Basic Electronics
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Module: 2 Bipolar Junction Transistors
Lecture-7
BJT Amplifier – Part 2

In the last class we discussed about common emitter amplifier and today we will discuss other type of amplifier like common base and common collector amplifier. Common base amplifier has the base common to both the input and output circuits. The input circuit is between the emitter and the base and the output circuit is between the collector and the base and the base is grounded. Let us discuss a common base transistor amplifier. In this common base transistor amplifier we are having two DC sources V_{EE} and V_{CC}.

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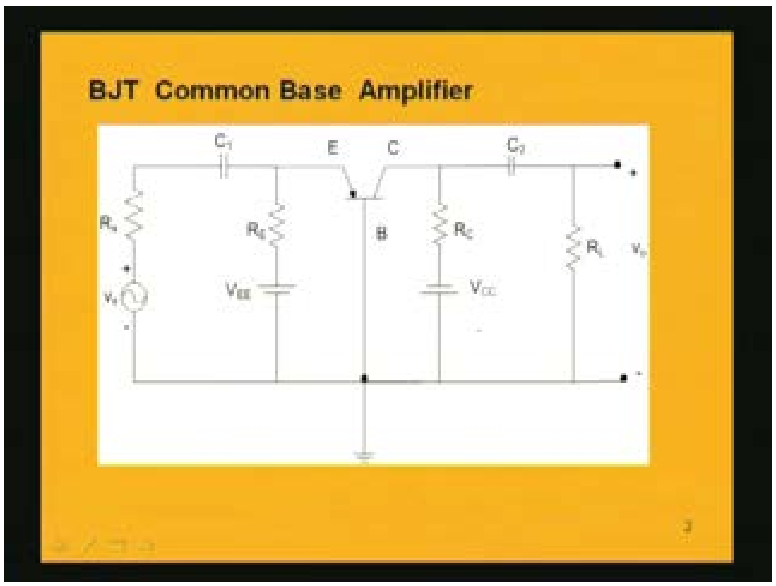

These sources are there for biasing the transistor in the forward bias as well as the reverse bias conditions. The emitter base junction will be forward biased by V_{EE} and the collector to base junction will be reverse biased by V_{CC}. There are two different sources here and the resistance which is connected from emitter is R_E and collector has resistance R_C and the source V_S which is a weak signal and which has to be amplified is coupled by the coupling capacitor C_1 and the source has a resistance R_S in series with it and the coupling capacitor at the output side is C_2 which couples the output voltage. It prevents the DC voltages and only allows the AC voltage. That is the reason for connecting these coupling capacitors. We are taking for example a PNP transistor which is indicated by the arrow mark in the emitter base junction and that is why the polarities of the DC sources V_{EE} and V_{CC} are like this and emitter base is forward biased by V_{EE} and collector base is reverse biased by V_{CC}.

In order to analyze this common base transistor amplifier as usual we will have to draw the AC equivalent circuit and we will have to incorporate the transistor model. The r_e model that we are discussing will replace the transistor. We will do that and we note that there is a load resistance at the output across which the voltage available is V_O and that voltage is the output voltage which we get after amplification. In order to draw the AC equivalent circuit for this amplifier, following the usual procedure we will have to first short circuit the DC voltages, make them zero and the capacitances are assumed to be quite large so that under the frequency of operation that is the frequency of the signal V_S these capacitors are offering short circuit path. Following these steps we will now draw the AC equivalent circuit for this amplifier. Here these two DC sources V_{EE} and V_{CC} will be grounded or made zero. The capacitor C_1 and C_2 will be now short circuited and amplifying circuit after drawing this AC equivalent circuit will look like this. Here after removal of the DC sources we are left with this circuit and the capacitors are also removed because they are short circuiting and the source is V_S along with this resistance R_S and we are having this resistance R_E and R_C. R_E is here in the emitter and R_C is in a collector; load resistance is there R_L in the collector side and the transistor is being replaced by the r_e model. This part is the transistor model. Here we have this resistance R_E, the emitter base forward bias resistance and the current which is flowing through R_E is the emitter current i_e.

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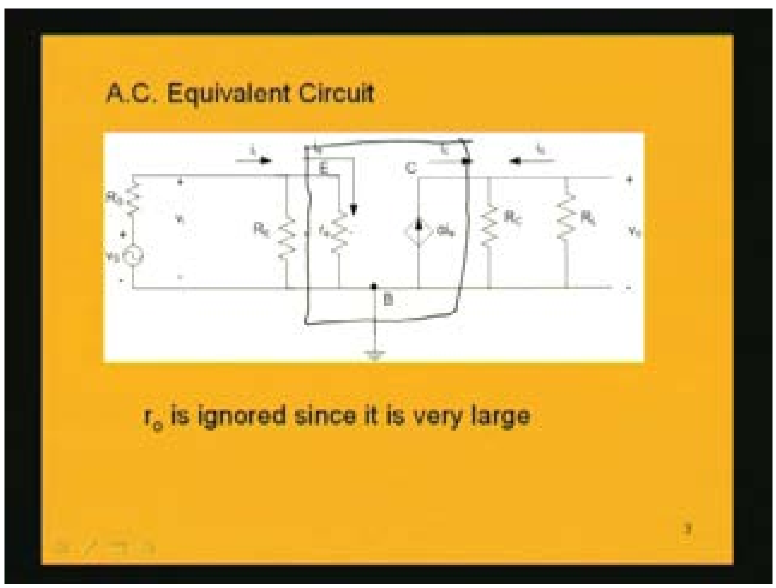

Because it is a common base transistor base is grounded and it is common to both input and output circuit and at this point emitter is the input current i_e and the collector current is at the collector or output which is i_c and remembering the relation between the collector current and the emitter current for a common base transistor we know that i_c by i_e equal to alpha. The current amplification factor for the transistor in common base is denoted by alpha. Alpha has maximum value of 1. So i_c equal to alpha times i_e. That is why i_c can be assumed to be a dependent current source whose value is alpha times i_e.

That is why we are writing alpha times i_e in the dependent current source and the direction of current for this PNP transistor is this. It will be going out of the device and input current i_e is coming into the device. This is the AC equivalent circuit. Here one thing to notice is that we are ignoring r_o. The transistor output resistance r_o is here neglected since we know that for a common base transistor the output resistance is very, very large even larger than the common emitter and we have seen earlier that the current in the output that is the collector current is almost horizontal with respect to the collector base voltage and we were having actually almost horizontal characteristic curves in the output characteristic, without any slope.

Even though we change V_{CB} there is not going to be any change in the collector current. That is why we can very well assume that this resistance which is actually present in the output of the transistor that is the output characteristics will give us the output resistance. But that is very, very large; we can assume that it is almost equal to infinity. Because it is very large, practically, ignoring it will not affect anything. Because if r_o is very large even though if there is the resistance r_o whose value is very large, no current can flow through this r_o because of this property that it is very, very large almost equal to infinity. That is why we are ignoring it conveniently in this circuit.

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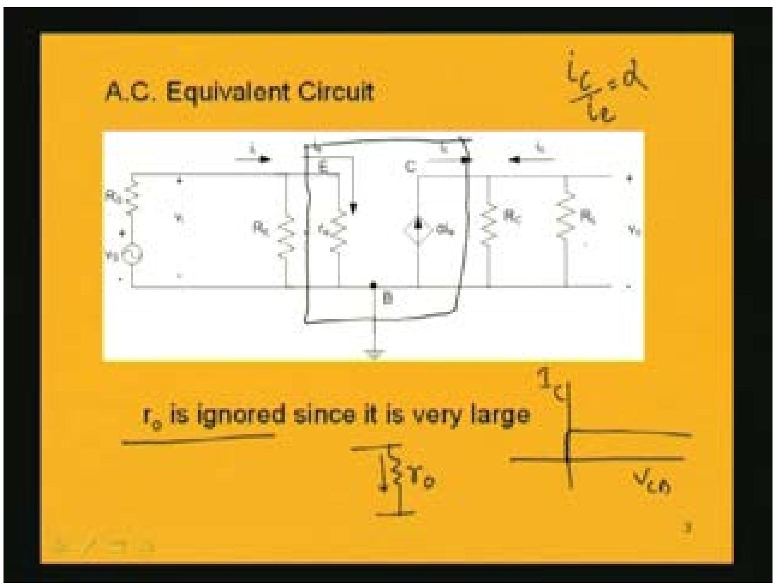

From this circuit we can proceed to find out all those parameters. The parameters of interest here are the input impedance, output impedance, voltage gain and current gain. We will find out input impedance first. The input impedance means the ratio between the input voltage v_i and the input current i_i. v_i by i_i will give the input impedance and replacing the value of v_i if we consider this circuit and find out the voltage at this point v_i input terminal, it is equal to the current flowing through this r_e multiplied by this R_E. v_i is equal to i_e into r_e. This is the input voltage or we can also write it in another way that, v_i is also equal to the current flowing through this resistance r_e into R_E. Anyway we write, ultimately we will get the same expression because what is i_e? In terms of i_i if I write i_e is nothing but i_i into capital R_E by capital R_E plus small r_e. This is the i_e current multiplied by small r_e. Even if you take this other resistance and find out the current, it will be i_i into R_E by R_E plus small r_e into capital R_E. That will give you the same expression. After writing down v_i equal to i_i into R_E by R_E plus re into small r_e divided by input current i_i we can now cancel out these two. The i_i, i_i cancel out so what will be left with is the input impedance R_E by R_E plus small r_e into small r_e and that is nothing but the parallel equivalent resistance between RE and small r_e.

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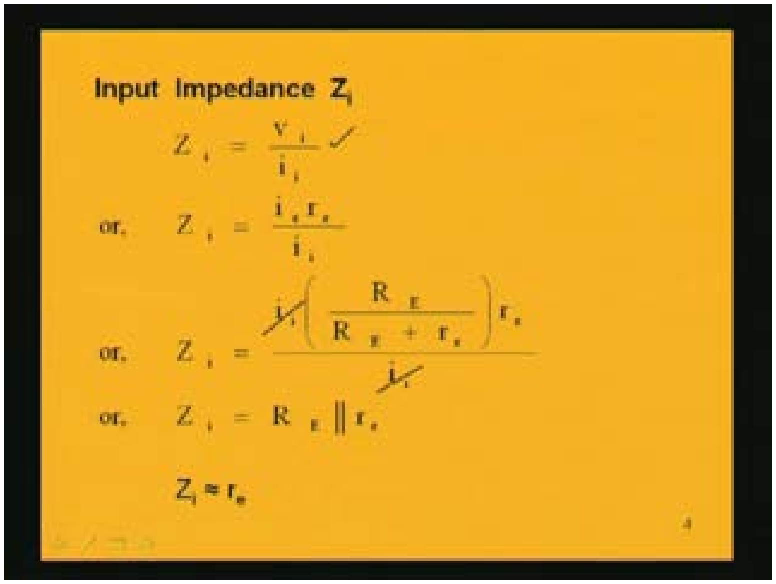

The input impedance is the equivalent impedance between the two parallel impedances capital R capital E, R_E and small r small e, r_e. That is very, very evident if we look from this input terminal into the transistor input circuit. We are having two resistances parallel. One point it is connected to emitter, other point is ground. These two are parallel resistances. So we have this parallel combination as the input impedance and mind it, here actually although I am using the term impedance but basically all are resistances. Z_i is nothing but actually input resistance because there are no other components like capacitance, inductance, etc; here only few resistances are there. So input impedance is nothing but input resistance, which is capital R_E parallel small r_e.

One thing to notice here is that out of these two resistances r_e is very, very small. It is in the order of ohms whereas typically the (13:15) R_E is generally is in the order of kilo ohms. As we know whenever we have two resistances in parallel one is having a large value and other is having a small value, the equivalent resistance approaches towards the smaller value. This parallel combination will give almost equal to R_E value. Even numerically also you can do and see but this is just to bring out the fact that input impedance of the common base transistor or input resistance of the common base transistor is very small. It is because it is almost equal to R_E and R_E we know the emitter resistance in the transistor model is having a value of around some ohms. Input impedance or input resistance is small in a common base transistor.

To find out the output resistance or output impedance, look into the amplifier from the output terminals. We have to look from this point to find out Z_O; from the load we will have to look excluding the load. If we want to find out the output resistance or output impedance we will look from the load into the output circuit making the input source zero. So V_S is made zero. Whenever V_S is made zero i_e will be zero, so i_c will be zero. We are left with this circuit having only R_C resistance.

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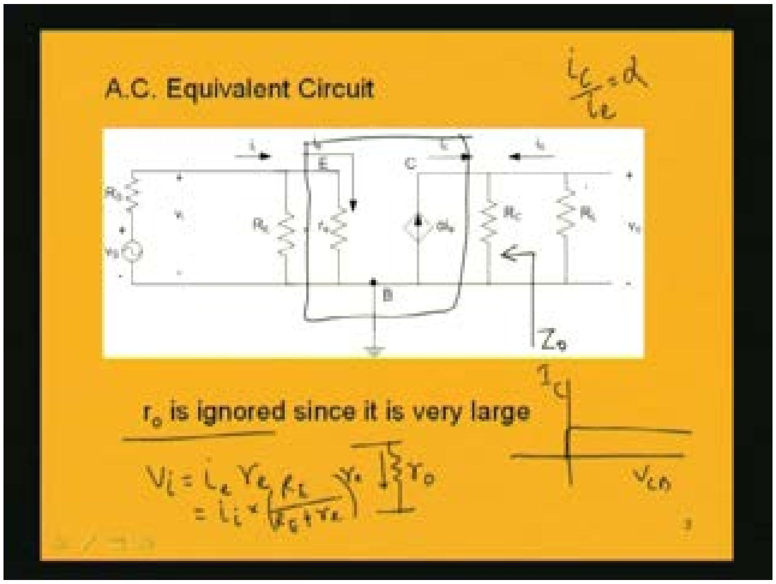

The output resistance is R_C. Output resistance or output impedance of this common base transistor is R_C. We have found out input impedance or input resistance and output impedance or output resistance for this common base transistor.

Next let us find out the voltage gain for this common base transistor. Voltage gain we know is the ratio between output voltage and input voltage. That means we have to find out v_o by v_i. Again looking into the circuit find out v_o by v_i. What is v_o? v_o is equal to minus i_o into R_L. This point is positive this point is negative; as far as v_o is concerned we are finding out i_o into R_L. i_o is basically flowing this way. This is i_o. i_o is this one, from bottom to top. Its direction is reversed than what we are assuming for v_o. So it will be minus i_o into R_L. Again what is i_o? i_o is nothing but that part of the current which flows through this resistance R_L coming from this source or dependent source, alpha i_e. Because we see here alpha i_e is divided into two parts, one is going through R_C, one is going through R_L.

The part of the current which goes through R_L is basically alpha i_e into R_C by R_C plus R_L but the direction is opposite to i_o. If I find out that part of the current, i_c is basically one part is flowing through this and one part is flowing through this. But we have assumed i_o to be in this direction; conventionally that is done like that. So again I have to have a minus sign. This i_o is basically minus i_c into R_C by R_C plus R_L and multiplied by R_L. Ultimately it will be positive. v_o is i_c into R_C parallel R_L.

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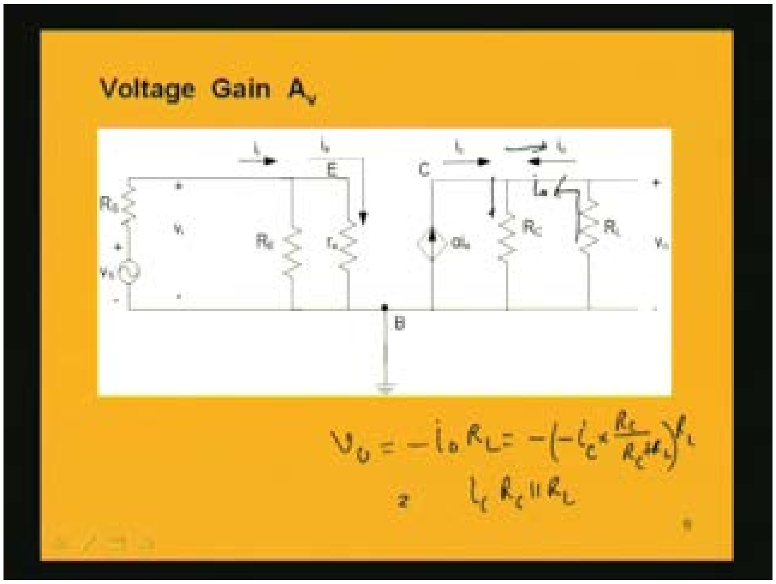

Again what is i_c? i_c is equal to alpha times i_e. Replacing again I get alpha times i_e R_C parallel R_L. This is the output voltage and input voltage we have already found out. From the earlier expression input voltage is i_e into R_E. Input voltage is small i_e into R_E. i_e is nothing but we can replace it by i_i into R_E by R_E plus small r_e. The whole thing multiplied by r_e. What we get is i_i into R_E parallel r_e. These two are the expressions that I get from v_o and v_i.

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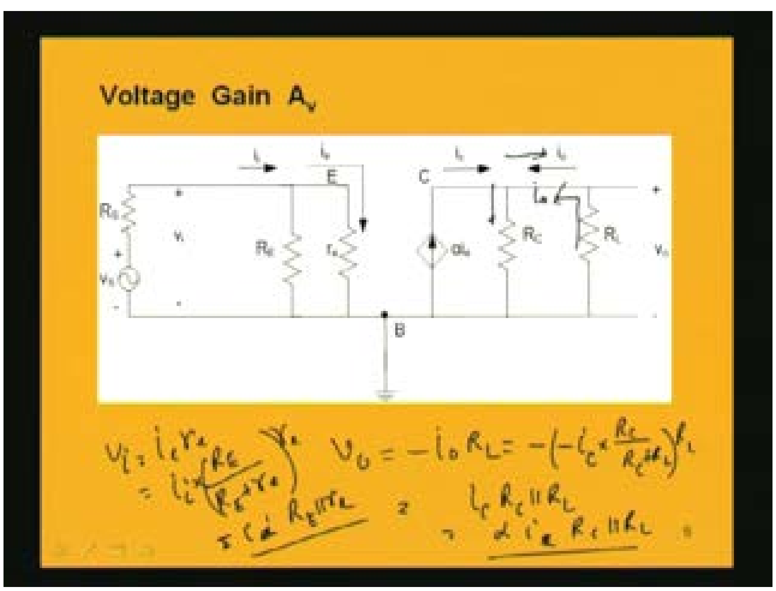

Replacing, here we are getting alpha times R_C parallel R_L. This is this output voltage and it is R_E parallel r_e.

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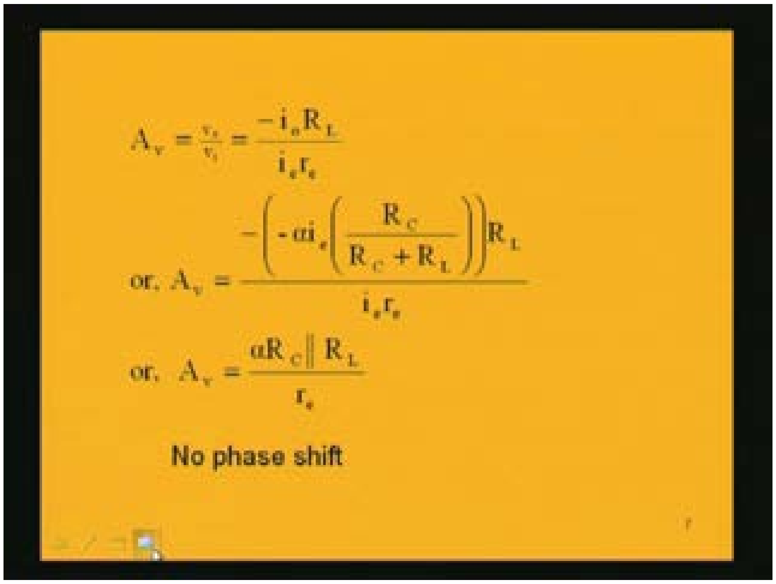

This input is i_e parallel R_E, so i_e, i_e can be cancelled out. Instead of expressing with respect to i_i let us keep it here. The numerator for this voltage gain, output voltage v_o is equal to, minus and minus becomes plus, so alpha times i_e into R_C parallel R_L and the denominator becomes i_e r_e; i_e, i_e cancel. What we get is alpha into R_C parallel R_L by r_e and one thing to be noted here is that in the voltage gain of common base transistor amplifier there is no negative sign in the expression meaning that there is no phase reversal or phase shift occurring in the output voltage with respect to the input voltage. That is different from a common emitter amplifier because in common emitter amplifier we have seen that the phase reversal of 180 degree takes place between input and output voltage but then here there is no phase shift as far as the voltage is concerned.

If we want to find out the overall voltage gain, as we have done earlier it is equal to the voltage gain A_v multiplied by Z_i by Z_i plus R_s.

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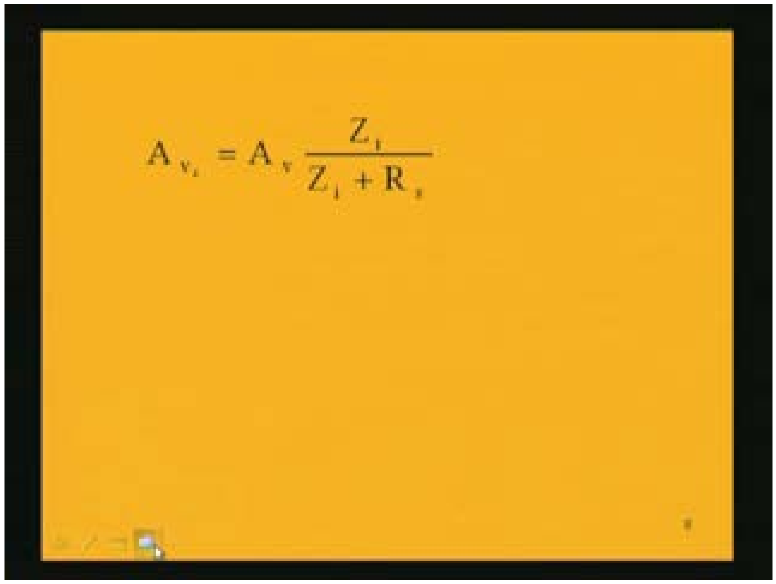

In order to find out current gain we will use this expression for current gain. Current gain is i_o by i_i, output current by input current. What is output current i_o? Output current is the part of the current which flows through R_L and this part of the current which is coming from i_c. But it is in the negative direction because i_c is having one part here and the other part here. This part is just opposite to the conventional direction of i_o. We can write it as minus i_c into R_C by R_C parallel R_L and i_i let us keep it as i_i. We can write i_c as alpha times i_e R_C by R_C parallel R_L and i_i.

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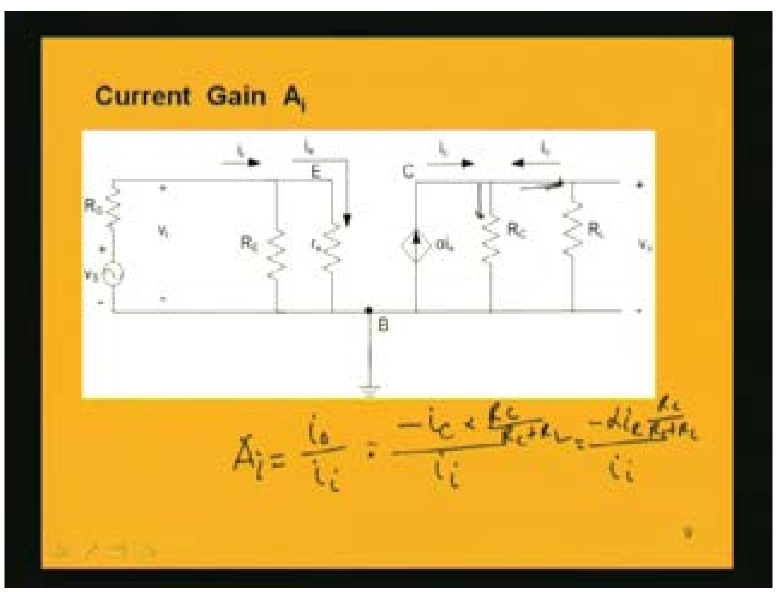

Proceeding in this manner, we have a minus sign here; that has to be noted. So it is minus alpha i_e into R_C by R_C plus R_L. Again I can write down this i_e as that part of the current, input current which flows through R_E and that is equal i_i into R_E by R_E plus r_e. So i_i into R_E by R_E plus small r_e. Replacing this i_e in the numerator by this expression we get minus alpha into i_i into this whole term and this term and the denominator is having i_i. I can cancel out i_i and i_i. Here the final expression for this current gain is obtained and here we have to note that the current gain is having a negative sign.

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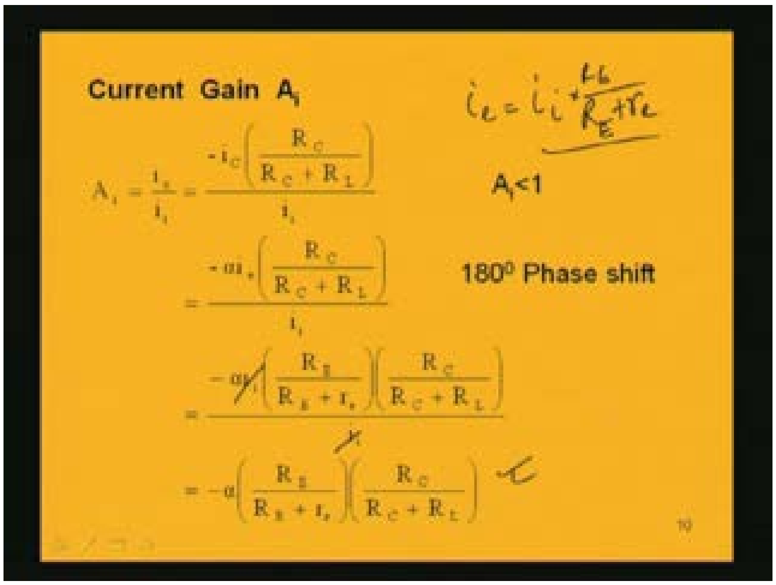

That means the current at the output and the current at the input they have a phase reversal of 180 degree. The voltage does not have a phase reversal; output voltage and input voltage are in same phase. But the current at the output and the current at the input i_o and i_i have a phase reversal of 180 degree that is denoted by this minus sign. Here this current i_i in this direction, the current i_i in this direction if we compare them i_o by i_i that has a negative sign because of this fact that they have a phase reversal.

Where is this common base amplifier mostly used? Actually the common base amplifier is very frequently used as a current buffer. The current buffer means suppose we want to use the common base amplifier as a buffer stage between a source and a load. When will we use it as buffer sources, buffer transistor? We will use it when we have a load very small as compared to the resistance which is in parallel with a current source. Suppose in this circuit we are having a current source having a current I and we know that all current sources are having a resistance parallel to it. Ideally that should be infinity because then no current will flow through the R_S and all the current will flow through the load. But practically that does not happen because the resistance which is in parallel with the current source is generally having a value less than infinity. What is happening here is that this load R_L is getting a current $I-I_{RS}$. I_{RS} is the current which flows through this source resistance which is in parallel with this current source and a part of it is only going through R_L.

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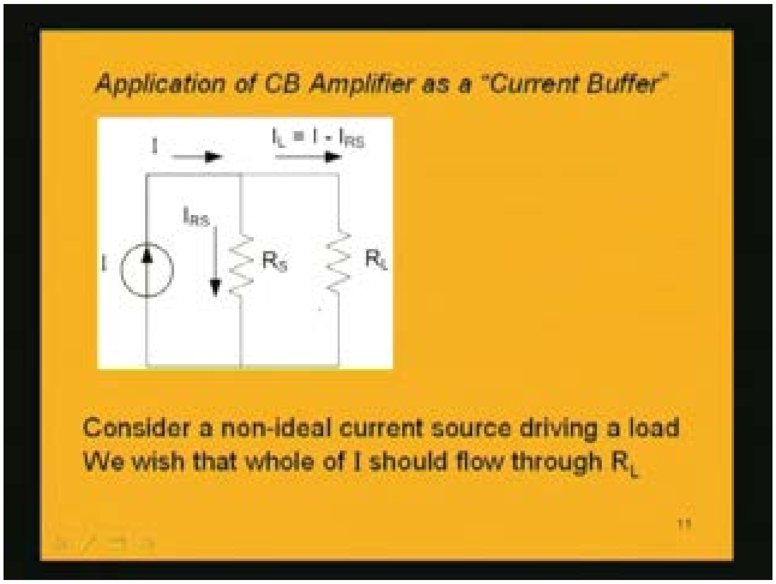

If the load resistance is very small but the source resistance R_S is very high; for example a typical case can be thought of where we are applying the output voltage to a loud speaker. Loud speaker has very small resistance, may be 2 ohm, 4 ohm, like that and if this resistance is not infinity then what will happen? The current which will be flowing I-I_{RS} as this is not equal to I then we have to basically think about something where we will be getting the whole amount of the current I and for that what is done is that there is a buffer stage common base amplifier and that buffer stage is included between the source and the load.

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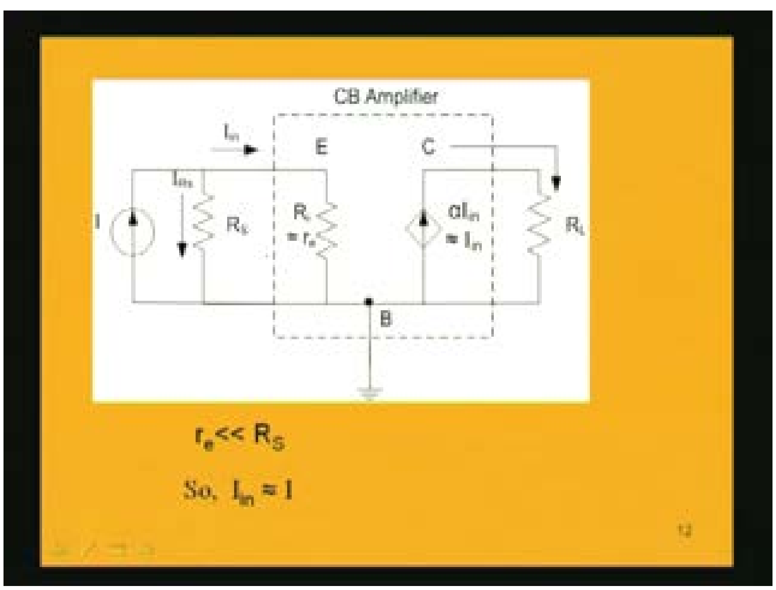

What will happen if we use a common base amplifier? Common base amplifier has input resistance which is very small because it is almost equal to R_E. This current source has a small resistance. At the input of this transistor there are two parts. But this has a very small value as compared to R_S. So mostly all the current will flow through this small r_e and this R_E being very, very small as compared to the resistance of the current source almost all the current will flow through r_e. The common base amplifier has a current gain of maximum value, 1. If we consider current gain of this common base amplifier, its maximum value can be 1. If we consider this output current, alpha times of i_e is this current. i_e means this current and that current is equal to the input current now. So alpha times I_n is the current here at this current source and this is almost equal to i_e because alpha is almost equal to 1. What we get is, here this current I_{in} is same as the current I, because of this fact that all the current is passing through this r_e. I_{in} equal to I means this load is getting the current I. Practically it is getting the whole of the current from the source. That is why common base amplifier is effectively used as a buffer stage in this type of examples. When we want to get all the current from a current source in a load then we can use it as a buffer.

Another amplifier which is used is common collector amplifier. Common collector amplifier has the collector as common to both input and output circuits. How this collector is common and grounded that we have to look for.

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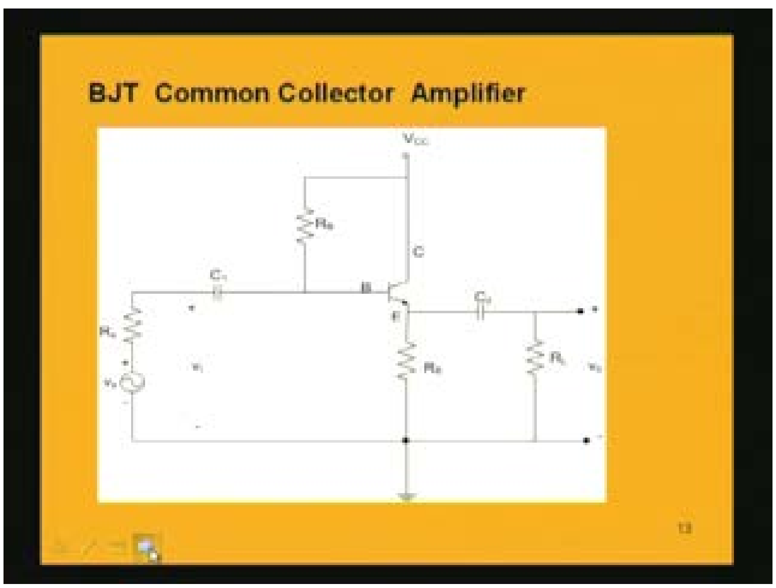

First let us discuss the circuit of a common collector amplifier having a resistance R_B, biasing resistance and this circuit looks similar to the common emitter amplifier. But only thing is here that the collector is not having any resistance R_C. It is directly connected to the source V_{CC} that is the biasing source and the voltage is obtained across the resistance R_E which is connected to the emitter. We are not getting the voltage as in earlier cases. In earlier cases we were getting the voltage between collector and ground but here between emitter and ground we will be getting the output voltage and this load resistance is also between emitter and ground. But as far as the biasing is concerned it is the similar to that fixed biasing circuit of the common emitter amplifier.

How it is common collector amplifier that means how this collector is common? In order to understand that let us first draw the AC equivalent circuit for this amplifier. If we draw the AC equivalent circuit following the usual procedures we will be making the V_{CC} source zero or grounded, so collector is directly grounded and the circuit will look like this. Here we are considering an NPN transistor. If we start from base, this is the base point, this is the emitter and this is the collector.

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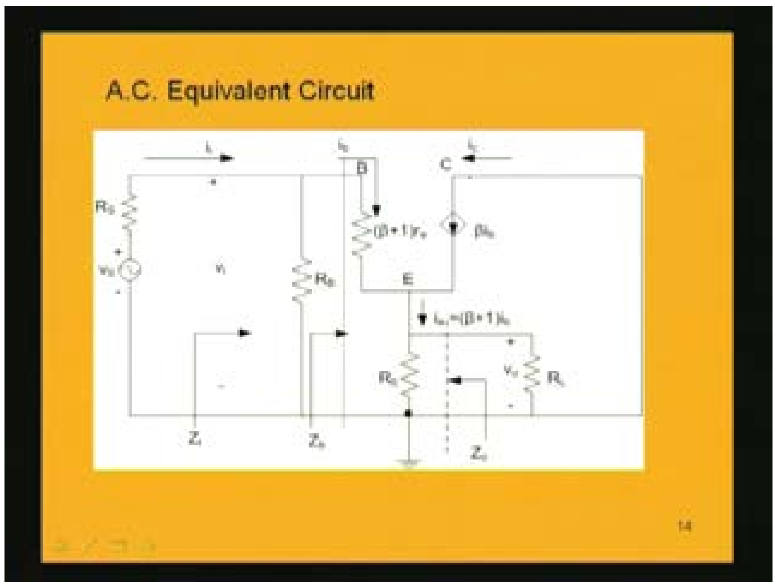

Here base is having this resistance R_B to ground because V_{CC} is grounded and B is also through this short circuited path. After eliminating this capacitance C_1, it will be having the source resistance and the source. This is the source resistance and the source, V_S. The collector is directly grounded and R_C is also not there. It is grounded, C point is grounded and emitter is having the resistance R_E because in this circuit if you look emitter is having this resistance R_E. This capacitance C_2 is shorted, so it is having this resistance R_L also which will be now parallel with R_E and connected to ground. This is happening here. R_L and R_E are parallel and connected to ground.

Now we understand why this is called common collector because if you look into the input and output circuits, input, base and this point is having the input circuit. This point is what? This point is nothing but this collector point. Collector point is directly grounded. As this collector is grounded we are having the input circuit between base and ground where collector is grounded and the output circuit, output circuit means we are getting the voltage across this resistance R_E, which is connected to the emitter. The output is between emitter and collector, collector is grounded. This is one part of the output circuit. This is input circuit, this is output circuit. Input circuit is through this is the whole loop and output, whole loop is this one.

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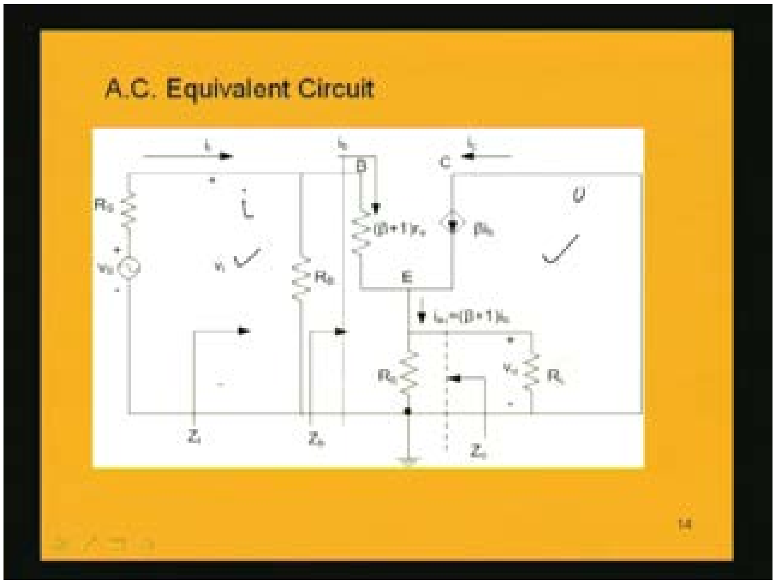

Here it is clear that the collector is common. This point is a common point which is grounded and that is nothing but this collector. This point is collector and this point is the same. This circuit is a bit different. In order to analyze it we must be careful because the current which is flowing through this base emitter circuit that is the transistor is being replaced by its model, so the emitter base junction as usual is having that resistance beta plus 1 r_e. The current which is flowing through this beta plus 1 r_e is i_b and from this point the current which is flowing is emitter current. Emitter current is beta plus 1 i_b and this is the collector current which is beta times i_b. Beta times i_b and i_b are joining here to give rise to the total current which is the emitter current.

The analysis of this circuit can be easily done to find out all those parameters like input impedance, etc. Input impedance can be found out by looking into the input circuit from the input terminals or rather from the source. If we look from this side Z_i, then we have to get the input impedance considering this circuit. But you have to be careful because here the input circuit is having RB as well as this resistance beta plus 1 r_e and there are 2 resistances in parallel, not only single R_E. That point has to be carefully noted; at this point we have the two resistances R_E and R_L in parallel. We want to find out input impedance by taking the ratio between v_i and i_i. What is v_i? This voltage from base to ground or collector is grounded. The voltage from this point to this point is i_b into this resistance. That is i_b into beta plus 1 into r_e plus voltage drop from emitter to ground and the voltage drop from emitter to ground is beta plus 1 i_b into the parallel impedance or parallel resistance between this R_E and R_L.

Doing that we find what is v_i? v_i is equal to i_b into beta plus 1 r_e plus beta plus 1 i_b into R_E parallel R_L and that can be combined. Taking common i_b and beta plus 1 we can get i_b into beta plus 1 into small r_e plus R_E parallel R_L. This is the expression for v_i.

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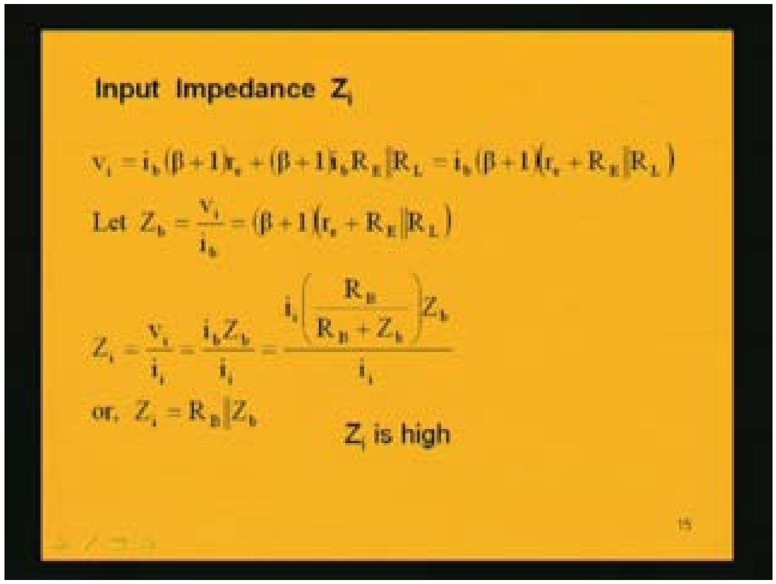

We can find out the value of resistance at the base to ground that is denoted by Z_b. To simplify the matter a bit let us find out what is Z_b? Z_b if I look from this point that is the resistance between input impedance or input resistance between this and this point. That means it is the ratio between the voltage v_i and current i_b. Z_b is v_i by i_b. Again v_i is beta plus 1 into R_E plus capital R_E parallel capital R_L because v_i is this whole thing divided by i_b. i_b, i_b cancels; so this will remain. If I want to find out Z_i by v_i by i_i, I can simply write down. What is v_i? v_i from this expression I can put down. So that is equal to i_b into Z_b. i_b into Z_b is v_i divided by i_i and that is equal to i_b again can be written as i_i into R_B divided by R_B plus Z_b. This is what we are doing; i_i into R_B by R_B plus Z_b into Z_b divided by i_i. Then these two cancel. What we are left with is this expression which is nothing but R_B parallel Z_b. If I replace Z_b by this value then we get the final expression.

One thing to be noted here is that the Z_i or the input impedance or rather input resistance is high in this common collector amplifier because both the values, R_B and Z_b will be high. Since Z_b is equal to this beta plus 1 into this thing and R_E plus this parallel impedance, this parallel impedance will be having higher order; so the whole thing will be high. That means even though it is parallel with R_B, i_b is again having a high value in the order of kilo ohm generally. The value of this Z_i in a common collector amplifier is high and next we find out the output impedance.

After input impedance we will find out the voltage gain. Voltage gain is v_o by v_i. v_i we have just now calculated that is ib into beta plus 1 into r_e plus R_E parallel R_L and v_o if you look into the circuit find out what is this voltage? The voltage between this point and this point or emitter and ground that is equal to the current flowing multiplied by the parallel impedance between these two. In that way if you look it is very easy to understand. What will be this v_o? v_o equal to the current i_e into the parallel impedance R_E parallel R_L. That is what is done here and what is i_e? That can be written as beta plus 1 into i_b R_E parallel R_L. This is the expression for v_o.

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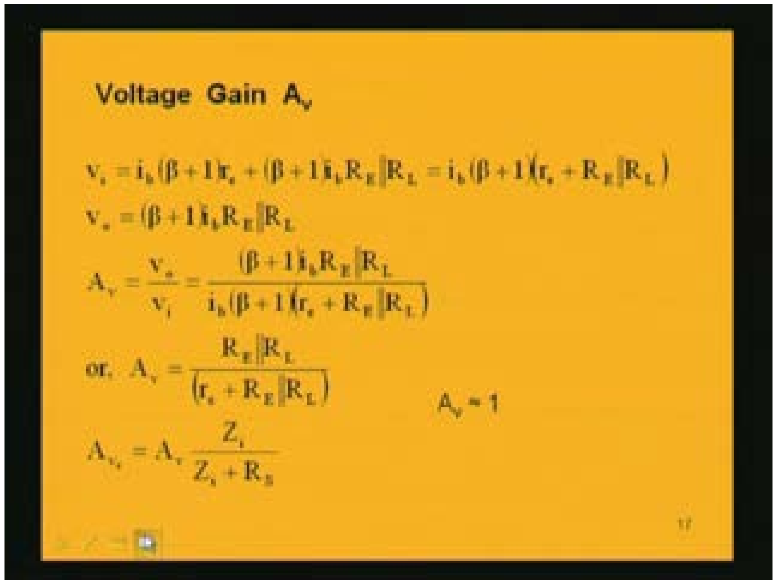

v_o is equal to beta plus 1 i_b into R_E parallel R_L. Dividing v_o by v_i, the whole expression by this expression we will get A_v. Replacing this we get A_v equal to this divided by this. We can cancel out i_b, i_b and also we can cancel beta plus 1 into beta plus 1. We are left with the expression R_E parallel R_L divided by small r_e plus R_E parallel R_L. If we notice carefully this expression then we see that the denominator is higher than the numerator because in the denominator we have another extra term r_e; small r_e plus R_E parallel R_L. But in the numerator it is R_E parallel R_L. That means we get a fractional value. Maximum can happen only if r_e is very, very small so that we can ignore. Then the numerator and denominator will cancel out and then it will be equal to 1. The inference from this is that the maximum voltage gain value can be 1. We generally do not achieve a voltage gain in this type of common collector amplifier and the overall voltage gain can be found out multiply A_v by Z_i by Z_i plus R_S. That will give you the overall voltage gain with respect to the source. Here this point is important; the voltage gain in a common collector amplifier is less than 1 and maximum it can be only 1, if we ignore this r_e totally.

In order to find output impedance we have to first look from the output side terminals, make the source zero. The same circuit let us consider again and you make the V_S, zero having only the R_S in this input circuit which is parallel to R_B and this is the transistor. At the output between say A_v terminals let us assume that these are the points. We will consider from A_v terminal, output terminal. Find out the output impedance for this transistor amplifier circuit. At the emitter this point if we consider, focus on emitter and between emitter and ground what do we have? We have a resistance R_E, we have a load resistance R_L. In order to find out the output impedance looking from this A_v terminal into the circuit we will have an output impedance Z_O dash. That Z_O dash will come in parallel with R_E and that will give the exact or the final output impedance. So overall output impedance for this amplifier is Z_O dash parallel R_E; so Z_O equal to Z_O dash parallel R_E. We have to find out what is Z_O dash?

In order to find out this output impedance Z_O dash we have to apply a source because we have made the source V_S, zero. We apply an external source. That is the procedure that we followed. Apply an external source at the output which is v_x and due to this v_x, the current following is say i_x. Then we have to find out v_x by i_x to know Z_O dash. We have to find out the expression between v_x and i_x. That will give you Z_O dash. That Z_O dash will be in parallel with R_E and that will give the actual output impedance of this whole transistor amplifier.

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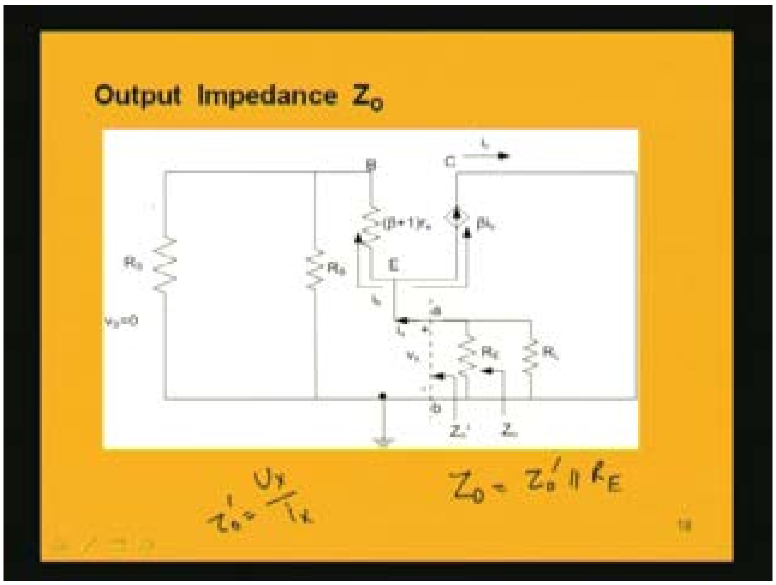

Let us do that. If we apply an external source from outside we are applying v_x. I am not bothered about what exactly the magnitude of voltage is because that is not necessary. We want only the ratio between v_x and i_x. v_x when we apply, the current flowing is say i_x. At this point the current is divided into 2 parts. One is this base current and the other is this collector current. We can write down that i_x equal to i_b plus i_c and again i_c is equal to beta times of i_b. The whole expression becomes i_x equal to beta plus 1 i_b. What is v_x? This voltage equal to, the voltage between these two points is this drop plus this drop. What is this voltage drop? i_b into beta plus 1 r_e plus i_b into the equivalent resistance between R_S and R_B. That is what v_x is. So v_x equal to i_b into beta plus 1 r_e plus i_b into R_B parallel R_S. We can now write down what is i_b? i_b is equal to i_x by beta plus 1. Replacing this i_b by i_x by beta plus 1 and writing down the other terms, the common term is R_S by beta plus 1. What will be left?

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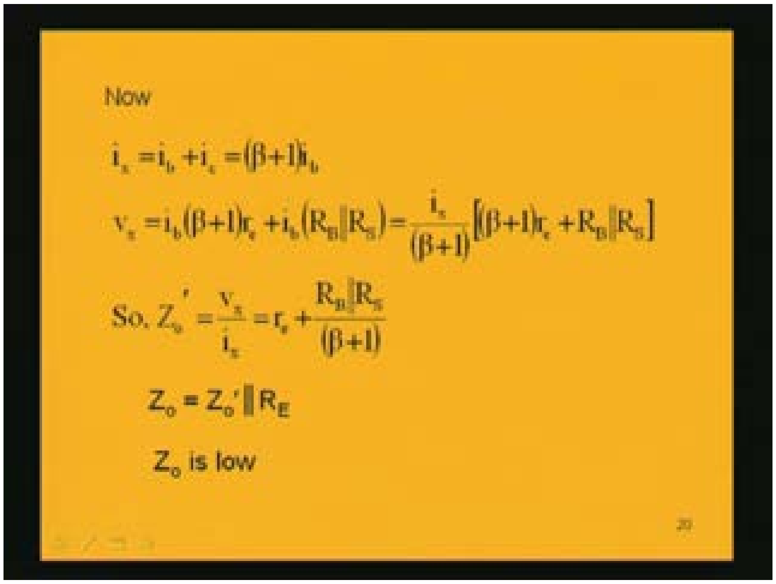

Left out term in the bracket will be beta plus 1 into R_E because we are taking i_b common and replacing that i_b by i_x by beta plus 1. It will be beta plus 1 into r_e plus R_B parallel R_S. Z_O dash is equal to v_x by i_x taking this ratio between v_x and i_x what we get is equal to r_e beta plus 1 and beta plus 1 cancel for this term; so r_e plus R_B parallel R_S by beta plus 1. That is Z_O dash. In order to find out Z_O, it is parallel with R_E. That is the output impendence or output resistance for this common collector transistor amplifier and here one thing we can notice is that the value of Z_O will be low since this Z_O is Z_O dash parallel R_E. R_E is a high resistance no doubt; but then what is Z_O dash? Z_O dash is equal to small r_e plus this term. Look into this term. It is a term which will have its parallel resistance R_B and R_S divided by beta plus 1. Beta plus 1 is generally a high value. The denominator will have a high value and then numerator is in the kilo order. But then overall term will not be very high and it is plus small r_e. This term Z_O dash is smaller in comparison to r_e. It will be approaching the smaller term means Z_O will be a small value. So Z_O is low for common collector amplifier. For common collector amplifier what we have noted is that the voltage gain is almost equal to 1, the input impedance is high and output impedance is low.

These facts can be used effectively when we want to use the common collector amplifier as a voltage buffer. That is common collector amplifier is used as a voltage buffer when ever we want to apply a voltage source to a load where the source resistance of the voltage source and the load resistance have a mismatch. Suppose we are trying to apply a voltage given from a voltage source say common emitter amplifier; we are using a common emitter amplifier as a voltage source and we know that common emitter amplifier has high output impedance. The resistance or impedance which will be in series with that voltage source will be having a high value. But suppose we want to apply this to a low load like a loud speaker which is having 2 ohm or 4 ohm; small value of resistance in the loud speaker. How much voltage will it is get? It will get only v_s into R_L by R_S plus R_L.

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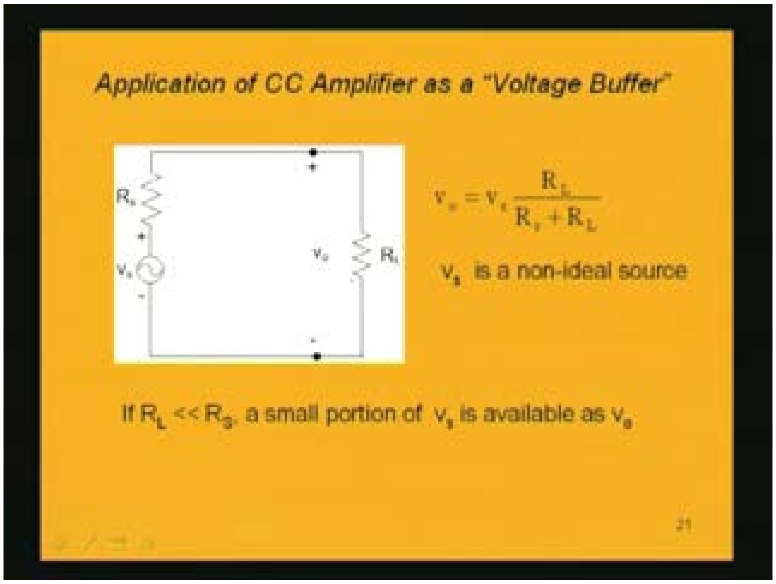

If you look into this term R_L is small. This is big because it is plus R_S. R_S is having a high value. Source resistance ideally should be small but practically we do not get a zero source resistance. Depending upon the source used, suppose we are using a common emitter amplifier this source resistance will be the output impendence of the common emitter amplifier. Then this whole term will have a small value because the denominator is higher than numerator. This will be a portion of v_s what we will get at the output. That means V_O naught will have a small portion of v_s, we are not getting exactly v_s. But our intention is that we must get the source voltage wholly at the load. In order to transfer the whole source voltage to such type of low loads we generally incorporate a buffer stage between the source and the load and that buffer stage is common collector amplifier. Why common collector amplifier is being used? There are particular reasons.

Look at this circuit. Here this common collector amplifier is inserted as a buffer stage between the source and the load. We are applying a source V_S having a source resistance R_S. R_S is high compared to the load resistance R_L where we want to get the source voltage totally equal to V_S. The common collector amplifier has certain specific parameter values because we have seen that the common collector amplifier has a high input resistance. R_i is high but it has low output resistance, R_O is low and the voltage gain is almost equal to 1. If I replace this common collector amplifier by its equivalent circuit having the input resistance, output resistance and voltage gain it can be drawn like a circuit given in this box.

Here it has R_i. This is the output voltage V_O or rather V_O dash. We are using V_O here. So V_O dash is the output voltage from the common collector amplifier and this is equal to nothing but A_v into V_i. That is almost equal to V_i because A_v is equal to 1. What is V_i? V_i is the voltage available across R_i. Since R_i is a high value whatever voltage we will get here it is almost equal to V_S. V_S into R_i by R_i plus R_S will be your V_i. This is high in comparison to R_S. We can equivalently write that it is R_i by R_i. This can be cancelled out if R_S is small in comparison to R_i; that has to be maintained. R_i is having a high value because it is a common collector amplifier. That can be actually managed to have a value higher than this source resistance and then this whole overall term will be almost equal to 1. So what we will get here at V_i is equal to V_S. That means this V_i is equal to V_S. Again there is a very small resistance at the output which is R_O. There will be practically very less drop almost say zero drop. Whatever voltage available here that will be wholly available at the output. The load resistance R_L will get the voltage which is equal to V_S. Because this is V_i, V_i is again almost equal to V_S. Out of V_i only a very small portion is lost here. The whole voltage we can get at R_L.

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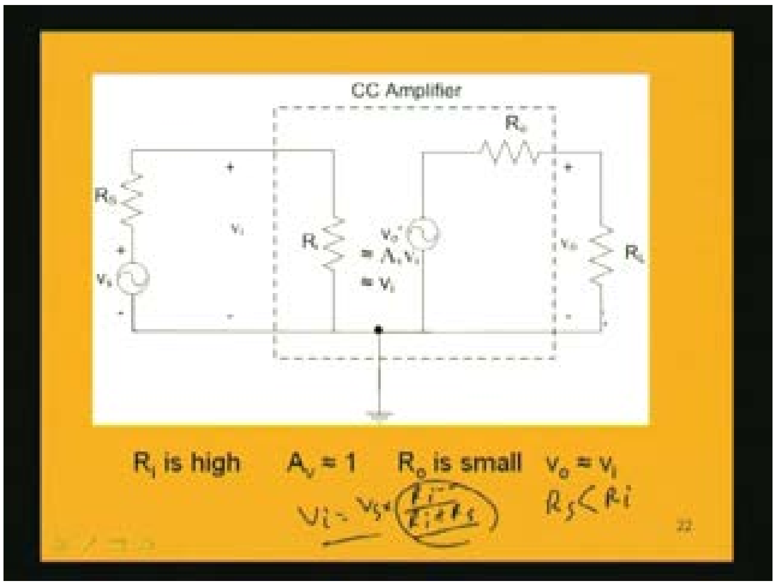

We are incorporating a buffer stage which is common collector amplifier, which is known as voltage buffer just to get this source voltage totally, equally at the output. We have seen this application. Suppose you want to find out different parameters, let us try one example here and this example is common emitter amplifier example and we are having all these values like shown here. But one thing to be noted here is that we are not having a source resistance and that means R_S is equal to zero. Source is having zero resistance and we are having a load resistance also. To know the no load voltage gain and the loaded voltage gain for this amplifier circuit you have to determine $A_{v(no\text{-} load)}$, $A_{v(load)}$, Z_i, Z_O and A_i.

In this circuit no load means, the load R_L is not here that means we will have no load voltage. Whenever you apply the load R_L, then whatever voltage available will be load voltage and there is a difference.

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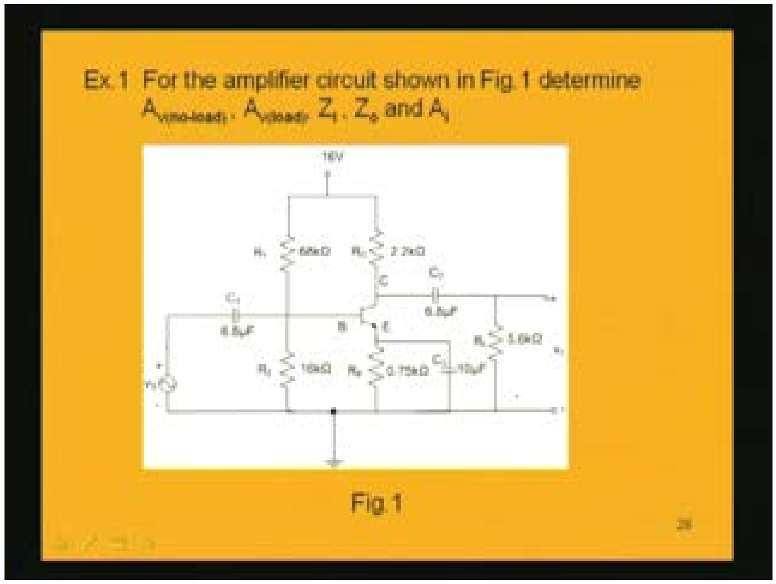

When R_L is coming into the picture, the R_L will also have to be included and that changes the voltage gain and loaded voltage gain will be less than no load voltage gain that can be verified for this circuit actually. In this circuit in order to know all these parameters we have already discussed about these circuits and we know what is Z_i expression. But then everywhere you will have to use this r_e value. r_e is 26 millivolt by capital I capital E, I_E. That has to be found out and in order to find out this we have to consider the DC equivalent circuit. DC equivalent circuit has to been drawn first. DC equivalent circuit means you ignore the AC sources and you ignore these capacitors also because capacitors offer open circuit for DC. What will we be left with? We will be left with these resistances; these are the potential divider biasing scheme, R_C and R_E will be there. This will be just open circuit; this will be also open circuit. We are left with this circuit which is like this. This is V_{CC}, R_1, R_2, R_C, R_E and this is a common emitter NPN transistor and beta value is given which is equal to say 100. This beta is 100.

The currents are I_C, this is I_E and using the Thevenin's equivalent circuit we can draw this Thevenin's equivalent circuit. This Thevenin's equivalent circuit will have this resistance R Thevenin and voltage V Thevenin; V_{CC}, R_C and R_E. We know what is V Thevenin and R Thevenin. R Thevenin is the parallel impedance between R_1 and R_2 and V Thevenin is V_{CC} into R_2 by R_1 plus R_2. Putting these values here, V_{CC} is equal to 16 volt; it is given as 16 volt. So V Thevenin is 16 into all these values is just replaced R_2 is equal to 16 kilo ohm and R_1 is 68. We will get 16 into 16 by 16 plus 68. Check these values; 3.05 volt we will get for V Thevenin.

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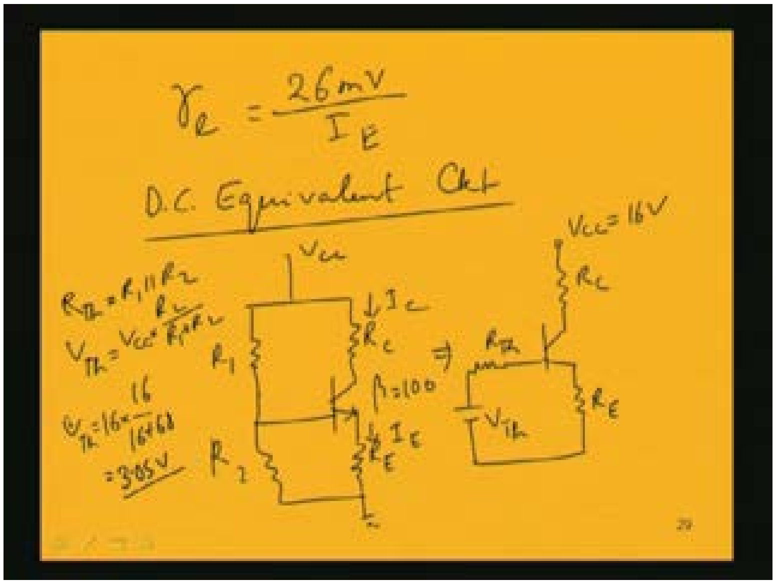

R Thevenin is this 16 into 68 kilo ohm and the value will be 12.95 kilo ohm. In this circuit if we look into I can find out base current, I can find out the collector current and emitter current. Kirchoff's voltage law if we apply to this circuit then V Thevenin minus I_b into R Thevenin minus V_{BE} minus I_R is equal to zero. Kirchoff's voltage law we have to apply and if we do that V Thevenin minus I_B, this is base current, into R Thevenin minus this voltage drop V_{BE}; if you look into the circuit you cannot ignore this voltage drop between base and emitter minus I_E into R_E that equal to zero. Putting all these values we get I_B equal to 0.0265 milliampere and from this we can find out what will be the collector current and base current also we can find out. Base current is equal to beta plus 1 into 0.0265 milliampere and beta value is 100. The value will be 2.677 milliampere and we can find out the r_e value. That is 26 millivolt by I_E is 2.677 milliampere and that gives us 9.71 ohm. Once we know r_e we can plug in this r_e wherever required in our analysis for finding out these parameters.

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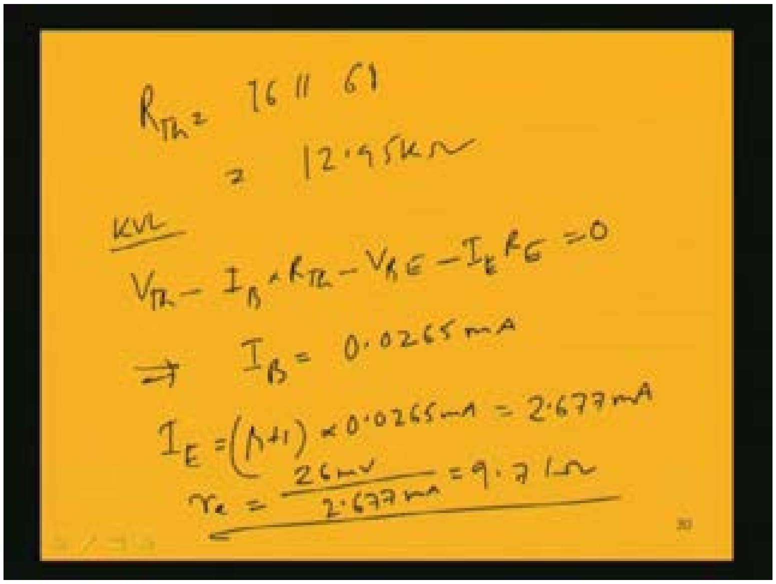

Here if you consider the no load voltage, $A_{v(\text{no-load})}$, we will have to look into the circuit to find out the no load voltage and no load voltage and loaded voltage will be different because no load voltage will be having no load here. The circuit will have only R_C and R_O is not mentioned. We will find out that no load voltage, v_o by v_i will be equal to minus i_o into R_C by v_i. v_i is I_b into beta plus 1 r_e. Here this i_o can be written as beta I_b into R_C by I_b beta plus 1 r_e; then I_b, I_b cancels. This is the value of the no load voltage gain whereas the loaded voltage gain is with taking into consideration load resistance. That we have already done, so you can find out the difference.

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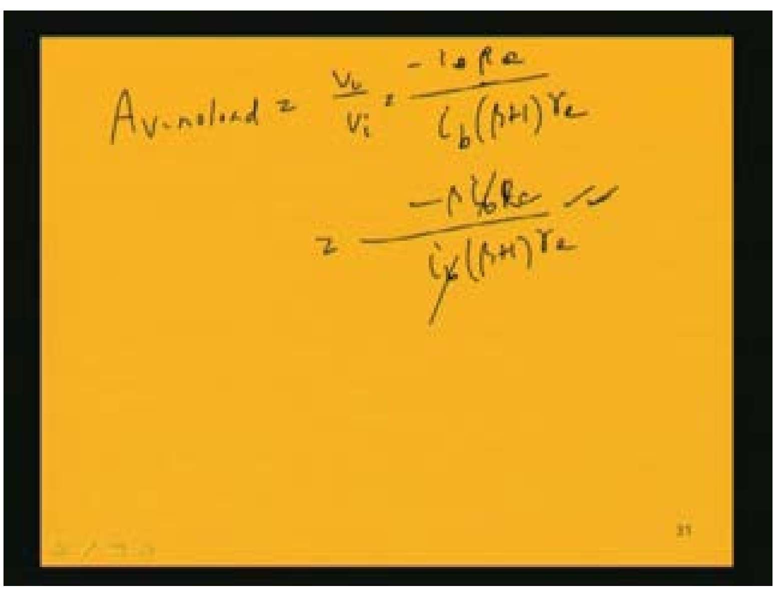

In this lecture we have today learnt about the common base and common collector amplifiers and the common base and common collector amplifiers have application as current and voltage buffers. But for amplification we have earlier discussed about the common emitter amplifier which is mostly used as an amplifier. We have totally seen all the different examples of amplifiers using BJT.