime normally will be much larger than r Pi + r x so this goes approximately = 1 but you must remember it is always less than 1 okay. This calculation also has revealed what the input resistance shall be, is not this absolutely clear what the input resistance is? If you look at the circuit it will be R B in parallel with whatever this phase is, what is the phase? r Pi + r x + Beta + 1 R L prime.

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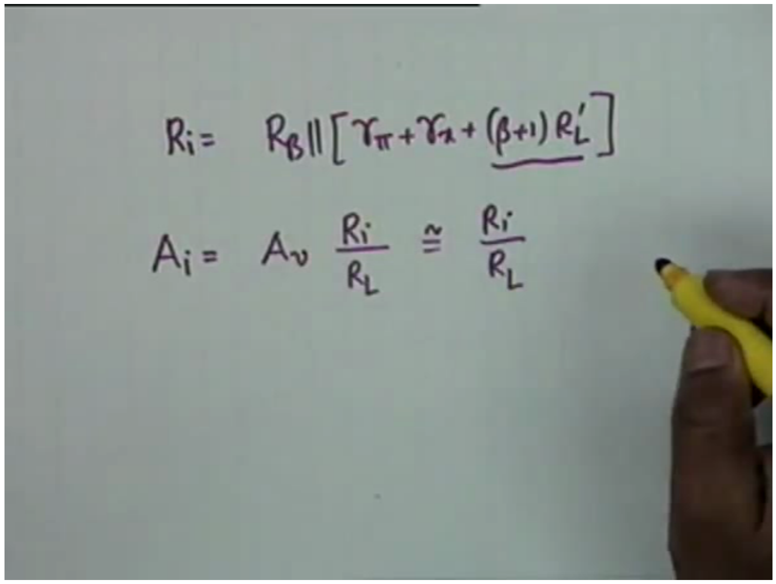

And therefore input resistance I write (())(43:54)without any more ado R B parallel r Pi + r x + Beta + 1 R L prime and you can see why this resistance is very large because of this Beta + 1 R L prime okay, and R B normally is a large resistance 110 was the value for our circuit. Now A sub i, we lost r 0 but not from our mind, A sub i is A v R i divided by R L and it can be calculated, we know the expression for A v, A v is approximately 1 so this is the simply R i divided by R L, can it be greater than 1? A v is approximately 1 so this is approximately R i by R L, it must be greater than 1 because R i is very large compared to R L okay it is much greater than 1 so you can get current gain, you can get power again also.

Now to determine the output resistance of the circuit this is not obvious, if you look at the original circuit what we have to do is to look from here and calculate R C it is not obvious because there is a V Pi, even if we kill V s, V Pi shall be there. Let us follow blindly the procedure; what do we do, we change the input source, connect a source at output to find out the current, let us do that then what do I get.

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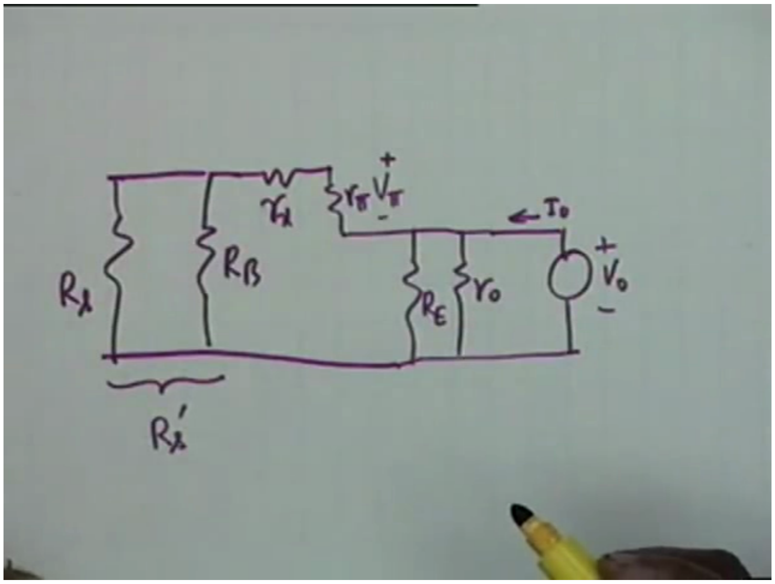

Let us say this source is V 0 and this current is I 0, this will connect to first r 0 it will connect to R L not R L, R L is what see this impedance okay R E, then we have an R Pi the voltage across which is V Pi + - we have an r x this is r x and then we have R B, what else? R s. So one thing we can do is let us parallel these resistors and call them R s prime.

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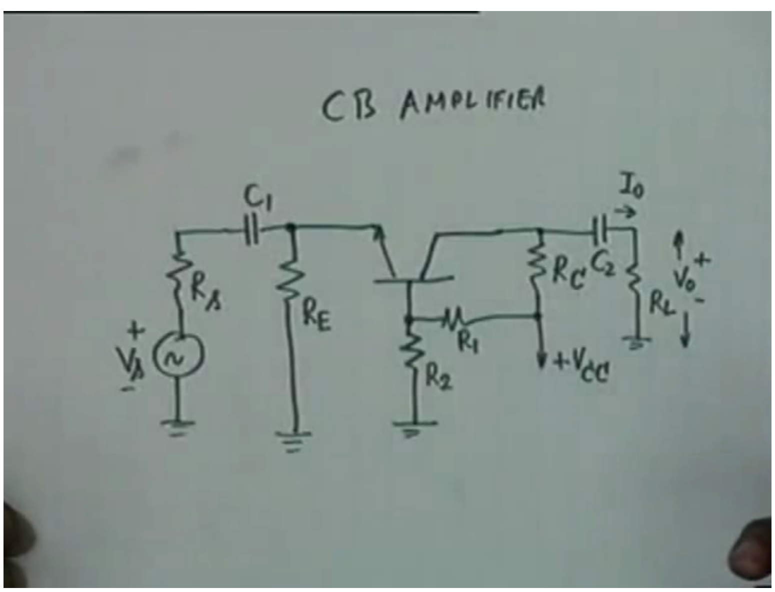

So my simplified circuit becomes V 0, I 0 can I combine these 2 also into an R E prime, R E prime = r 0 parallel R E then I have a r Pi let us write it in this way + - is the polarity alright?

Okay, then we have a resistance R s prime. Now you see even if the source has been killed, V Pi is not killed V Pi is the potential division between r Pi and R s prime.

“Professor–student conversation starts”

Student: (())(47:50)

Professor: Because we want to find out what R L faces what does R L see? What resistance does R L see?

Student: (())(48:11)

Professor: That is right we are finding Thevenin equivalent resistance so we are killing the input source and connecting a source at the outside or the output (())(48:21) okay.

Student: (())(48:24)

Professor: No it did not, R s prime is R s parallel R B okay so can we write the expression for V Pi?

Student: Sir r x...

Professor: Oh r x okay...yes...

Student: What about dependent current source?

Professor: Which current source?

Student: Connected to input... Beta + 1.

Professor: Very good, so we will go back.

Alright I intentionally lose that, there should have been a current source here g m V Pi this should come here okay there should have been a current source here and this should come here agreed g m V Pi this should come here. And if you now calculate if you now calculate I 0, you see I 0 consists of 3 components; one is g m V Pi, one is V 0 by R E prime this current is V0 by R E prime and the 3rd is this component and this component is V Pi by r Pi. So if you write here I

0 would be = g m V Pi - V 0 by R E prime + V Pi by r Pi, is that point clear there are 3 currents and V Pi is related to V 0 how is V Pi related to V 0, it is V 0 multiplied by r Pi divided by r Pi + R s double prime. Is there a "–" sign? Is there a "–" sign? One of our student is saying there should be a "–" sign and I have no alternative but to agree with him. There is a – sign because this polarity does not agree with the polarity of V 0.

So what else do we want to know, I know I 0 in terms of V Pi and I know V Pi in terms of V 0 and therefore I can calculate now V 0 by I 0 and the expression I skip the algebra, is the procedure clear?

Student: No.

Professor: Procedure is not clear, what I do is I right KCL at this point, I 0 = g m V Pi.

Student: + g m V Pi.

Professor: Okay that is right I write I 0 + g m V Pi – V 0 by R E prime then – V Pi by r Pi so I know R 0 in terms of...

Student: + V Pi.

Professor: + V Pi, see this 3 currents are coming so this + this + this – this = 0, what does this equation contain? This contain I 0, V 0, and V Pi, substitute for V Pi for this expression therefore you will be left with an expression containing only I 0 and V 0.

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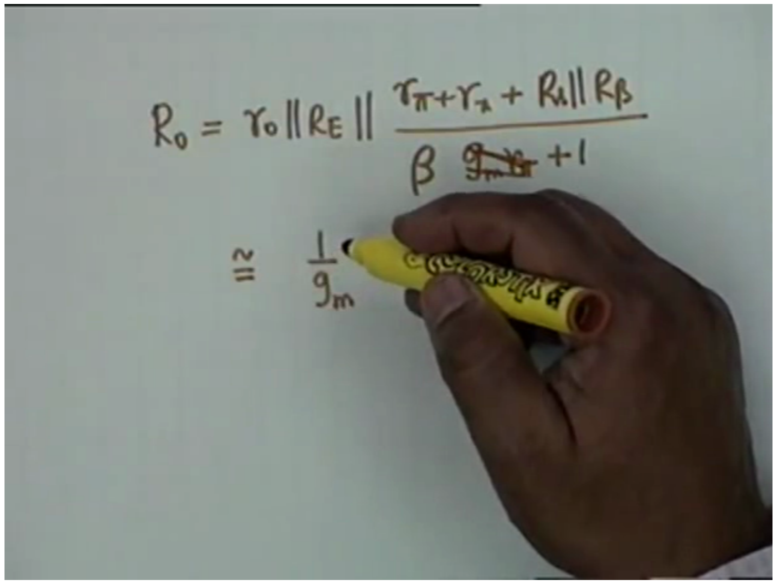

And then R 0 is the output resistance and then you can show that this is r 0 parallel R E parallel which I had called R E prime parallel r Pi + r x + R s parallel R B, we had called this as R s prime and the combination is R s double prime, we are now putting this explicitly divided by g m r Pi + 1 well it is simply Beta + 1 okay we write this as Beta + 1 this is the expression. Now it is not as simple as the calculation of output resistance in the case of CE or CB amplifier, you can show from practical approximation that this is approximately = 1 over g m and the reason is very easy to see.

You see R s parallel RB + r x would be less as compared to r Pi and therefore r Pi by Beta is 1 by g m, 1 by g m is of the order of 25 ohms, R E is of the order of K, r 0 is 139K so this shell out, they do not have any contribution to make and output impedance is approximately 1 by g m which is independent of any external resistance connected for emitter follower has the property that it is high input impedance and a very low output impedance okay, we will stop here