Electronics for Analog Signal Processing - I
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Lecture – 23
Stable way of biasing

In the last class, we solved Example 7 and Example 8. In Example 7, V B E comes out as how much? – point 538 and not point 63 as indicated earlier. So, please make this correction; and accordingly, the other values will be adjusted. So, please calculate.

In Example 8, I asked you to find out R 1 and R 2 for biasing; and that comes out as R 1 equal to 35 K and R 2 equal to 140. So, these are the answers which you should have obtained in your hostel while calculating. All these problems, you must work out and see whether these values are correct or not.

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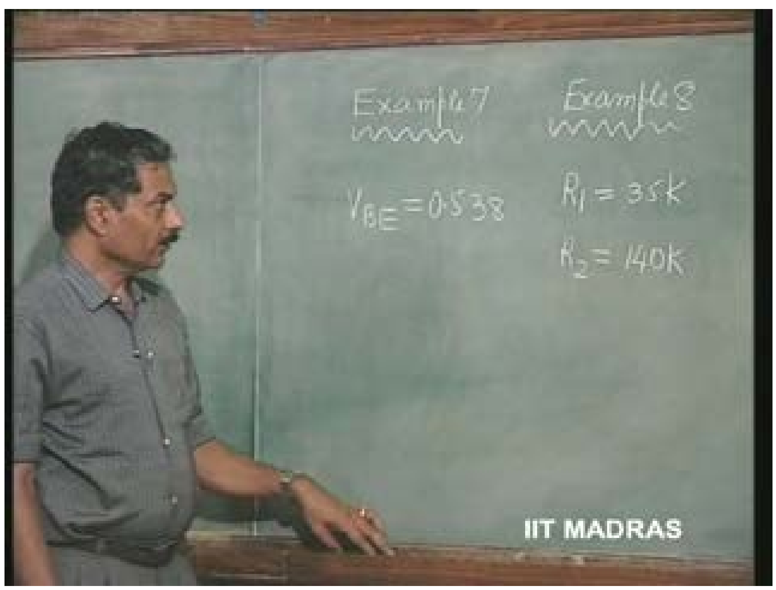

So, we will continue further with discussion about transistor amplifier. We had discussed transistor biasing. We know how to bias a bipolar junction transistor so that it is in the active region; and we also know how to bias it in a stable fashion. Now, some variations in this.

We have put, in general, a resistance through a supply voltage R 1 R 2. This is the generalized way of biasing that we have discussed.

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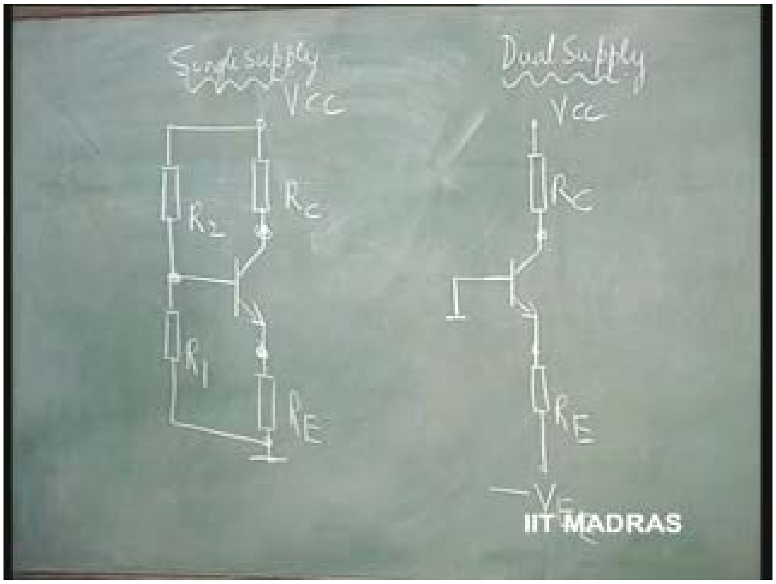

Now, how to feed a signal is what we are going to discuss for this circuit. So, we have a general scheme using single supply; we have another scheme using dual supply. These are stable ways of biasing. Both these schemes, we have discussed. In this scheme of single supply, we have to use additional resistances R 1 and R 2. In this, we are using only two resistances. So, let us discuss both these schemes. This is single supply, dual supply.

In single supply scheme that we had discussed, we saw that this can be equivalent to R C, V C C, R E, R B and V B where V B was equal to V C C into R 1 by R 1 plus R 2 – Thevenin's voltage; and R B was equal to R 1 R 2 by R 1 plus R 2, parallel combination of R 1 and R 2.

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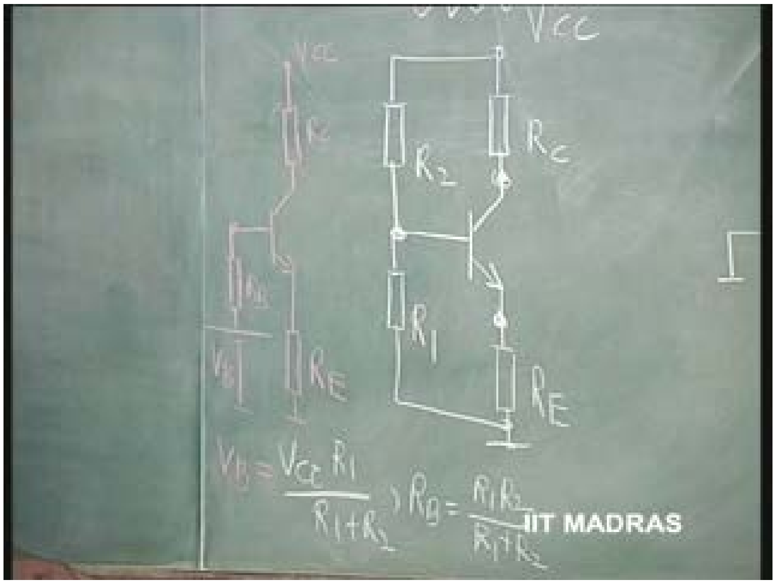

And, we had designed it in such a manner that Beta plus 1 times R E is much greater than R B. For fixing the emitter current in both the circuits; emitter current is getting fixed. In this, it automatically gets fixed; in this, only when this condition gets satisfied it is the emitter current... gets fixed as, in this case, V E E minus V Gamma divided by R E.

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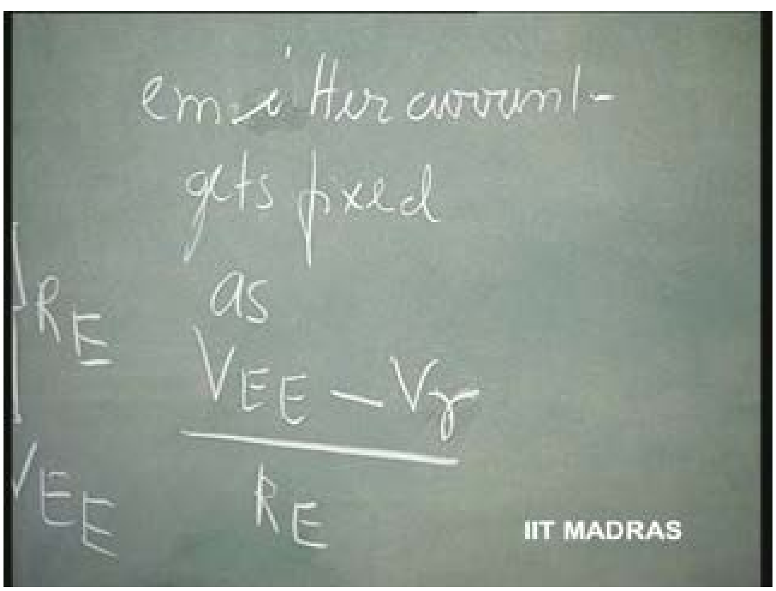

In this, it is going to be V B B minus V Gamma by R E. So, this is how the emitter current gets fixed.

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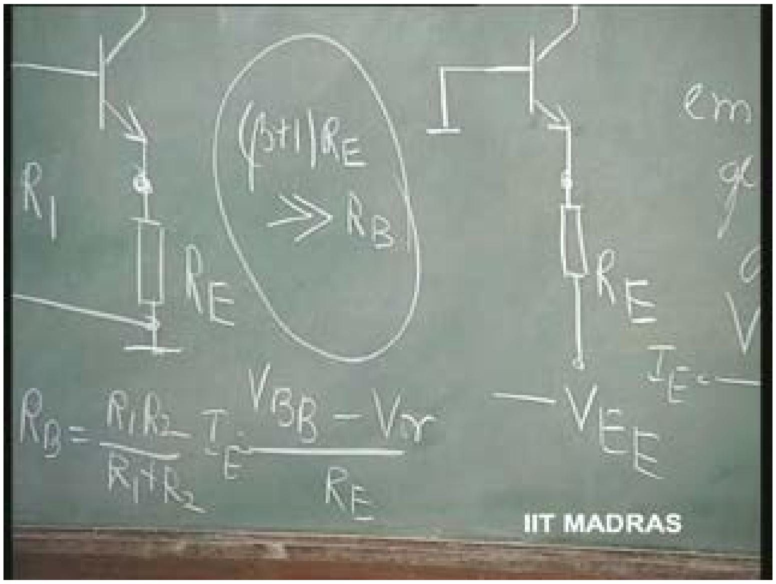

What happens is the drop across R B which is I B into R B is small compared to I E into R E. That is what is this one. So, with this knowledge about biasing, we would now like to see how signal can be applied to the transistor. So, how do we apply signal?

Signal, as we know, is a time varying component which we would like to amplify. And... let us consider this circuit first. In this, we had grounded this; output can be taken from here, no problem. I want this to appear as a common emitter amplifier. This is no longer, as far as D C is concerned, this is not a common emitter configuration; this is a common base configuration. Base is common. The potential, with respect to, of the base is zero; and potential of every other terminal is measured with respect to the base here. So, base is grounded.

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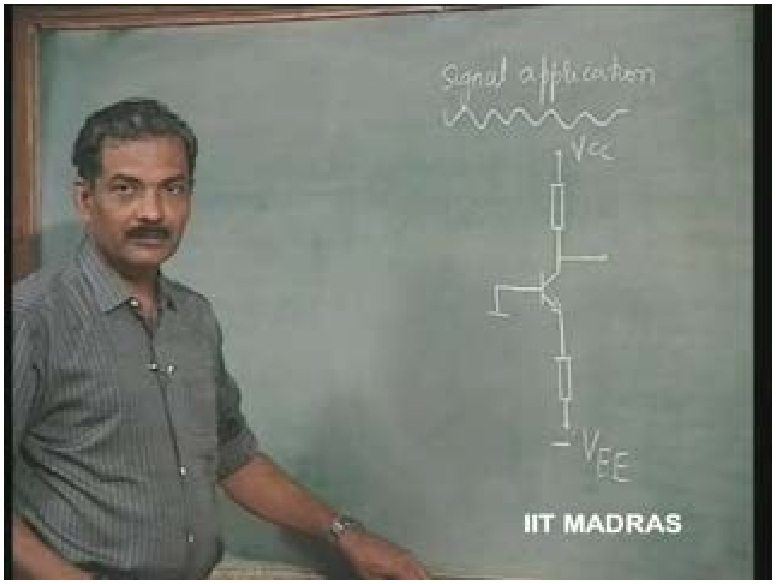

I want it to, as far as signal is concerned, to appear as common emitter. I want to apply the signal, still between emitter and base. So, the emitter is, with respect to D C, lifted; but, I want it to be grounded. So, for this purpose, we use what is called a bypass capacitor.

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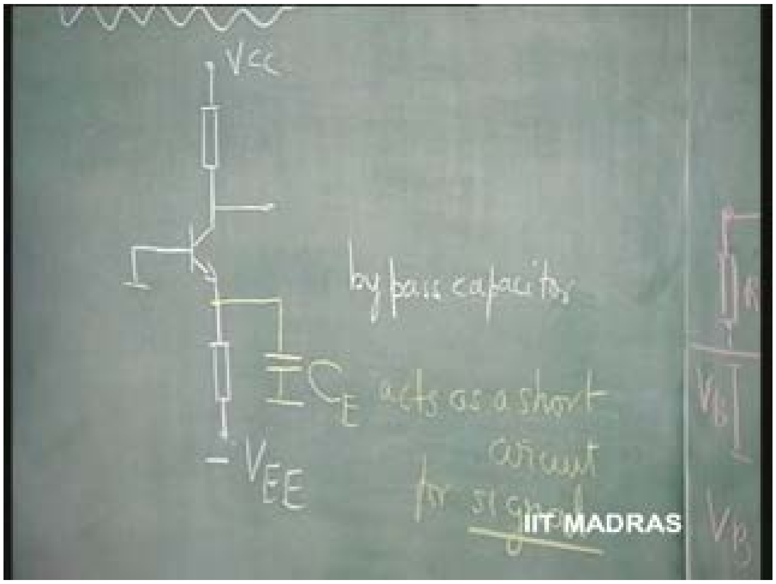

The capacitor for the signal will act as a short circuit. For signal, capacitor acts as a short circuit. This is called bypass capacitor. Short circuit compared to what? This is an important concept. This is grounding it. That means potential across this, as far as the A C is concerned is zero. That means this has to be compared with something that comes in series with it.

We want the potential to appear between base and emitter terminals, base and emitter terminals. That means the entire input potential which I am going to apply here now as a signal, this is the signal source; this signal source is assumed to appear between ground and this terminal. This base is directly connected to the other end of the source. So signal, it might have a source resistance, does not matter, is directly coupled. So here, signal source is directly coupled. This is called direct coupling.

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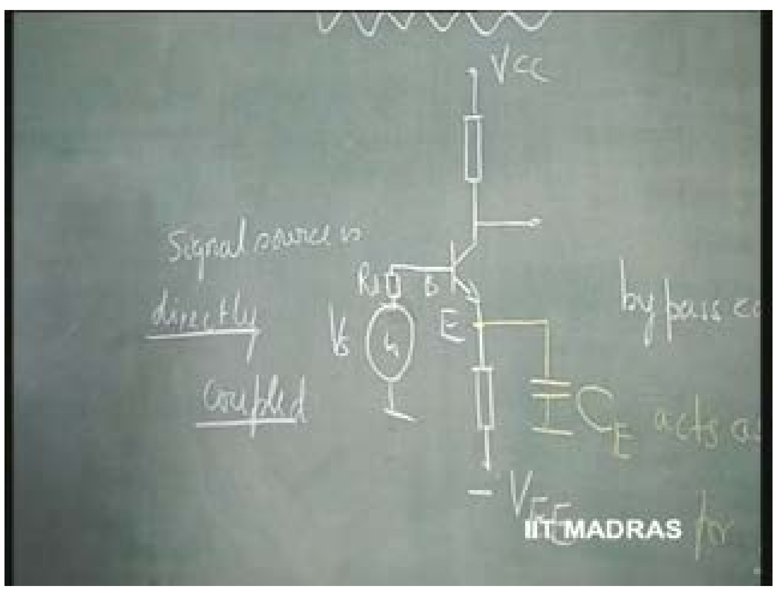

Since the base current is very small, the base D C current is very small, in this case, direct coupling may be allowed because source may tolerate that small amount of D C current flowing through it. Then, I can directly couple this source. So, base is connected to one end of the source; the other end of the source is grounded. So, this has to be grounded with respect to what? – base to emitter junction.

So, whatever drop occurs here, that should be large compared to the drop occurring across the capacitor. So, the capacitor is a short circuit compared to the impedance level that is occurring here. The impedance level that is occurring here is nothing but r e, small r e. So, the capacitor should be very small; that is, capacitive reactance should be very small compared to r e. That means r e should be much greater than 1 over 2 pi f into C; this is the capacitive reactance, C e.

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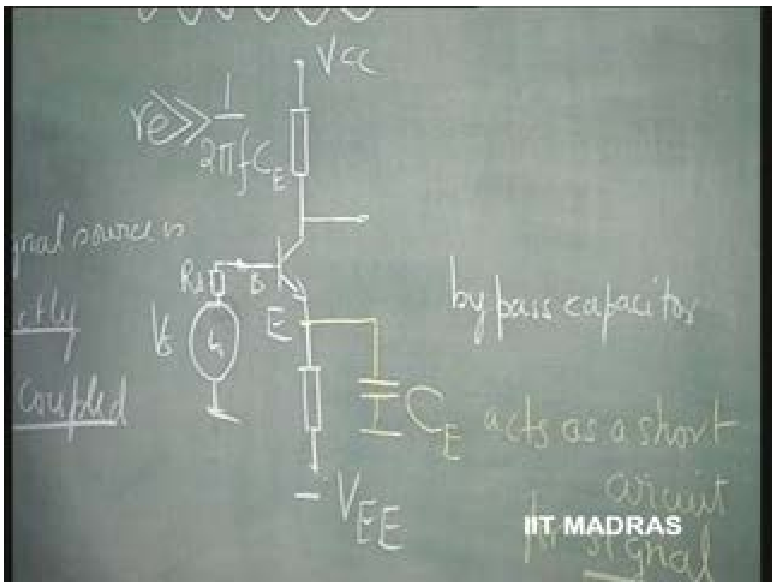

If you assume that for small signal, the resistance between base and emitter can be replaced by r e... what is r e? r e is V T divided by I E Q, which is nothing but Delta V B E divided by Delta I E. This, we had already discussed earlier. Delta V B E by Delta I E, small change in input voltage V B E, divided by small change in current, which is defined as small signal resistance at the emitter, V T divided by I E Q, where V T is equal to 26 millivolts at room temperature.

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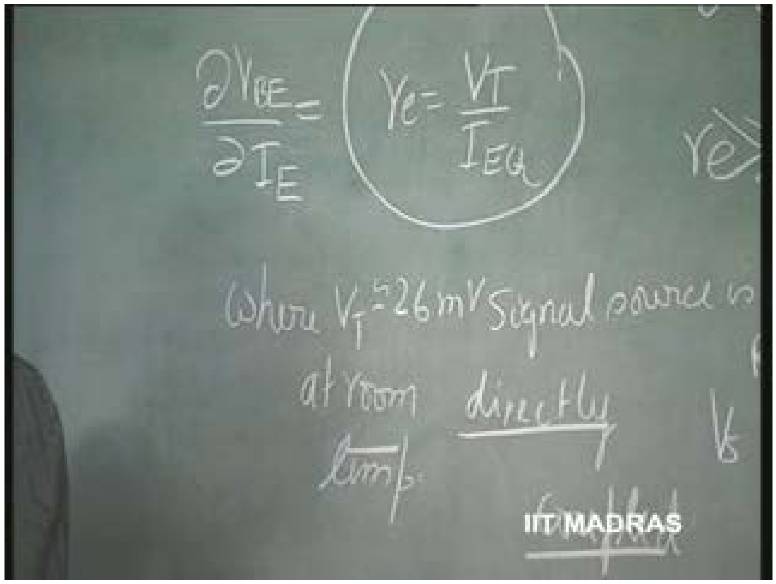

So, this is a useful design equation. So, the bypass capacitor, please remember, is bypassing what? – this path, which the current would have taken. The current now takes this path; and the current is going to be determined mostly by this impedance because, this is negligible. Reactance is negligible compared to this impedance here, R E.

So, this is something that I want to point out; that, you have to worry about this impedance while evaluating the value of the capacitor needed to act as a short circuit. Remember, it is bypassing the capital R E. Capital R E is going to be very large compared to small r e. For signal, you have to make this as short circuit compared to small r e, which is going to be of the order of tens of ohms.

So, C E therefore, is going to be chosen to be much greater than this 1 over 2 pi f into r e, at the worst case. The worst case is corresponding to the minimum frequency, if you design minimum frequency of use of this amplifier. Let us say, signal minimum frequency that you want to amplify is 100 hertz. Then, f minimum is 100 hertz. Above 100 hertz, it is automatically getting valid. So, this equation is automatically getting valid.

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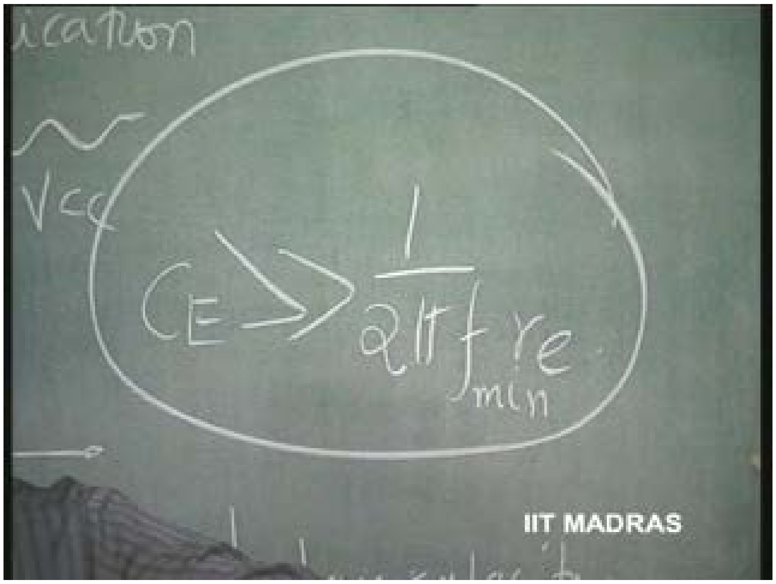

So, you have to design it for the worst case; that is, for the minimum frequency, it should still appear as a short circuit. Compared with what? – small r e. So, selection of the bypass capacitor is very very important. How do you do the measurement in the lab?

You have the voltage that you can measure with respect to ground. Measure the base voltage with respect to ground; and measure the emitter voltage with respect to ground. Emitter voltage with respect to ground should be very nearly zero compared to the base voltage. That means, most of this voltage, source voltage, is appearing between base and emitter. So, if this is done, this is a good way of bypassing the circuit. It is assumed that R S itself is going to be very small so that the source voltage is very nearly same as the open circuit voltage here, V S.

Now, the actual equation requires that the C E is so chosen that the reactance of C E is small compared to the impedance coming across it. This is like any other design that we have discussed earlier; the coupling capacitor also. Any capacitor is chosen, bypass or coupling, in such a manner, that 1 over 2 pi f minimum C E, that is the reactance, is much less than the resistance across what? – C E.

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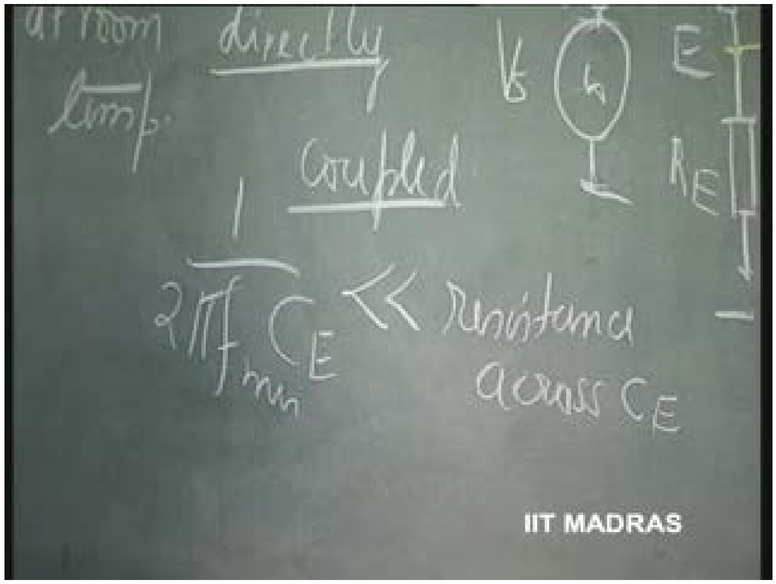

Now, let us see whether we have done it properly. Resistance across C E is this resistance to ground, this one resistance to ground, that is, capital R E. This resistance is coming from here to ground. Then, from here to ground, we have to trace the path. So, capital R E parallel small r e, this resistance, small r e – from here to here we have come; and if the source is this having resistance, then that R S divided by Beta plus 1.

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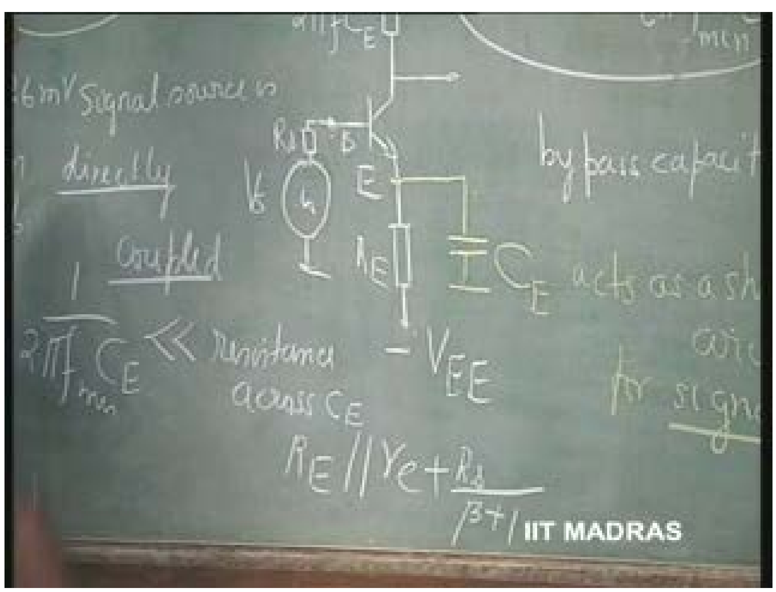

Why? You can see. If the current here is unity, emitter current is unity, capital R E will come. The current in this is Beta plus 1 times less. So, whatever impedance is there, its drop is also going to be Beta plus 1 times less. So, the current in this and the current in this differ by Beta plus 1. So, any impedance here can be transferred to this side as R S divided by Beta plus 1. So, the effective this thing, capacitor, should be such that its reactance should be very small compared to capital R E parallel re plus R S by Beta plus 1.

Then, why do we take this? That is because Beta is normally very high; and R S itself is very small. So, this factor is normally negligible. Then, capital R E is going to be very large compared to small r e; and therefore, this parallel combination itself results in r e.

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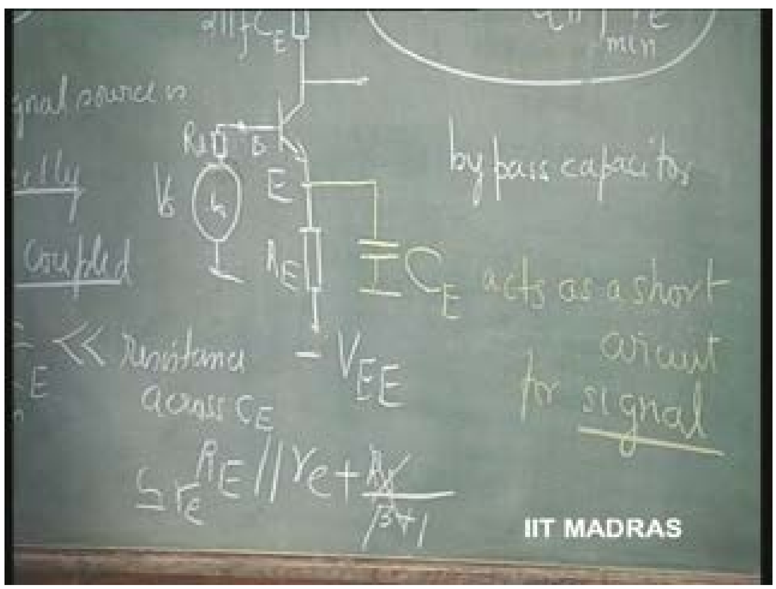

So normally, this design is going to work properly here, for selecting. Otherwise, if this approximation cannot be made, then you use the expression, r e parallel capital R E plus R S by Beta plus 1 as the actual resistance for fixing up the value of C E at the minimum frequency of interest for the amplifier.

So, we will once again discuss about these impedance levels later, while evaluating input impedance, output impedance, etc. But, please remember that what we are seeing is the impedance seen from here.

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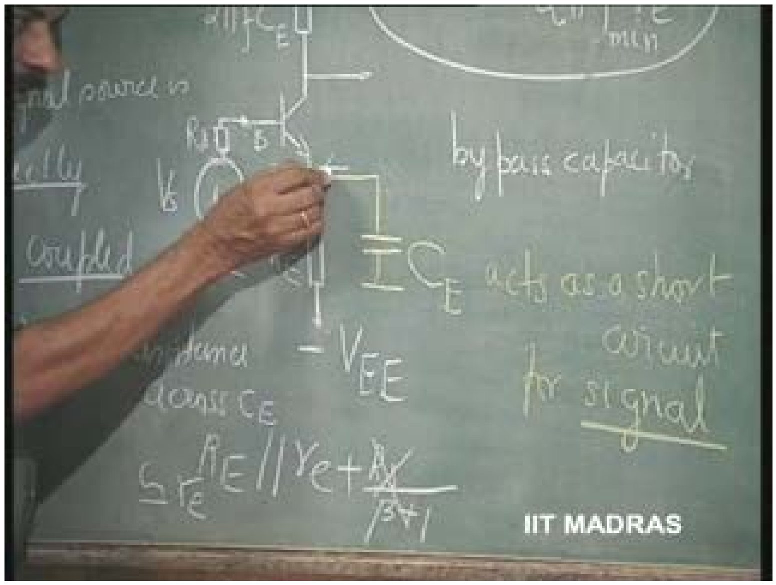

The impedance seen from here is going to be this resistance to ground because battery is going to be short circuited; because, there will not be any Delta V E E by Delta I E change, because, this is the constant source. So, this will be grounded. As far as the A C is concerned, this will be grounded. Then, this is going to be replaced by R E and this resistance, because it has Beta plus 1 times less current than this, is going to be replaced by an impedance which is R S by Beta plus 1. So, this is an important design criteria for fixing the value of the bypass capacitor, C E.

Now, I have made this a common emitter amplifier, by biasing it properly, fixing the emitter current and grounding this emitter point, as far as signal is concerned, using the bypass capacitor. After we do this, let us see what happens, when we now apply this signal V S. As far as the signal is concerned, now, I can put down the equivalent circuit for this as R S, V S; then it comes to the base. Then this base point is going to be replaced, let us say, by small r e, which is nothing but Delta V B E by Delta I E. This is the equivalent resistance between the base and emitter, it is going to be; and emitter is now grounded through the bypass capacitor. So, the entire signal picture on this side of the loop is just going to look like this.

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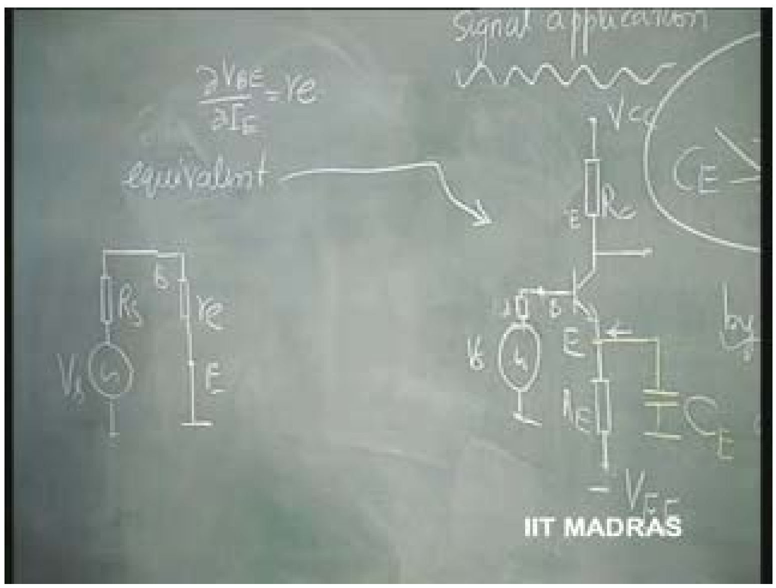

Now, as far as this side is concerned, this junction, if this is Delta I E, current, let us say Delta I E, then this current is going to be Alpha times Delta I E, which is the transistor equation; because, we know that I E into I C is equal to Alpha times I E plus I C naught.

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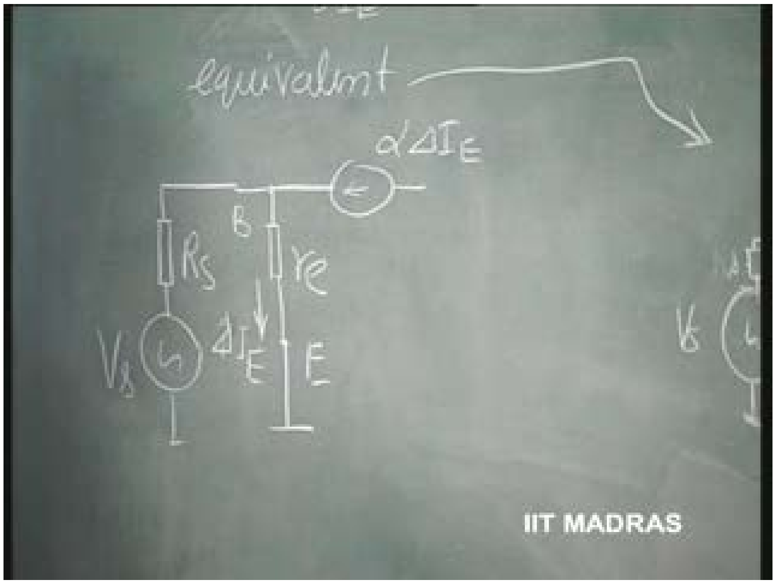

So, Delta I C by Delta I E is equal to Alpha here. I C naught is a constant current. So, Delta I C by Delta I E also is called Alpha. So, Alpha is the current amplification factor which we have discussed, which is very close to 1; typically of the order of point 99, point 995, etc.

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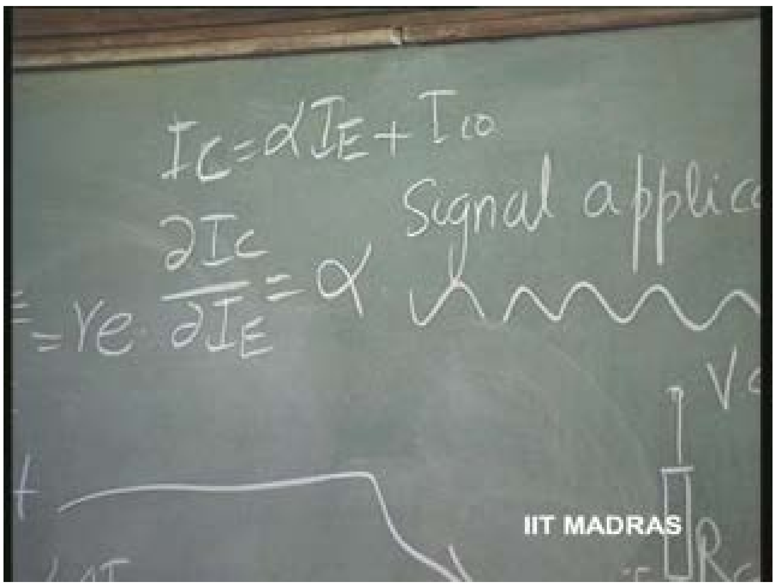

So, we have this current flowing through this like this; then we come to the collector. And from the collector, we have a resistance to ground. This is what is called as equivalent circuit for this common emitter amplifier.

Once again, let us trace this. V S is replaced by V S signal. R S, R S. This is a small signal; so, strictly speaking, I would put it as, we will put it as, Delta V S, indicating it is small signal. So, corresponding to which, we have replaced this transistor by Delta V B E by Delta I E; so r e. And, that Delta I E is supposed to flow through r e, resulting in a collector current of Alpha times Delta I E, from this relationship. And this whole thing is an equivalent circuit. This is the simplest equivalent circuit one can think of for the transistor.

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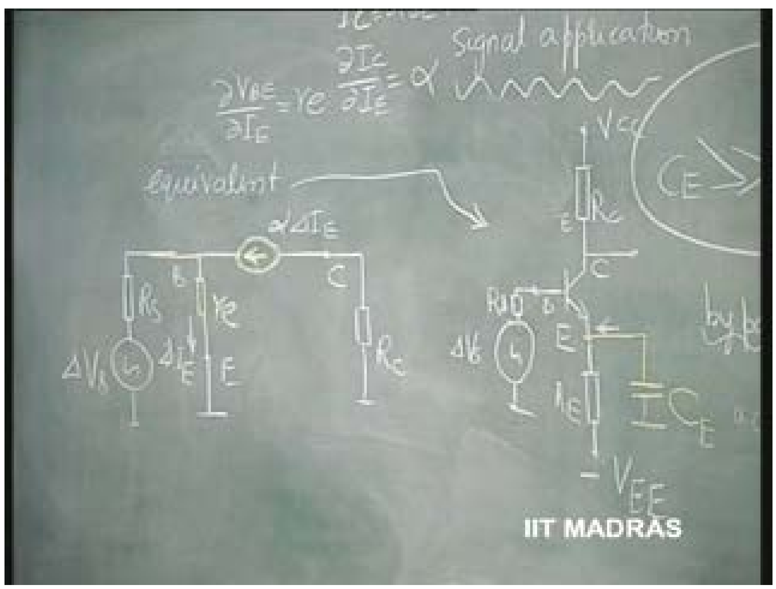

Now, we will find out what is this current that is flowing through the input of the transistor which is called Delta I S, let us say. Let us find out from this. I know that this is Delta I E and this is Alpha times Delta I E. So, what is this going to be? This is Delta I E, this is Alpha times Delta I E. So, what will be this current?

So, Delta I E has gone over this and this is Alpha times Delta I E. So, this will be 1 minus Alpha times Delta I E. Is it clear? – so that, this plus this comes out as Delta I E. So, this Delta I E, subtract this Alpha times Delta I E from that; that will give you the resultant current – 1 minus Alpha times Delta I E.

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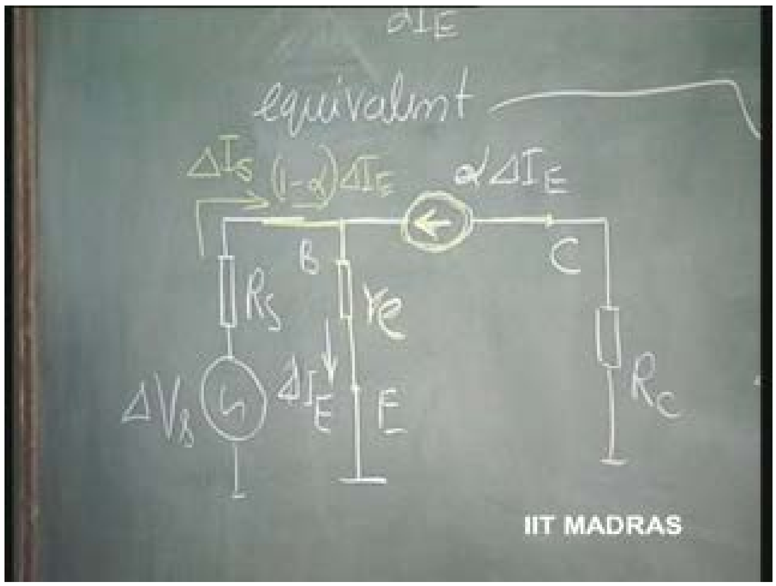

So, Delta I S is equal to 1 minus Alpha times Delta I E, from the Kirchhoff's current law. And, what is Delta I E? If this is a voltage here, Delta V i, we will call this Delta V i, the voltage between base and ground, directly between the input and the amplifier. So, Delta V i is equal to Delta I E into r e. This Delta V i, voltage across this, is nothing but Delta I E into r e. Delta I E into r e.

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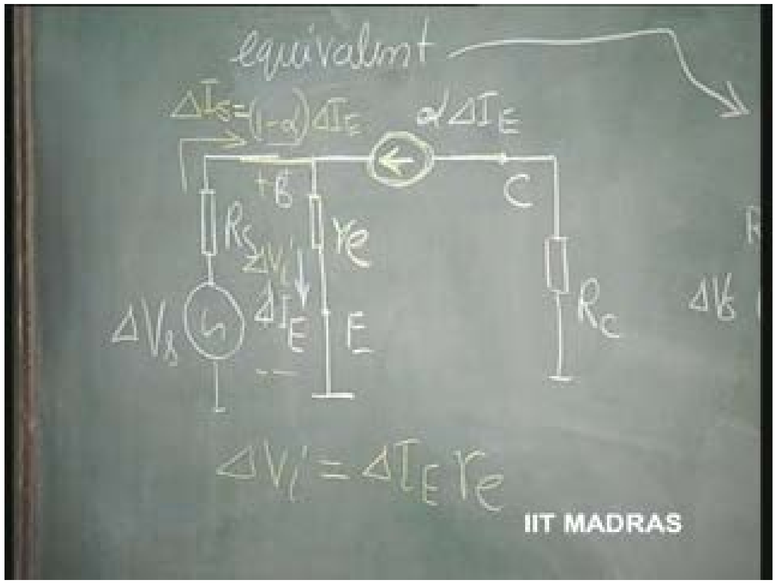

So, what is Delta I S? 1 minus Alpha times Delta I E. So, we can represent this as r e; and Delta I E can be replaced as Delta I S by 1 minus Alpha. So, in this loop, we can therefore write as Delta V S, which is this voltage, is equal to Delta I S times R S; Delta I S times R S plus this drop. That is the Kirchhoff's loop equation; Delta I S by 1 minus Alpha times small r e.

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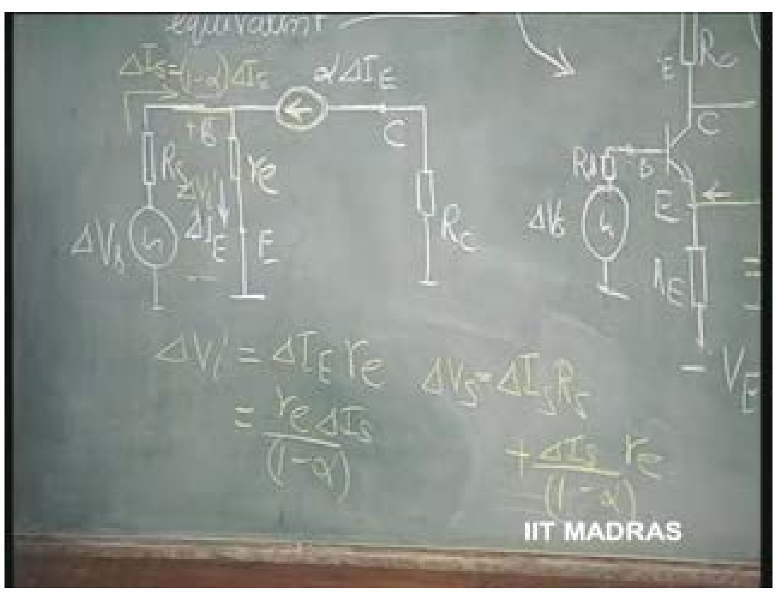

So, you can see that Delta V S by Delta I S, effective resistance seen from here, is nothing but R S plus r e by 1 minus Alpha. That means, it is the original R S through which Delta I S flows; and this r e which is there between base and emitter appears as r e by 1 minus Alpha. So, that is called the input resistance of the amplifier.

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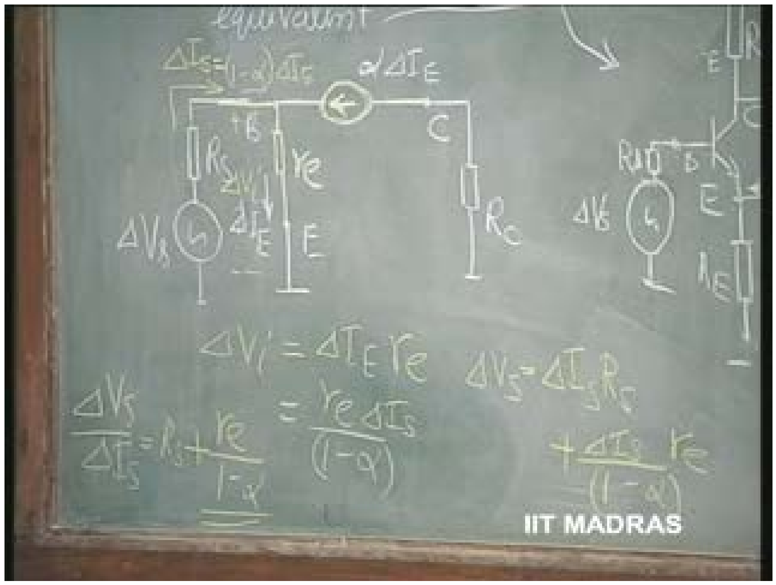

So, when I connect a source with a source resistance of R S, from that source, the current that flows, that is determined by an impedance which is R S plus r e by 1 minus Alpha. So, what this amplifier is going to offer as impedance is r e by 1 minus Alpha.

So, input resistance of the amplifier is nothing but r e by 1 minus Alpha or is equal to r e into... I have told you, Alpha is Beta by 1 plus Beta. If you replace it by that, Beta by 1 plus Beta, we will get this as r e into 1 plus Beta. So, as far as common emitter amplifier is concerned, the input impedance is r e into Beta plus 1.

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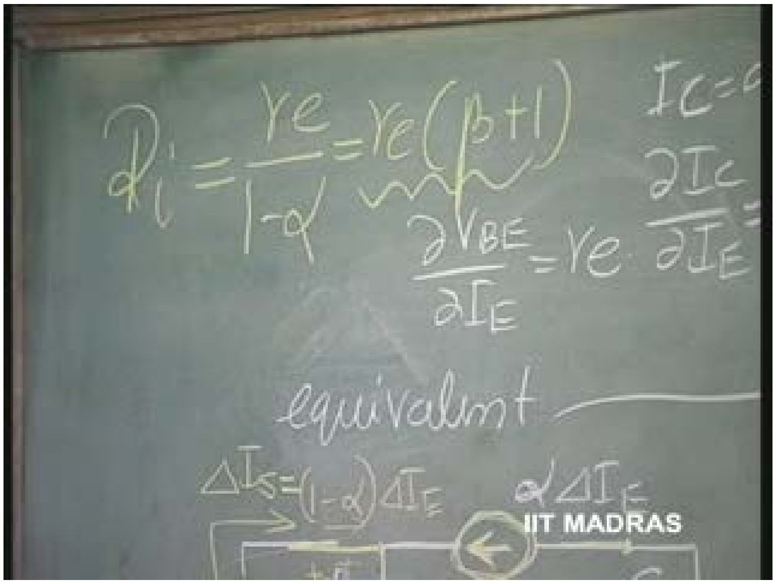

Now, as far as the output voltage is concerned, let us check. Output voltage is going to be, how much?

R C into current which is Alpha times Delta I E. This is equal to minus Delta V naught, because current is flowing this way; and I have assumed Delta V naught is positive this way. So, minus Delta V naught is R C Alpha Delta I E. Or, Delta V naught is equal to minus R C into Alpha into Delta I E. Delta I E is nothing but Delta V i, Delta V i divided by r e.

So, from this... This is Delta V i; that divided by r e is Delta I E. So now, from this you can get, Delta V naught by Delta V i as equal to minus Alpha R C divided by r e; very important equation.

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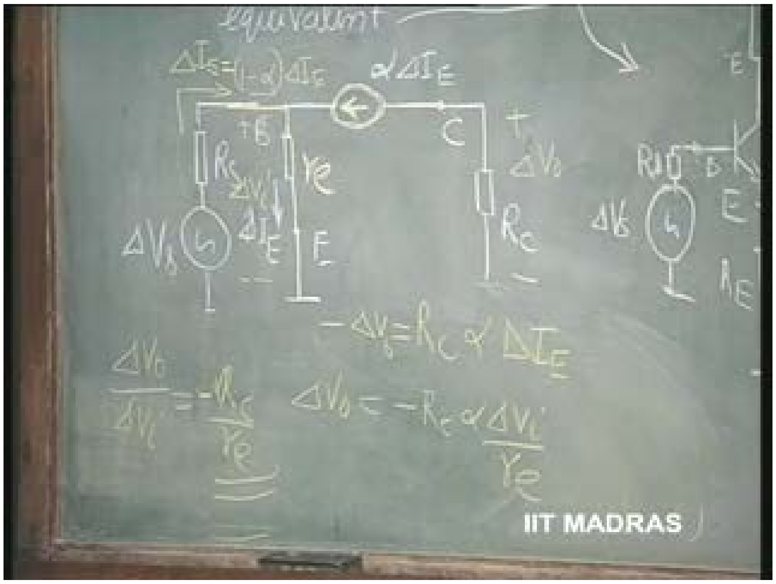

Alpha is very nearly equal to 1. So essentially, the gain of the amplifier, Delta V naught by Delta V i is Alpha R C, minus Alpha R C, divided by r e. r e is already known as V T divided by I E Q. So, the gain of the amplifier is minus, indicating there is an inversion. If the input is increasing, output will be decreasing. There is an inversion.

This also we had discussed earlier for a general amplifier; and its value is minus Alpha R C divided by r e. What is minus Alpha by r e? This is called, Alpha by r e is called, g m, transconductance of the amplifier. This also we have defined. Delta I C divided by Delta V B E. Delta I C divided by Delta V B E is nothing but Delta I C divided by Delta I E into Delta I E by Delta V B E. Delta I C by Delta I E is Alpha. Delta I E by Delta V B E is 1 over r e. So, this is nothing but Alpha divided by r e, which is called the transconductance, g m, of the transistor.

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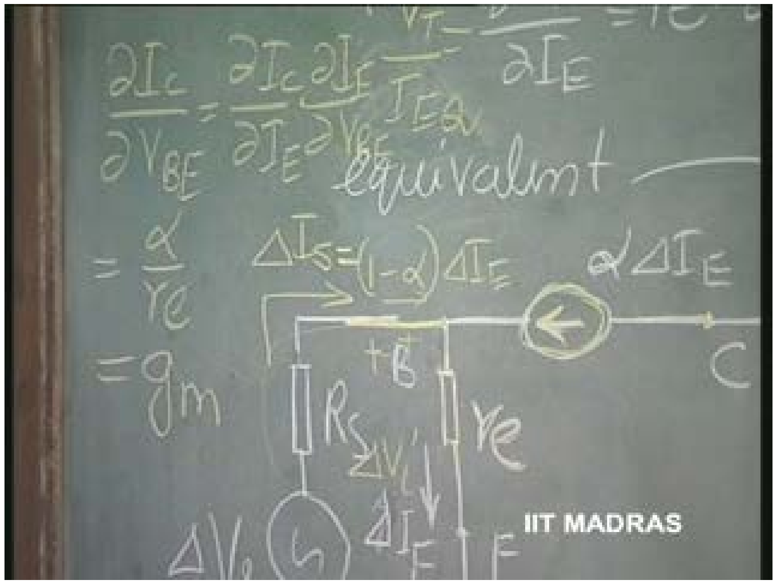

So, this gain is equal to minus g m R C. This also, earlier we had discussed. So, we have now obtained the input impedance of the amplifier, the gain of the amplifier, output divided by input; and what is the output impedance? Seen from here, since there is a current source, output impedance is infinity in this case, from here. So, if it is an ideal current source output, then obviously, output impedance is infinity.

Of course, there is a high resistance between this and this, indicating some leakage resistance between collector and base. If it is having a leakage resistance, then of course, there will be a finite output impedance. So, it is enough if we learn in this basic thing about the common emitter amplifier, its input impedance is going to be small r e divided by 1 minus Alpha; or, r e into 1 plus Beta, and its gain is g, minus g m into R C.

So, let us now take an example to illustrate this; Example 9. Design a common emitter amplifier to operate at I E Q equal to 1 milliampere; V C B Q equal to 5 volts; and V C C equal to 10 volts; V E E equal to minus 10 volts.

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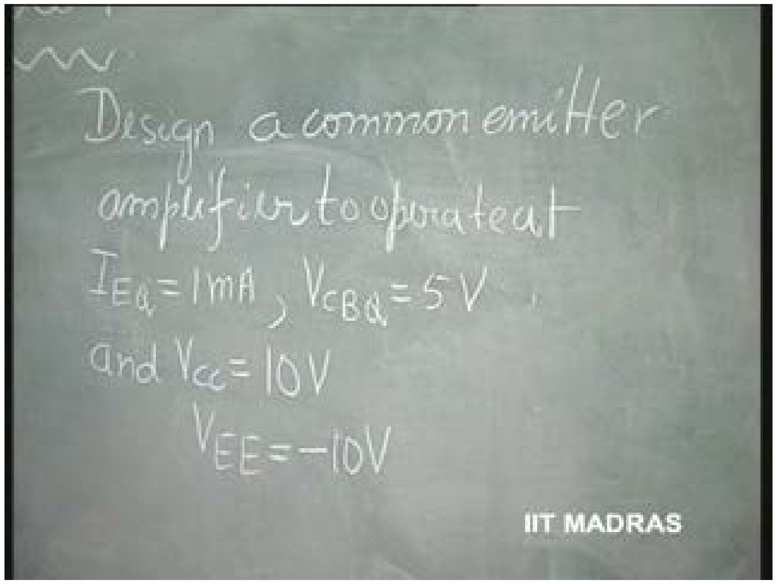

Then, obtain the voltage gain and input resistance of the amplifier.

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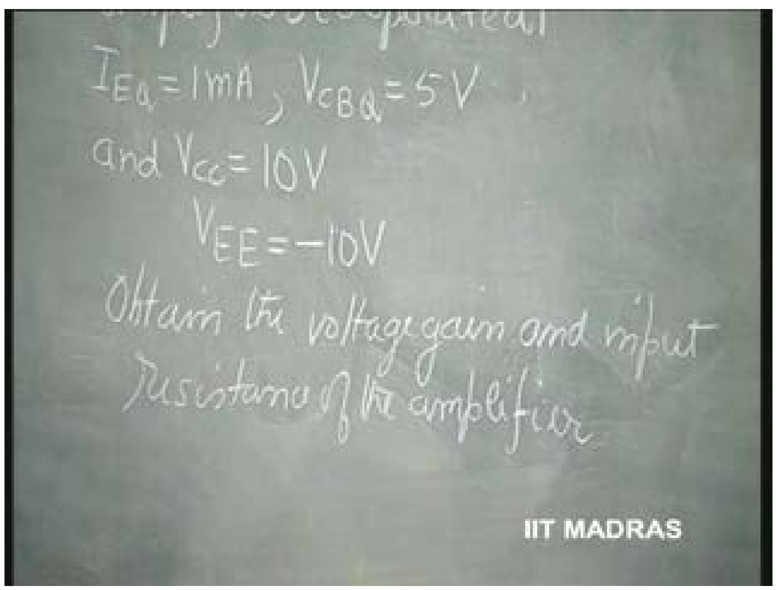

So, let us continue with the Example 9. We have here the pictorial representation of the same amplifier with biasing scheme using dual supply; plus 10 volts and minus 10 volts; connected through R E to emitter; connected through R C to collector, connected through R S, the input signal, to the base; emitter grounded. So, it is grounded emitter amplifier.

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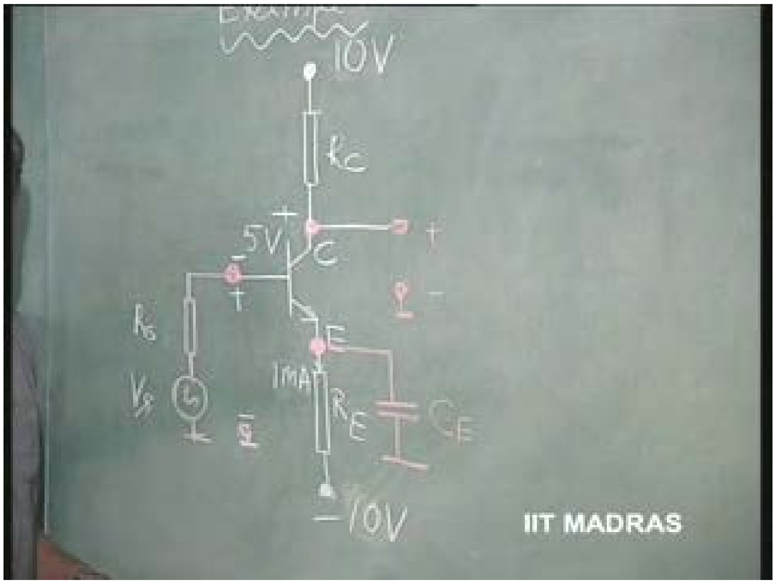

Now, bias current I E Q flows through this R E; it cannot flow through the capacitor. So, it is the same current here as well as here; and that has been prescribed as 1 milliampere. This voltage V B E Q is not given; but we can... whenever it is not given, we can take it as equal to point 6 volts, this we know. So, this is point 6 volts. So, nothing has been mentioned about the source and all that. So, as far as this is concerned, we will consider that the source is being fed here; but for the time being, we do not know anything about R S. So, we will assume R S is zero.

The source is going to be connected here. So basically we have, as far as D C is concerned, this having zero D C potential. Otherwise, the base current will also source through the source resistance. So, please remember: if the base current is I B, then this... if there is direct coupling, then through R S, the base current will flow.

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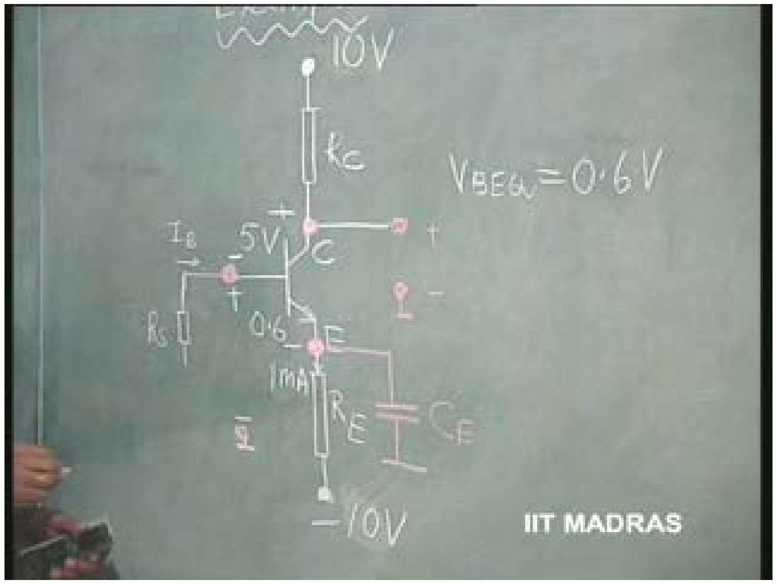

So, in an actual situation, you will see that this potential is going to be I B into R S, D C potential. If the source resistance is not given, nothing is mentioned about it, we will assume R S is zero and this is grounded.

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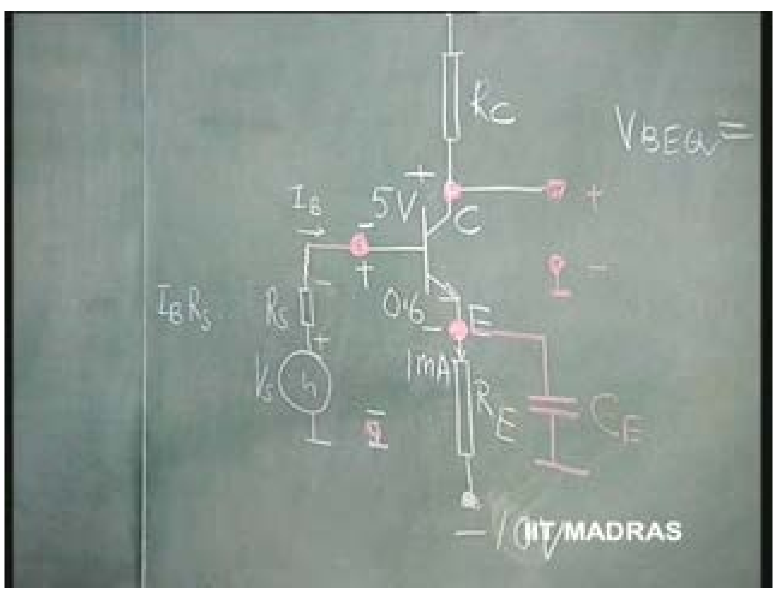

If source resistance is given, then we have to consider this D C drop along with point 6 volts. So, how do you know this drop? If you know the Beta of the transistor, let us take, Beta is assumed to be about 200; then, this I B into R S is same as I E divided by Beta plus 1. I E divided by Beta plus 1 is I B, into R S. So, I E is given as 1 milliampere and R S may be known, let us say, 1 Kilo ohm. So suppose R S is 1 Kilo ohm; 1milliampere into 1 Kilo ohm. So, that is going to be about 1 volt drop. So, that divided by Beta plus 1, which is about 201. So, 1 volt divided by 201, which is negligible. It is about the order of 5 millivolts.

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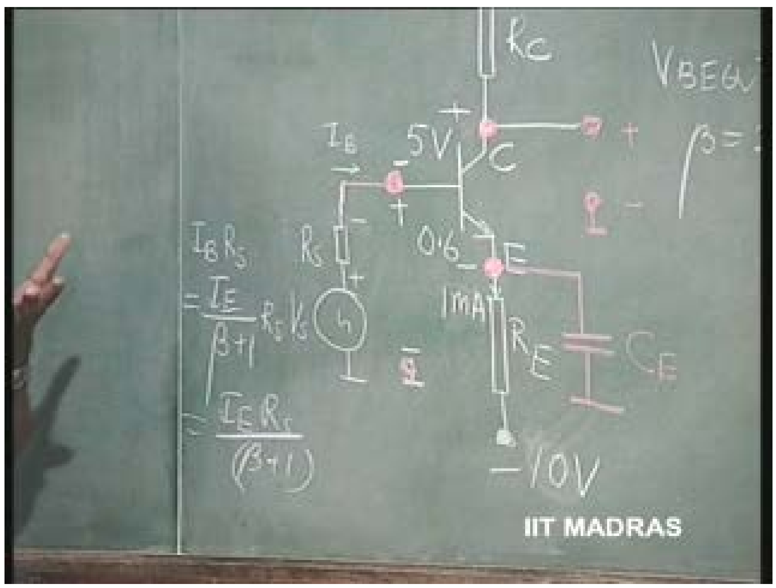

This itself has been assumed as point 6. This is not point 6. This may be point 625 or some 63. So, there is no point in considering this drop at all and therefore normally, under normal source resistances of the order of Kilo ohms, this is negligible. If it is not negligible, take it into account. It should become comparable to point 6 volts. Then only, you need to take into account. So otherwise, this is always negligible.

So, this is going to be almost at D C ground potential, under normal circumstances, because of this exception. So, the base is going to be still at D C ground potential. This is point 6. This is 5. And therefore, the current in this is going to be 10 minus point 6 divided by R E.

If this is at, let us say, some potential which is I B into R S, then that I B into R S should be added to point 6; otherwise, it is 10 minus point 6 divided by R E. So in this loop, the D C drop, A C signal is zero. So, the D C drop, quiescent drop, when the signal is not there is 10 minus point 6 divided by R E. That is to be made equal to 1 milliampere. So, R E equals 9 point 4 Kilo ohms.

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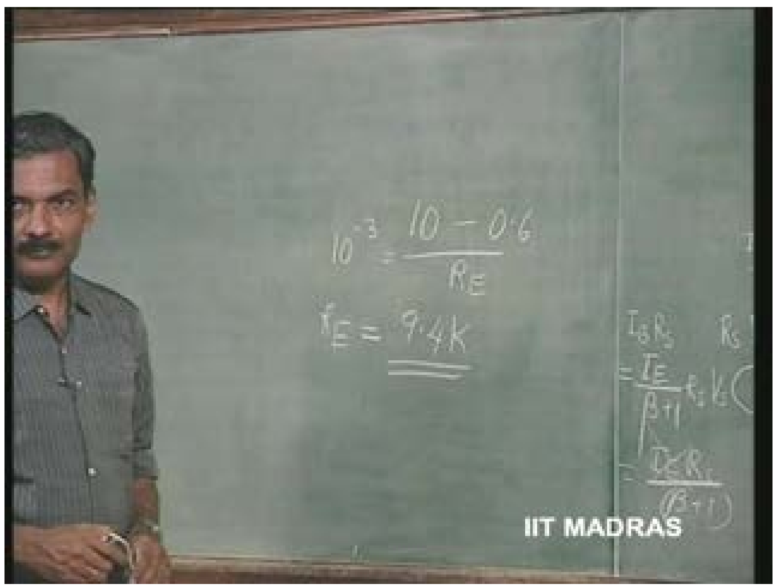

So, R E has been now fixed to make the I E Q equal to 1 milliampere, given this voltage is 10 volts. So, even in a general situation where R S is given, you have to verify whether this is true and make this assumption that this is negligible compared to point 6 volts.

Then, this is at 10 volts and this is very nearly at the ground potential; and therefore, this is very nearly from the ground, equal to 5 volts, this is given, because V C B is given as 5 volts. So, if this is at 5 volts, then the drop across this R C is 5 volts. So, drop across R C which is, I C Q into R C, is equal to 10 minus 5, which is 5 volts. So, R C is equal to 5 volts divided by I C Q, which is very nearly equal to 1 milliampere, we can assume. It is

Alpha times 1 milliampere. Alpha is going to be point 995 because Beta is given as 200. So, Alpha is going to be point 995.

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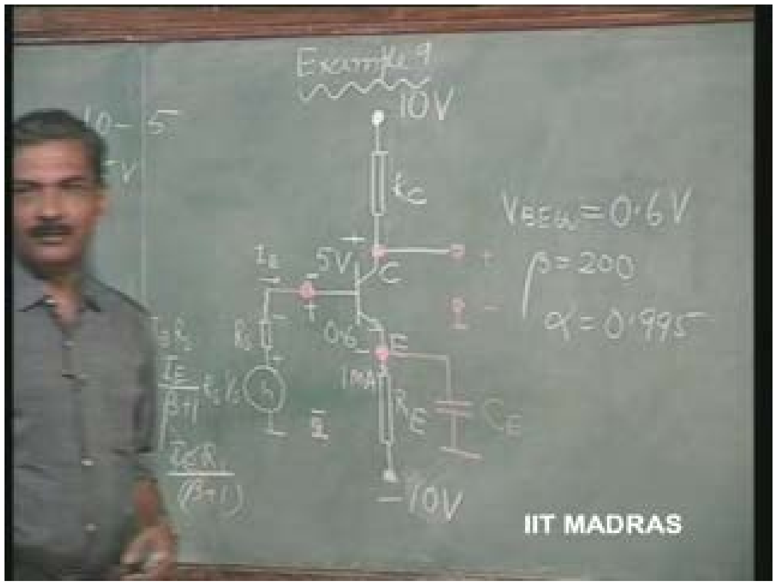

So, we can assume that this is pretty equal to 5 Kilo ohms. Is this clear?

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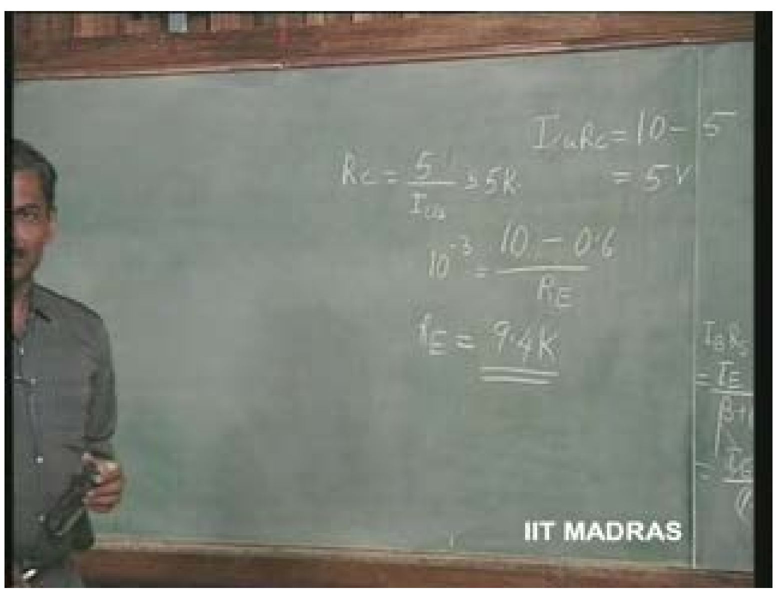

So, we have R C also fixed now as 5 Kilo ohm and R E is fixed as how much? – 9 point 4 Kilo ohm. Then, C E – 1 over 2 pi f min into r e. C E should be much greater than this, according to this. We can again check. R S is assumed to be zero. If R S is not zero, then, we have to compare with R E plus R S divided by Beta plus 1, parallel 9 point 4 K.

Anyway, R E is going to be of the order of 26 ohms because, 26 R E is 26 divided by I E Q, which is 1 milliampere. So, it is equal to 26 ohms; so, should be greater than 1 over 2 pi... Let us say, f minimum, we will take it as... if it is not given, let us say, we are going to fix as, let us say, 200 hertz. We are not interested in any frequency less than 200 hertz. So, this into 200 hertz into 26 farads.

So, can somebody quickly evaluate how much this is. 2500. So, 30... Again, all of you verify. So, much greater than 30 point 6 microfarad. About 300 microfarads is the typical value for this kind of frequency, wherein, this capacitor is going to act as a short. So, it is enough if we take C E equal to, let us say, 300 microfarads.

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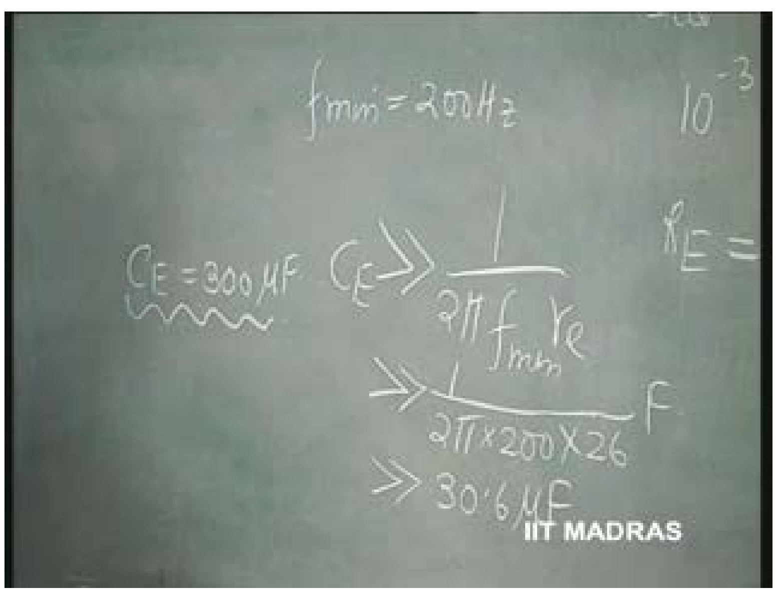

So, we have now designed a nice common emitter amplifier which we can use. Now, let us see its performance factors. What are they? Input impedance and gain. So, let us... we have made it work beautifully in the active region by biasing it at 1 milliampere and V C B equal to 5 volts. It is in the active region; that we have made sure of. Whatever be the transistor that we put here, the bias point is not going to get altered. That is why it is called stable operating point. That we had assured; and now, we can see if its performance is alright.

Input impedance which is equal to Delta V B E divided by Delta I B; because, Delta V B E is the input signal here. Delta V B E. This is zero drop; from here to ground, emitter to ground, it is grounded. So, Delta V i is going to be added to this as Delta V B E. So, Delta V B E by Delta I B - that is the input impedance; which is equal to Delta V B E divided by Delta I E into Beta plus 1.

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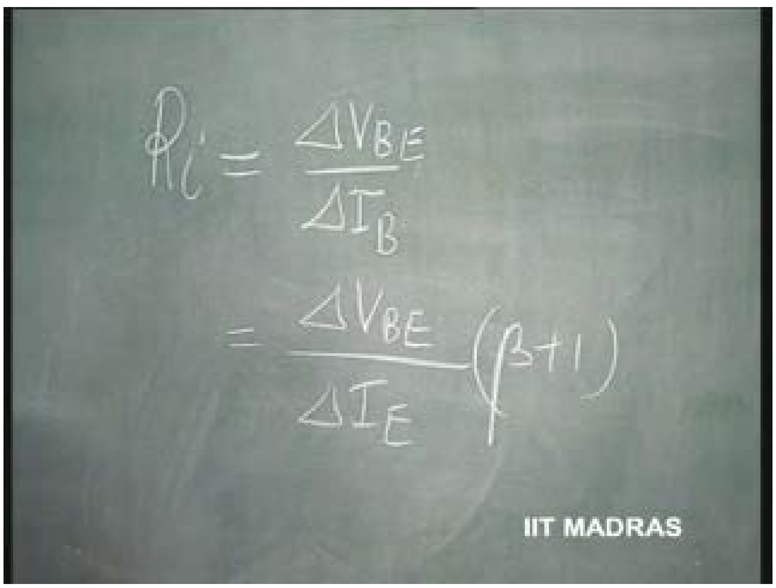

Delta I B and Delta I E are related by this factor, Beta plus 1. Delta V B E by Delta I E is nothing but r e. This is what we had done earlier also; r e into Beta plus 1. And r e is 26 ohms into 201. So, this is equal to 26, 52, 5 point 226 K, Kilo ohm. This is the input impedance resistance of our common emitter amplifier.

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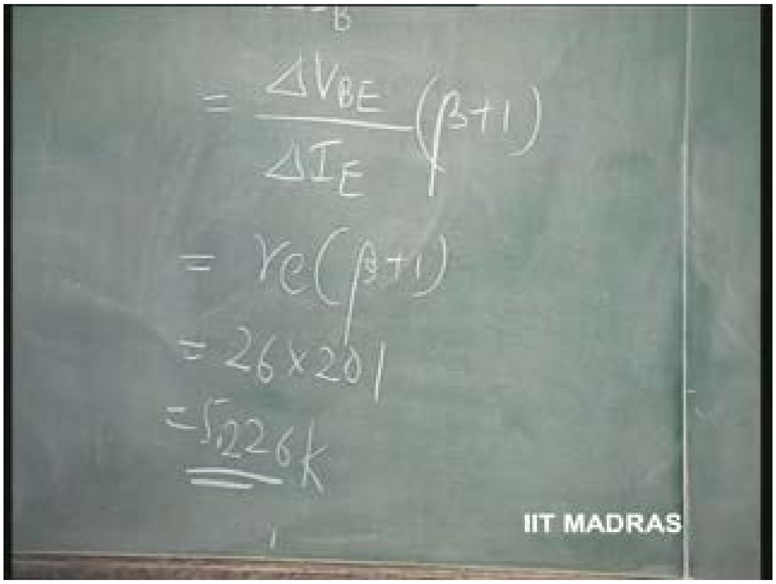

Now, Delta V naught, which is going to be taken here, divided by Delta V i is going to be equal to minus Alpha R C divided by re; which is going to be minus point 995 into R C, which is 5 Kilo ohms, divided by 26. It is about 200. How much is it? Please calculate. This is about 200. 191. That is the voltage gain. So, we have worked out all the performance factors of the amplifier.

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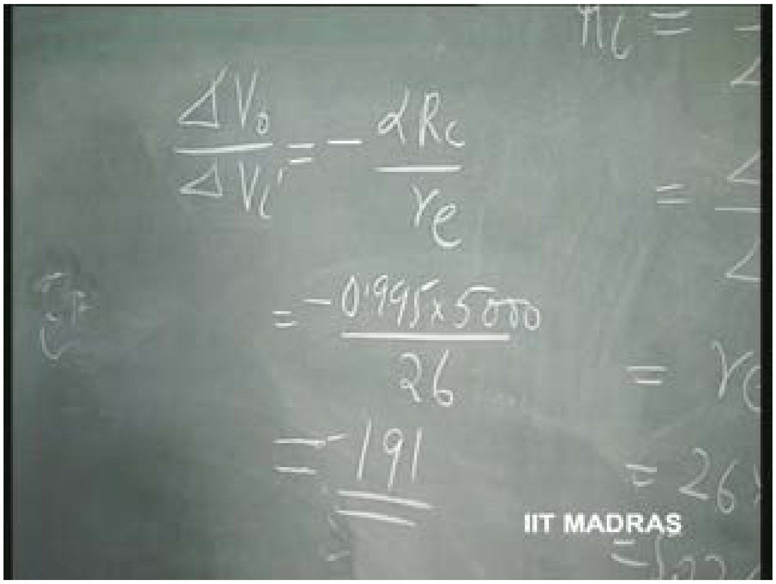

Now, let me just tell you something more about this amplifier so that it is clear. When the signal is fed, this is going to be the signal, let us say, Delta V S. So, the potential here is going to be changing by Delta V S, above the ground. Further, there will be, through this, I B Q flowing, and then there will be Delta I S flowing. I B Q plus Delta I S flowing. So, I B Q is the quiescent current. Here we have I C Q flowing. So, this is 10 minus I C Q into this thing. This is very nearly equal to 5 volts, V C Q.

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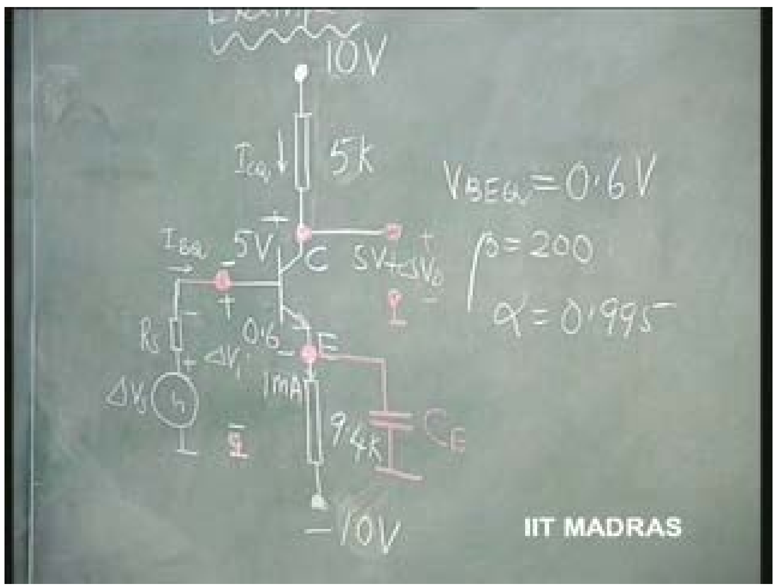

So around 5 volts, you will have this plus Delta V naught. So, this 5 volts is the quiescent output voltage. Around this 5 volts, Delta V naught is going to be available. If this voltage increases by some amount, this voltage will decrease.

Let us assume that this is a sine wave. So, this point is very nearly at about 1 to 2 millivolts quiescent; that we have found out, for R S of the order of Kilo ohms. So, it is very nearly at ground potential; and then it is going to change in this pattern.

What is this? This is the Delta V i? So, this is Delta V i. So, Delta V naught is going to be about 191 times Delta V i, but with a negative sign.

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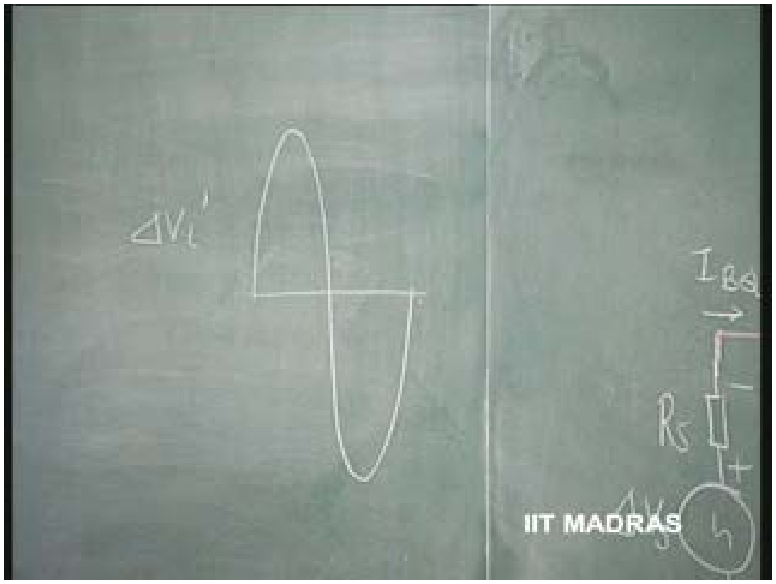

What it means is, it is going to be amplifying it; but it will be negative. That means, it will be decreasing and it will be 109 times amplified. This is not to scale. This is just to indicate that this is how it is going to look like. This is the quiescent situation zero and if you plot this also around zero, the output, this is how the output will look like. But, this output will be on a pedestal of 5 volts.

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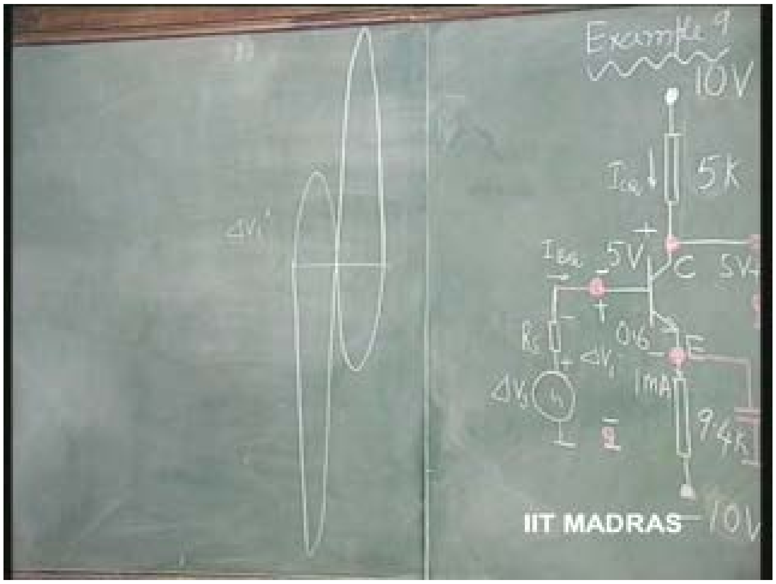

Suppose therefore, Delta V i is of the order of, let us say, 10 millivolts, peak. So, this is 10 millivolts. Then, this will be 10 into 191. That means, this will be 1 point 91 volts; around 5 volts. So, the quiescent state of this output will be around 5 volts and it will be decreasing like this, and going like this. And 1 point 91; that means 5 minus 1 point 91 is this point and this point is going to be 5 plus 1 point 91 volts. That means, this will be 6 point 91 and this will be 904, 4 point... is it correct? – 3 point 09 volts.

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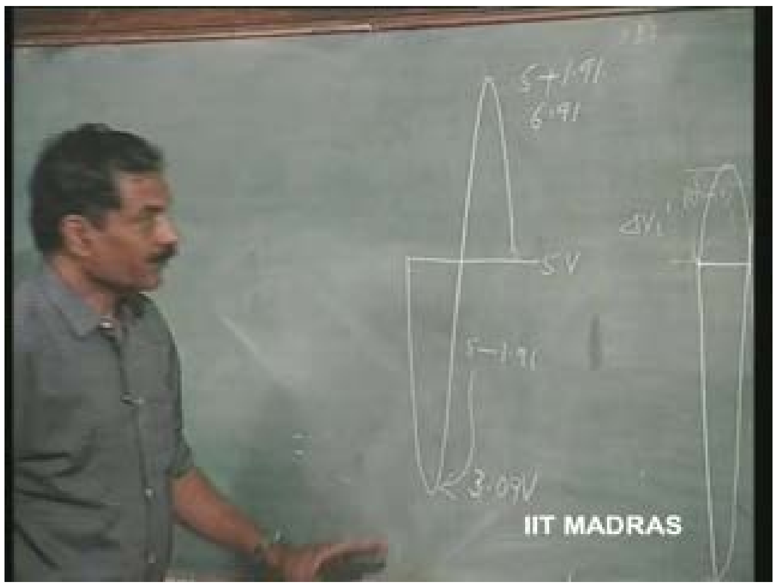

So, that means, output will change now in the same manner as the input, as long as the input is a small signal; and it will be proportional to the input. But, there will be a phase shift. So, if the input is sinusoidal, output will be also the same sinusoidal with a phase inversion, but it is going to vary from this value to this value.

When this is happening, this voltage here is going to decrease. Up to what value can it go on? It can go on until this voltage becomes equal to zero. This, I have told you. V C B equal to zero. It is entering the saturation. That means, this signal, if you keep on increasing, this signal will keep on increasing; and this point will be coming towards a point where this voltage is nearing zero. This is already close to zero. Then, V C B is going to be zero. Then, the transistor enters saturation.

On the other side, what is happening? This is going on increasing. Up to what point can it go? Why is it increasing? Because, the instantaneous value of the current here is decreasing. Why was it decreasing? Because, the instantaneous value of current was increasing. This I C Q was becoming equal to plus Delta I C and this Delta I C was increasing so much that this was going to saturation.

When this is decreasing, this Delta I C can become at most equal to minus I C Q so that this current is zero. Then, the transistor is off. Instantaneous value of collector current is zero. So, the voltage will be 10 volts. So, this will go up to 10 volts. This has now gone to 6 point 1. This can go up to 10 volts. At that point, the transistor is cut off because I C is zero. So, there are two points. I C, instantaneous value of I C becomes equal to zero. That is called what? – Cut off. Transistor is cut off; and here what? – this will go to a saturation. What is saturation? Instantaneous value of V C B is equal to zero.

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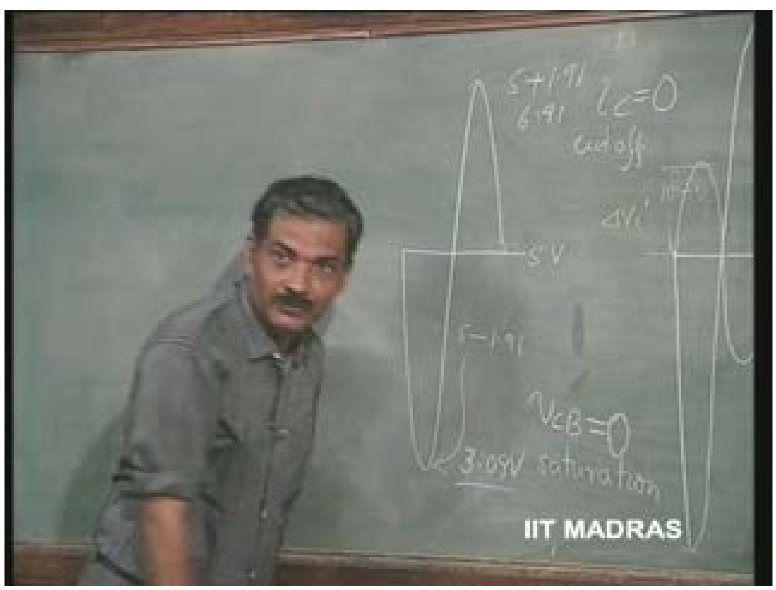

So, please remember this. Our amplifier is able to follow the signal, increase or decrease, only up to these two points; where instantaneous value of collector current is zero; that is called cut off; and where instantaneous value of collector base voltage is zero, which is called saturation.

Now, the question that I am asking is what value of signal output will this go to saturation? It is very easy; because we have selected V C B Q as 5 volts, the maximum it can have is 5 volts. That means this swing here on this side can go as much as 5 volts. So, important thing – if you want a swing of 5 volts, select V C B Q of minimum equal to 5 volts. Then, the swing also is governed on the other side by I C Q. So, if I C Q is chosen as 1 milliampere, then, for it to become, instantaneous value to become zero, Delta I C should become 1 milliampere. That means the swing on the other side is 1 milliampere; that is, I C Q times R C, which is in this case 5 volts.

So, in this design, I have chosen purposely a symmetrical swing. That is, when it goes to saturation, it is also going to what? – cut off. So, the operating point has been intelligently chosen here so that it is having symmetric swing of 5 volts, both on the positive side as well as the negative side.

This will be distorted because the relationship between input current and output current is linear; but input current and input voltage is exponential. So, this waveform will not look like a sine wave at all, when you have this much swing. But, it can swing by that amount for a specific swing at the input. If we can swing the input correspondingly, then you can go to saturation and cut off here. The waveform will not look like sine wave any longer, because of the non-linearity of the amplifier.

So, you can therefore always locate the operating point in such a way that this symmetric swing limits get reached, if you are amplifying sinusoidal signals. If you are amplifying some other type of signal, then, depending upon the positive and negative going signal, you can accordingly select the operating point, so that, it is all the time in the safe range of operation.