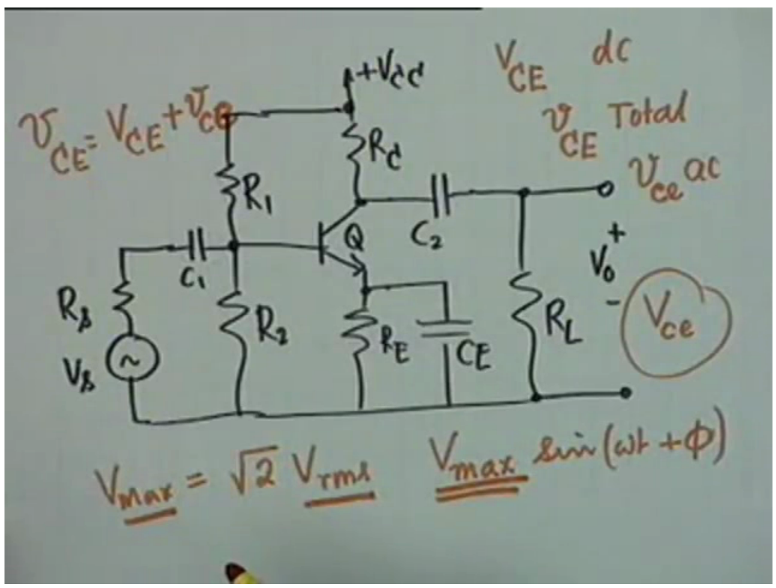
Analog Electronic Circuits
Professor S. C. Dutta Roy
Department of Electrical Engineering
Indian Institute of Technology Delhi
Lecture no 11
Module no 01
Mid-Frequency Analysis of CE and CB Amplifier

This is the 11th lecture and we are going to discuss mid-frequency analysis of the common emitter and common base BJT amplifier.

(Refer Slide Time: 1:19)



The common emitter amplifier circuit is as you very well know by now has an R sub C, R sub E, a bypass capacitor C sub E, coupling capacitor C 2 goes to a load R sub L, the voltage output voltage is measured here capital V subscript 0 I am going to explain this simple in a minute. This goes to + V CC and the base biasing let us consider the usual biasing in which there are 2 resisters R1 and R2, the input signal is applied through a capacitor C 1 from a source whose resistance we indicate as R s and this is the source V s, this is the simple circuit of a common emitter amplifier, the transistor is Q.

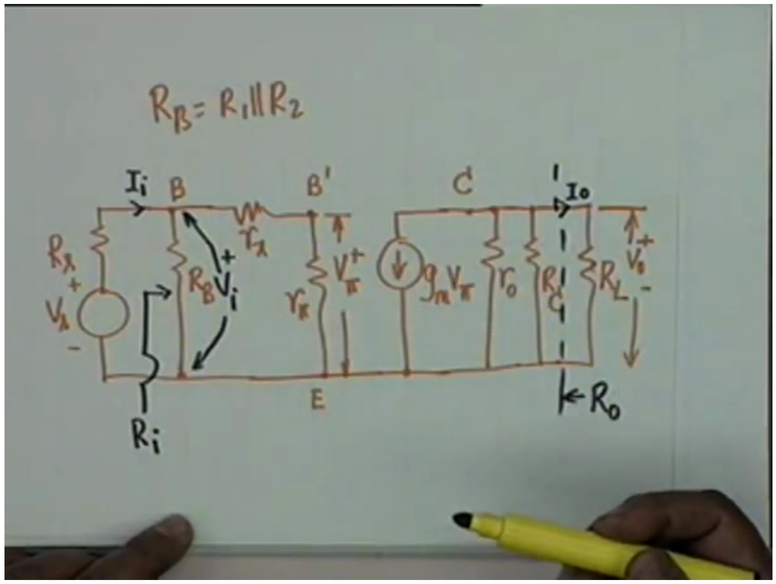
Now we have so far used 3 kinds of symbols; one is let us say any let us say let us say V CE, we have used V subscript CE as the DC voltage from collector to emitter okay, DC voltage. We have also used the symbol small v subscript CE as the total voltage across the collector to emitter terminals total voltage. And the symbol V sub c as the incremental part or the signal part or the AC part which means that capital V sub CE = v subscript CE + - or +? – okay. What is use to us v CE = V CE the DC part + v ce this is the symbol that we have used that is correct small e, please do correct me v ce alright, now I am going to use another symbol.

Now I am going to use another symbol, the only thing that is reserved up till now is capital V subscript ce this is the only thing that is reserved, I have used all of the combinations, but it must be clear that throughout the course this is the symbol that we are going to use. Now our signals will mostly be sinusoidal signals alright in the amplifier analysis whenever we are considering a linear circuit, our single will be AC either a pure sinusoidal or a combination of sinusoid. For example, if it is an audio amplifier it is sinusoid starting from about 16 Hertz to approximately 16 kilohertz so our signals are mostly AC sinusoidal signals which as you know a voltage an AC voltage is described by maximum value time Sin of mega t + maybe some phase Phi, where this is the maximum voltage okay.

And you know that maximum is root 2 times V max is root 2 times V rms okay, and that for AC analysis we can use a so-called phasors alright. Now the phasors that we shall use in the context of this analysis would be either the root mean square voltage or the maximum voltage. So long as we are consistent that is if our phasors if the voltage phasor is the RMS value, if the voltage phasor magnitude = the RMS value then all other voltages and all currents in the phasor diagram shall be RMS value otherwise they will all be maximum values okay. So we shall use this symbol of the phasor alright, capital V subscript ce will be the voltage developed from collector to emitter, the AC voltage or the signal voltage it is which is represented by the phasor V ce is that okay, this is the symbol that we shall use throughout.

Whenever we like capital I subscript small c, we mean a phasor corresponding to the AC voltage okay, so in equivalent circuits for example we shall use this particular symbol okay. Now since we are making an AC analysis or signal analysis, we can replace this by an equivalent circuit with the transistor replaced by its hybrid Pi equivalent circuit. And since we are considering mid frequencies, all external capacitor C 1, C 2, C E shall act as short circuit and all internal capacitors like C Pi, C Mu and C 0 will act as open circuit, therefore our equivalent circuit would basically be resistive circuit.

(Refer Slide Time: 7:37)



Let us draw this carefully, we start from the source R sub s, now we are using this symbol V s to represent the phasor corresponding to the signal and this phasor can be as I said either the RMS value or the maximum value but you must be consistent okay. Then the capacitor C 1 is a short, the parallel combination R 2 and R 1 shall come in parallel as far as AC is concerned so we combine them into a single resistance R sub B, R sub B = R 1 parallel R 2, usually a large quantity compared to what it faces. Now this is the external base B, from the external base to the internal base as you know there is a small resistance r x and from internal base to the emitter terminal there is a resistance r sub Pi, the voltage across we denote by V Pi, now this capital V represents the phasor voltage okay, the phasor voltage across r Pi.

Then we have a current generator which I can represent either in terms of Beta or in terms of g m so we represent this we find it convenient to work in terms of g m because g m can be calculated from the Q point it is 40 times I sub C in I sub C expressed in milliamps okay, so it is g m V Pi and then we shall have from the collector this is the collector terminal, from the collector to the emitter we shall have the early resistance r sub 0 which is usually a very large value large resistance and then we have the biasing resistance R sub C, C 2 act as a short-circuit and therefore R L comes in parallel, this is the resistance of load resistance R L and it is this voltage V 0 that we are interested in, V 0 also corresponds to the phasor value of the output voltage.

Now mostly what we shall be concerned with is the gain, V 0 divided by V s alright the voltage gain or the current game, we can take the current through the load on our output and the current supplied as the input I sub i, then current gain would be I 0 divided by I sub i, these are also phasor quantities. Or we could have been interested in the input impedance faced by this source, we shall call this as R sub i, input impedance faced by the source or the output impedance faced by the load that is from the load end what is the impedance that it faces, we shall call this as R 0 okay. R i obviously is, if this voltage is called V i once again a phasor if this voltage is V i then R i is obviously V i divided by I sub i.

Output resistance however cannot be calculated like this because there is a source here, for calculation of output resistance you must connect a source here and find out the current that goes into the circuit, we shall see how to do this a little later, but you realise that all quantities that you are interested in is a ratio of 1 phasor to another, if it is a gain then you say voltage phasor by voltage phasor, if it is input impedance then say voltage phasor divided by current phasor and therefore whether you take the maximum value of the root mean square value it does not matter, root 2 and root 2 cancel out. That advantage of phasor is that it takes account of the magnitude and also the phase and therefore we shall be in in. One thing that you want to do one thing that have you ignored in this circuit?

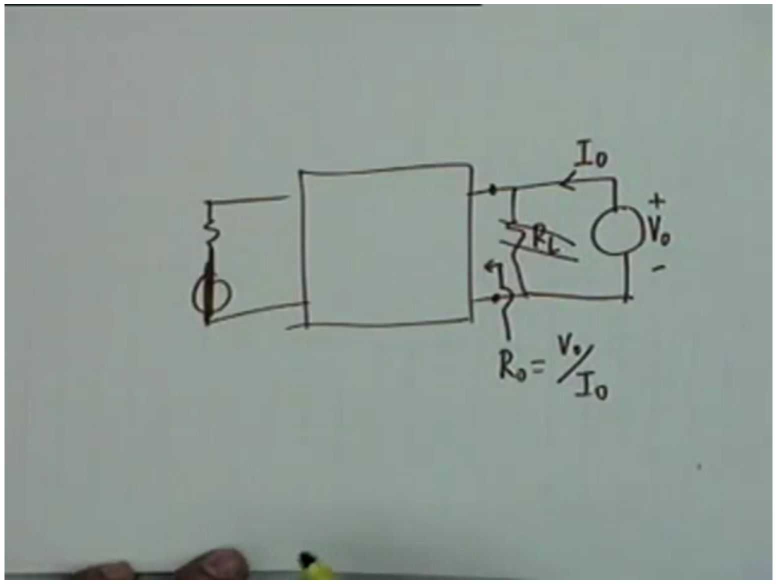
Student: R Mu.

R Mu we have ignored, usually r Mu is a very large quantity and therefore we are justified when we are ignoring this, we will show this by means of a dotted diagram r Mu. If r Mu is there then you see to solve or to analyse the circuit we have to write 3 node equations, one is here one is here and other is here, 3 node equations and you have to solve them okay, we have to invert a 3 by 3 matrix, 3 node equations will mean there will be a coefficient matrix whose dimension is 3 by 3, we have to invert a 3 by 3 matrix to find out these voltages. On the other hand if r Mu is not there, analyses can be done almost by inspection and this is what an engineer desires, by looking at the circuit you should be able to write down the gain and other things, let us see how to do this analysis.

Student: Sir, can you just repeat how you find output impedance?

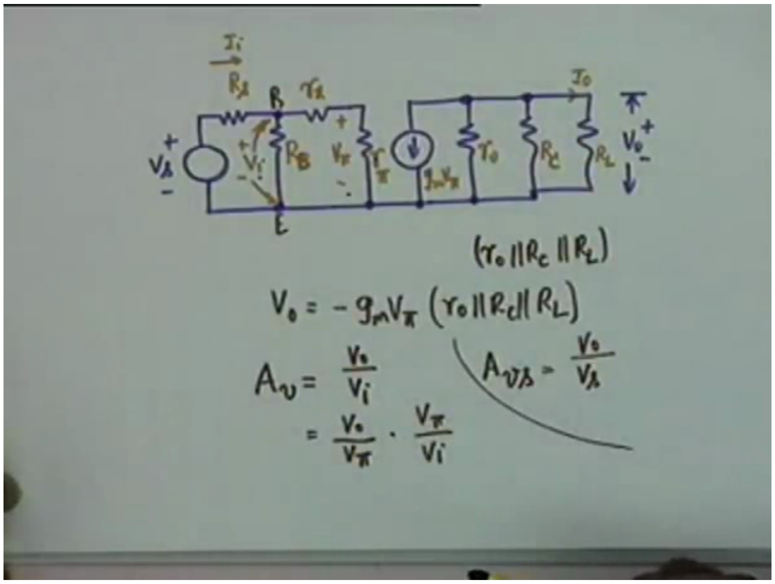
Professor: How we found out the impedance okay.

(Refer Slide Time: 13:22)



Given a circuit any circuit amplifier or otherwise, which is connected to a source and to load, if I want to if I want to find output impedance what I will do is, output impedance is the impedance seen by the load okay so what I do is I 1st disconnect this R L and I connect a source here, let us call this as V o some voltage source V o and find out this current I sub o by short-circuiting the input source, input source should not be there, it should be short-circuiting, if it is a current source you open circuit the source. So you find out I 0 in response to V 0 and output impedance will be V 0 divided by I 0, we shall calculate this from the amplifier circuit that we have just drawn.

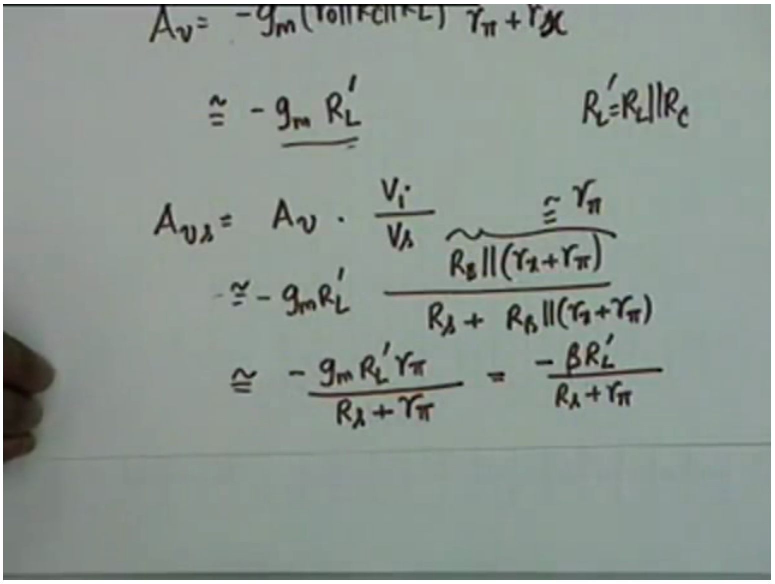
(Refer Slide Time: 14:30)



Now, as far as the gain is concerned this is same circuit, what I do is I 1st notice that the voltage V 0, these 3 resisters are in parallel so I could replace them by a single resistor, single resistor of value r 0 parallel R C parallel R L. No, but before that okay you notice that if I replace this by a single resistance, I lose I 0 is not that right, the identity I 0 is lost but V 0 is not loss, how is V 0 produced? This current passes like this through this single resistance and therefore I can immediately write V 0 = - because the current and this voltage they do not agree with each other so – g m V Pi times this equivalent resistance r 0 parallel R C parallel R L alright.

Then the thing that remains to be found out is V Pi in terms of, now I can define 2 gains; one is I shall define A v as V 0 divided by V i, V i is the actual voltage that is connected from the base to emitter, actual voltage that appears from base to the emitter, this is one gain and the other gain I will define as A vs that is the output voltage divided by the actual source voltage V s there are 2 voltage gains. And if you know if you know how to calculate 1, it is very easy to calculate the other, we shall show this but what I need is if I want to calculate A v but what I need is I have an expression for V 0 by V Pi so all I need is V Pi divided by V i and do not you see by inspection that V Pi = V i multiplied by r Pi over r Pi + r x, it is a simple potential division.

(Refer Slide Time: 18:51)

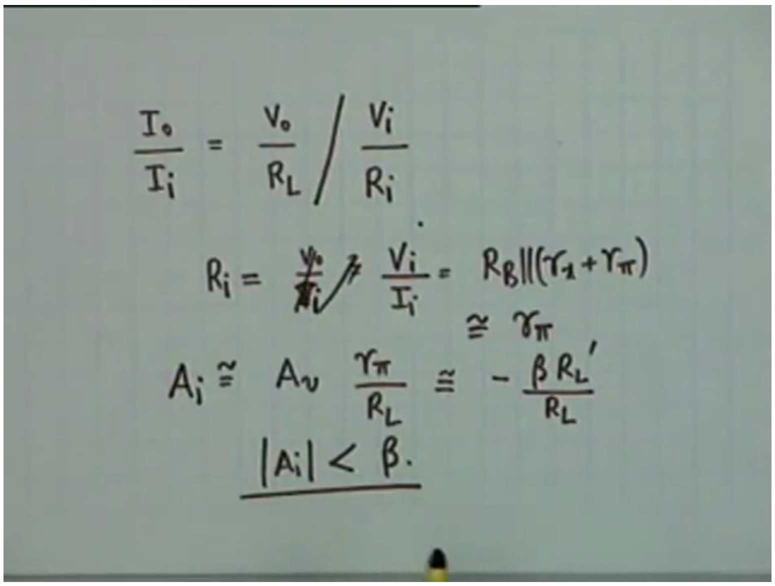


Therefore, my gain becomes A sub v becomes = - g m times r 0 parallel R C parallel R L multiplied by r Pi divided by r Pi + r x alright. And you also know that R 0 is usually of the order of Mega and R C and R L are of the order of Kilo and therefore the parallel combination of r 0, R C and R L will be approximately the same as g m R L prime, where R L prime = R L parallel R C, I have written the approximation sign and we also know that r x is of the order of 100 ohms and r Pi is of the order of kilo and therefore we can ignore this also and therefore the gain simply becomes – g m R L prime. By looking at the circuit we did not write the root equation, we did not write the node equation, we did not invert any matrix, I calculated this only by inspection okay this is an...

Now if I want to find out A vs then all I need is A v is to be multiplied by V i divided by V s and therefore this will be – g m R L prime, now V i by V s if you again look at the circuit it is also potential division, not R B by, R B comes in parallel r x + r Pi that divided by r x + this equivalent okay. So it would be R B parallel r x + r Pi divided by R s + R B parallel r x + r Pi alright. And a very good engineering approximation would be R B usually is a very large quantity compared to r x + r Pi is of the order of 10s of K, 34k was the value in our previous example, r x is a small quantity so this whole thing can be replaced by r Pi, approximately = r Pi and therefore my gain becomes approximately, this is also an approximation – g m R L prime times r Pi divided by R s + r Pi.

And you know that the product of g m and r Pi is simply beta and therefore this = – beta R L prime divided by R s + r Pi, also by inspection the 2 gains. As far as the current gain is concern what we do is, any equation on this? No.

(Refer Slide Time: 20:04)



Current gain is very simple, I 0 by I sub i is simply V 0 by R L divided by I sub i is yes V i over R i the input resistance. Now input resistance as you can see from the circuit let us go back to the circuit, the input resistance is simply the parallel combination of R B and r x + r Pi okay, so I get V 0 divided by V i multiplied by R i... Pardon me...

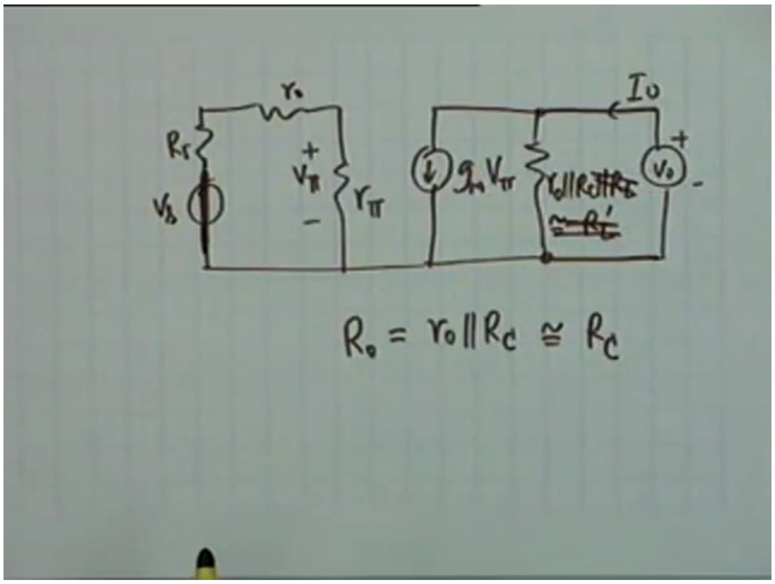
Student: V 0 divided by I i.

V 0 divided by I sub i yes that = let me write it correctly... V i divided by I sub i okay that = R B parallel r x + r Pi and this is approximately = r Pi and therefore I 0 by I i, which I shall write as A i, the current gain would be = A v V 0 by V i multiplied by R i divided by R L, which = r Pi divided by R L, this is approximately the current gain. It can be it is very easy to see that this is approximately = – is there a '–' sign okay, this is – no A v is minus, okay that is how it comes, then if you substitute for A v what is Av? – g m R L prime and g m and r Pi make a Beta and therefore this is approximately – Beta R L prime divided by R L. Which one is greater R L prime or R L?

Student: R L

R L and therefore A i the current amplification factor is now less than Beta, the short-circuit value = Beta, Beta is the short-circuit current amplification factor, whenever there is a load the current amplification factor will be less alright. Finally we go to the output resistance, let us see how to calculate the output resistance.

(Refer Slide Time: 22:59)

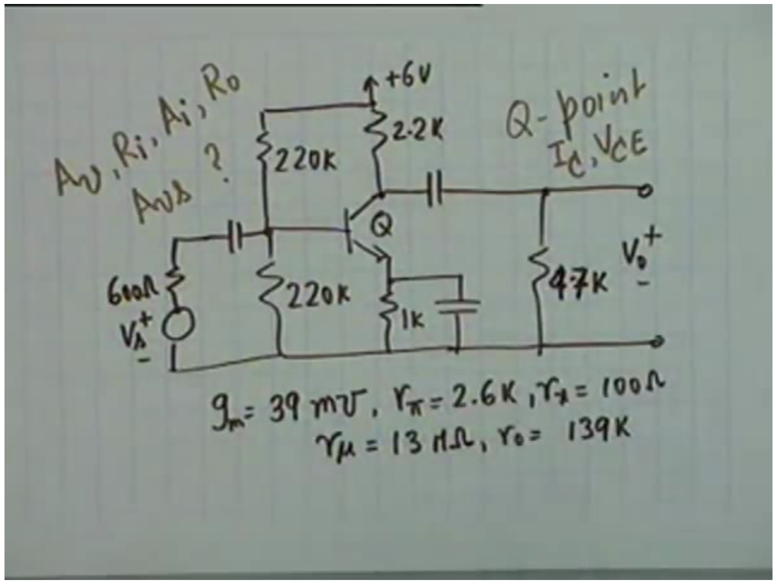


Well, what we have is let me draw the circuit quickly, R s then you have r x, r Pi, g m V Pi and then you have this parallel combination of... let me combine this into a single resistance, R 0 parallel R C parallel R L, which is approximately = R L prime, can I do that? No I cannot...

Student: Sir we have to find out output resistance, which is separate...

Which is faced by R L alright so I cannot combine, I simply combine R 0 and R C, for finding the output resistance, output resistance is the resistance faced by the load, so you must couple the load, load is taken of a voltage source V 0 is applied here and the current I 0 is to be found out after short-circuiting V s. If we do that then what is V Pi, if I short-circuit this, V Pi obviously shall be 0 agreed, so the current generator shall give a 0 current and therefore R 0 by inspection therefore = r 0 parallel R C, which is approximately = R C that is the output resistance, let us take an example, any questions on this? Let us take an example, a practical example.

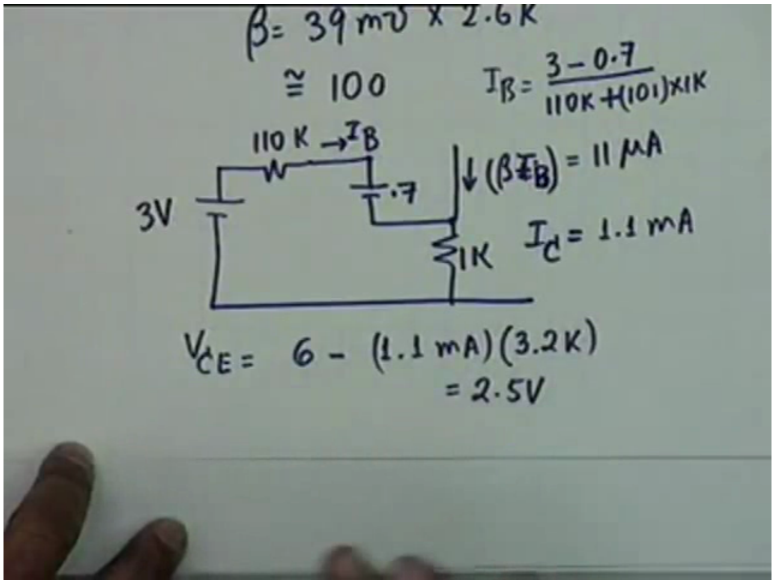
(Refer Slide Time: 24:40)



A transistor which has a 1K, a bypass capacitor, 6 volt source, a 2.2K R sub c, a coupling capacitor, load is also 4.7k, this is my V 0 and I have the base biasing is done by 2 resistors of equal value 220k and 220k, then I have a capacitor, a source of resistance 600 ohms voltage source therefore resistance should be low and a signal source V s, this is the transistor Q. And what are given are the parameters are given g m is given as 39 mV, what is the collector current? I should see approximately 1 milliampere, it is slightly more because of that 26 factor. Okay, g m is given, r Pi is given as 2.6K r Pi is given, r x is given 100 ohms, r Mu is given as 13 Megh we ignore this, r 0 is given as 139K we ignore that also it is very large 139K.

The capacitors are short, you are required to find out 1st of all the Q-point, which means that you are required to find out I sub C and V CE okay and then all these gains A sub v the voltage gain, the input resistance R sub i, the current gain A sub i and let us say the output resistance R 0 and also A vs, these are the quantities to be found out for this particular circuit. The 1st thing that you have to find out is Q-point okay let us find out the Q-point yes. Question... No. As far as Q-point is concerned, our procedure is very simple, our V BB, we 1st find the I B the base current and then multiply this by Beta so you have to find out the beta 1st, what is Beta?

(Refer Slide Time: 28:02)



Beta is 39 millivolts multiplied by 2.6 K and this comes out approximately as 100, so we are going to find out I B our V BB is 3 volts agreed and R sub B is 110 K, then there is a voltage drop from base to emitter of value 0.7 alright then this goes to R E, which is 1K alright the current that comes here is how much? I sub C which is approximately same as I sub E, it is Beta I B it is Beta I B okay and this current is I B I have made a mistake, can you tell me what the mistake is? (())(29:12) I am making DC analyses, this symbol must be capital B, capital I sub capital B this is capital B alright this is what we have.

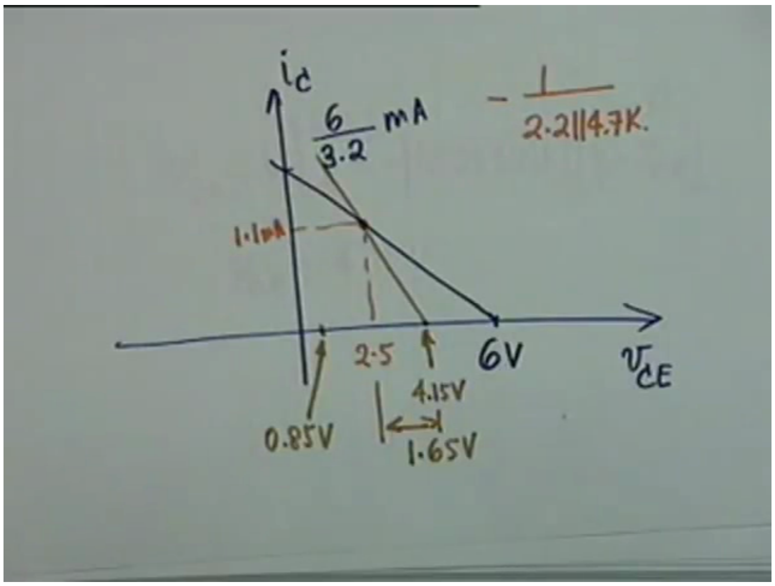
Student: How do we know that emitter resistance is 1K?

Professor: This value is given, this value is given as 1K you did not note it alright.

Therefore my I sub B now it should not require with a little bit of experience it should not require drawing of this equivalent circuit, you should be able to do it by inspection. I sub B is simply 3 V BB – 0.7 divided by the total resistance in the circuit, the total resistance is 110K + 110 multiplied by 1K is that clear, because current in this is not I B, it is Beta + 1 I B. Now if I calculate this, it comes out as 11 micro ampere and therefore my I sub C the collector current would be Beta times this which = 1.1 milliampere and if I know the collector current then I know V CE

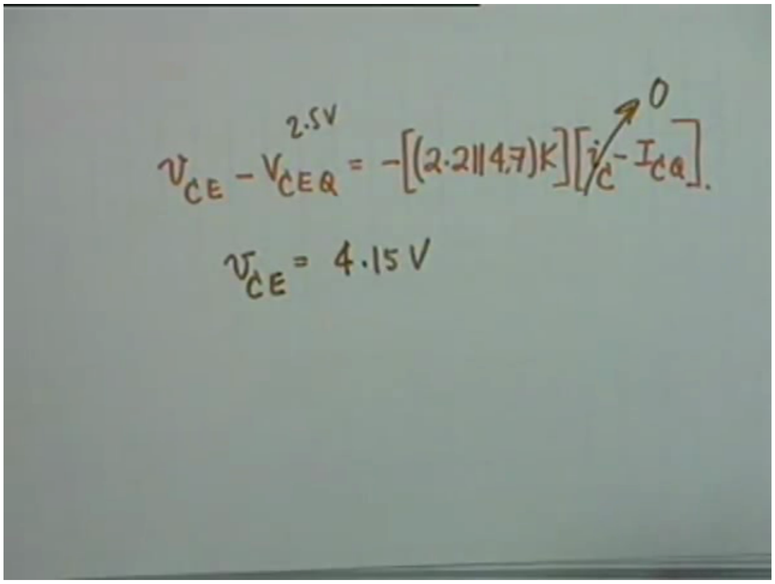
Let us not make a mistake, V CE would be 6 volts – the drop in 2.2K and 1K and this drop and the currents are approximately equal, so I multiply 1.1 milliampere by 3.2K and this comes out as 2.5 volts, this is perfectly okay now we can go ahead with the calculation of the gain and input and output resistances, but let us look at this point of time whether this is a good amplifier or not, whether this is a good Q point or not okay, how to judge this?

(Refer Slide Time: 31:40)



To judge this we take the characteristics i sub C, v sub CE and our DC load line is something like this, starts at what value? 6 volts and ends at 6 divided by 3.2 so many milliampere this is the load line. And the Q point is somewhere here Q point has 2.5 volts so it is somewhere here, this is 2.5 and the current is 1.1 milliampere, this is the Q point, we have to judge whether this is a good Q point or not. Now to judge this we require to draw first the AC load line and the AC load line will have a slope of - 1 by R C parallel R L which is 2.2 parallel 4.7K, what does this mean?

(Refer Slide Time: 33:29)

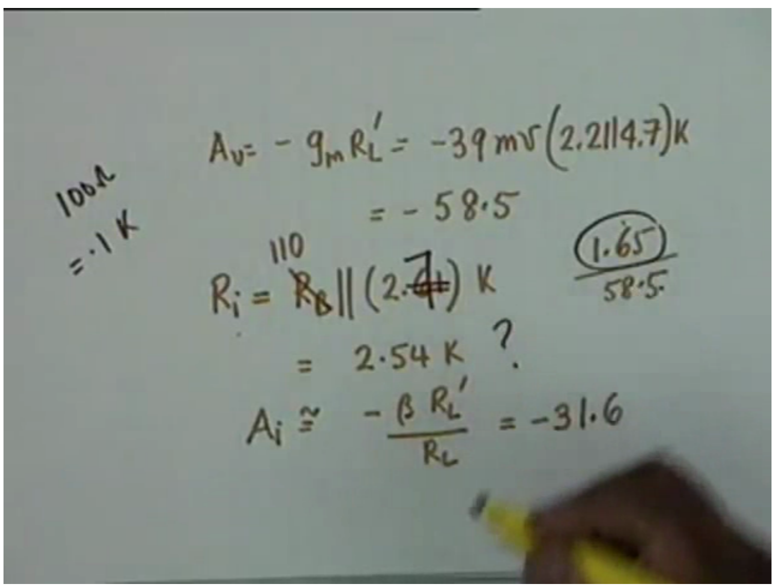


It means you know the AC load line is the plots of this characteristics, v sub CE – V CEQ = - 2.2 parallel 4.7K multiplied by small i capital C – I CQ alright, to be able to draw the load line AC load line it is sufficient to draw a line through the Q point with this slope it is sufficient, is not this right? Now let us see where this load line touches the, let us see where it touches this this line, we have to find this to judge whether it is a good amplifier or not, let us see where it touches. At this point what is the value of the total collector current? It is 0 so this point will be determined by if you put th= 0 then you can show by putting the values numerical values that v CE comes as 2.5 + this quantity, this comes as 4.15 volts alright. This calculation is numerical, you put V CEQ as = 2.5 volt and I CQ a 1.1 milliampere alright, I am skipping this numerical calculation.

But what it means is the following that this voltage this point is 4.15 volts so what is the swing that is permitted? 4.15 – 2.5 which is 1.65 volts that is that enough this is swing on the right side, what about the left side? If I go 1.65 volts here where do we touch? 0.85V is this a good point? Suppose it went to 0.2 then we would have been worried because that the swing would be limited, but 0.85 is okay it is as far away from saturation and therefore this is a good operating point and it will be a good amplifier, good amplifier with a swing of 1.65 volts on either sides, which means that the maximum AC signal that you can get out of the amplifier is 1.65 Volts peak value the root mean square value of would be 1.65 divided by root 2 is that okay?

Now if you now find the gain if you now find the voltage gain then you know what can be the maximum driving signal, is that point clear? Output swing permitted is 1.65 so if you divide this by the gain of the amplifier then you will know what is the maximum swing of the input AC, if you drive the transistor beyond this then it will go to cut off on one side alright, and if you drive further that you go to saturation on the other side, is that clear? Okay, let us calculate the gains now. This I thought I had given a pictorial representation and clarification of the AC load line. DC load line and AC load line are 2 very important characteristics of an amplifier, once this diagram is can be drawn from almost everything else will be clear, you will know what amount of AC signal can you put at the input alright.

(Refer Slide Time: 37:19)



So now let us calculate the gain, now it is the matter of applying the formula or you can draw the hybrid Pi equivalent circuit and do things for inspection. Here A sub v which is – gm R L time would be = – 39 millivolts multiplied by 2.2 parallel 4.7K and this comes out as - 58.5. And therefore you know the maximum V sub I capital V subscript I that can be applied, this is not the source voltage because the source has a 600 Ohms resistance, a source voltage may be higher, the maximum V I would therefore be peak value 1.65 divided by 58.5, this is the maximum signal maximum peak signal that you can apply to the input okay A sub i.

R sub i the input resistance is simply R B which was 110 K parallel r x + r Pi how much is that? 2.6 kilo is r Pi and 100 Ohms is r x so it is 2.61 even if you want to take r X into account, R B is

110 so many kilos and this comes out as very nearly 2.6 that is 2.54 K. Ignoring R B would not have cause much of a deviation, it is only 2.54 so 0.07 into 60 is less than 3 percent alright, this is R i. A sub i which is – Beta R L prime divided by R L approximately this comes out as - 31.6 Beta was 100, so it is approximately one third you lose in current amplification, you are asking for voltage amplification so you lose in current amplification okay yes.

"Professor–student conversation starts"

Student: How about the voltage gain if we figure out what input voltage did we apply?

Professor: If I know the output voltage, output voltage peak value is 1.65, I divide by the gain so this gives you the input voltage, what is the definition of gain? Output divided by...

Student: 1.65 and the voltage...

Professor: That is right peak value that we found out from the AC load line okay, so the peak input that you can apply from base to emitter is not the source voltage from base to emitter agreed? It is not the source voltage because source has a resistance of 600 Ohms, so voltage will be higher than this that also you can calculate.

Student: R x is 110?

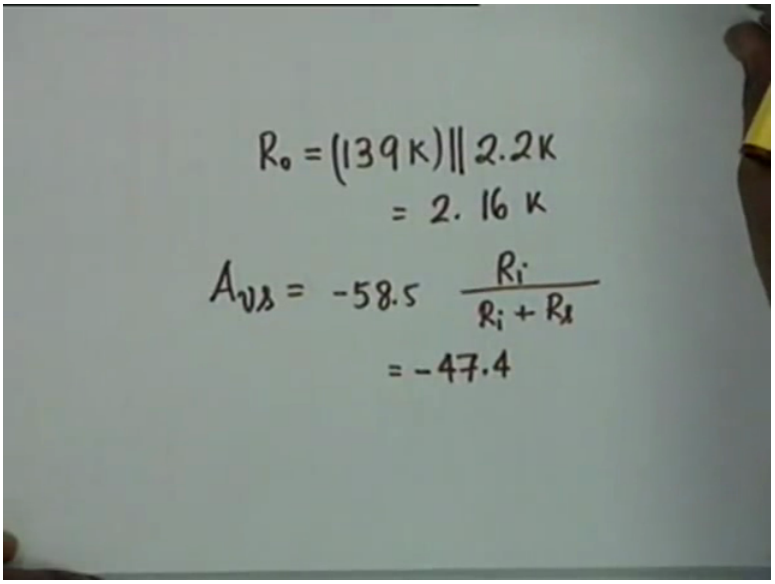
Professor: R x is 100 ohms.

Student: R x + r Pi is 2.7.

Professor: No, 100 Ohms is 0.1 kilo and this is 2.6 oh okay alright, I made a mistake, sorry about it this will be 2.7 so you can correct this, thank you for pointing this out I had made a mistake.

"Professor–student conversation ends"

(Refer Slide Time: 40:53)



Alright what remains to be found out is R 0, is you know R 0 is the parallel combination of small R 0 here given as 139K, if the figure is given you sit and show that it is negligible. This is parallel to what should I parallel with? 2.2K and this comes out as 2.16K, it is not very different from 2.2K, we could have safely neglected this. And A vs what do you think this would be? Would it be greater than A v or less than A v? It would be less because there is a potential division between R s and R i okay, this would be A v – 58.5 multiplied by R i divided by R i + R s, we have found out Ri , R s is given as 600 Ohms and this comes out as – 47.4. You of course realise the importance of this negative sign, what does the negative sign indicates that there is a phase shift, phase shift of 180 degrees okay. Any questions about this example?

"Professor–student conversation starts"

Student: Excuse me Sir.

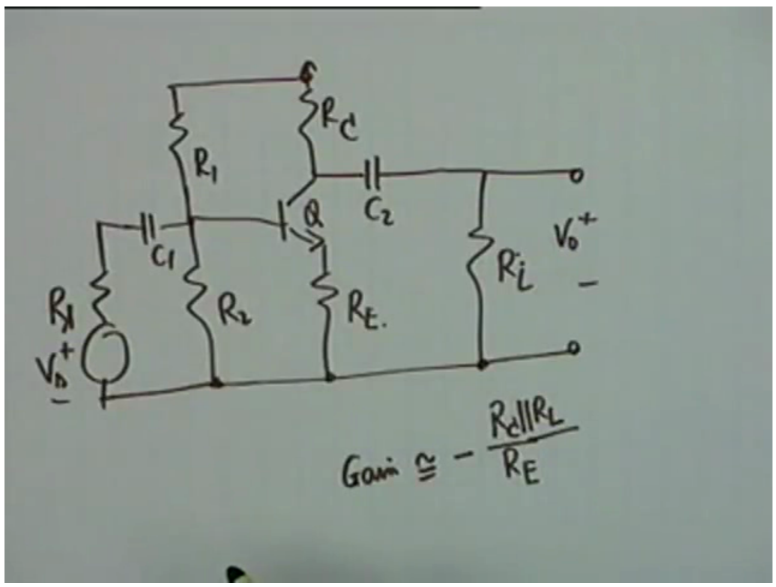
Professor: Yes.

Student: Sir instead of R L if we keep an open circuit, all the current gain and voltage gain will increase.

Professor: That is correct, unfortunately R L is not your choice, as I said if this is an audio amplifier for example, R L could be the loudspeaker 8 Ohms alright, 4.7K typically could be the input impedance of another amplifier to which you are going to fit this, 1 amplifier can give you a gain of only 60, if you require a gain of 1000 obviously you require another amplifier and R L could be input impedance of the next amplifier. It is not your choice, if you can keep it open go ahead, get all the gains that you that you want okay.

“Professor–student conversation ends”

(Refer Slide Time: 43:12)

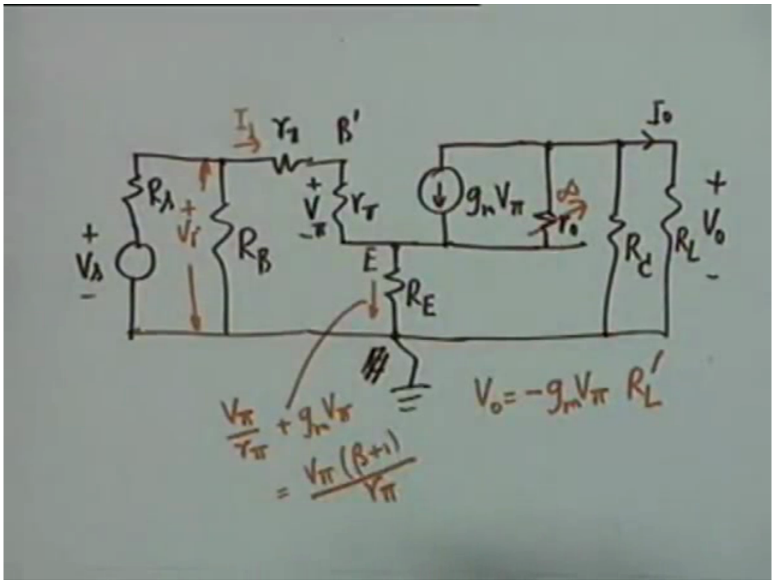


Now a complication arises in this circuit if R E is not bypassed if R E is not bypassed. Let us draw the circuit again, R C, C 2, R L, V 0 -, R 1 and R 2, C 1, R s and V s, complication arises if R E is not bypassed because bypass capacitor is absent. You will see that in many circuits in practice R E is not bypassed, it is intentional. Why it is so why it is required we shall explain later, this stipulates the gain which makes the gain insensitive to variations of other parameters but if it is so how do we analyse the circuit. We shall show engineer’s rule if the transistor we will proof this but let me state this, engineer’s thumb rule is if R E is bypassed then the gain is approximately = the ratio of R sub C to R sub E approximately the voltage gain is approximately = this.

If both the resistors are equal 1K and 1K then the gain is... no I made a mistake, this is R C parallel R L that is equivalent load, if the equivalent load and R E are equal then again is simply -

1 alright, we will see how this drastic reduction in gain occurs by drawing as usual the equivalent circuit.

(Refer Slide Time: 45:09)

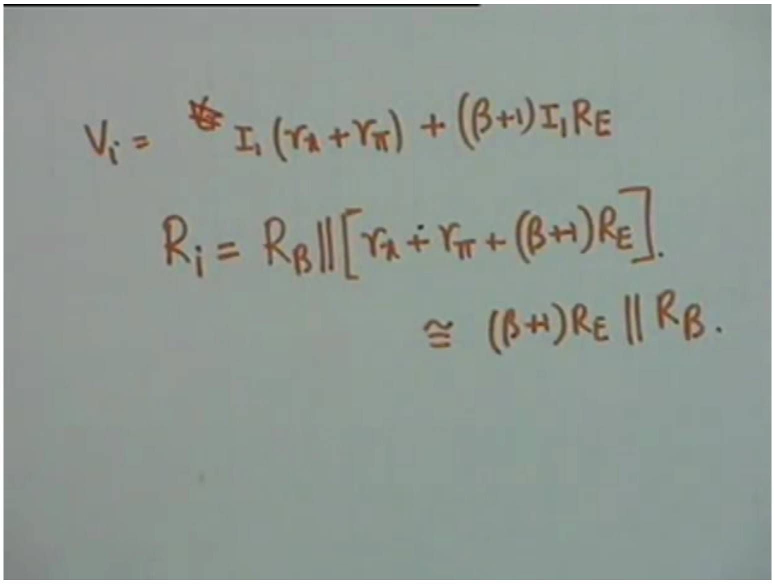


That is we will see this makes a hell of a lot of difference, whether R E is bypassed or not bypassed. We have the usual equivalent circuit R sub B, then you have r x, r Pi, now we cannot take it to emitter because R E is not bypassed, so r Pi shall go to R E, which goes to emitter terminal... Thank you, this is the ground. From internal base to emitter yes this resistance is r Pi, the voltage is V Pi and then we have here from collector to emitter g m V Pi then we have where is r 0? Again between these 2 terminals r 0, then we have from here to ground is R sub C and in parallel R sub L, this current is I 0 and this voltage is V 0.

Now this creates a complication in the analysis but several things should be obvious, 1[st] that we can ignore r 0 goes to infinity so this is open and the voltage V 0 is still due to the current g m V Pi flowing through this combination agreed, that is V 0 is still = – g m V Pi multiplied by R L prime, is that clear? Okay, the same current this current must come through, like this, if you combine this into a single resistance, V 0 must be the drop in effective load RC parallel RL prime due to the flow of g m V Pi alright, this is by inspection. By inspection we also see this voltage is V i, what we need now is V i, you see that the current through this resistance what is the current? This is V Pi divided by r Pi, this current comes from the left and from the right comes g m V Pi, so this = V Pi times Beta + 1 divided by r Pi is that okay?

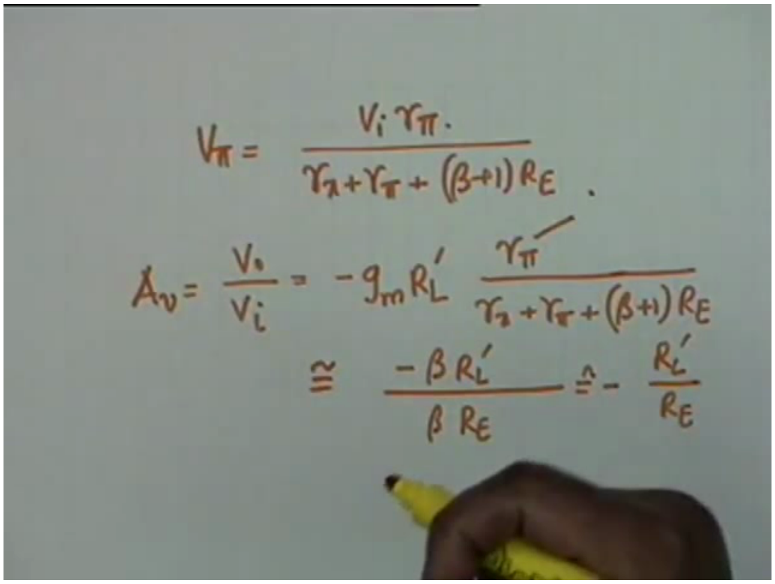
Alright so the drop across this is not due to V Pi by r Pi only, the drop across this is due to a current which is beta + 1 times higher than V Pi by r Pi, so as far as input is concerned let us write this equation. I can write it on the same sheet but I hope you remember.

(Refer Slide Time: 48:40)



My equation is V i the input voltage is let us they V Pi just a minute, let us call this current as I 1 then it is I 1 times r x + r Pi + Beta + 1 I 1 multiplied by R E agreed, is this point clear? Okay, which means that if I look here to the right, the effective resistance that I see is r x + r Pi + Beta + 1 R E and therefore my input resistance if I look here then it would be R B parallel this increased resistance alright, which means that R i = R B parallel r x + r Pi + Beta + 1 R E, and usually R B is large, r x is small and Beta + 1 R E would be much larger than R Pi, R Pi is of the order of k so is R E but this is 101 times R E so this will be approximately same as Beta + 1 R E, but this large resistance is now in parallel by another large resistance so R B you cannot ignore, this will come in parallel with R B this is the input resistance.

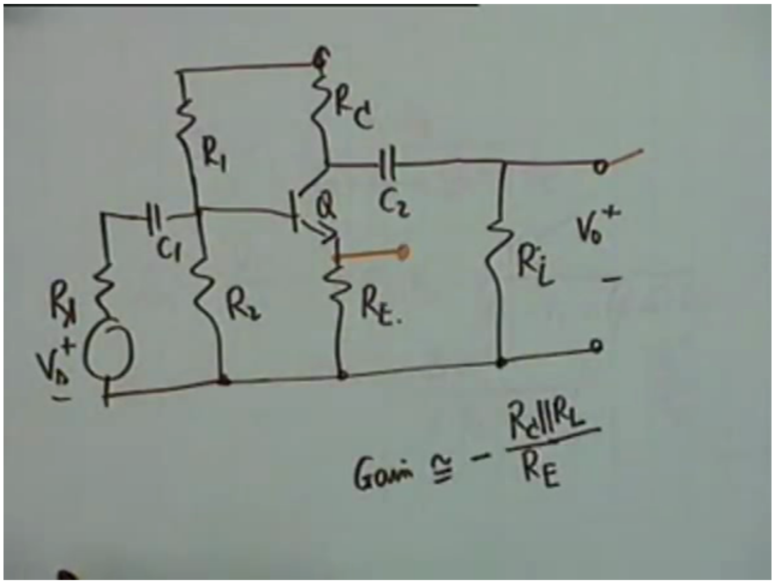
(Refer Slide Time: 52:02)



Can you tell me now from this circuit what is V Pi? V Pi would be = V i divided by r x + r Pi + Beta + 1 R E multiplied by r Pi and therefore the gain of the circuit A v, which = V 0 divided by V i would be = – g m R L prime and instead of the Pi I should write this quantity so it would be r Pi divided by r x + r Pi + Beta + 1 R E, is it okay. The gain now as you can see is reduced by this factor, again with R E bypassed, R E bypass means what? R E effectively = 0 so this factor drops out and r Pi by r x + r Pi is approximately = 1 and therefore the gain with R E short-circuit is simply this factor – g m R L trying which we calculated earlier and there is now a drastic reduction of gain, r Pi is the order of k and this is about hundred K okay, 100 no 110 times R E so the gain would be drastically reduced okay.

So we had calculated the gain, this you can write approximately as a simple expression now, - Beta R L prime divided by... g m r Pi prime becomes Beta divided by if you ignore all this then beta + 1 ignore 1... beta R E which means that this is approximately – R L prime by R E which was a rule of thumb that we had stated in the beginning of the analyses that is simply the ratio of effective load at the collector to what you can consider as load at the emitter, this resistance R E is kind of a node at the emitter, but then an interesting side line is the following, I want my circuit again.

(Refer Slide Time: 53:46)



An interesting side line is yes you can take the output from here 1 output V 0, you can also take an output from here is not that right? And if these 2 resistors if the effective loads are equal if R C parallel R L is same as R E then these 2 voltages will have the property of equally equality in magnitude but out of phase, opposite phase alright Pardon me...

“Professor–student conversation starts”

Student: Please repeat this is.

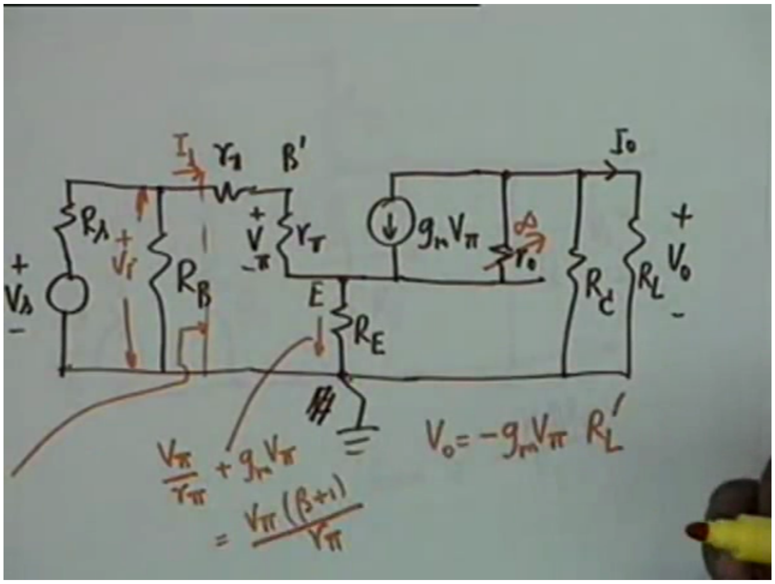
Professor: Okay, the voltage here and the voltage here are out of Phase.

Student: Why?

Professor: Why... Okay, you have to calculate the voltage let us look at the equivalent circuit.

“Professor–student conversation ends”

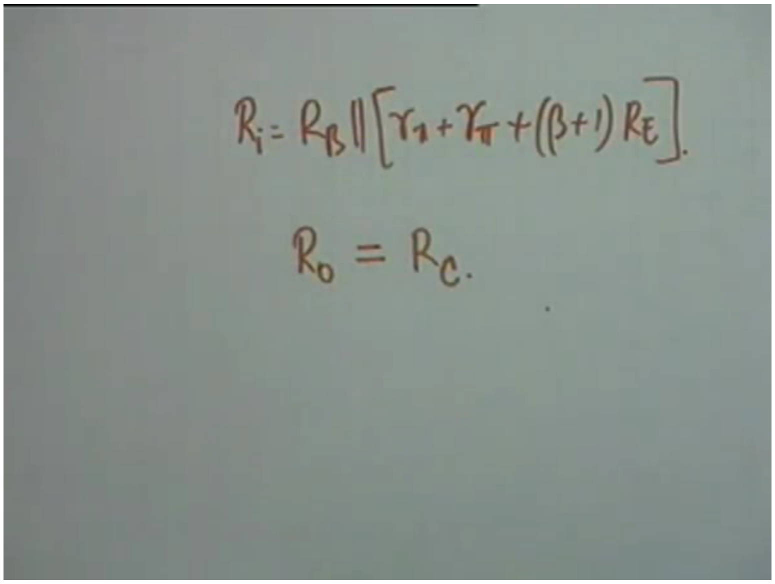
(Refer Slide Time: 54:33)



The voltage here is the drop due to V Pi by r Pi times beta + 1 and V Pi is in phase with V i and therefore this voltage will be in phase with V i. On the other hand, this voltage is out of phase with V i so the point that I am making is that this circuit can be used to get from a single voltage 2 voltages of equal value and 180 degree out of phase, such voltages are required in many electronic circuits, 2 voltages identical magnitude but opposite in phase from a single source alright. In that if it is that particular use then it is called in literature as a Paraphase amplifier okay, this is one of the uses of this un bypass capacitor.

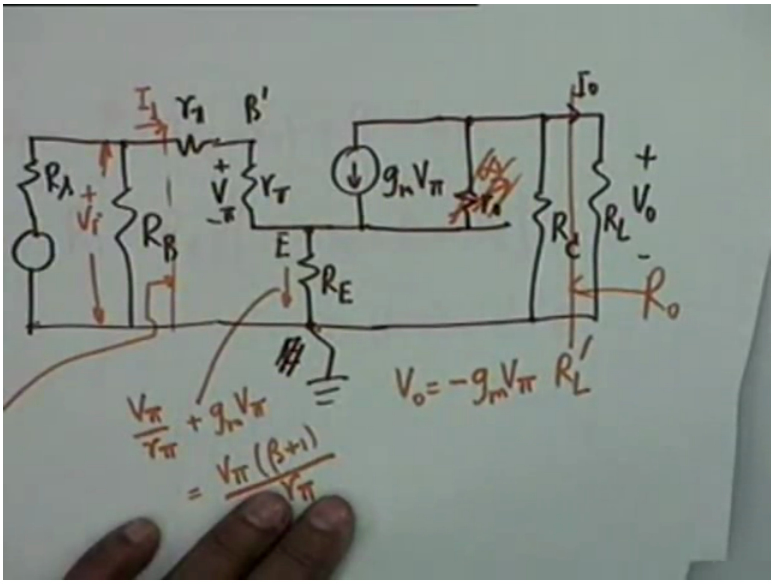
The other used as you can see since the gain is R L prime by R E, you have made the gain insensitive to the transistor, it is does not depend on g m, it does not depend on r x it does not depend on r Pi, it depends only on these external resistors. In integrated circuits the ratio of 2 resistors can be very accurately tuned and can be made absolutely stable, even though individual resistors may vary the ratio with temperature or humidity or any other environmental variation, ratio can be kept constant and therefore this is a configuration in which you can get a gain, R L prime could be 100 times R E then you get a gain of 100, the gain is insensitive to transistor parameters. Even if the Q point shifts slightly even if the transistor bias was not stabilise properly even then this gives you a gain which is insensitive to transistor parameter variation.

(Refer Slide Time: 58:26)



If you continue this calculation oh we have already found out R i that is R B parallel r x + r Pi + Beta + 1 R E, now what was the input impedance in the case of a bypass amplifier? This term was absent and it was approximately = r Pi of the order of k, now if the beta is 100 and R E is of the order of k, can get input impedance of 101k right, parallel another let us say 101k so 55k is a very large resistance so this is one of the ways to increase the input impedance of the amplifier okay and by passing the emitter resistor creates a high impedance so this has the property of high impedance. If you calculate R 0 the output impedance, what do you think this would be? This would be the same as previous case, where is R 0 taken, across the load that is from the collector to ground and this would be = R sub C.

(Refer Slide Time: 59:20)



"Professor–student conversation starts"

Professor: Can you tell me why why R E does not come into the picture? Let us take the equivalent circuit then you will learn this.

Student: Sir because the current through R E is 0.

Professor: No.

Student: Sir V Pi is 0 volts.

Professor: V Pi is 0 but g m V Pi that is close to R E.

Student: Yes that is open circuit.

Professor: You see what I am doing is I am calculating the impedance looking her R 0 and I am claiming that it should be R C yes.

Student: It is same.

Professor: Why does it remain the same, why does not R E effective?

Student: Because R L is much larger than R E.

Professor: Let us say R 0 is infinitely take it off... You cannot combine R 0 with R E because R 0 comes in parallel with g m V Pi there has to be a fundamental concept.

Student: Because that current source is open.

Student: There would be no current through it.

Professor: Okay if I short-circuit this, there is no current through R E why no, g m V Pi... V Pi is 0 but that is not the consideration, the current is 0 so what?

Student: Sir you open that g m branch.

Professor: You see this g m V Pi is the current source, what is the internal impedance of a current source?

Student: Infinity.

Student: Infinity.

Professor: What is infinity + R E.

Student: Infinity.

Professor: Infinity so R C is parallel by an infinite impedance and therefore the output impedance is R C, we will continue this on Monday.

“Professor–student conversation ends”