Basic Electronics
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Module: 2 Bipolar Junction Transistors
Lecture-9
Frequency Response of BJT Analysis Part – 2

Let us find out the lower cut off frequency due to the coupling capacitor C_2 and ignore the other two capacitances. The circuit of the amplifier having the coupling capacitors C_2 only we will be looking. Look at this circuit where the capacitor C_2 which is at the output side is coupling the output signal basically.

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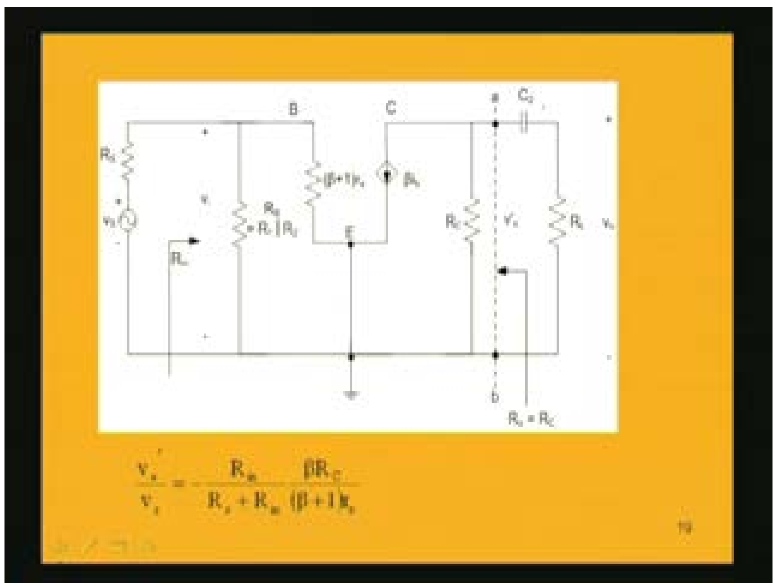

The circuit is having the other portion almost same like the mid frequency region analysis. We can find out what will be the gain from V_S to V_O dash where the V_O dash is the voltage at the terminals AB just before the capacitance C_2. Separating this part from the output side where we have this capacitance C_2 in series with the load resistance R_L, let us find out first V_O dash by V_S. That we know. We are familiar with the voltage gain that is equal to minus R_{in} by R_{in} plus R_S into beta times of R_C by beta plus $1r_e$. We do not consider the output resistance R_O; only R_C which is the output resistance, it is R_O equal to R_C. V_O dash by V_S is this quantity.

Let us consider the output side circuit having this voltage at V_O dash and the rest of the circuit. V_O dash is equal to minus V_S into R_{in} by R_S plus R_{in} into beta R_C by beta plus 1 r_e. That is from this expression we are having the voltage V_O dash.

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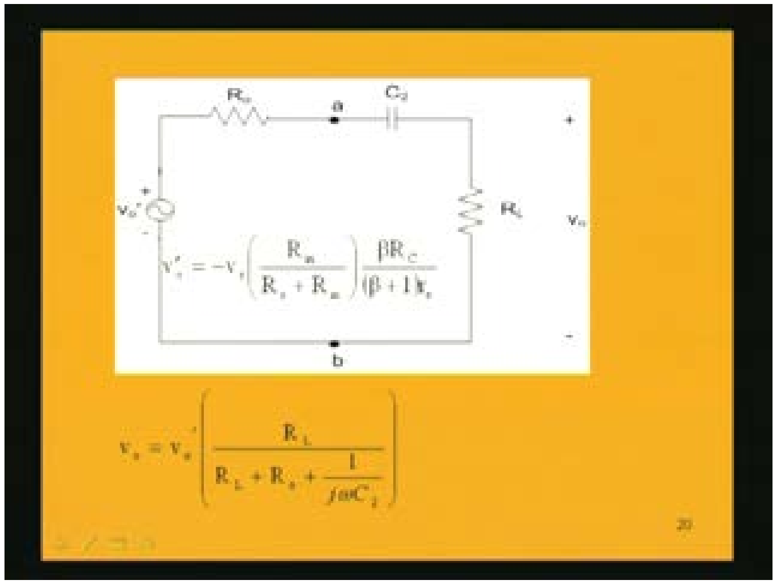

It is having a resistance R_O in series and that resistance is the output resistance which is nothing but R_C. The whole left side of this circuit from AB is having the voltage V_O dash in series with R_O and the rest of the circuit will be connected there. The rest of the circuit means to the right of AB we have C_2 and R_L. In this circuit we can find out what is V_O at this point? V_O equal to the voltage across these two points which is having the resistance R_L. V_O equal to V_O dash into R_L divided by R_L plus this series resistance and capacitances. The denominator will be R_L plus R_O plus 1 by j omega C_2. That is the output voltage finally we get here.

We find V_O equal to V_O dash into this quantity which can be further simplified. We will take the ratio between V_O and V_O dash. That is equal to R_L by R_L plus, R_O can be replaced by R_C. Because if we look into the circuit R_O the output resistance when you look from the output terminals it is nothing but only R_C because V_S has to be short circuited and that makes this I_B zero. We have only R_C across it. That is the output resistance R_O. Replace R_O by R_C and in the denominator again I am writing this quantity by minus j by 2 pi f C_2. Simplifying a little further taking common R_L plus R_C in the denominator I get 1 minus j by 2 pi f R_L plus R_C into C_2.

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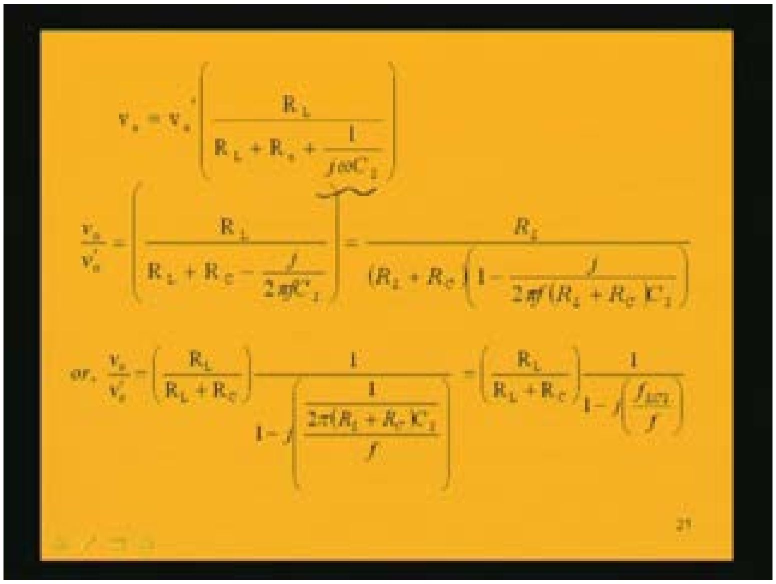

V_O by V_O dash equal to R_L by R_L plus R_C into 1 by 1 minus j into 1 by 2 pi f R_L plus R_C into C_2. This quantity can be written as 1 by 2 pi into R_L plus R_C into C_2 divided by f. Replacing this whole quantity 2 pi into R_L plus R_C into C_2 by f l C two divided by f we get in the denominator and the f_{LC2} which we are denoting by this 1 by 2 pi into R_C plus R_L into C_2. We will find out the overall voltage gain V_O by V_S. Using the chain rule it is V_O by V_O dash into V_O dash by V_S. V_O by V_O dash just now we have found out. We will replace by this quantity here R_L by R_C plus R_L into 1 by 1 minus j f_{LC2} by f and the rest of the quantity that is V_O dash by V_S; V_O is equal to minus R_{in} by R_S plus R_{in} into beta R_C divided by beta plus 1 into r_e.

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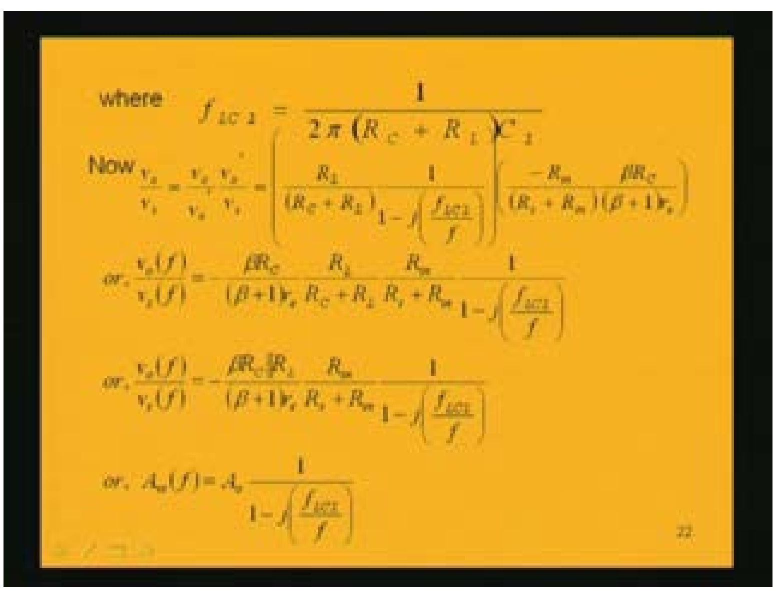

The whole expression of V_O by V_S will be equal to minus beta into R_C by beta plus 1 into r_e. Then this whole quantity written together; this is the overall expression. If we look into this numerator, the portion R_C into R_L by R_C plus R_L can be written as R_C parallel R_L. In the numerator we have minus beta into R_C parallel R_L divided by beta plus 1 r_e; as it is we will write. The rest of the part is R_{in} by R_S plus R_{in} into 1 by this quantity. We can write $A_{vs}(f)$ as equal to this quantity of minus beta R_C parallel R_L divided by beta plus 1 r_e into R_{in} by R_S plus R_{in}. This is nothing but the voltage gain A_{vs} in mid frequency region. That is nothing but A_O and the rest of the term will remain.

If we consider only the magnitude of $A_{vs}(f)$ it is the magnitude of A_O into 1 by root over 1 plus f_{LC2} by f whole square because that part is the magnitude of the complex quantity. When the frequency f becomes equal to f_{LC2}, then in the denominator we will have only 1 plus 1 that is equal to root 2. We have the magnitude of the voltage gain as 1 root times A_O; 1 by root 2 is nothing but 0.707. That is what we are getting if we make f equal to f_{LC2}.

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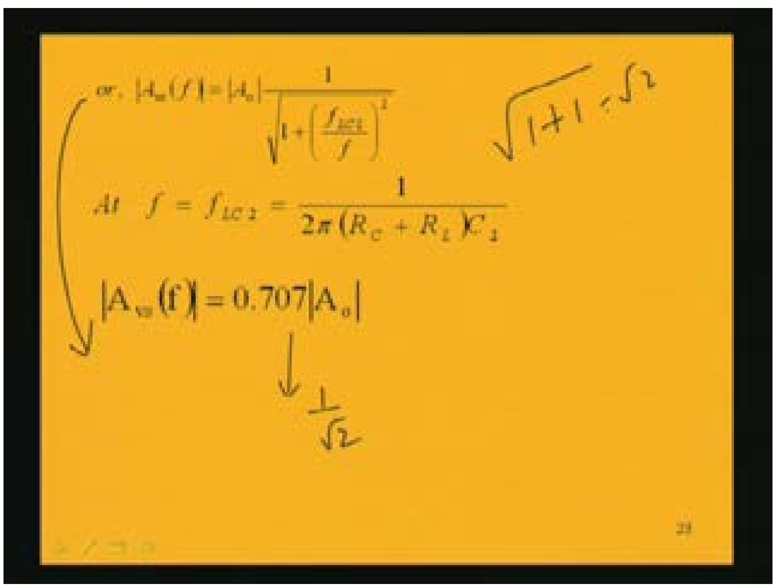

That means it verifies that the lower cut off frequency due to C_2 which we have assumed as 1 by 2 pi into R_C plus R_L into C_2 because we have replaced here this f_{LC2}, we are replacing for this quantity, 1 by 2 pi into R_L plus R_C into C_2. Replacing that by f_{LC2} and further analyzing we have finally got that when the signal frequency f becomes the frequency given by this quantity f_{LC2}, then the gain reduces to 1 by root 2 times the mid frequency gain A_O. That verifies that the lower cut off frequency due to C_2 is equal to 1 by 2 pi into R_C plus R_L into C_2 and basically that is nothing but if we look into the circuit and find out what is the effective resistance across C_2 and then find out what is the time constant from that we get the same lower cut off frequency only. That is a very simple analysis. We can straight forward find out. We can get directly the lower cut off frequency which is equal to 1 by 2 pi into effective resistance across this capacitance into the capacitance.

What is the effective resistance across the capacitance? To find that we have to look into the circuit from that capacitance; that means from this portion of the circuit we will look into. Making this capacitance open what will be the effective resistance? Making V_O dash zero we will be left with these two resistances in series because this is the capacitance C_2. This is R_O which is equal to R_C and this is R_L. When I look from this point across C_2 I am having R_O and R_L that means R_C and R_L are in series. I get the effective resistance for this capacitance C_2 as R_C plus R_L into C_2.

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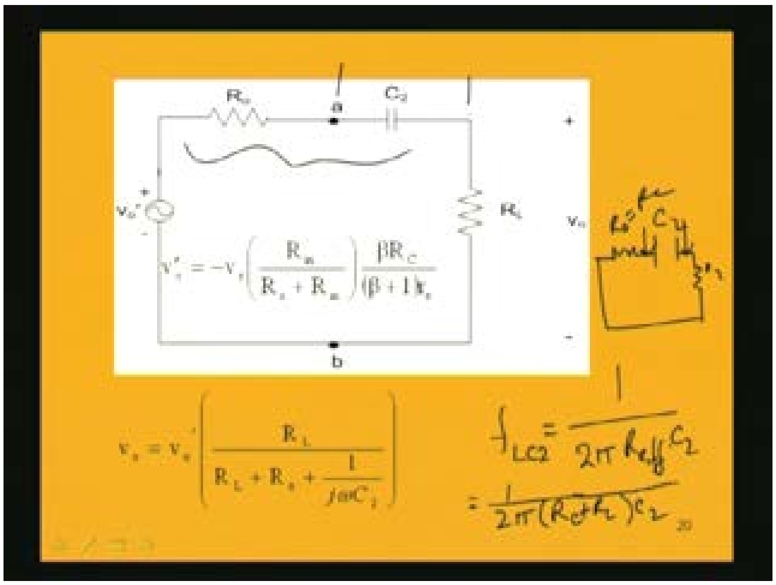

From this I get the cut off frequency because this is nothing but the time constant; R into C is the time constant. From that you get the cut off frequency. Actually from this whole analysis we are finally ending up in getting that frequency only which is the frequency obtained for C_2. We find out the effect of C_E.

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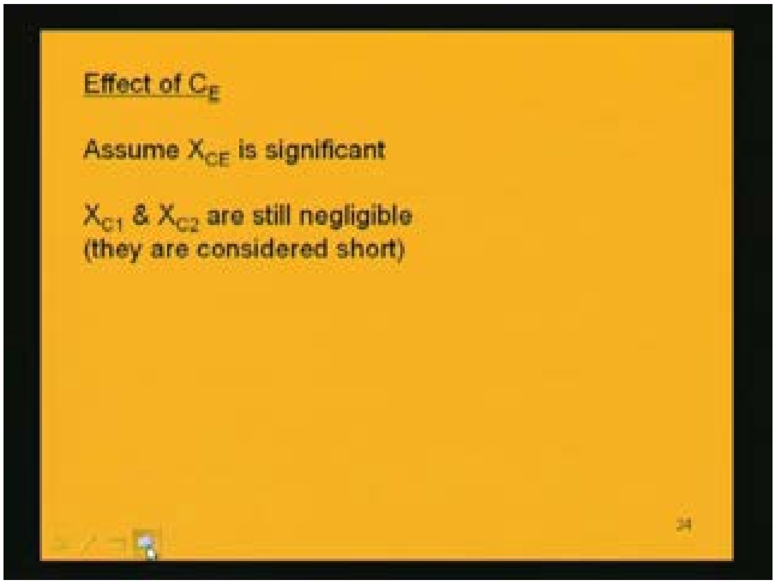

C_E is the bypass capacitor across the resistance R_E. Considering only C_E and ignoring other coupling capacitors C_1 and C_2, we will find out the lower cut off frequency due to C_E. What will be the circuit? The circuit will have C_E but the other capacitances will be absent because we are assuming a short circuit. This capacitance C_E is there. We have to find out the lower cut off frequency due to this capacitance. The easiest way we will adopt.

We will find out the effective resistance across this capacitance C_E. In order to know the effective resistance across this capacitance C_E we remove this capacitance, open circuit it. At these points we are disconnecting this C_E and look into the circuit to find out the effective resistance. That is what we are doing here. The resistance across this capacitance C_E can be now found out which is R_O and R_O which we will find out across these two points will be in parallel with R_E. R_E is there but we have to find out at these two points AB, the resistance R_O looking from this terminal AB and that resistance R_O if it is in parallel with R_E that will be the effective resistance due to C_E.

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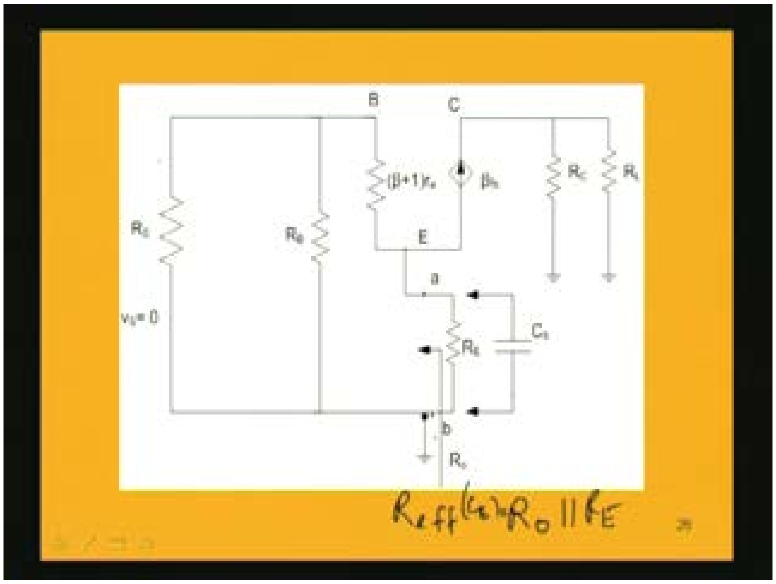

In order to find that out we will find out the resistance of this left side circuit from this AB terminal. For that we apply an external voltage v_x. This external voltage will make the current flow in the circuit. One part will go through this one part will go through this circuit to the right and mind it we have made V_S is equal to zero because the independent source has to be made zero. When you have to find out the effective resistance across these two terminals you make the circuit inactive means the independent source you make zero but here actually we will have to apply an external source. To know this output resistance look into the circuit from this terminal AB because there is a dependent current source and that source beta times of I_B will be having one part of the current which is due to this external source. This is the way to find out the output resistance and because of this V_X, I_X current flows and one part goes to this side which is beta times of I_B where I_B is the current flowing through this resistance.

The total current i_x is equal to i_b plus i_c. i_c is that current which is through the collector point and through the base point i_b current flows. That means i_x is equal to beta plus 1 into i_b because i_c is equal to beta times of i_b. We get that i_b equal to i_x by beta plus 1. What is this voltage v_x? v_x is equal to the drop across beta plus 1 r_e plus this drop across these two points. The drop across beta plus 1 into r_e is equal to the current i_b into beta plus 1 r_e. Again i_b is equal to i_x into beta plus 1 r_e. This and this cancel plus the voltage across these two points is current i_b which is flowing in this direction into the equivalent resistance between these two parallel resistances R_S and R_B. This part is equal to i_x by beta plus 1 which is this current i_b into R_B parallel R_S.

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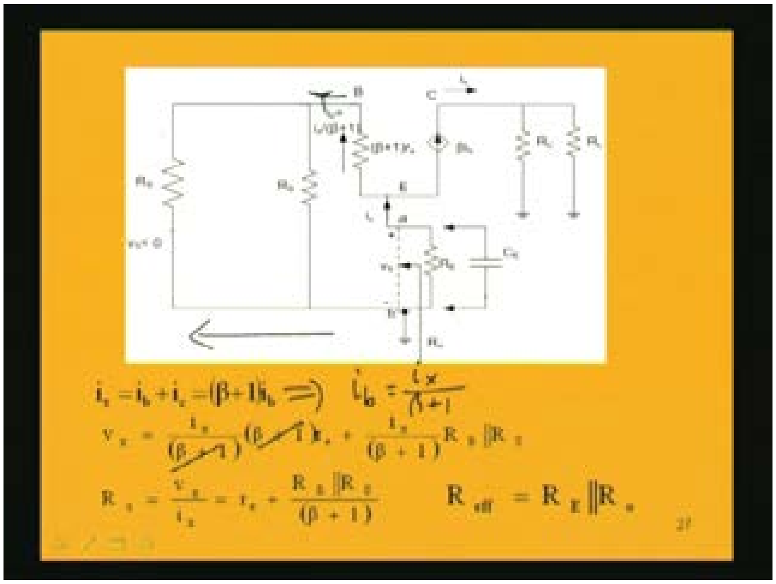

Take the ratio between the v_x and i_x which is equal to R_O. That is equal to small r_e plus R_B parallel R_S by beta plus 1. This is the effective resistance across this capacitance C_E. We can easily find out the time constant associated with that capacitance C_E which is R effective and C_E and R effective we have just now found out to be equal to R_E parallel this component.

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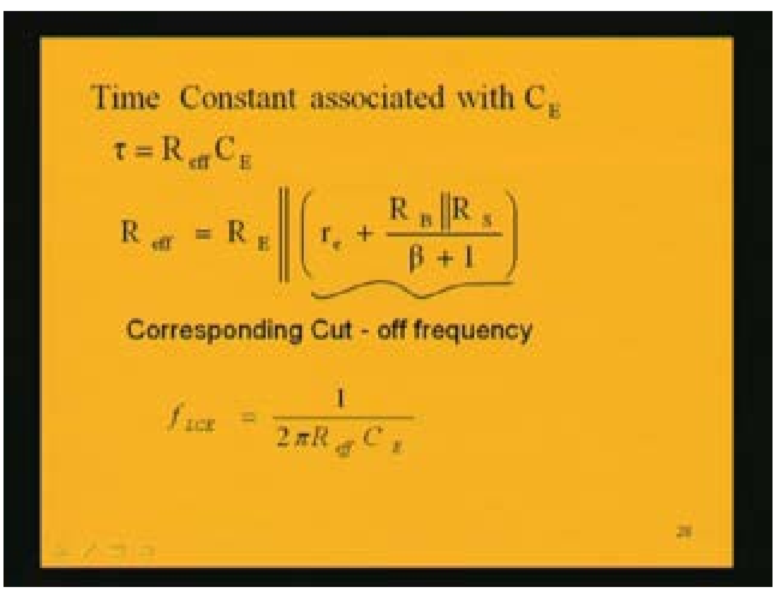

We have found out R_O. But exactly what will be the effective resistance across this capacitance? It is R_E parallel R_O. R_O is this component. Effective resistance is equal to R_E

parallel this whole term. That will give the corresponding cut off frequency as f_{LCE} which is 1 by 2 pi R effective and C_E. This is due to C_E. This lower cut off frequency f_{LCE} is due to the emitter bypass capacitors C_E. By finding out the effective resistance across each of the capacitor straight forward we can find out the lower cut off frequency associated with each of these capacitors. We have found out there are 3 lower cut off frequencies due to each of this capacitors. In order to find out the overall cut off frequency of the amplifier considering all the 3 we will take the largest value of all these lower cut off frequencies. Out of f_{LC1}, f_{LC2} and f_{LCE}, we will be taking the largest value and that is the overall or the final lower cut off frequency of the amplifier.

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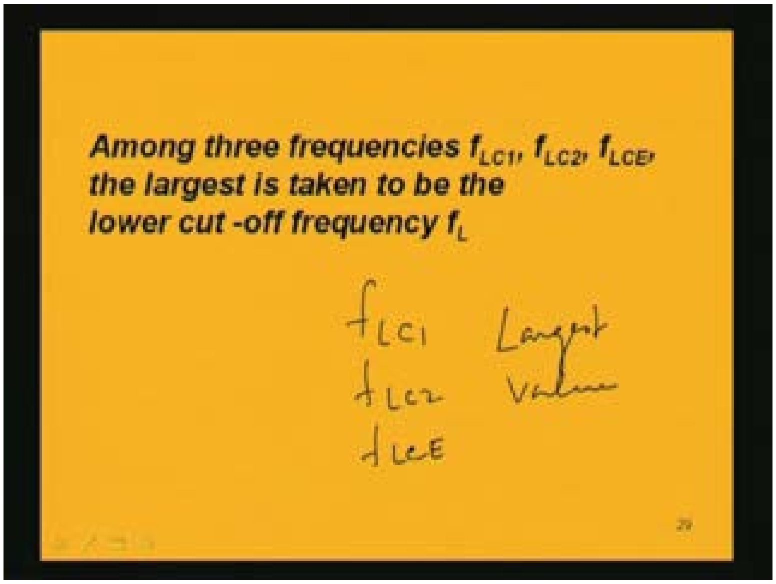

After knowing the lower cut of frequency, let us proceed to find out the upper cut of frequency. Then we will consider the amplifier in the high frequency region. As per our earlier analysis in the high frequency region the capacitances which will be having effect are, the transistor junction capacitances; that is C_{be} base to emitter junction capacitance and C_{bc} collector to base junction capacitance. But the others that is the coupling and bypass capacitance will be now ineffective because they are almost like short circuit. At high frequency region again let us consider the overall amplifier circuit. It is the overall circuit diagram having all the capacitances; once again we are recalling that circuit. The effective capacitances will be these two because these capacitances are no longer open circuit. Their capacitive reactances are smaller so that a part of the base current is shunted out through these two capacitances. Out of the current which is coming into this point one part will be shunted out through this capacitance. Another part will be shunted out through this capacitance C_{bc} and the rest will be only flowing through the resistance beta plus 1 r_e.

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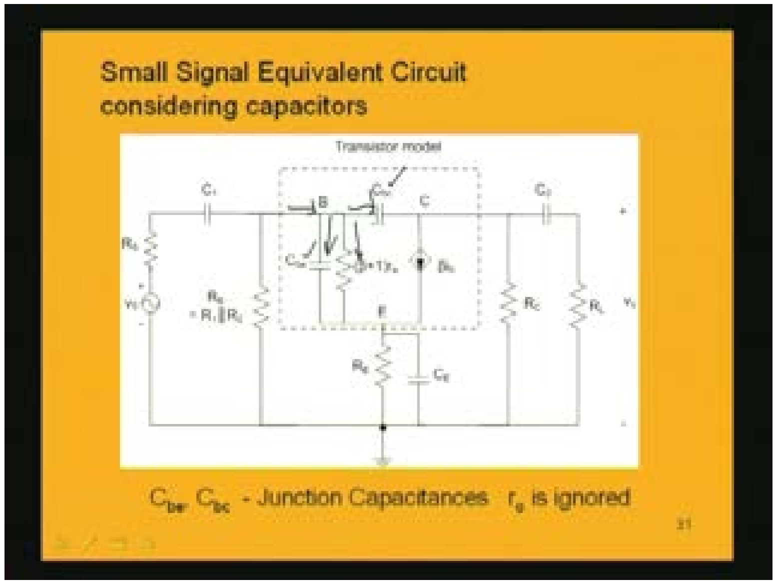

The current which is now flowing through this resistance and finally through this resistance will be not i_b as in the earlier case but it will be a portion of i_b only. i_b now is less than its earlier value when it was in the mid frequency region. If i_b is now reduced because of the shunting away by this capacitances then the collector current will also be reduced; beta times of i_b will also be reduced. That is why the voltage gain V_O will be also reduced because the voltage at the output is dependent on this current source. We are considering at high frequency and we will try to find out what is the upper cut off frequency.

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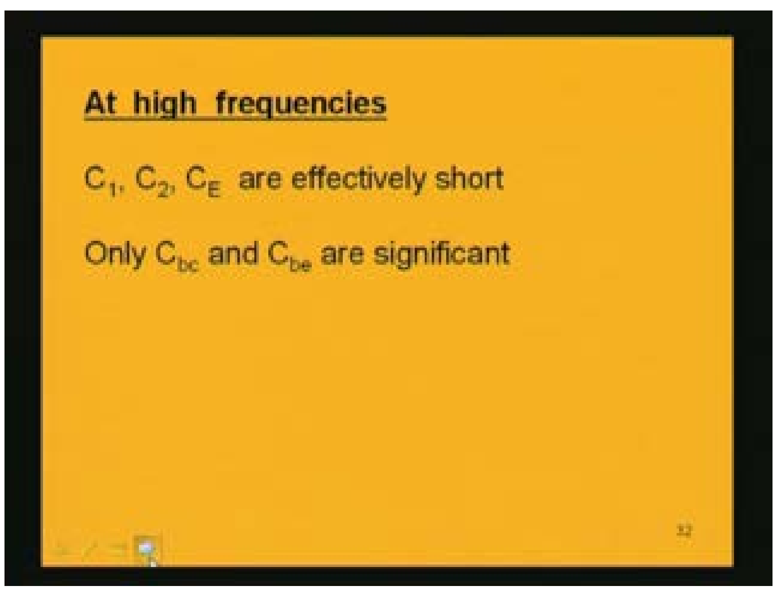

Ignoring the effect of all other capacitances and keeping only the shunting capacitances due to the transistor which are C_{bc} and C_{be} we are considering the circuit again.

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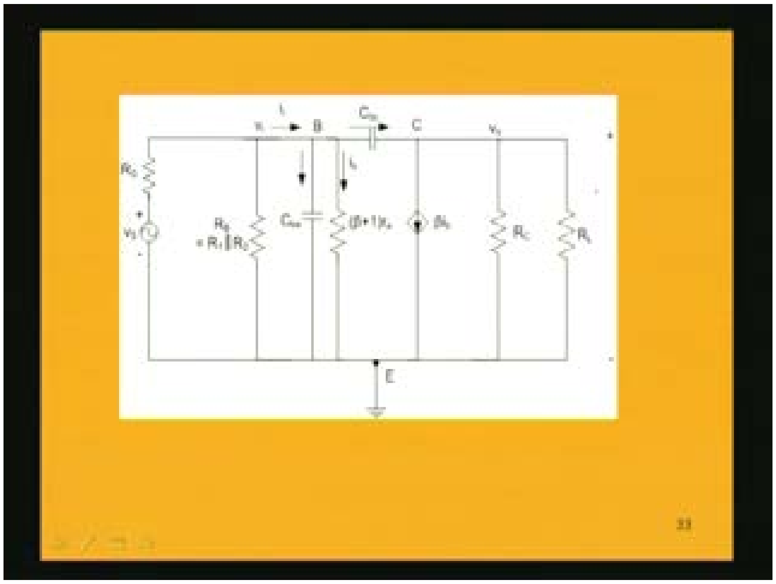

In this amplifier circuit as shown by the arrow marks of the current, the input current which was coming has now 3 parts. One will go through this C_{be}, one will go through C_{bc} and the rest or finally what is left that will be the base current. We have difficulty in analyzing the circuit. It is not a simple circuit because this shunting capacitance C_{bc} is giving problem. It is now across these two points B and C. This capacitance C_{bc} is not allowing the whole circuit to be divided into input and output circuits but there is a part from base to collector. This capacitance C_{bc} as it is shunting between base and collector we are having a trouble for separating the input and output circuits out. Because in order to analyze the circuit it is better to have the input and output circuits separated out but here the problem is coming because of the shunting capacitance between the input and output that is base and collector. If somehow we can simplify this circuit further by separating out the input and output circuit then it will be better for our analysis.

In order to separate out the input and output circuits we have to distribute this capacitance C_{bc} in the input and the output circuits and there by removing it from this part. That can be done by taking help of a well known established theorem known as Miller's theorem. We will discuss first what is Miller's theorem and how we are going to apply it in this circuit to simplify it? The Miller's theorem says that we have a number of nodes, N being the node to ground. This is the ground node. Other nodes are 1, 2, 3, 4; there may be many nodes. The voltages at these notes are V_1, V_2, etc. and here there are impedances, say Z. We are considering only between these two nodes 1 and 2 say for example. To simplify and to analyze this or illustrate this point first what is Miller's theorem, let us take V_1 and V_2 at the two nodes 1 and 2 having impedance in between them which is Z.

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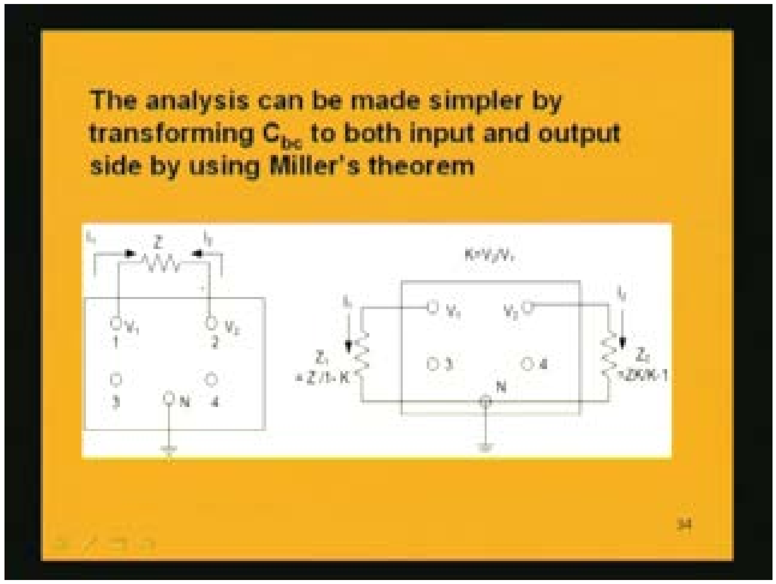

The current I_1 is flowing through Z from V_1 to V_2 and current I_2 is flowing from V_2 to V_1. We want to simplify the circuit and Miller's theorem says that this Z which is between V_1 and V_2 can be distributed between 1 and ground that is node N as well between 2 and ground that is N. The corresponding values which will be between 1 and node will be Z by 1 minus K where K is the voltage ratio between V_2 and V_1; that is the ratio between the voltages V_2 and V_1 is say K. Then we can distribute Z into the input and output circuits removing it completely from this part between 1 and 2 to make the circuit easier or simpler and the value of Z_1 that is connected between 1 and ground will be Z by 1 minus K. The original value of Z divided by 1 minus K, K being V_2 by V_1, this ratio and similarly the value of Z_2 which is between 2 and ground, this V_2 and ground that will be Z_K by K minus 1 and then we can easily find out the current also.

The values of Z_1 and Z_2 as we are writing here can be verified actually. How we are getting the value of the resistance between 1 and N being Z by 1 minus K and the other being Z_K by K minus 1. That can be verified if we consider that the currents in both the cases and make them equal. Because the currents are still I_1 is flowing from V_1 to ground, I_2 is flowing from V_2 to ground and earlier this was the current I_1 from V_1 to V_2. These two are equivalent circuits. To prove the point that these two are equivalent circuits let us proceed from the current. Let us find out the current in this circuit. I_1 is equal to V_1 minus V_2 by Z. That can be written as V_1 into 1 minus V_2 by V_1 divided by Z. Again V_2 by V_1 is nothing but the voltage ratio K. We can write it as V_1 into 1 minus K by Z and again we can write it as V_1 by Z by 1 minus K. Finally we are getting an expression which is V_1 by Z_1. We are writing Z_1 for Z by 1 minus K and this is the current which is flowing in this circuit.

Similarly we find out I_2. V_2 minus V_1 by Z can be written as V_2 into 1 minus V_1 by V_2 by Z. That is equal to V_2 into 1 minus, V_1 by V_2 will be 1 by K, by Z and that is equal to V_2 by Z by 1 minus 1 by K. Let us write it by V_2 by Z_2. If we look into this quantity V_1 by Z_1, V_1 is with respect to ground. So we get the second circuit current which is V_1 by this impedance Z_1, which is nothing but Z by 1 minus K. Instead of writing I_1 in this way we have written it in this form. These two are equal. This current expression and this current expression we are just writing it in a different way. But that can be realized in this circuit because V_1 by Z by 1 minus K means that this is the current where the voltage is with respect to ground and that is what is here. V_1 is with respect to ground divided by this impedance Z by 1 minus K and that is the impedance which is in the part between voltage V_1 and ground. Similarly in the second case we are getting V_2 by Z by 1 minus 1 by K. This is the voltage with respect to ground. V_2 is the voltage with respect to ground and the denominator is having a value of impedance which is Z by 1 minus 1 by K.

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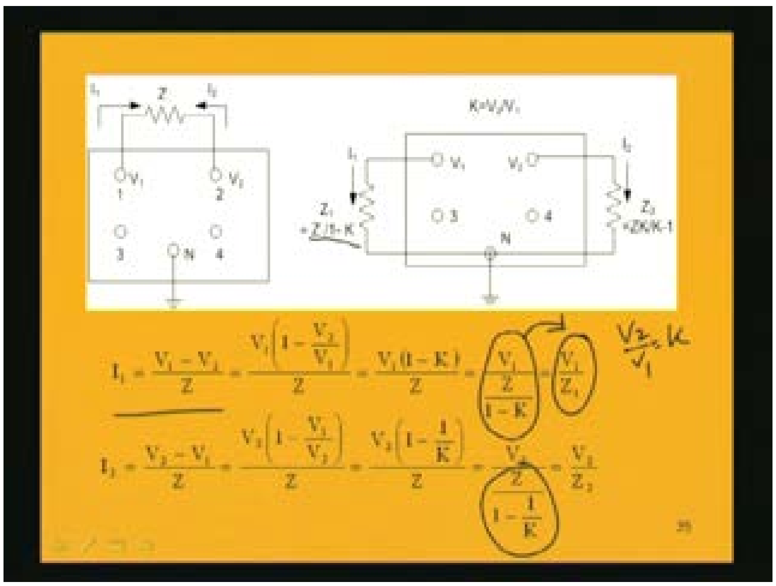

That impedance is between this node 2 and ground which is Z by 1 minus 1 by K. Z by 1 minus 1 by K can be written as Z into K by K minus 1. From this figure we are proceeding and finally we are getting a circuit which is having the input and output sides separated out with respect to ground but here it was having a shunted impedance in between the two nodes. This theorem will be now applied to our amplifier for distributing the capacitance between base and collector and separating out the input and output side circuits. Let us do that now. Finally we are having the impedance Z_1 and Z_2 which are equal to Z by 1 minus K and Z_K by K minus 1, K being the value between V_2 and V_1.

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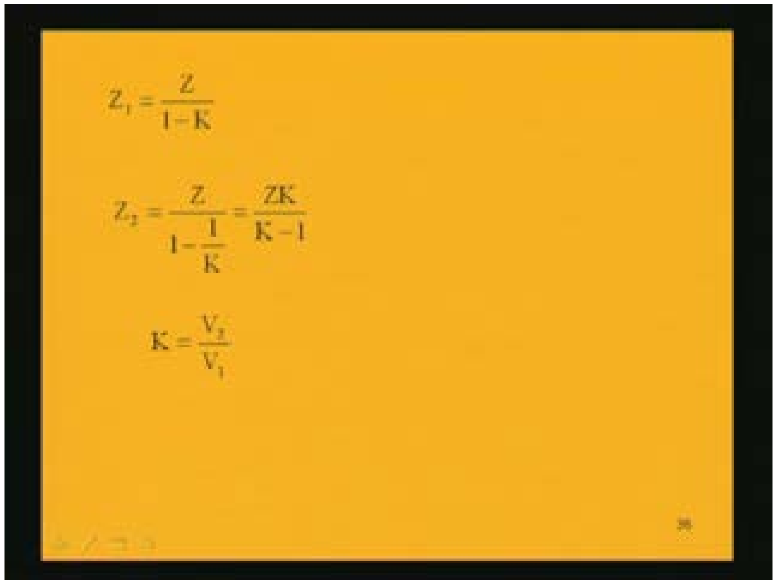

Exactly from here we can immediately write down the impedance values due to the capacitance in the two sides, input and output side. Let us revisit that circuit again. In this circuit we are now going to distribute this capacitance C_{bc} in the input and output circuit.

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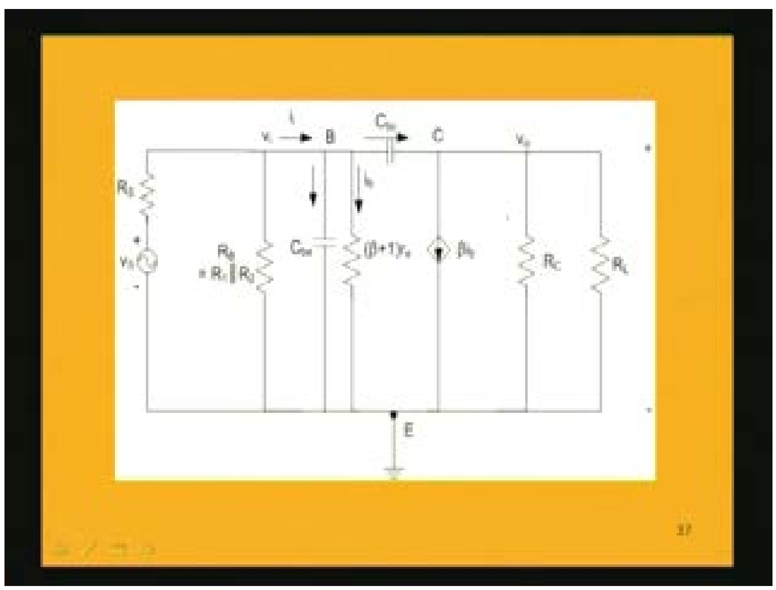

For that we have to find out the impedance value of this C_{bc} and then correspondingly we can distribute it into the two sides, input and output if we have the ratio of voltage that is K. K value is V_O by V_I. That is V_2 by V_1 means output voltage V_O by input voltage V_I. That is the voltages at these two points across which we are redistributing the capacitance. This point is nothing but having the voltage V_I and this collector point is having the voltage V_O. Let us do that. We are distributing this in between capacitance which was here, C_{bc}. That is this capacitance C_{bc} is now divided into two Miller equivalent capacitances known as or denoted as C_{Mi} and C_{Mo}, Miller input capacitance and miller output capacitance. What will be the value of the capacitances C_{Mi} and C_{Mo} or rather what will be the corresponding reactances or impedances offered that we can calculate; others are all same.

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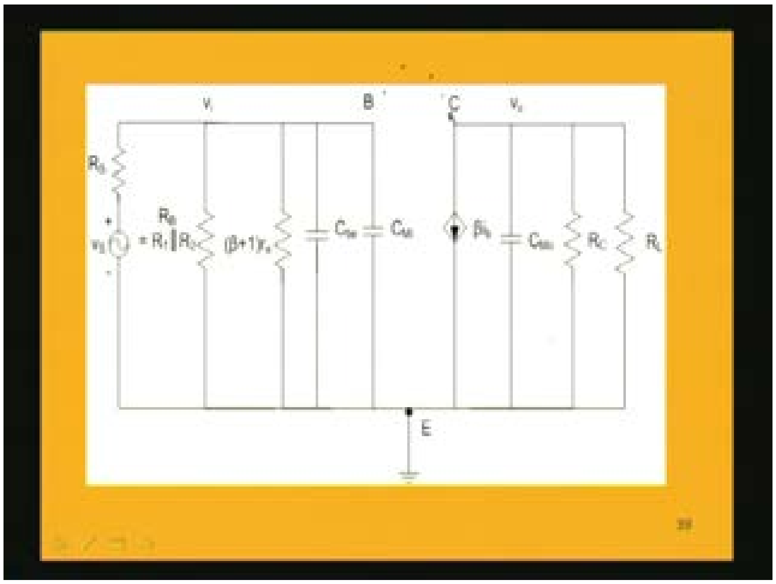

C_{be} is already there and it is not creating any problem since it is between base and ground. The problem was created by C_{bc} because it was shunting between these two and we were not being able to analyze the circuit because input and output sides were not separated out, we will have to use this technique.

What will be this C_{Mi} and C_{Mo} and MO we are going to find out. The voltage gain is V_O by V_I and that we know is the voltage gain A_V. The input side will have the impedance and impedance due to a capacitance is equal to 1 by j omega C. Here C is equal to C_{bc}. The impedance offered by this in the original shunting part is 1 by j omega C_{bc} and we will first find out what will be this capacitance in the input side. We will find out C_{Mi} because following this Miller's theorem which we have just now seen in the input side it will be Z by 1 minus K. In the input side C_{Mi} will have the impedance 1 by j omega C_{Mi} that is equal to 1 by j omega C_{bc} divided by 1 minus A_V. We are just replacing Z. The value of the Miller's capacitance Z_1 we are finding out which is equal to Z by 1 minus K. Here Z_1 equal to 1 by j omega C_{Mi} because when I consider Z, I must find out the reactance or impedance and Z being the original capacitance is j omega C_{bc} divided by 1 minus A_V. That is what is here and that is nothing but 1 by j omega C_{bc} into 1 minus A_V. Now we can find out what is C_{Mi}? These are same and cancel out. C_{Mi} is equal to C_{bc} into 1 minus A_V.

Similarly in the output side I want to find out the value of C_{Mo}. Proceeding in a similar manner we know that Z_2 in the output side is equal to Z_K by K minus 1 or Z by 1 minus 1 by K. 3611 That we have seen here; Z by 1 minus 1 by K. Putting that here Z_2 means 1 by j omega C_{Mo}; C_{Mo} we are going to find out that is equal to 1 by j omega C_{bc} by 1 minus 1 by K. K is A_V. From this we can cancel out. So C_{Mo} is equal to C_{bc} into 1 minus 1 by A_V.

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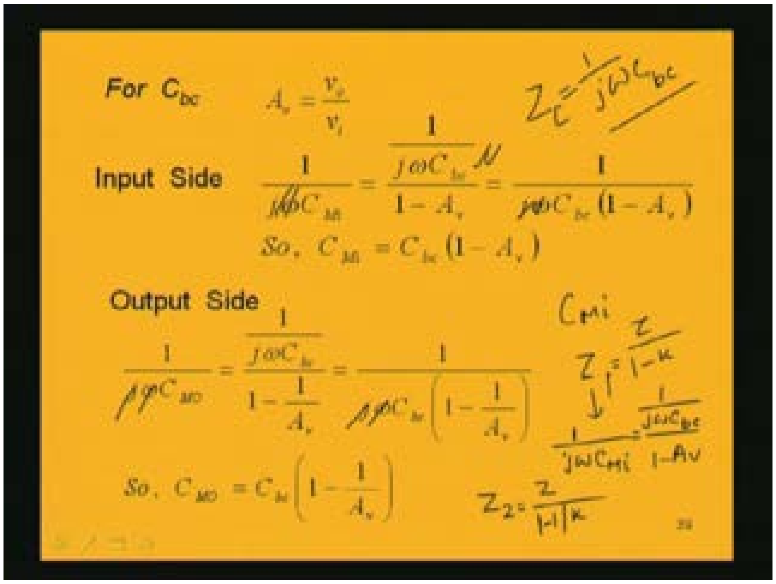

We can replace these values and find out C_{Mi} and C_{Mo}. We will have in our figure or the amplifier two capacitances in the input side because C_{Mi} is there and already C_{be} is there and in the output side there is one capacitance. We can combine these two parallel capacitors because we know that parallel capacitances give the equivalent just by summing up. C_{be} and C_{Mi} can be combined together by summing up and writing it as C_I. Only one single capacitance I am writing by combining both of them which is the input capacitance and the output capacitance is C_{Mo}.

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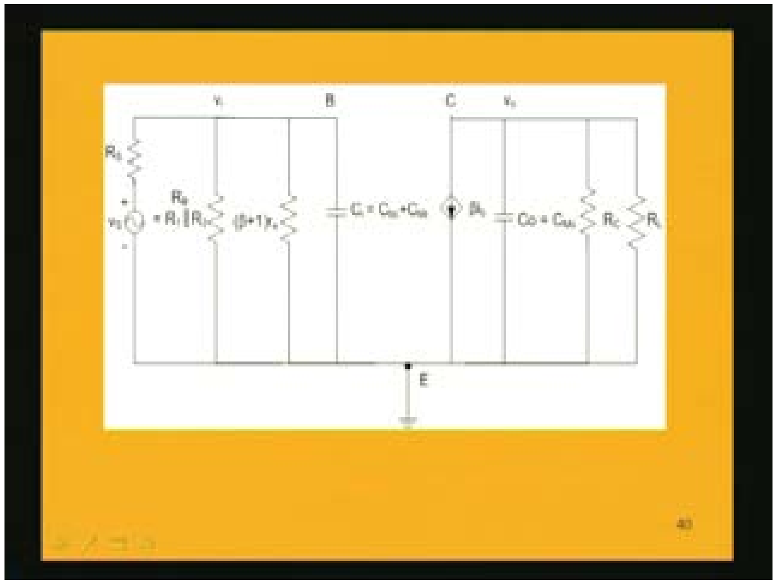

This is a simplified, very easy circuit to analyze or to handle. We are going to find out the upper cut off frequency. For that we have actually two capacitances. Here also we will consider one at a time. The effective resistance if I find out for C_1 from this side, what will be the effective resistance? Look from this C_i. There are 3 resistances in parallel; beta plus 1 r_e, R_B and R_S. That will be the effective resistance R_S parallel R_B parallel beta plus 1 r_e due to C_i.

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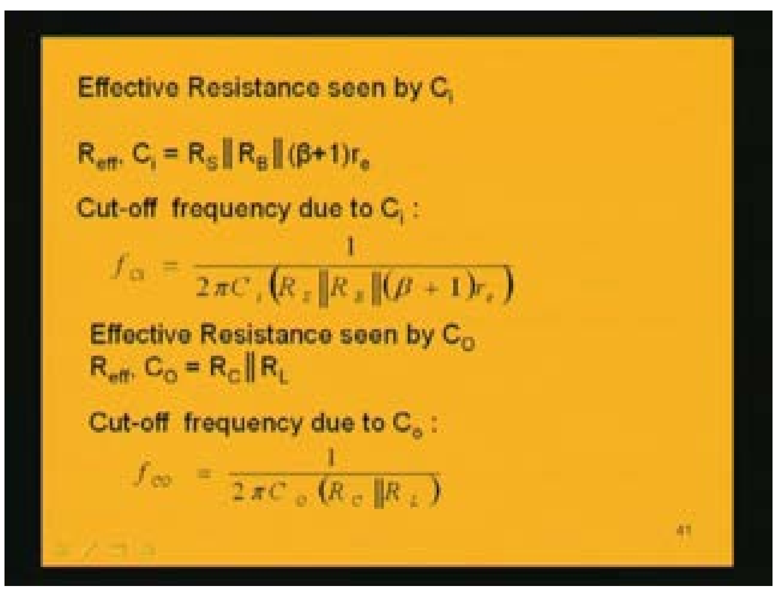

The cut off frequency due to C_i can be written as 1 by 2 pi into effective resistance into capacitance. That is the cut off frequency due to C_i. 1 by 2 pi into C_i into effective resistance R_{eff} is nothing but this value. Similarly effective resistance seen by capacitor C_O is nothing but C_{Mo}. If I look from this side into the circuit and look to find out the effective resistance seen by this capacitor, there are 2 resistances in parallel R_C and R_L. That will be the effective resistance, so effective resistance due to C_O is R_C parallel R_L. We can find out the cut off frequency due to C_O. f_{CO} equal to 1 by 2 pi into C_O into R_C parallel R_L. We have the 2 cut off frequencies. Earlier in low frequency analysis also 3 cut off frequencies we got and took the largest of the 3. Here we will take the lowest among the 2 because if we have a number of cut off frequencies we will be taking in the high frequency region the lowest value. Whichever is having the lowest value that will be the cut off frequency; overall cut off frequency is the smaller of the 2 cut off frequencies.

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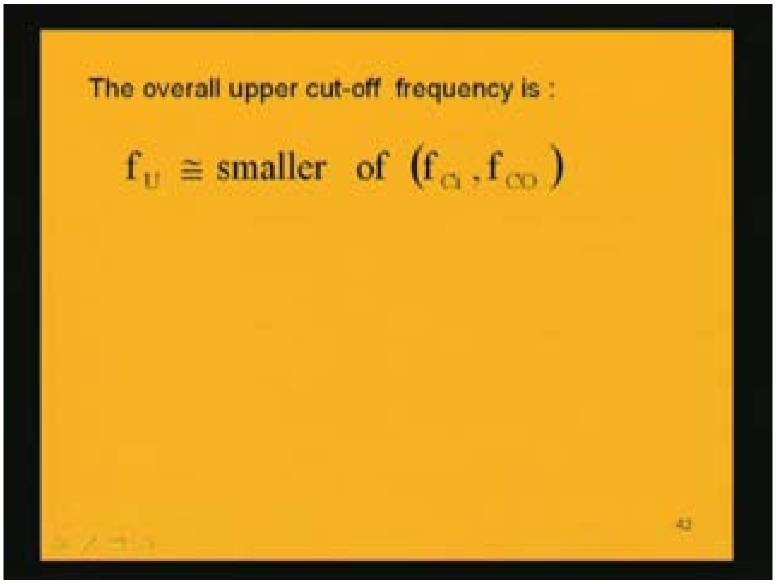

In this analysis we have seen how to find out the lower and higher cut off frequencies. From this we can now do one example to find out the lower cut off frequency for this amplifier shown in this circuit. This is the coupling capacitor and this is the emitter bypass capacitor. We have to find out the lower cut off frequency. In order to find out the lower cut off frequency we have to find out the effective resistance for each of the capacitances and then find out the corresponding cut off frequencies and out of all the cut off frequencies which we obtained for these 3 cases we will be taking the largest value and this circuit is nothing but a common emitter amplifier and here R_O is equal to infinity is given to us.

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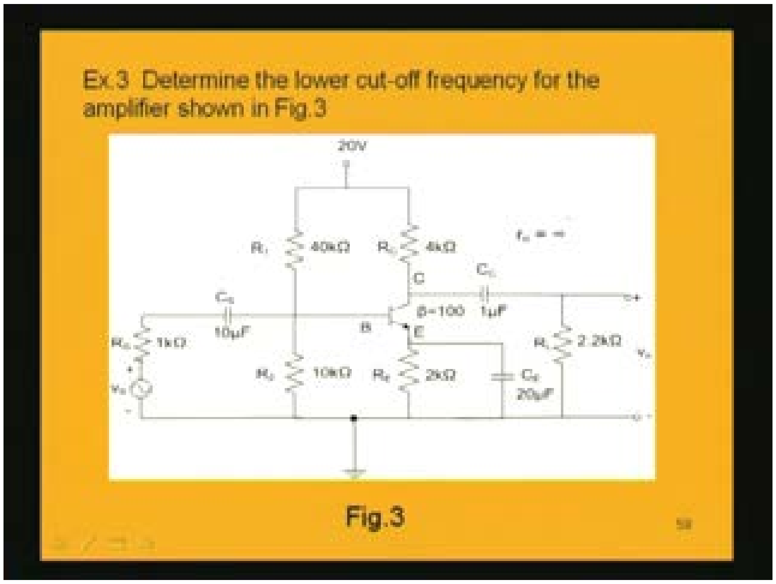

We consider the equivalent circuit. Let us consider first the capacitances together. All of them we will consider and this is a common emitter amplifier. We know that output side is having this current source, dependant current source beta i_b. This is i_b this is beta plus 1 r_e. This we are all familiar with; R_E, C_E and C_S is the source capacitance. R_S is source resistance and V_S is the voltage at the input that is the small signal at the input. R_C is there, R_O is ignored. This is the coupling capacitor and R_L. This is the circuit; this is V_O. This is R_B which is nothing but R_1 parallel R_2 because this circuit is a potential divider biasing circuit having 2 resistances in parallel. R_B will be R_1 parallel R_2.

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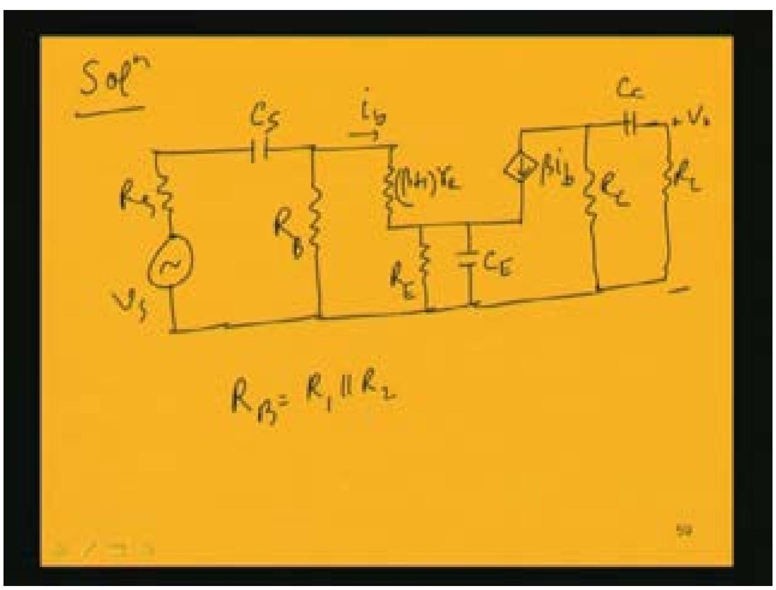

In this circuit R_1 parallel R_2 is the base resistance R_B. In order to know this r_e we have already seen that we have to find the DC equivalent circuit and from that only we can find out what is small r small e, r_e. If we consider DC equivalent circuit it is having resistances R_1 and R_2 and this is R_E, R_C; this is V_{CC} which is equal to 20 volt. R_1 is equal to 40 K ohm.

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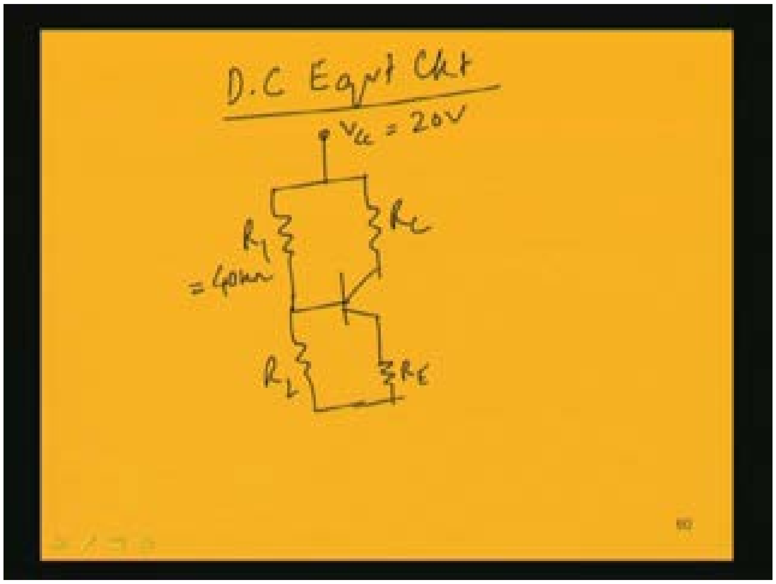

We have discussed about the mid frequency region as well as the low frequency region and high frequency region for the signal which is applied in the input of the amplifier and we have seen the voltage gain. The voltage gain is not affected by frequency in the mid frequency region of the signal but it goes down when we have the low frequency and the high frequency in the signal being applied. Let us do 1 or 2 examples. We will recall our analysis for the mid frequency region that is when the capacitive effects are not there. Such an example let us take for a common emitter amplifier. In this figure is shown a common emitter amplifier where you have to find the voltage gain at no load and also the voltage gain at load and the input and output impedance and current gain. In this amplifier we have to first draw the equivalent circuit in the small signal analysis and what is to be noted here is that there is no series resistance in the source and we will also not consider the R_O because R_O is not mentioned.

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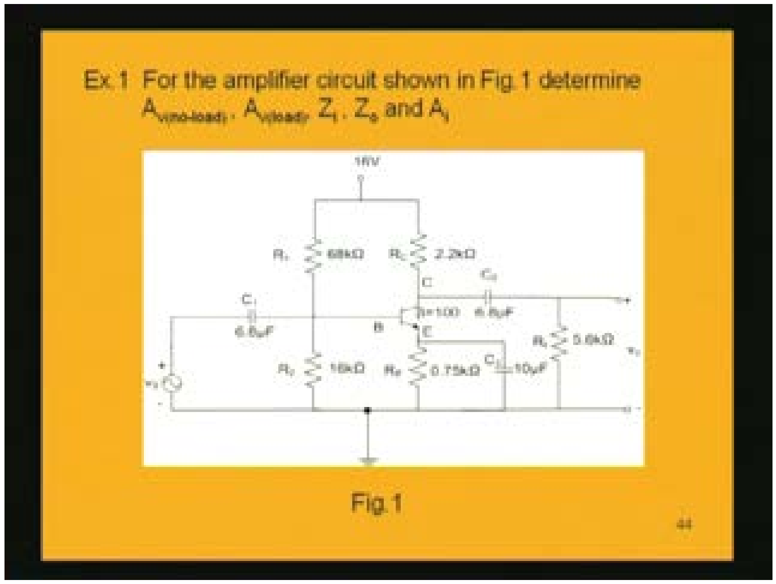

We will consider that the R_O is sufficiently high like it is open circuiting. We will do this example considering the signal analysis in the low frequency region. Let us first draw the small signal equivalent model. Here we have the common emitter amplifier and at the output side the collector resistance and the load resistance R_L, R_C will be there and this is beta times of i_b which is the collector current; beta plus 1 r_e. This is the emitter point, base point and collector. R_B is the resistance at the input which is nothing but the parallel resistances between R_1 and R_2 and this is the signal which is applied and this is v_i at this point, v_o is here. The input current is i_i say and this is the base current.

In order to know r_e again we have to consider the DC equivalent circuit. The value of R_L and R_C are given and the value of beta for this circuit is given as 100. In order to know r_e let us consider the DC equivalent circuit. The DC equivalent circuit if we consider we have the resistances R_1 and R_2 and this is a common emitter circuit. It has R_E. R_C is there. R_C value is given as 2.2 k ohm. R_E value is given as 0.75 k ohm. R_1 is equal to 68 k ohm and R_2 is equal to 16 k ohm. V_{CC} is given as 16 volt. For this amplifier beta value is 100.

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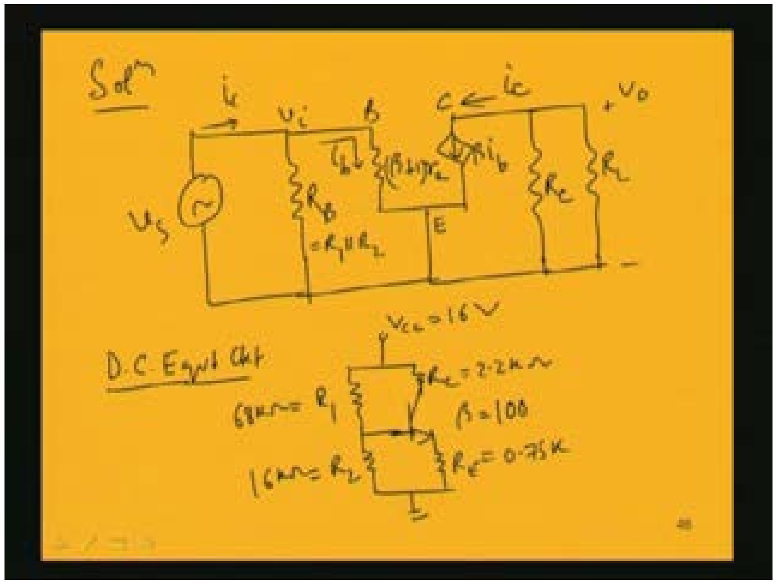

In order to find out this r_e we know that we have to find out capital I capital E, I_E because 26 millivolt by capital I capital E that is equal to the r_e. In this DC equivalent circuit in order to know what is the emitter current flowing we have to draw this Thevenin's equivalent across this base to ground and that will be given by a parallel resistance R_1 and R_2 and a Thevenin equivalent resistance V Thevenin is equal to V_{BB} say which is equal to V_{CC} into R_2 by R_1 plus R_2. V_{CC} in this case is 16 volt, R_2 is 16 k ohm and R_1 is 68; 68 + 16. V Thevenin is equal to 3.05 volt and R Thevenin which I am denoting by R_{BB} is equal to R_1 parallel R_2 that is R_1 into R_2 by R_1 plus R_2. Value of R_1 is 68 into R_2 value, which is 16; 68 into 16 by 68 plus 16 and that come to 12.95 kilo ohm.

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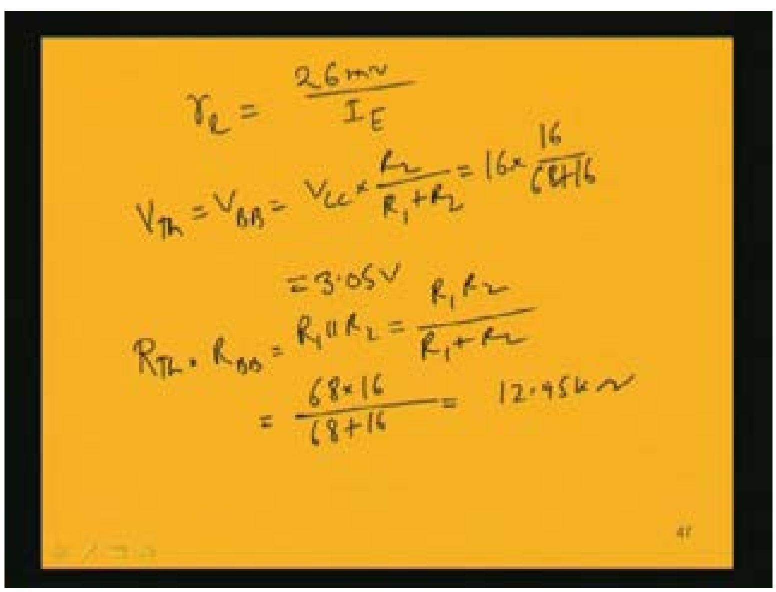

Now we can find out what is the emitter current in this circuit. We can draw the circuit like this. This is V_{BB} which is V Thevenin, R_B that is R Thevenin. The values are 3.05

volt and R_B is equal to 12.95 kilo ohm and then this side is having this resistance R_E which is equal to 0.75 kilo ohm and R_C is there which is equal to 2.2 kilo ohm and this V_{CC} is 16 volt. I_E, this current we are interested in finding out. We know I_E is equal to beta plus 1 I_B. If we consider this input side, the current which is flowing here is I_B, here is I_C and here it is I_E. V_{BB} minus I_B into R_B minus V_{BE}, base to emitter drop, minus I_E into R_E that is beta plus 1 into I_B into R_E that is equal to zero. Replacing the values, 3.05 minus I_B we have to find out; so taking common R_B plus beta plus 1 R_E minus 0.7 is V_{BE}, we have to take 0.7. What is I_B? I_B is equal to 3.05 minus 0.7 divided by R_B plus R_B is nothing but 12.95 plus beta plus 1; beta is 100 for this transistor. 100 plus 1 into R_E value is 0.75. That gives the I_B value to be 0.02651 milliampere. We now know the value of I_B. So we can find out the value of I_C and the value I_E. So I_C is equal to beta times of I_B and I_E value can be found out to be beta plus 1 I_B. Putting the values, beta is equal to 100 and I_B is equal to 0.02651, we get 2.677 milliampere. This is I_E.

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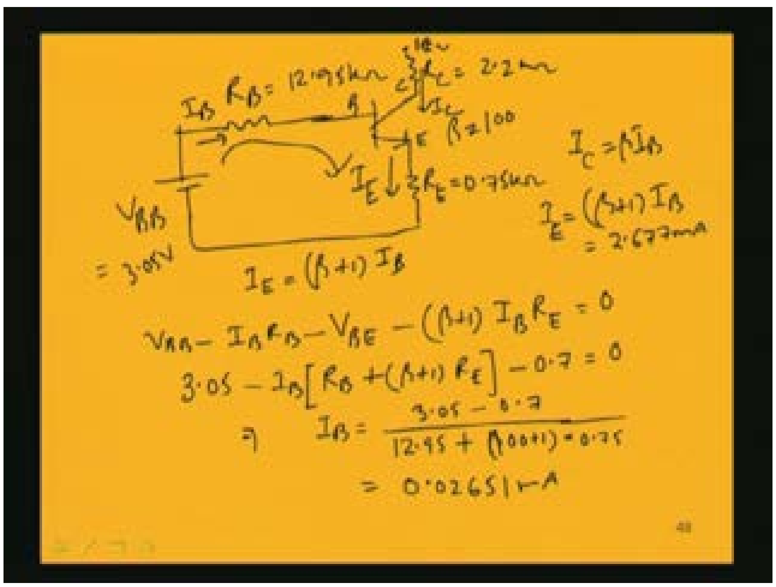

Now we can find out what is small r_e; 26 milli volt by capital I capital E, I_E. 26 milli volt by capital I capital E is 2.677 milliampere. If we calculate this value, it comes to 9.71; this much ohm. After this we can find out the required parameters like $A_{V(no\text{-}load)}$. We want to find out $A_{V(no\text{-}load)}$. That means without this load, if we do not consider this load, what will be the voltage gain with respect to v_o and V_i? If I now calculate v_o, what will be v_o? v_o is equal to the current which is flowing through R_C multiplied by R_C. The current which is flowing through R_C is beta times of i_b if we do not consider R_L. That is called no load. We are ignoring the load means we are having only up to R_C. R_L is like open circuit. So this is called no load voltage. That is v_o by v_i is equal to minus i_o into R_C by i_b into beta plus 1 r_e. If we look into the circuit the v_i is equal to i_b into this resistance beta plus 1 r_e and the current which is flowing through R_C is the same current beta i_b which is nothing but i_o because i_o will be now same as i_c without load. So multiply it by R_C that gives the output voltage and i_o is nothing but beta times of i_b; so minus beta times of i_b

into R_C by i_b beta plus 1 r_e. We get minus beta R_C is equal to minus 100; R_C is 2.2 k and beta plus 1 is 100 plus 1 and r_e we have found out to be 9.71. But this is in ohm. We have to convert it to kilo ohm and this gives the value of -224.33. This is no load voltage gain.

If I consider load, A_{vload}, this value of v_o by v_i will be minus i_o into R_L by denominator will be same. Finally i_o can be written as beta i_b into that part of the current which flows through R_L and that is beta times of i_b into R_C by R_C parallel R_L into R_L by i_b into beta plus 1 r_e. This value when you put, it will be equal to minus 100 into R_C value is 2.2, R_L is 5.6 kilo ohm by 100 plus 1 and R_E value is 9.71 into 10 to the power -3 and that value is equal to -161.06.

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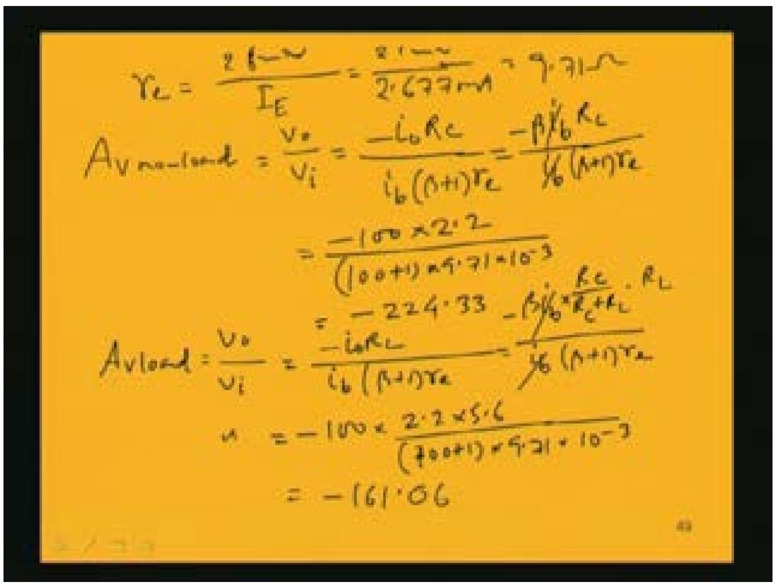

We see that when it is with load the voltage gain reduces because of the fact that now the load resistance R_L will be in parallel with R_C. The equivalent resistance at the output will be reduced. That is why we are getting a lesser voltage gain than without load.

What is input impedance? That is v_i by i_i. v_i is i_b into beta plus 1 r_e and i_i in the denominator If I look into the circuit i_b is equal i_i into R_B by beta plus 1 r_e. Putting this value i_i into R_B in R_B by R_B plus beta plus 1 r_e by i_i into this small r_e will be there. This is equal to R_B into r_e plus R_B plus beta plus 1 r_e. This is beta plus 1 r_e in the numerator because I am writing i_b with this quantity and beta plus 1 r_e there. This is nothing but R_B parallel beta plus 1 r_e and if you find out this parallel impedance of 12.95 and 100 plus 1 into 9.71 into 10 to the power -3, that comes to 0.91167 kilo ohm. Finally we get that. It is 911.67 kilo ohm. Similarly we want to find out what is the output impedance? Output impedance looking from this point is nothing but only R_C. When you make this V_S equal to zero this i_b will be zero. It will be open circuit. We are left with only 1 resistance at the output and that is equal to R_C. The value of R_C is equal to 2.2 k ohm.
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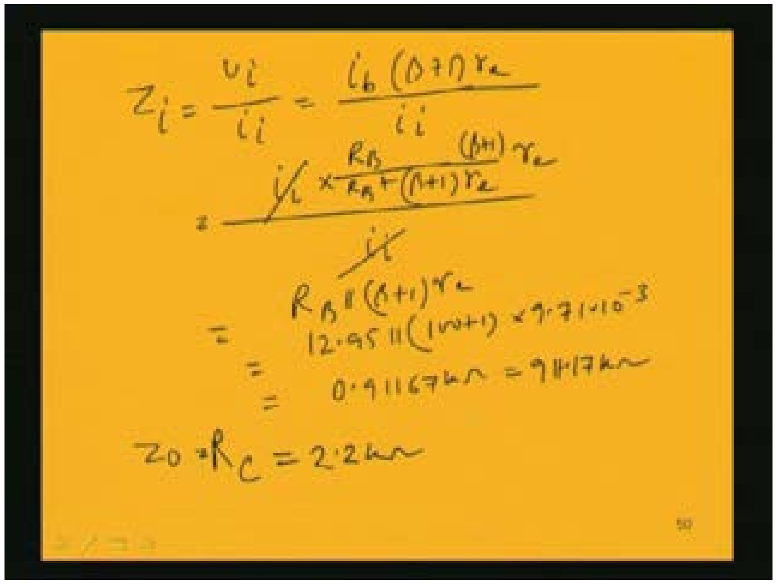

The output impedance is 2.2 k ohm. In this circuit we have considered an amplifier circuit having no effect of capacitance. That is we are considering only in the mid frequency region and we are finding out the voltage gain and other impedances like input and output with no load as well as with load. But that will not be the same analysis if we consider it in the lower frequency or higher frequency region because this voltage gain we have found out will be not the same, it will be reduced.