Electronics for Analog Signal Processing - II
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Lecture - 4
Y – FEEDBACK

In the last class, we considered Y feedback and we saw how we could obtain current controlled voltage source, near ideal, using that. Today we will see an example on the Y-feedback.

The transistor feedback amplifier, this is only a signal picture, has the transistor with Beta equal to 200, operating at point 5 emitter current, milliamperes. Determine the loop gain, forward transfer parameter, input resistance and output resistance. So, what it means is that we have to identify the feedback and determine the proper loop gain and forward transfer parameter, in this case.

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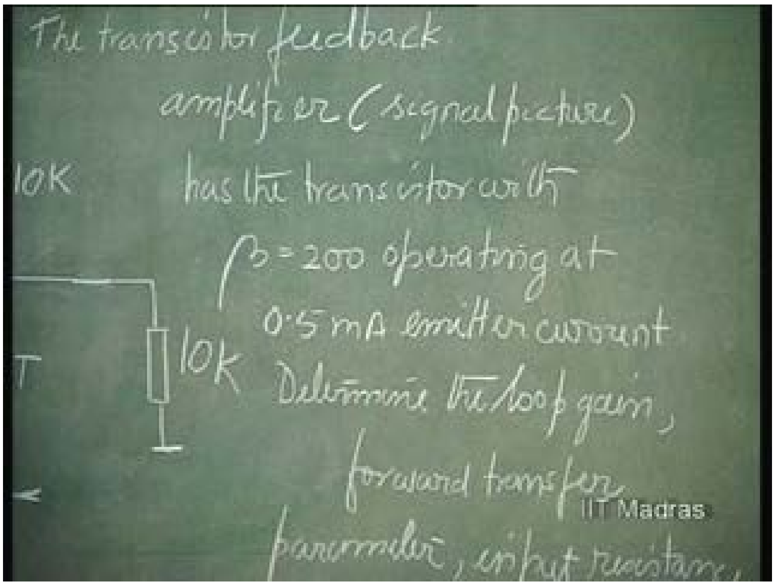

We have identified this as Y-feedback earlier itself. So, this is the feedback resistance, this is the amplifier, this is the load. So, we have the output taken across this. This is the input. This is the output current. So, in this situation, we take the y parameters, because the y parameters of the amplifier add to the y parameters of the feedback network.

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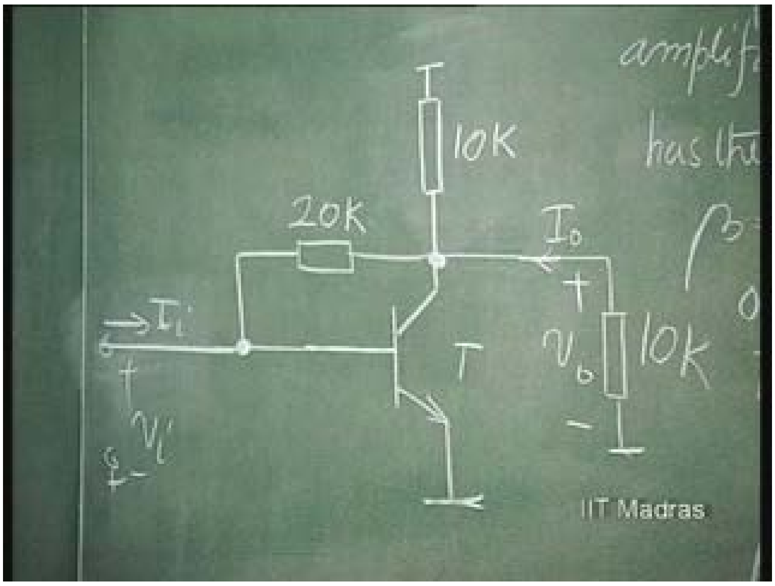

And, I am now taking the composite y parameter, which is very easy. When we define the paramet…y parameter, output is shorted. So, this 20 K comes in shunt with the input resistance of the amplifier, which is Beta plus 1 times r e. So, r e… since it is point 5 milliamperes, is going to be 50 ohms because of point 5 milliamperes current. So, Beta plus 1 times r e; Beta is 200; so, 200 into 50 - 10 K, approximately.
So, we will actually modify this so that our answers become... Beta equal to 199.

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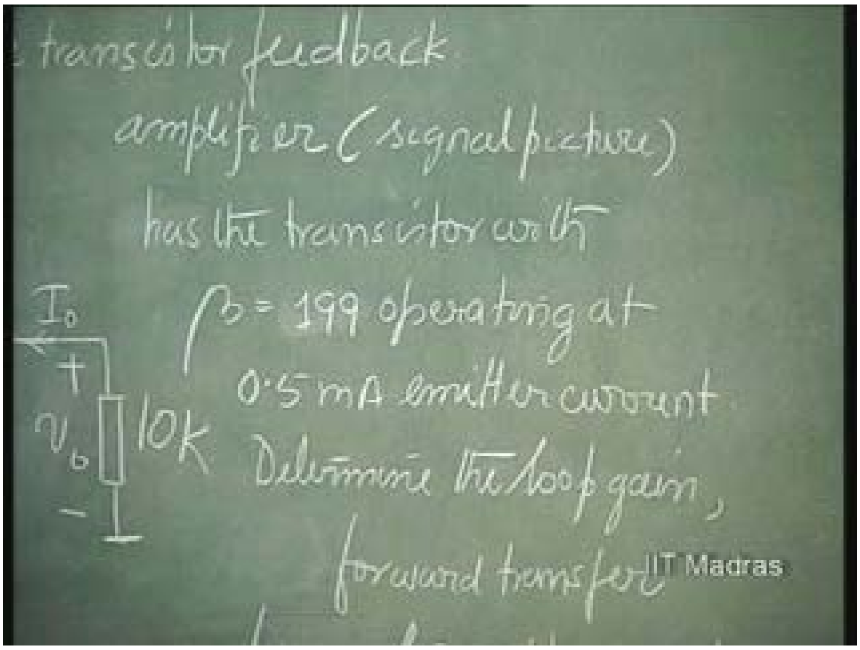

So, this is exactly equal to 200 into 50; so, 10 K. So now, we have y parameter at the input. When this is shorted, 20 K comes in shunt with 10 K.

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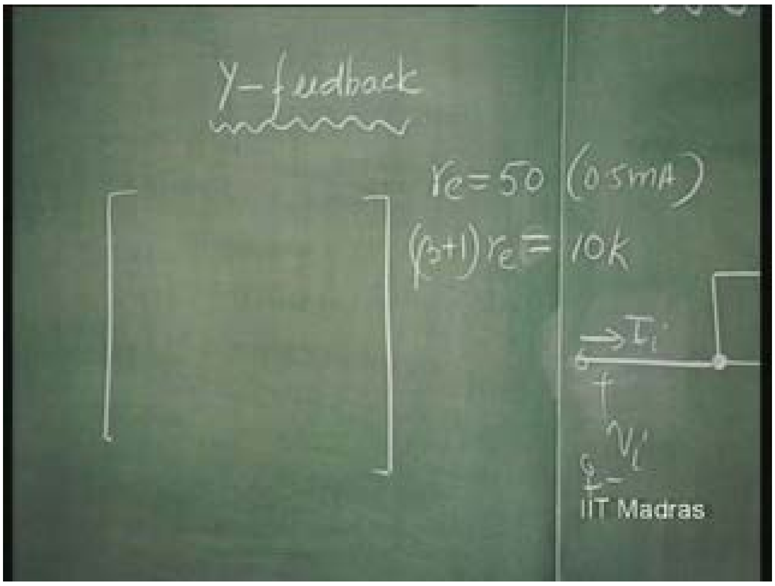

This is the y i of the composite structure; this is that of the amplifier; this is that of the feedback network; and the other parameter is, when it is shorted, we have to find out because of applying a voltage here. g m times v i is the current in the collector. g m times v i is the current in the collector; and that will be flowing through the short circuit. Apart from that, v i by 20 K also will be flowing. v i by 20 K will be flowing in the opposite direction.

So, we have minus 1 by 20 K here. Apart from that, we have g m into v i. g m is nothing but roughly Alpha over r e. That is, 1 over r e is 50. So, that is 1 over 50. That means 1000 by 50 millisiemens. So, both these things are expressed in terms of millisiemens. So, in fact, we can remove this K and express this in millisiemens. So, all these things are expressed in millisiemens; remove the K.

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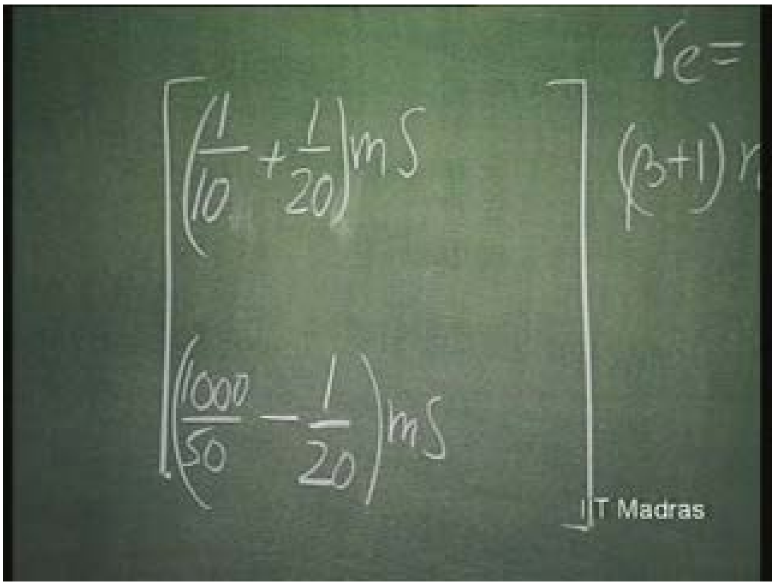

So, these two are over. Now we want from the output...we apply a voltage at the output, short the input and find out the other parameters, two parameters. So, output admittance is going to be... this 1 over 20 K will anyway come. Then, we have 1 over 10 K. 1 over 10 K. 2 over 10 K.

So, if you say millisiemens, so many millisiemens. 1 over 20 K, 1 over 10 K plus 1 over 10 K. So, when I short this at the output, we have these. If we had been given the output admittance of the transistor, that also will get added to this. So, this is the total output admittance under input being shorted.

Now, only this parameter, when I apply an output voltage with this shorted, the only reverse transmission is due to this 20 K. So, minus 1 over 20 millisiemens; this is the only reverse transmission. So, everywhere we have put this amplifier thing first. Amplifier, y parameters. This is zero; forward, reverse transmission for the amplifier is zero; and these are the feedback y parameter. They are getting added.

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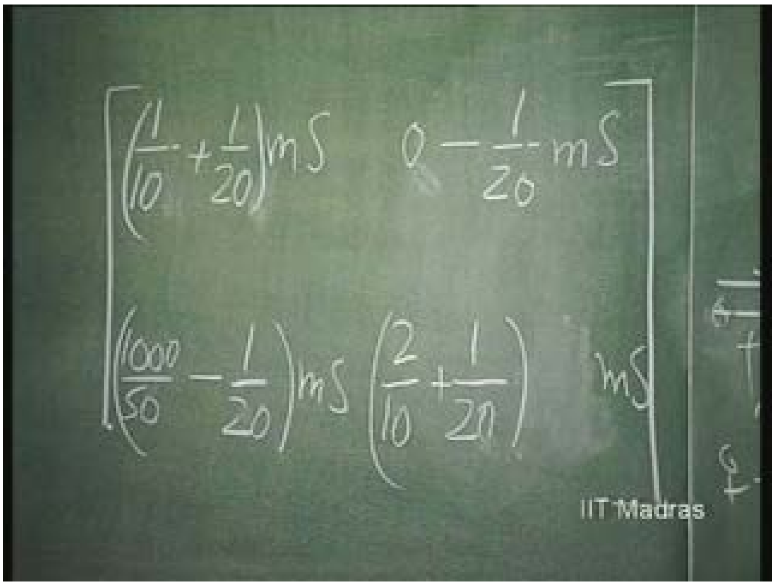

So now, the composite y parameter, therefore under this situation is, 1 over 20, is really 1 over 10, is 2 over 20 plus 1 over 20. That means, 3 over 20 millisiemens minus 1 over 20 millisiemens. This is 20. 20 minus 1 over 20 which is… How much is it? 19 point 95 millisiemens. So, this is again 4 over 20 plus 1 over 20. That is 5 over 20 millisiemens, all expressed in terms of millisiemens. So, this is the y parameter of the composite network.

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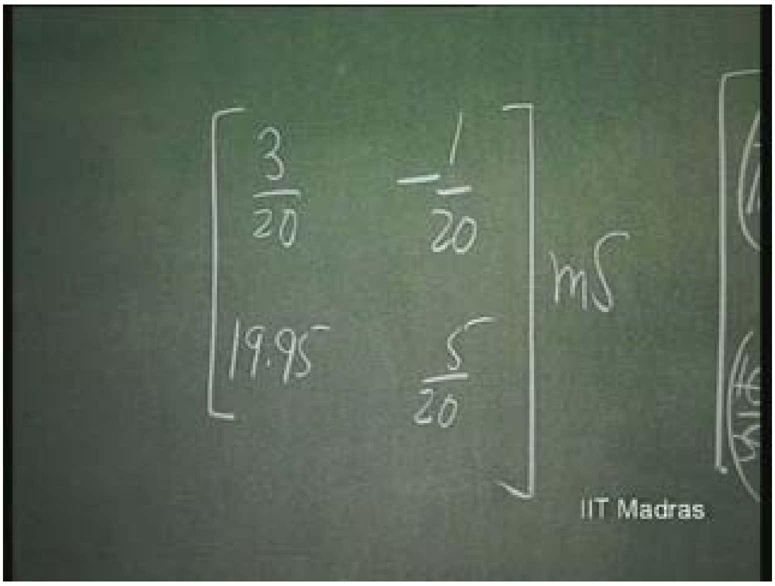

So, how do I find out the loop gain? Loop gain is equal to y r into y f. So, 1 over 20, minus of that into 19 point 95, very nearly 1, of course. 3 over 20 into 5 over 20.

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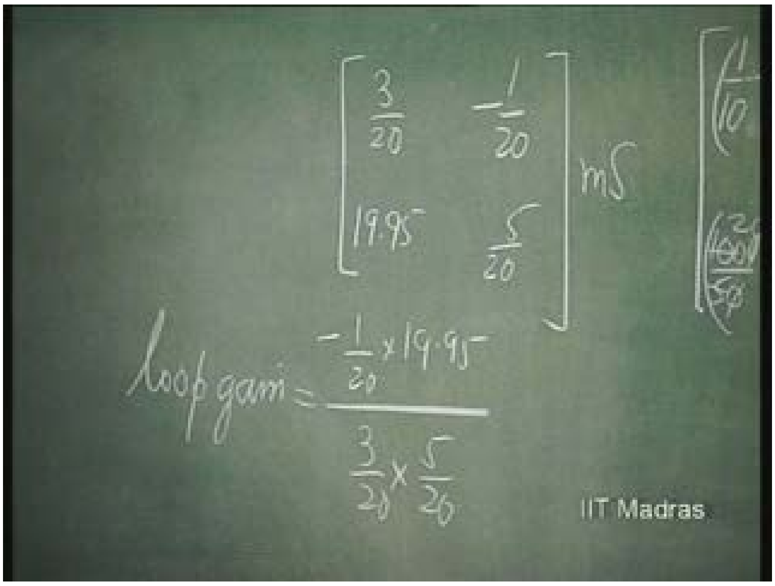

So, this is the loop gain. How much is this? This comes out and this is very nearly 1. 15, 400 by 15, roughly. Minus, approximately, 400 by 15. 26 point 6 or 7 or whatever it is. That is the loop gain. So, it is negative, indicating that it is negative feedback. It is much greater than 1. So, all these things are valid. So, good loop gain.

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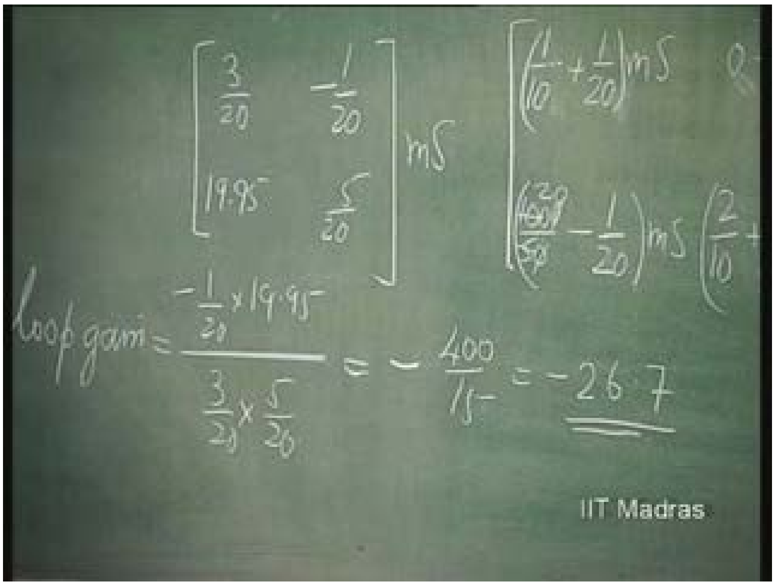

Now we want to convert this… In order to find out the forward transfer parameter input resistance and output resistance, we have to convert it into Z parameter. It is the Z parameter that is the idealized parameter for this kind of feedback structure. So, we have to obtain the Z parameter.

So, this is easy. These are all millisiemens. So, actually speaking, we have everywhere, this into 10 to power minus 3, into 10 to power of minus 3, into ten to power minus 3, into 10 to power minus 3, coming into picture. So, Z parameter is going to be 5 by 20 into 10 to power minus 3. That is, Z i, this divided by this into this plus this into this. Therefore, what is the Delta y? That is, Delta y is equal to 5 by 20 into 3 by 20 into 10 to power minus 6 plus 19 point 95 by 20 into 10 to minus 6.

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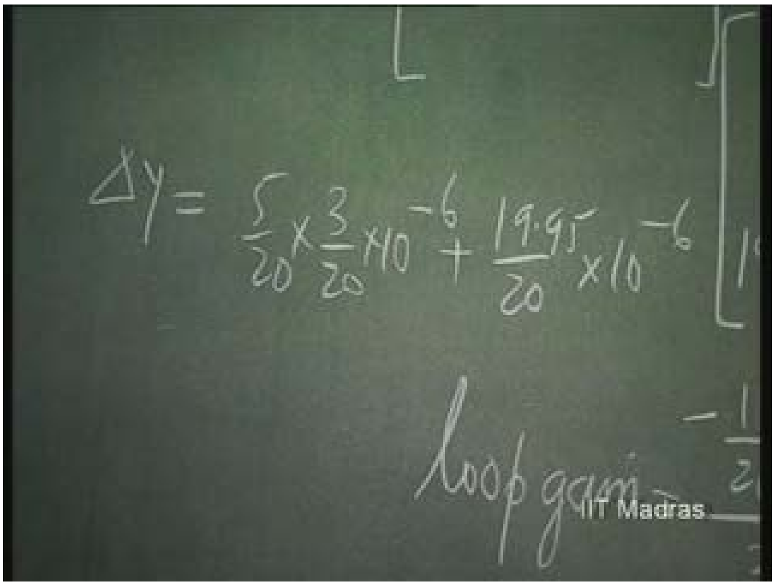

So basically, effectively, this one, very nearly 1 into 10 to power of minus 6; and this will be 15 divided by 400 into 10 to power minus 6 which is very nearly equal to… How much is it? 10 to power minus 6, roughly. This adds on to this. So, very nearly equal to 10 to power minus 6. So, dividing by 10 to power minus 6 now. Is it clear? So, dividing by 10 to power minus 6, we get the Z i.

Z r is 3 by 20 into 10 to power minus 3. This divided by again 10 to power minus 6. Z f is minus 19 point 95 into 10 to power minus 3 divided by 10 to power minus 6; and finally Z f is 1, plus 1 by 20 into 10 to power minus 3 by 10 to power minus 6.

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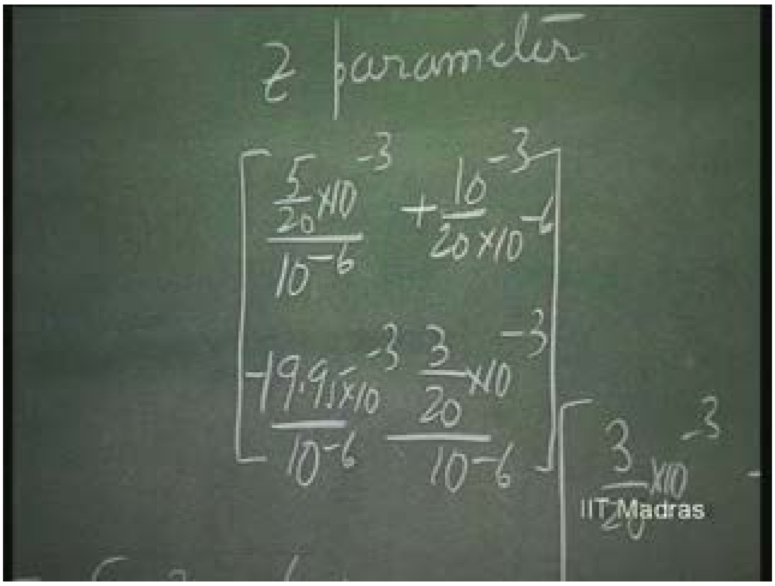

So, out of this now, what is asked is, first, the forward transfer parameter. That is straight away here. So, the forward transfer parameter, forward transfer resistance now is equal to this. So, it is about minus 19 point 95 into 10 to power 3. So, you can see this. This is very nearly equal to the 20 K that we have used. This was the feedback resistance, 20 K; and ultimately, the forward transfer parameter should be equal to minus 20 K. This is what we have surmised earlier. So, we are getting it as very nearly equal to minus 19 point 95. So, always very close to the feedback resistance, in the case of Y feedback.

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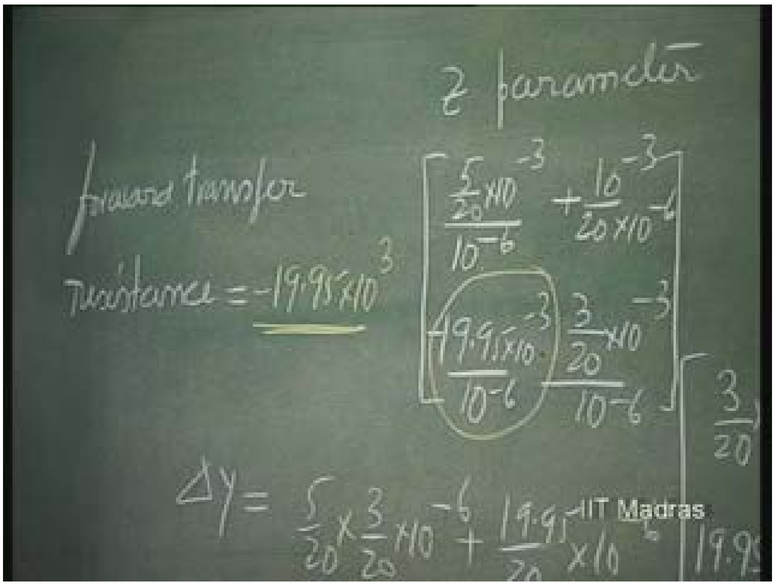

Then, the input loop gain is already evaluated. Input resistance, this is nothing but 5 by 20 Kilo… This is 19 point 5 K. So, this 5 by 20 K, which is really speaking, 5000 divided by 20, 250 ohms.

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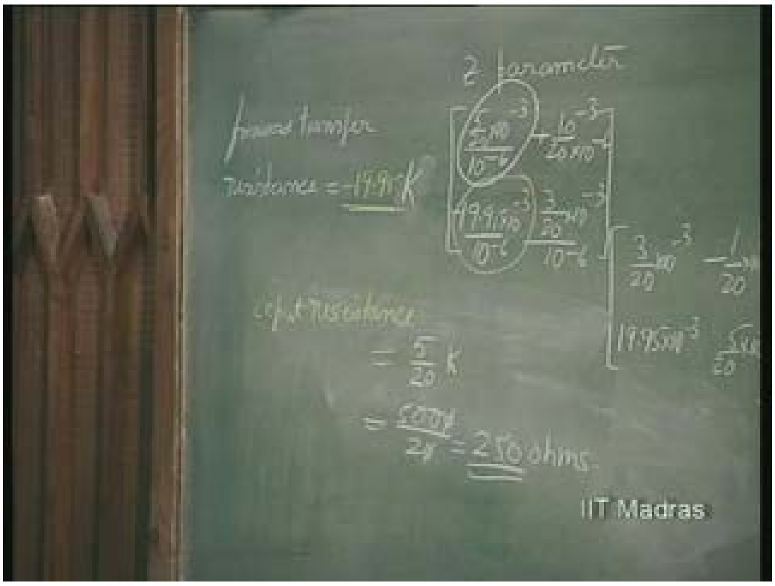

So, input resistance is pretty low. See, it is current controlled voltage source. Input resistance should go down and output resistance also should go down. So, let us see the output resistance. That is this. So, 3 by 20 K. That is, 3000 divided by 20 ohms; 150 ohms. So, you can see that the output resistance also is pretty low; 150 ohms.

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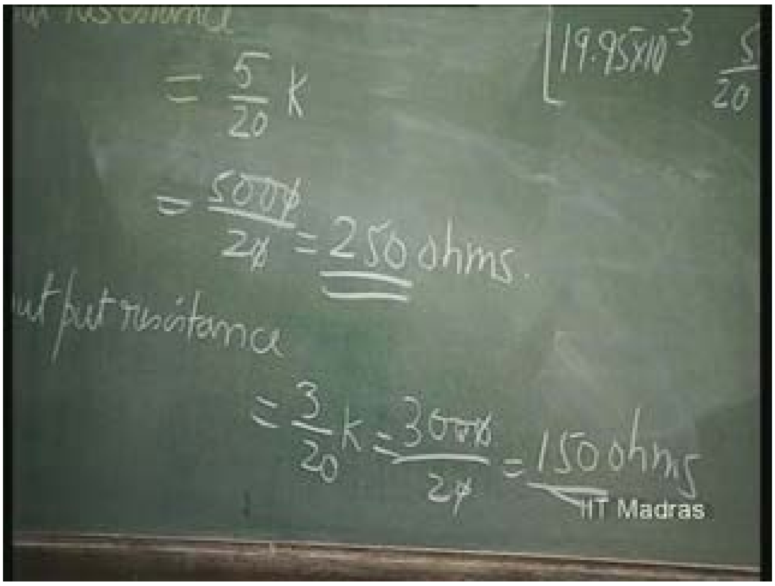

Output resistance is low; input resistance is low and forward transfer resistance has become almost nearly the passive resistance of 20 K. So, this is the way it is going towards its idealization. So, you all are using a single transistor. We have seen how this negative feedback network modifies its functions so that we can realize a fairly good current controlled voltage source.

We had earlier considered Y feedback in order to realize idealized current controlled voltage sources. Now consider Z feedback applied to a single transistor. This is the single transistor amplifier.

Since we are applying Z feedback and going to…we are going to use Z parameter. We have to consider the r c e, the output resistance of the transistor, as finite. We cannot consider it as infinite. This is important because we are considering open circuit parameters; r c e must be considered as finite. We cannot consider the current source as having infinite output resistance.

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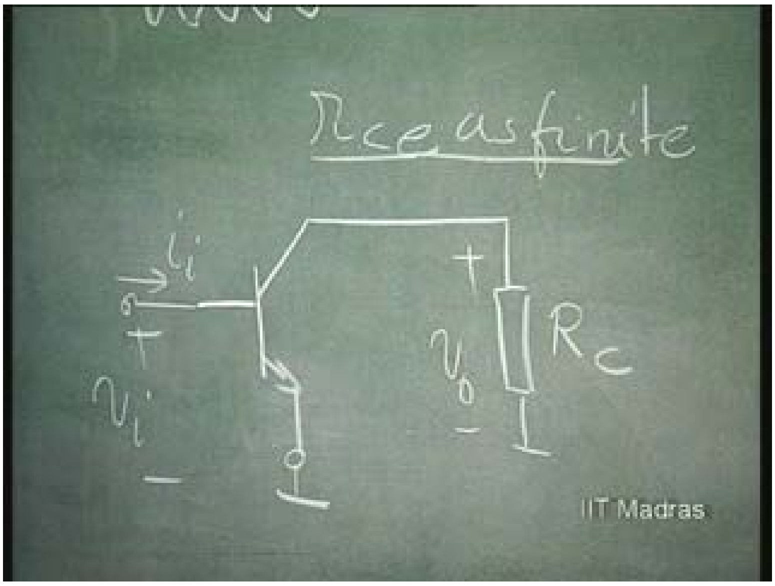

So, we are now going to put in series with this input. This is going to be removed from ground and we are going to put in series with it, a resistance R E. This is the feedback resistance. So, this comes in series with the feedback voltage here. So, the v i is from here to ground now. This earlier input comes in series with this, this output comes in series with this.

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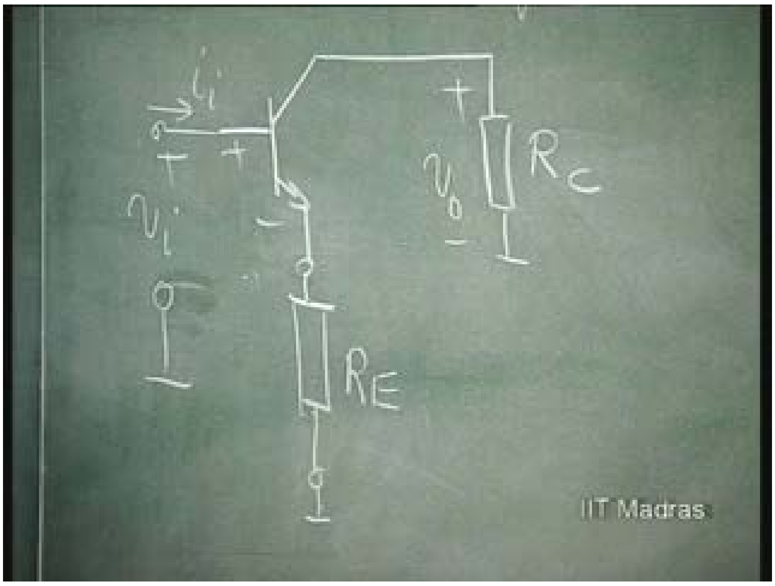

Now the composite z parameter, we have to write. This has to be written very carefully. Now, composite z parameter is that parameter, when this is opened, open circuited… find out… apply an input current and find out the output voltage. So, we will put down the equivalent circuit here as our original equivalent circuit r e. If this is I i, then we have Beta times I i as the collector current and shunting this we are assuming that there is an output impedance of r c e. So, this is the structure of equivalent circuit.

So, for this now, we have to establish the composite Z parameter. So, when this is opened, if Ii is supplied, Beta times I i will flow like this and this will flow like this; establish a voltage here. Beta times I i times r c e; plus in this direction, minus in this direction.

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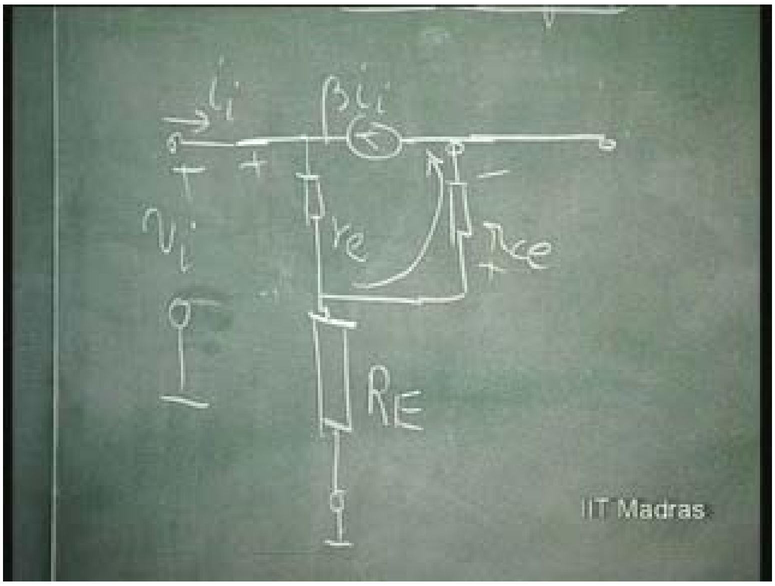

So, the voltage that is established, open circuit voltage, is minus Beta times r c e, here; and since this I i is flowing here, this also should be I i because this is open circuited. There is a circulating current of Beta times I i in this; and therefore, when I i is this, this is also I i.

So, the voltage here is I i into R E. So, this is going to be a further additional voltage in series with this. So, output voltage is this plus this. This is minus Beta times r c e times I i and this is I i times R E. So, this is the effective ratio of output voltage to input current. This is the forward transfer parameter of the composite structure.

Now, as far as the input impedance is concerned, if this is I i, this is Beta times I i. This one is Beta plus 1 times r e times I i; and this is simply I i plus R E. So, this is going to offer an impedance of R E. That is over. As far as input impede...input impedance and forward transfer para…impedance is considered, this is...

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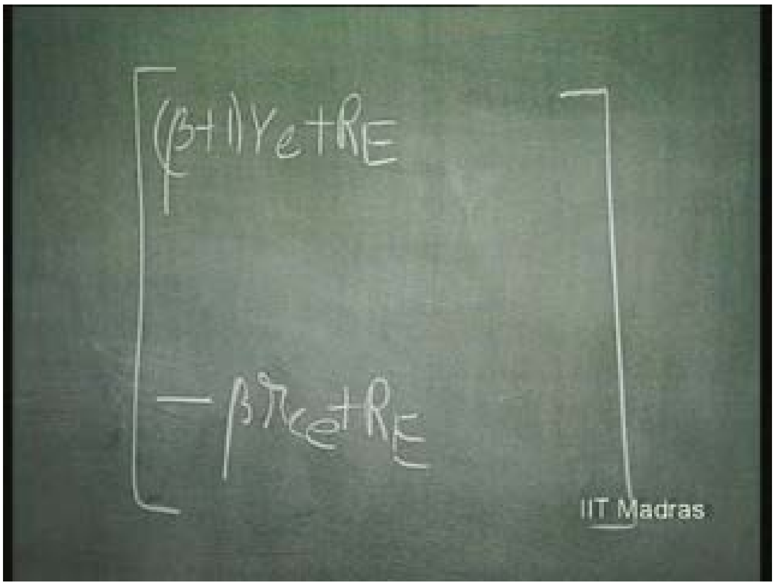

Now, make the output current zero, input current zero and apply a voltage here, apply a current here. If this is zero current, there is no current in this, if this is open circuited.

So, when I apply a current here, this current will be forced to flow through this like this; and therefore, output impedance, open circuit, is r e plus r c e; simply series combination of… And the voltage, input voltage, for this current is going to be I naught into r e.

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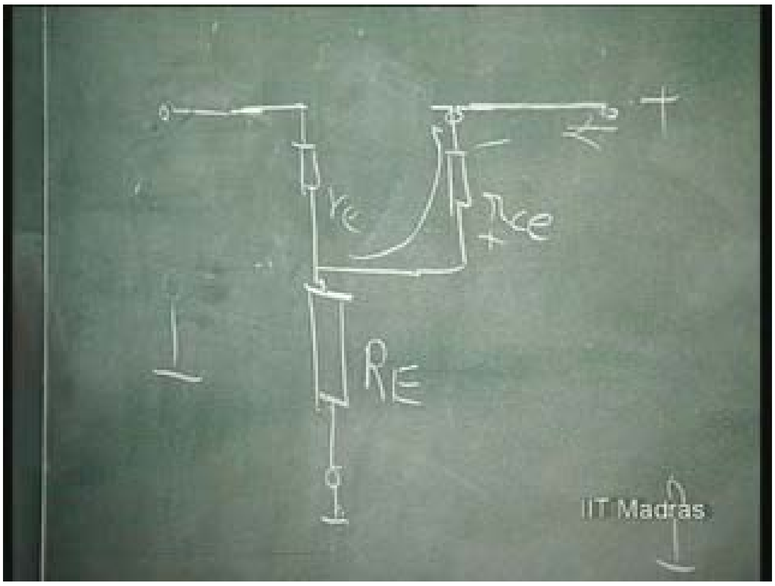

So, this is going to be, reverse transfer impedance is going to be R E. This, the input voltage; for an input, output current I naught.

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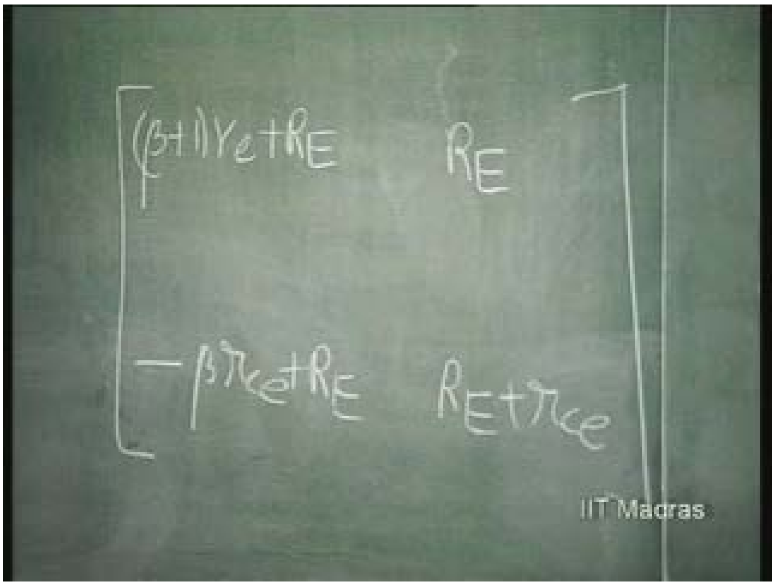

So, this is composite z parameter of this feedback structure which is nothing but this.

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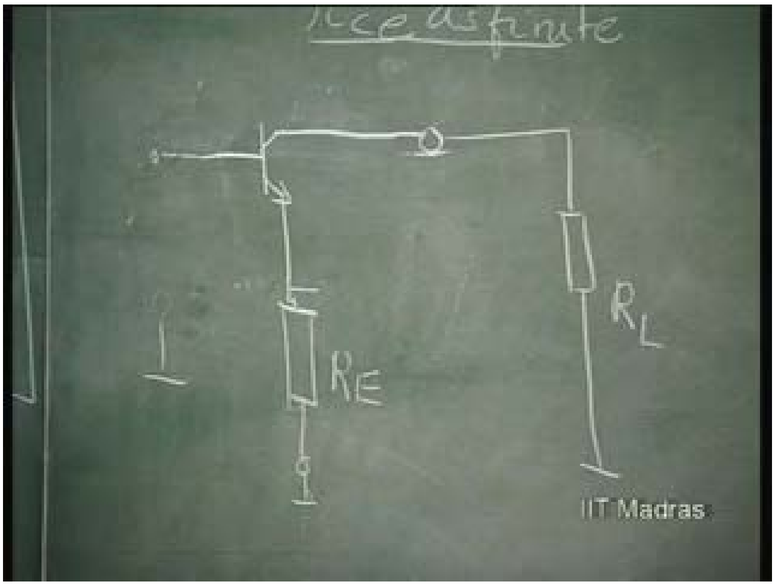

So now, we have to find out the loop gain which is nothing but this into this divided by this into this. So, minus Beta r c e plus R E into R E. For it to be negative, this should be dominant compared to this. This is always the case. r c e itself is very high.

Beta times r c e is still higher. So, you can neglect this…divided by Beta plus 1 times r e plus capital R E; whole thing into R E plus r c e.

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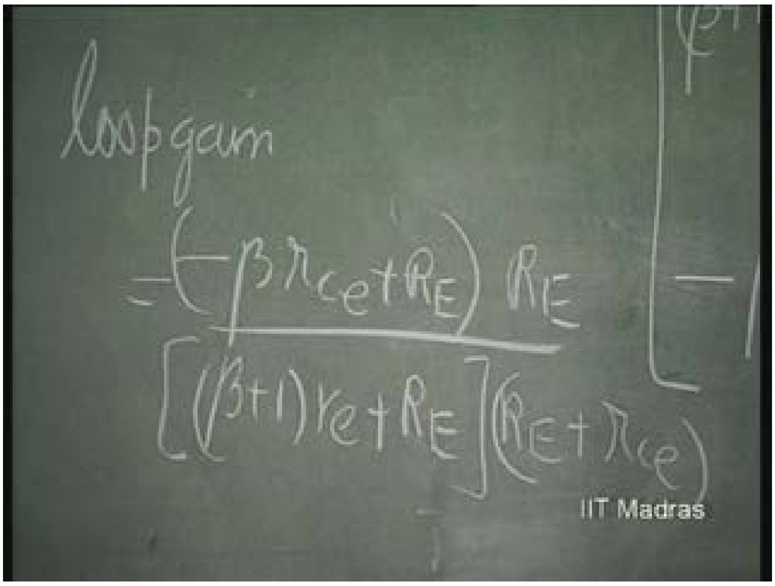

Once again, how to neglect? This is large compared to this. Neglect this. R E is small compared to r c e. Neglect this. Here, we cannot say anything about. This may be of the same order of magnitude. So, we get r c e getting cancelled with r c e.

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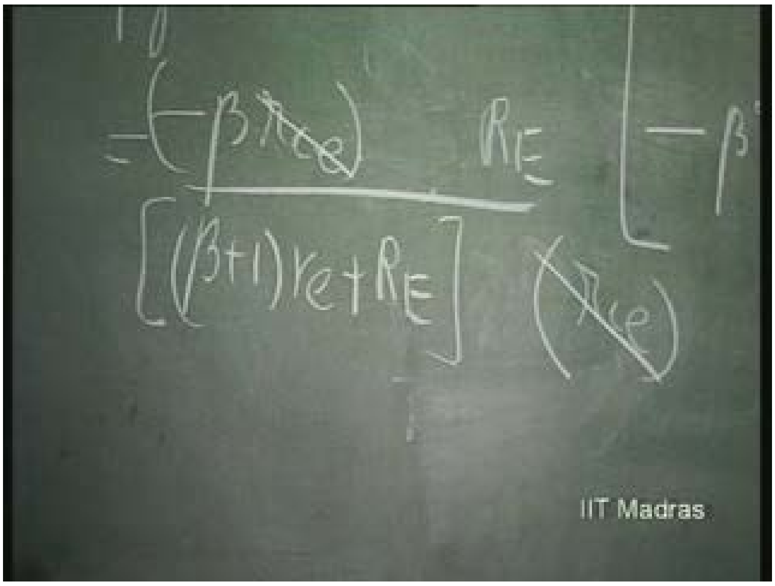

And in effect, we have the loop gain equal to minus Beta divided by 1 plus r e by capital R E into Beta plus 1.

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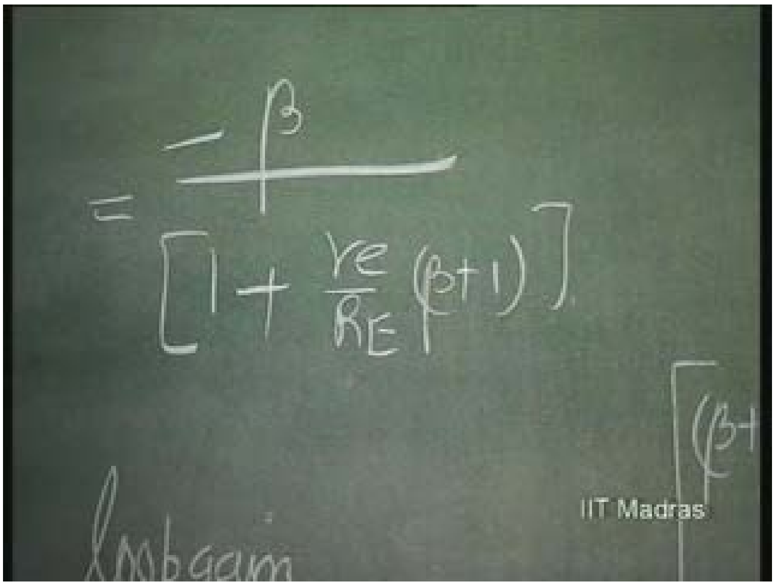

So, this is the loop gain which is going to be much greater than 1. As long as this factor is not too high, r e into Beta plus 1 is going to be of the order of capital R E; and therefore, this is going to be of the order of Beta by 2 or 4, which is pretty high. So, we know that the loop gain is negative and is high. Then we can convert it into y parameter by finding out Delta Z is equal to this into this minus this into this. That is, Beta plus 1 times r e plus R E into... I will neglect this.. r c e... plus R E, I will make it r c e itself... plus Beta r c e. I am neglecting this, into R E.

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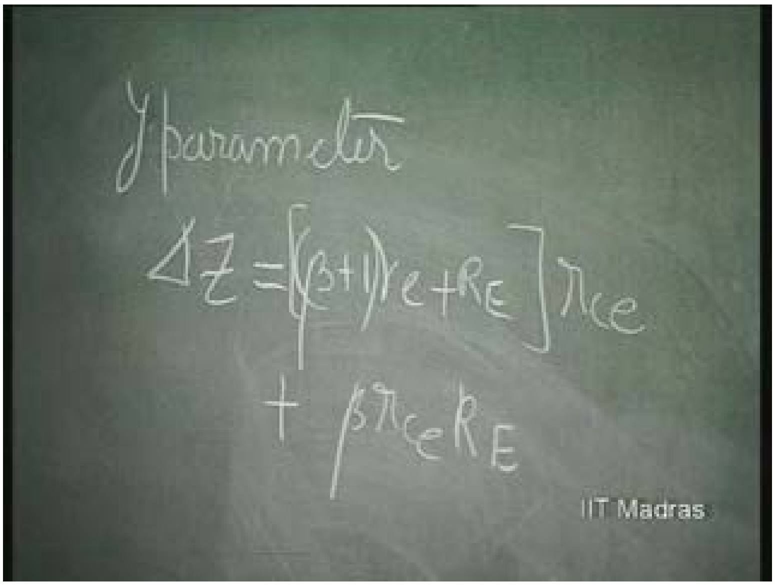

So, this is the loop gain. That is, Delta Z, which involves the loop gain. So, this is the modification factor of all the parameters. So, let us now first find out the forward transfer admittance which is going to be…plus Beta r c e divided by this becomes plus, plus Beta r c e minus R E. That minus R E is neglected. Divided by this factor, which is Beta r c e capital R E plus r c e into R E. That can be again ignored compared to Beta r c e R E. r c e R E. So, plus r c e Beta plus 1 times r e.

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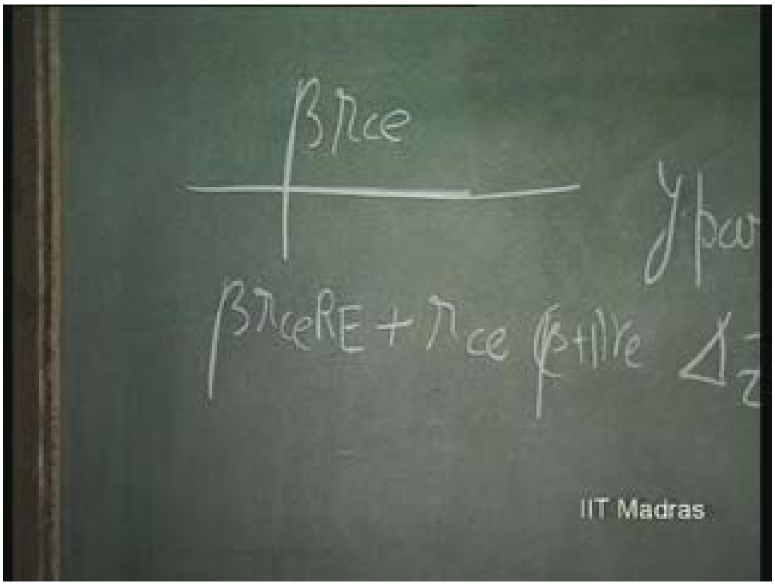

So, this again is negligible. So, we can see here that Beta, Beta gets cancelled. r c e, r c e gets cancelled. This is approaching a value of 1 over R E, as expected. So, this part, that is, the Y f of the modified thing is approaching 1 over R E.

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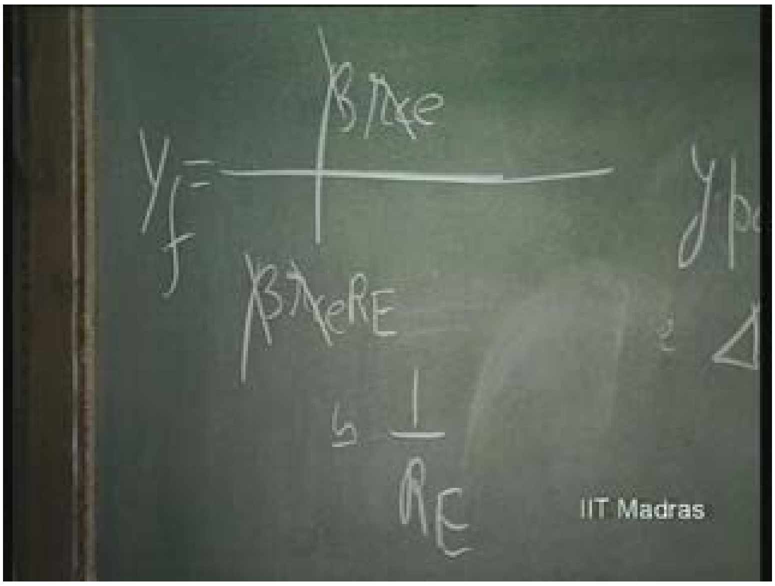

So, it is nothing but a voltage controlled current source whose forward transfer parameter is simply 1 over R E. Now, it has boosted up input impedance. You can find out that by getting the y i. y i is going to be, once again, R E plus r c e in which R E is going to be ignored. This divided by Delta z in which Beta r c e R E dominates.

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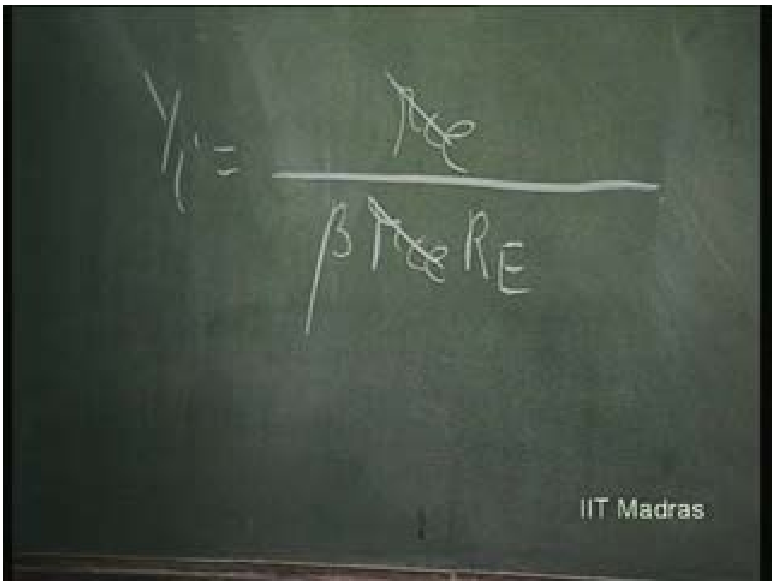

This is the dominant factor. So this can be really ignored. This is very nearly equal to…Delta z is very nearly equal to…Beta r c e R E. So, Beta r c e R E… you can see here. Y i is 1 over Beta times R E; or z i of this network is known to be Beta times R E, approximately. So, you can see that the input impedance is increased; output impedance also is increased.

So, that is, this R E plus r e into Beta plus 1 divided by this is output conductance. That divided by Beta r c e R E. So, actually speaking, you can say that this is Beta r c e R E divided by output impedance, divided by R E plus R E into Beta plus 1. So, you can see that it is nothing but Beta R E into r c e.

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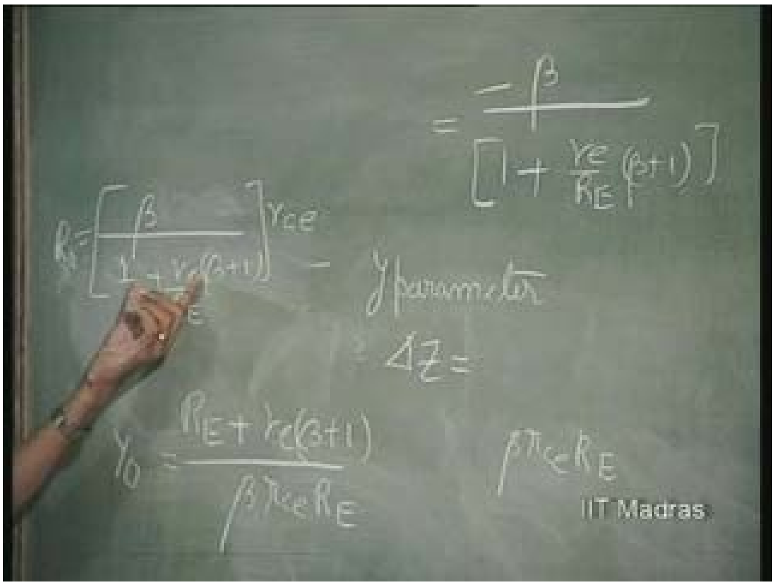

So, you can just divide this by this. We had already considered as loop gain, Beta divided by 1 plus r e by capital R E into Beta plus 1 is the loop gain. So, original r c e gets multiplied by this loop gain. That is the output impedance. So, you can see that almost every way it is going towards voltage control current source idealization.

So, this is a very simple negative feedback circuit. This is…also can be thought of as…this also can be thought of as a situation where emitter bypass capacitor has been removed and consequently it gives feedback.

In our earlier common emitter amplifier, assume that emitter bypass capacitor has been removed. Then what happens? This is what happens. This, we have illustrated in the lab experiment by removing this capacitor and showing that the amplifier becomes linear; input impedance increases; output impedance increases.

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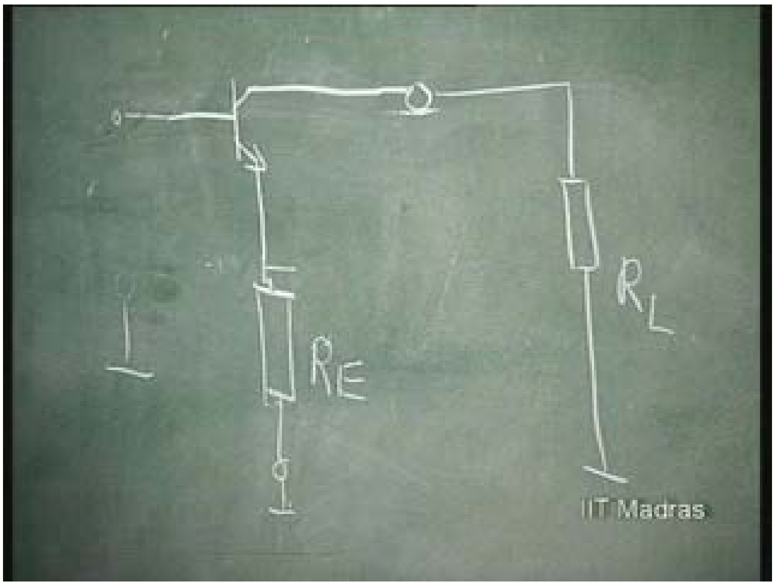

Now that you have understood thoroughly single transistor Z feedback and Y feedback arrangements, I would like to discuss the very fundamental concept about negative feedback using a single transistor where no passive network comes into picture. That is, total negative feedback.

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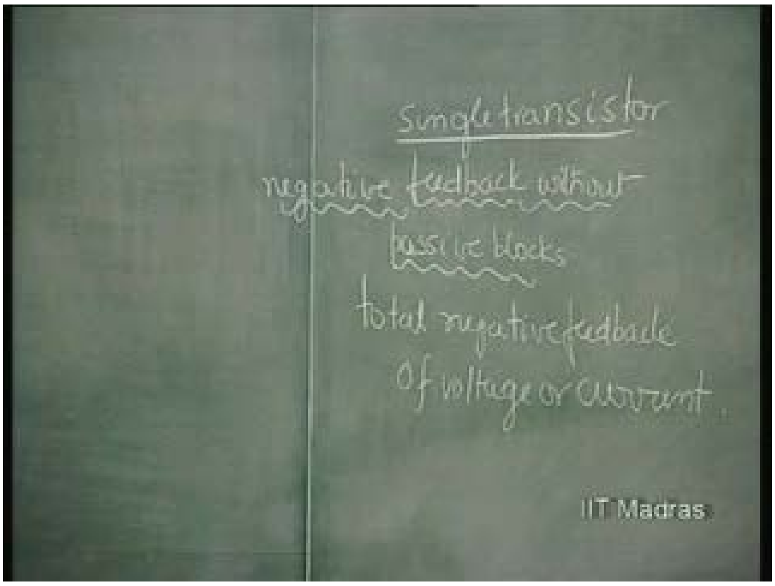

Total negative feedback of voltage or current. What happens? This is the interesting part.

Consider the single transistor circuit. This is the input terminal. Normally, output is taken there. There is no reason why output should be taken there. It can also take it at the emitter itself. But I would like to now see that, if this is v i, g m times v i is the output current. But, that output current is also available here, almost nearly at this point. Please note that and I want to give complete feedback of the output voltage. That means, output voltage…if it is going to be taken here…

Suppose let us say, output voltage is taken here. This output voltage is fed back to the input. This is the amplifier, input terminal. This is the actual input before feedback. This is grounded. So, this input was directly getting applied to base and emitter junction. Now, base emitter junction comes in series with the actual output voltage. So, I can take the output as well at this point because g m times v b is also available as current here. So, I connect this to ground and take the output voltage here. So now, this input voltage minus this output voltage is this.

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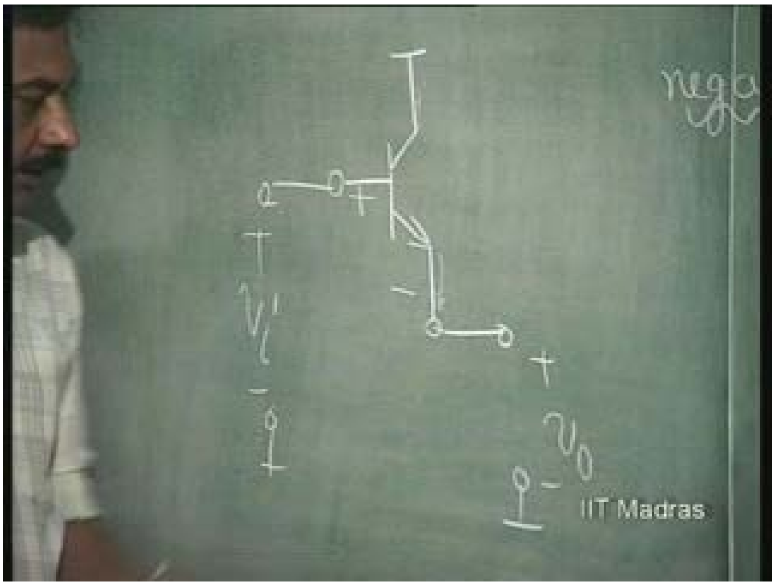

So, this is exactly what we had considered earlier. This is my amplifier. I do not have any feedback factor here; no passive network is being used. Output voltage is completely fed back to the input. So, this is V i minus V naught. This is amplified as A times V i minus V naught. So, what happens to V naught over V i? In this total feedback arrangement, this g is equal to A. So, you get…if A is very high, this becomes 1.

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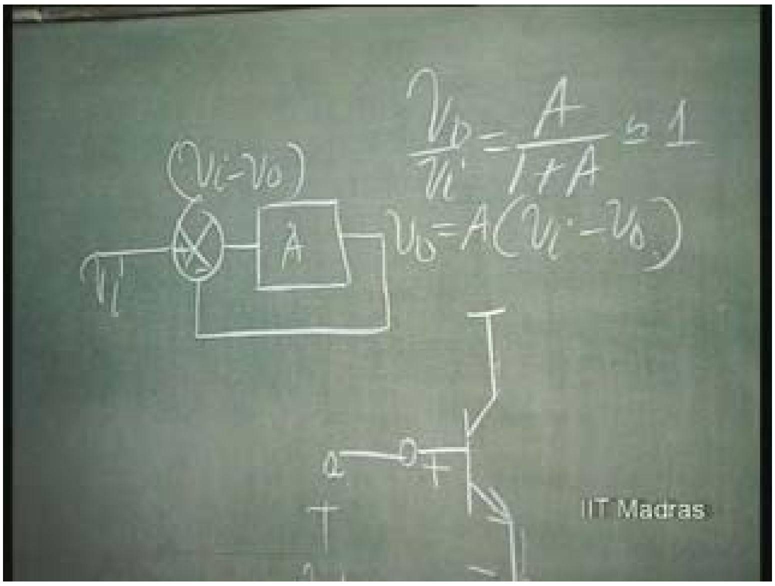

So, the basic concept of feedback network; we have put an amplifier with a gain G that is equal to A in this case and there is an error detector here which will just take V i minus V naught and apply it to the input. If this is V i, this is V naught; V i minus V naught is what is applied to the input terminals of an amplifier. So, this V i minus V naught is really the V B E. g m times that, g m times V B E, which is nothing but V i minus V naught, is the output current. That is the collector current; emitter current is Alpha times higher than that.

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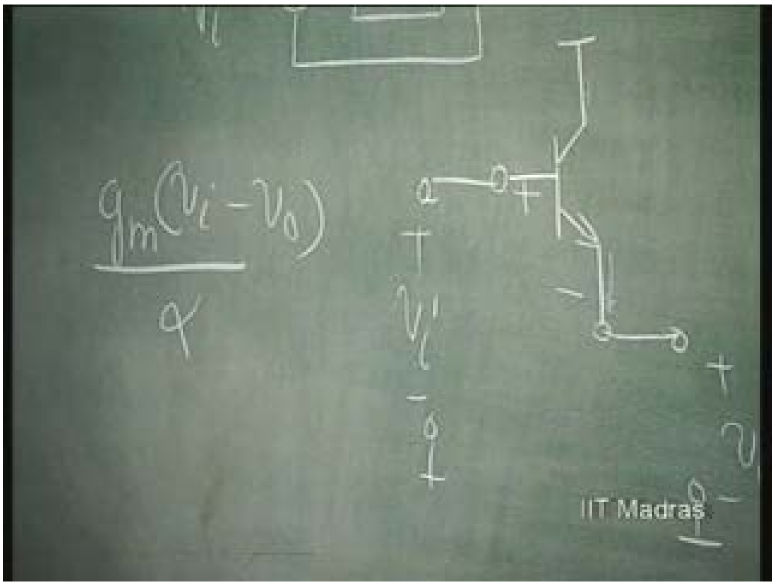

That is the current that is flowing; 1 over Alpha times that. So, that is the current that is flowing here. So, if you have a resistance here as R L which is normally put as R E, let us say; so, this current is going to flow through R L and that will be the output voltage.

So, what is the A factor? Nothing but g m R L by Alpha in this case. Same thing; g m R L, which is nothing but g m R E in this case; R L is same as R E. So, I am putting a load which is called R E. So, gain is g m into r e instead of R L. R L equal to R E. So the gain, A factor, is nothing but g m R E by Alpha. So, what is V naught over V i…is going to be nothing but A by 1 plus A, which is R E g m by Alpha divided by 1 plus R E g m divided by Alpha. Or, this can be rewritten as 1 by 1 plus… divide this whole thing by this factor; Alpha divided by g m into R E.

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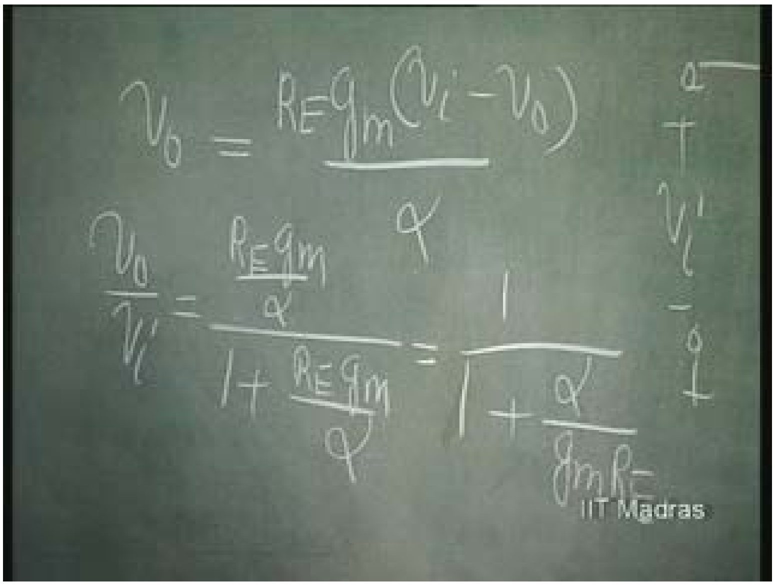

Alpha is very nearly equal to 1; g m into R E is a huge value supposedly and therefore this is going to be very nearly equal to 1.

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This is called common collector amplifier because the earth is common to input and output; and that is grounded here. Emitter is not grounded. Emitter is the point where the output voltage is taken. So, this is the case of total negative feedback, as far as output voltage is concerned. No feedback network is used, alright? So, you can see that this is the gain of the circuit, which is very nearly unity gain. This is also called voltage follower.

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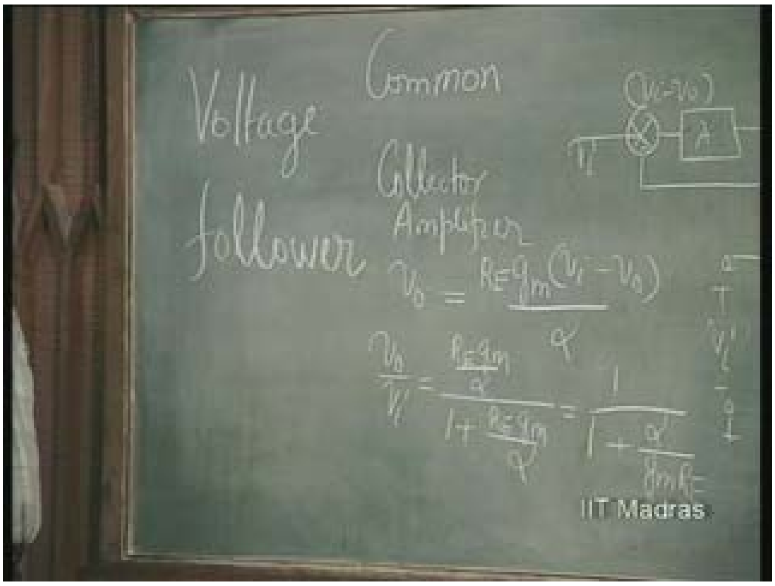

Output voltage will be following the input voltage always; and since this output voltage is fed back to the input, input, it is coming in series with the original input. So, input impedance is increased. It is the output voltage which is sensed and therefore output impedance will come down. So, this is an idealization towards voltage control voltage source; ideal voltage control voltage source.

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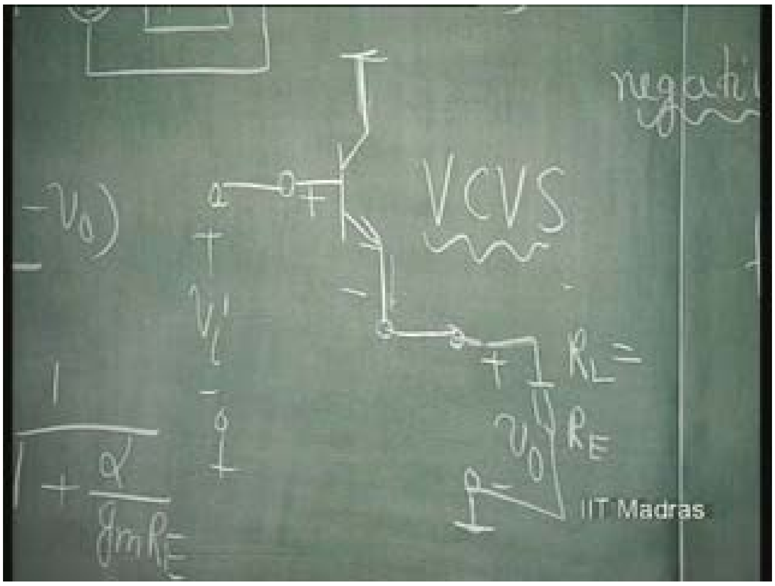

Unity gain with feedback; this gain is going to be very close to unity, irrespective of the load resistance that you use. So, this is a common buffer stage used between source and another amplifier so that the loading of the source does not occur by the amplifier. So, this is used commonly as a voltage buffer.

Similar to this could be a situation of total negative feedback which is current. That also we have to see. Let us now consider that. So again, if I give total current negative feedback, the current gain has to become close to 1, like voltage gain coming close to 1.

Let us consider this amplifier of ours. This is the input current; this is the output current. What is I naught by I i? This is equal to Beta, already defined. This is the short circuit current gain Beta, if I short this. So, this is a current amplifier.

So now, I…let us suppose…give current feedback. What will I do? I give this total current as feedback at this point. Now, that is a very easy thing, I told you; current feedback. This was originally I i and at this point now, you will get the error current, which is nothing but I i minus I naught because this is I naught.
So, I naught is flowing like this. So, this current, base current, is I i minus I naught. So now, this does the current feedback; it is shunt. In instead of in series, now the current

feedback is always in shunt with the original current. So, I naught, I i minus I naught is the error current. This into Beta is equal to I naught.

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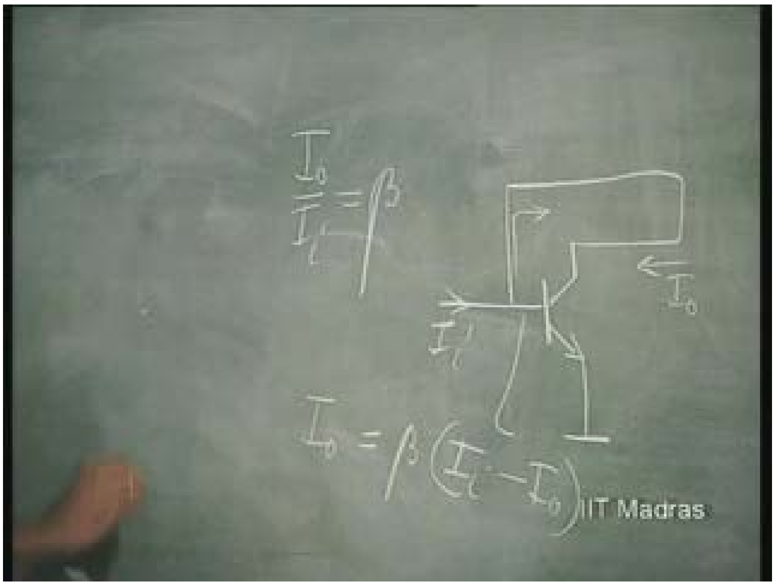

That means, I naught by I i is equal to Beta divided by Beta plus 1; or 1 by 1 plus 1 over Beta, which is very close to 1, which is, actually speaking, equal to Alpha.

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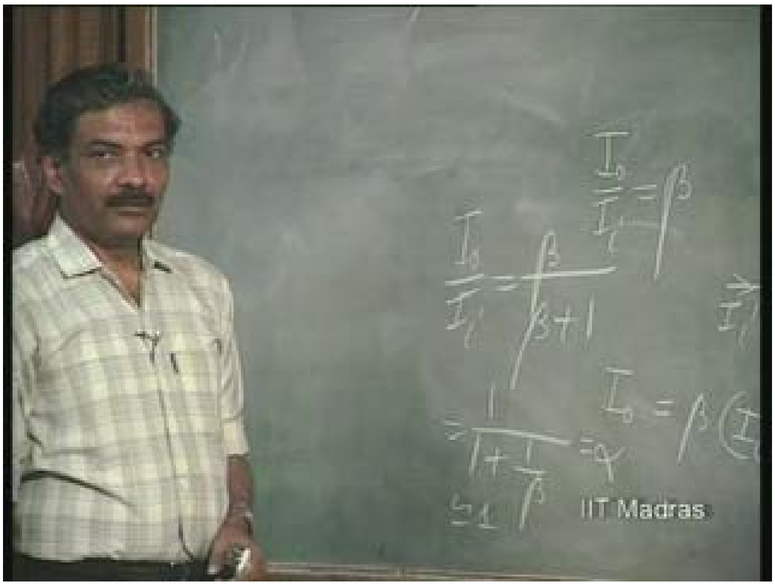

So, you can see... This structure, if you consider only in terms of current, this is the input terminal for the current. This is the output terminal for the current. What is common to this? You can put a load here also. No problem. That does not affect it at all. The current feedback is still... So, this is the output terminal for the current. This is the input terminal for the current. What is common to it is nothing but the base. You need…so this is common to this. This is therefore called common base amplifier.

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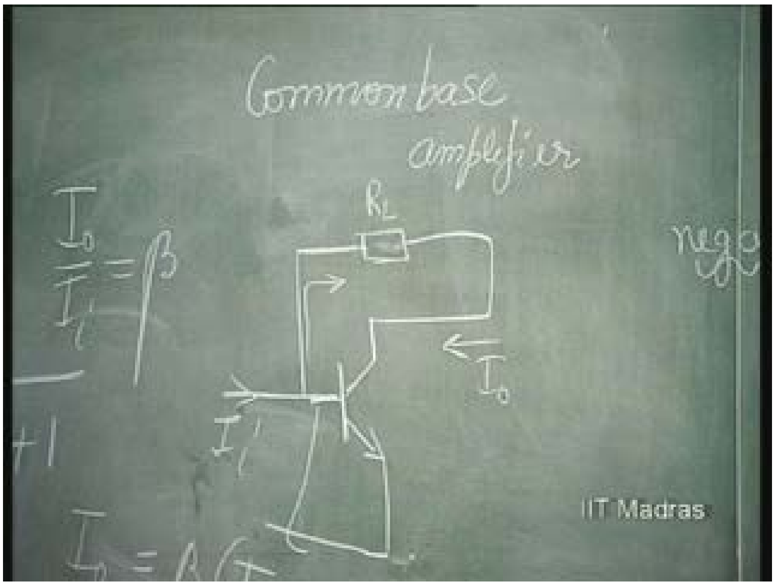

The earlier one was common collector amplifier. This is one with total current feedback from common emitter amplifier. This is called common base amplifier. The current gain from here to here now is going to be Alpha, because this is emitter current. That you know anyway. This structure now becomes automatically common base because actual input current is nothing but the emitter current; and therefore, this is common base amplifier.

So what happens? Input impedance comes down because it is shunt at the input; output impedance goes up by a factor corresponding to loop gain. What is the loop gain? Beta. So, if earlier output impedance is r c e, the present output impedance is Beta times r c e.

If earlier input impedance is R E into Beta plus… Beta…the present output impedance is r c e. That is, R E into Beta divided by Beta, R E. And the gain is also modified by loop gain plus 1; Beta by Beta plus 1. So, these are the fundamental issues involved. So, this is an idealized current controlled current source.

So, you have now seen using a single transistor, without using any feedback network, by giving total voltage feedback, we have realized a common collector amplifier, which is called voltage follower. This, we have realized. The common base amplifier which is called a current follower, you can call it. Or, it can be used for current buffer stages. Instead of voltage buffer stages, we can have current buffer stages. So, current control current source with unity gain.

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So, these are therefore also called wide band structures. The common collector and common base structures will have a bandwidth which is going to be again, loop gain times higher than the common emitter amplifier bandwidth, respectively for voltage gain, in the case of common collector; current gain for common base.

It is the current gain whose bandwidth is improved by a factor of Beta plus 1 of common base structure. It is the voltage gain whose bandwidth is improved by a factor of Beta plus 1, in the case of common collector stage.

So, this is the basis of the basic amplifier stages. The fundamental amplifier which we had considered earlier is the common emitter amplifier and negative feedback configurations are common collector and common base respectively with total voltage and total current negative feedback. So, we will consider double transistor stages or transistor pairs for negative feedback amplifiers, in the next class. We will note that using feedback networks, it is not possible to get h and g negative feedback structures with single transistor.

Of course, if you consider these basic stages, they are h and g feedback structures; but these are not using additional feedback networks for the feedback. If you want to use additional feedback network, passive network, and these passive networks are to be becoming effective, then there is no possibility of giving negative feedback with h and g. We will see that h and g will become negative feedback only when we use a pair; and in the case of a pair, you cannot get y and z as negative feedback. If you want y and z as negative feedback, you have to use a treble.

So, this is the fundamental issue of negative feedback. If you use y and z with pair, you will come up with only positive feedback structures. The loop gain will be positive. This, you can actually work out and see for yourself, by evaluating the loop gain, by the method that we have followed.

So, please see that if you use a pair, y and z feedback will be automatically positive. A pair can only have h and g as negative feedback, so on and so forth. So, the odd number of stages will always be…it will be suitable for y and z feedback. Even number of stages are always suitable for h and g negative feedback structures.