Analog Electronic Circuits
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Lecture - 24
Common Emitter Amplifier (Part A)

Dear students, welcome back to our NPTEL course on Analog Electronic Circuits.

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Myself Doctor Pradip Mandal from E and EC Department of IIT Kharagpur. So, today's topic of our discussion it is Common Emitter Amplifier. So, this is a basic amplifier and many of the concepts need to be getting cleared in this amplifier. Some of the prerequisites we already have covered, which are necessary to understand and appreciate the operation of the common emitter amplifier. So, according to our overall plan let us see how we are into the overall plan.

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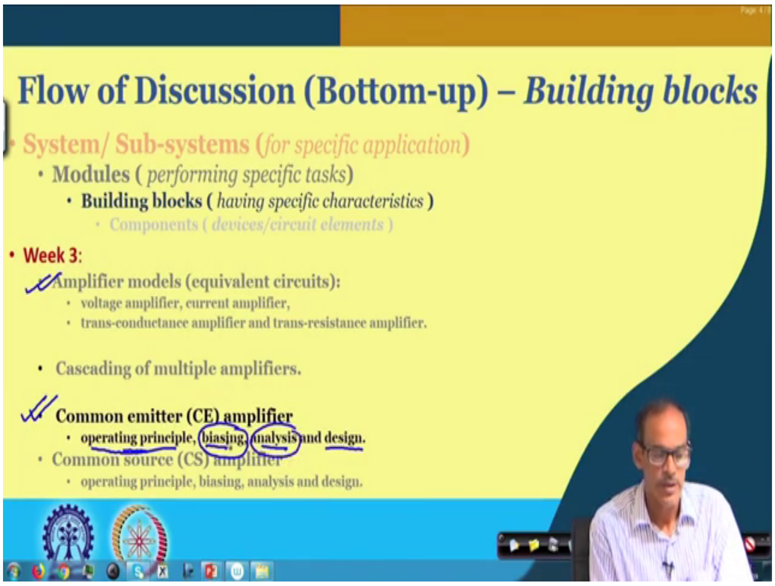

So, in the overall flow, we are in week 3 and in the previous day we have discussed about the amplifier models, voltage current amplifier trans-conductance, trans impedance and so and so. And, then we also have a plan to cover cascading multiple amplifiers, but we will be covering after we consider some of the practical circuits like common emitter amplifier and common source amplifier.

So, today's main discussion here it is the common emitter amplifier and it is a working principle, biasing scheme, then analysis, may be some part in case if time permits we can cover some design also today or maybe next day. But, I must say that so far whatever the topics we have covered namely the device model and then methodology of analyzing non-linear circuit, then the notion of small signal and large signal model of the BJT and maybe MOS, those concepts it will be frequently used.

In fact, while we have explained about this small signal model of BJT or MOS. We have discussed some extent about the operating principle of the CE amplifier. So, we may not be going detail of or rather we will not be repeating, whatever we have discussed in the circuit operation, rather our primary focus it will be on biasing and then the corresponding analysis.

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So, what are the concepts we are going to cover today? It is the we will start with the operating principle of CE amplifier, but again as I said that we will not be going very deep into that. And, then main thing is that the biasing of CE amplifier.

In this course primarily we will be covering 2 types of biasing of BJT amplifier; one is fixed bias and, then subsequently you will see that, what may be a better option. And, then in the fixed bias CE amplifier we will see that, how we find the operating point and then how do we get the small signal model and small signal analysis.

And, then we will be covering the what are the issues are there particularly a very common issue it is called D c operating point is very sensitive to beat our transistor. So, as a result in case if you are replacing a transistor by another one having different beta then it is operating point completely gets shifted elsewhere, or in if the beta may not be changing due to replacing the device it may be due to temperature effect.

And, due to maybe higher temperature beta will increase and then that directly affects the operating point of the common emitter amplifier. So, that issue we will be discussing and then we will be giving a pointer what may be a better option or the solution of that problem ok.

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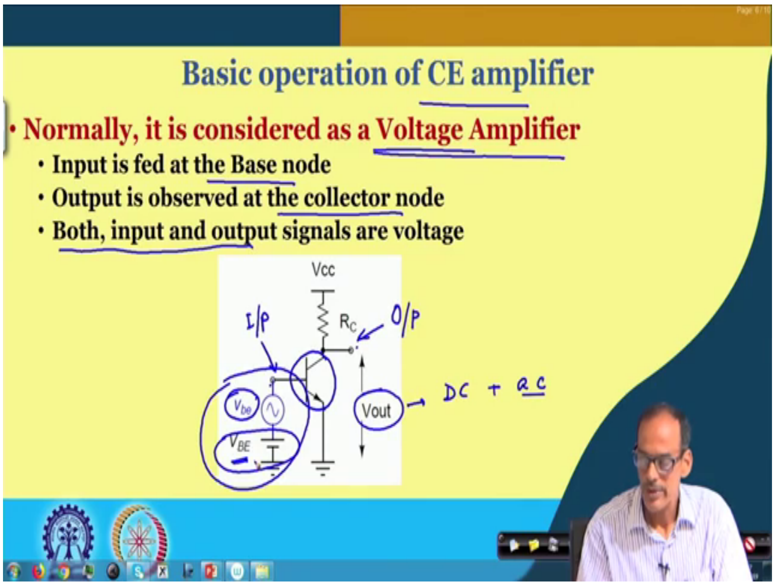

So, yeah so, what we have the CE amplifier again we will be just touching the basic operation, but before that I must say that, whenever we call the common emitter amplifier. the input it is fed at the base of the BJT and then output it is observed at the collector node. So, you can see that the input we are feeding here and then output we are observing at the collector node.

And, whenever you are considering signal at the input and output terminals normally, the signals we are considering in the form of voltage. It is possible to consider input signal in the form of current as well, so likewise output also can be considered as current ah. So, this same CE amplifier it may be considered as the current amplifier or trans conductance amplifier or trans impedance amplifier, depending on our specific interest, but predominantly unless otherwise it is stated this CE amplifier it is considered as voltage amplifier.

So, what does it mean is that as I said that both input and output signals are voltage. So, whatever the analysis will be doing now is basically from considering that the signal will be will be feeding in the form of voltage. Namely, the signal source resistance thevenin equivalent resistance we want it should be as small as possible, and while we will be observing the output we may not be loading the circuit by any you know load at the output and namely parallel resistance at the output. So, that it need to be taken care.

And, now let us see how we proceed at the input you can see that the while we are feeding the signal, it is also accompanying a DC voltage. And, while you are observing the output this output may be having a DC part as well as the AC part.

So, probably the AC part we can extract we can block the DC by a capacitor or the output, but typically getting a signal source having a appropriate or having a meaningful DC voltage is most of the time it is not possible and feasible. So, whatever the input port we are considering here namely the signal small signal source in series with DC voltage and that DC voltage should be appropriate for the BJT, may not be you know you should not be expecting.

So, it is of course, it is having some practical circuit. So, we will be covering we will be discussing about the practical circuit. And, also the voltage amplifier parameters and any voltage gain and input resistance, those parameters values are very strong function of the bias condition or the operating point of the transistors. So, designing one amplifier it is very important to consider the biasing concepts, how we get the operating point.

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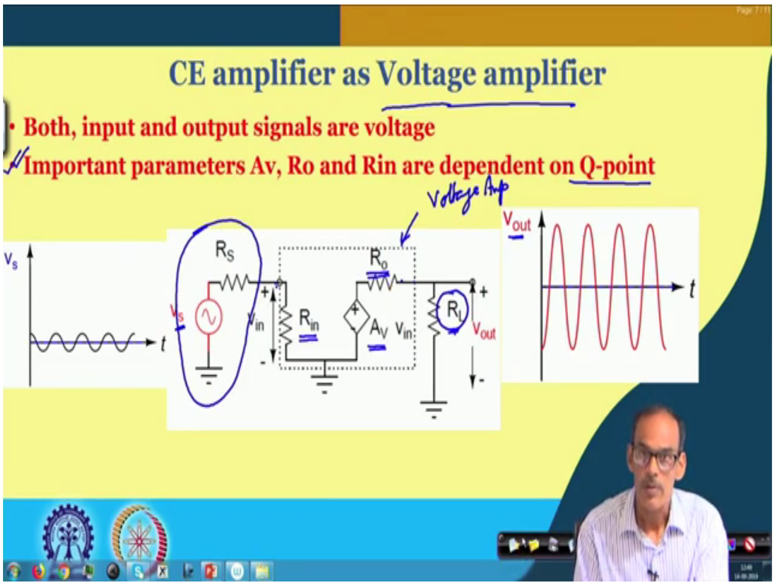

So, let us go little detail of that so, in the next slide we will be discussing that, but here as I say that since you are looking for the circuit as a as a voltage amplifier. Typically, this is a small signal model of the voltage amplifier right.

And, as we can see that this is the boundary of the amplifier. it consists of open output voltage gain A v. Then also it is having output resistance R o and then the input resistance of the amplifier, which we have discussed about the these three parameters and significance of these three parameters in voltage amplifier model. And, these three parameters of course, they are very strong function of the operating point right.

So, this is one important point that while we like to get a voltage amplifier having a good steady gain, we need to keep the DC operating point appropriate. In addition to that, since we are feeding the signal here, signal it is voltage. So, at the input the signal it will be voltage form, which may be having the main equivalent resistance called R s.

So, likewise at the output while we will be observing the corresponding output, we need to consider only the signal part. And, when you consider signal it is expected that in case if we are connecting in any load, the this load should not be directly affecting the operating point of the circuit.

Otherwise, this load may change the operating point and then indirectly they may change these signal parameter yeah. So, we need to be careful while we are fixing the operating point of the circuit or the biasing of the circuit need to be properly taken care.

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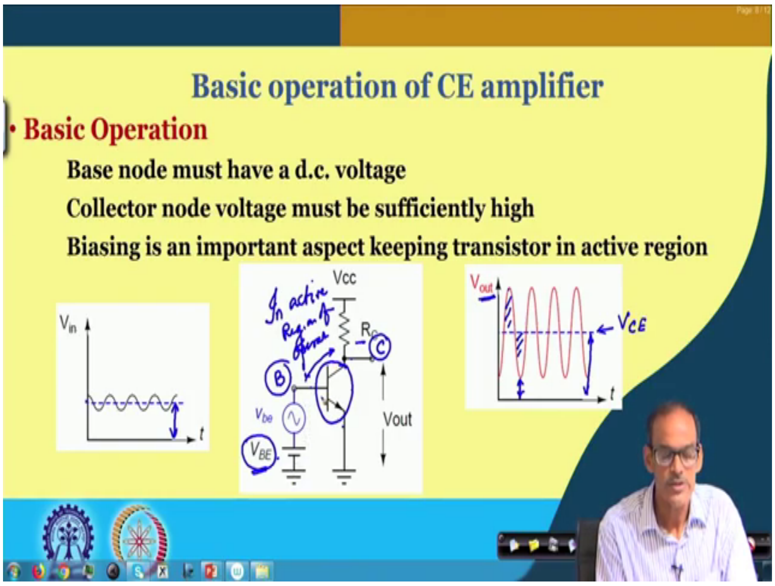

So, what we are considering now practical circuit biasing circuit. So, what we have it is the requirement wise as I said that the input, we do have signal which is riding over a DC voltage. In this case we are calling this is V be. So, likewise at the output we do have a DC voltage, so we need to remove those things.

So, just now what I was telling that the to have meaningful operation of the amplifier, we need to keep this transistor in active region of operation right; so active region of operation. So, for that we require a meaningful DC voltage that supposed to bias the base to emitter junction in forward bias condition.

And, likewise at the output it should be having sufficient DC voltage, so that while at the output we do have a signal and the instantaneous output voltage should be sufficiently high even in this critical case, when the signal it is going to the minima.. Even then this junction base to collector junction should remain reverse bias condition. Otherwise, there will be huge distortion at the output.

So, it is very important that the operating point should remain constant. So, that the gain should be remaining constant and the second thing is that the DC voltage here should be appropriate. So, that the base emitter junction is getting forward biased. And, whatever the bias you do have here for that the DC current, which is DC current collector current flowing through the transistor, which is incidentally flowing through this R C, then whatever the voltage we are getting here namely V capital C, that should be so, this is the V capital C E that voltage should be sufficiently high.

So, that while the signal it is riding over that the instantaneous voltage, even in this critical condition the transistor remains in active region of operation. So, on the what may be the practical circuit let us look into that. So, as I said that biasing is very important.

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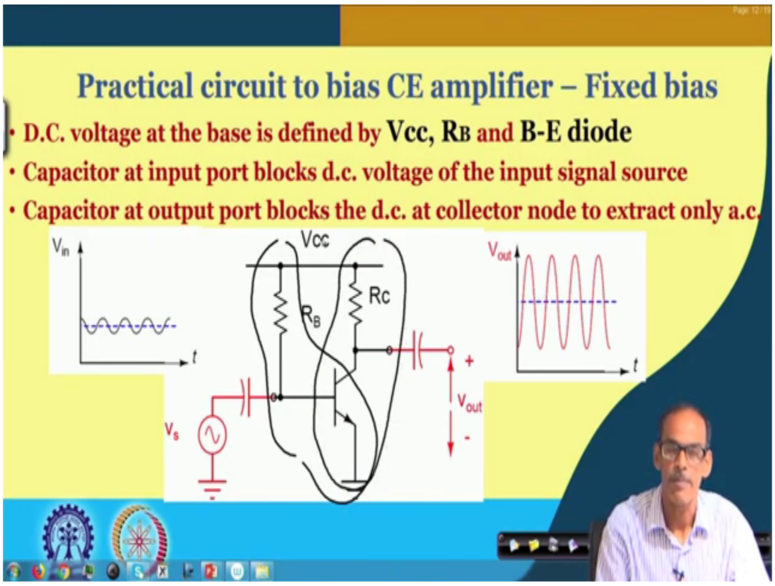

So, let us look into the input port, so what you are talking about the ah whatever the equivalent circuit we can see here. And, then after that we will see the output port circuit here.

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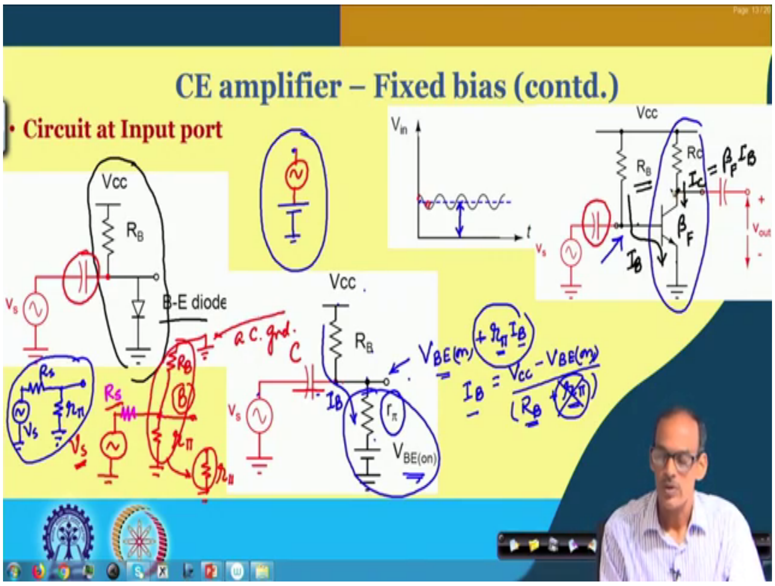

So, the input port if I consider, here you can see at the input port we do have we do have this R B, which is connected to base terminal of the transistor, and base to emitter terminal we do have a diode forward bias diode. So, equivalently I can say that we do have R B in series with diode. Of course, this diode it will be slightly different kind of normal diode, namely this junction though it is forward biased, but most of the collector currents are coming from the emitter junction. So, as a result the level of current flow here it will be less.

However, if I consider the current and voltage characteristic of this diode ah; obviously, it will be having the exponential relationship. So, for this analysis definitely we can consider this is similar to a normal diode. Now, this diode can be replaced by it is equivalent circuit, which is shown here, which is having a DC voltage in series with on resistance of the diode.

The on resistance of the diode here we are representing by r pi it is primarily coming from the pi model of the BJT, but for the time being you can consider it is on resistance of a diode and this resistance it is very similar.

Now, once you have say supply voltage and this circuit connected the DC voltage coming here, it is I can say that V BE. So, we can say this DC voltage it is V BE on plus r pi multiplied by this current, whatever the current we do have here call say I B, I capital B. And, this I B on the other hand it can be obtained by considering this loop. So, that is V cc minus V BE on divided by R B plus r pi.

Practically this resistance it is very high in the range of few 100s of kilo ohms to maybe mega ohm. And, r pi on the other hand it is very small; it is value it will be in the range of few kilo ohms only. So, since this is 100s of kilo ohms and this is kilo ohm so, you may ignore this part then from that you can consider the I B and from that you can find what will be the DC voltage coming. And, that DC voltage it is this DC voltage.

Note that this base current as well as this r pi, typically it is very small. So, this part it may be very small compared to V BE on. So, we can say that this DC voltage it is very close to V BE on, but slightly higher. So, once we have the DC voltage obtain there next thing is that the capacitor ah it is helping for the signal to feed in.

So, we do have this coupling capacitor, signal coupling capacitor, which is coming from in the original circuit there. And so, this signal; signal frequency we assume that it is sufficiently high compared to the cut-off frequency defined by this C and the equivalent resistance coming there, or you may say that the value of this capacitor it is sufficiently large, so that the signal it is directly coming to this point.

So, at this point if you observe the voltage, instantaneous voltage it is having a DC on top of that it is having the small signal. So, it is equivalently it is making a small signal riding over the DC voltage; So, it is riding over the DC voltage.

So, earlier we are having this simple stimulus at the base ah, but of course, it is an ideal ah model. Practically, this is how it is obtained by combination of this R B and C, we are getting a voltage here which is having a meaningful DC and on top of that we are successfully feeding the small signal ok.

So, we will be seeing that what may be the equivalent circuit of this one later where small signal equivalent circuit, where we may short this capacitor and then this DC voltage you can consider it is the AC ground, and then this DC voltage you can drop. So, for AC signal will be practically will be having this R B and this r pi and then this signal it is also coming.

Since, we are not considering any Thevenin equivalent resistance here this resistance it is 0. So, as a result this voltage it will be for AC signal it will be directly VC. So, just now what I said is that for this is the total signal total circuit and for small signal on the other hand at the base, we do have only the v s coming there and then this is the base node. And, at the base node we will be having this corresponding r pi which is connected to ground.

And, then of course, we do have the R B; R B also there, but since this R B as I said it is very high, we may ignore. And, then we do have the DC voltage here which is of course, the ac ground. And, so, that is what the voltage it is coming to the base terminal.

In case if we have a; so, the signal here it will be across this r pi it will be same as v s, but in case if I consider a practical source resistance say R s, then of course, the voltage here it will be slightly different. So, in that case these two resistances we can map into equivalent input resistance together and these two together practically it is coming r pi only and then this r pi. So, this r pi it is and then R s they will define what is the voltage coming here from the signal source.

So, to further conclude what will be having at the base, we do have for small signal at the base will be having the vs having a source resistance R s. And, then the base to ground node resistance, this resistance it is it is parallel connection of R B and r pi, but we can say this is r pi. So, this model will be using whenever we will be talking about the small signal analysis. So, at the base that is the equivalent circuit we do have at this point.

Now, let us look into the output port of the circuit, let draw the corresponding the equivalent circuit. To start with we will be going for the large signal first and when you consider large signal this I B whatever the I B it will be flowing here, after multiplying with beta F we do have I C here. So, this I C it is coming from this I B after multiplying with beta F.

So, we have to be we are assuming that this circuit once it is decided. Next thing is that so, which means that the I C it is also getting decided, then we can see what is the corresponding voltage coming here. So, let us look into the output port in the next slide.

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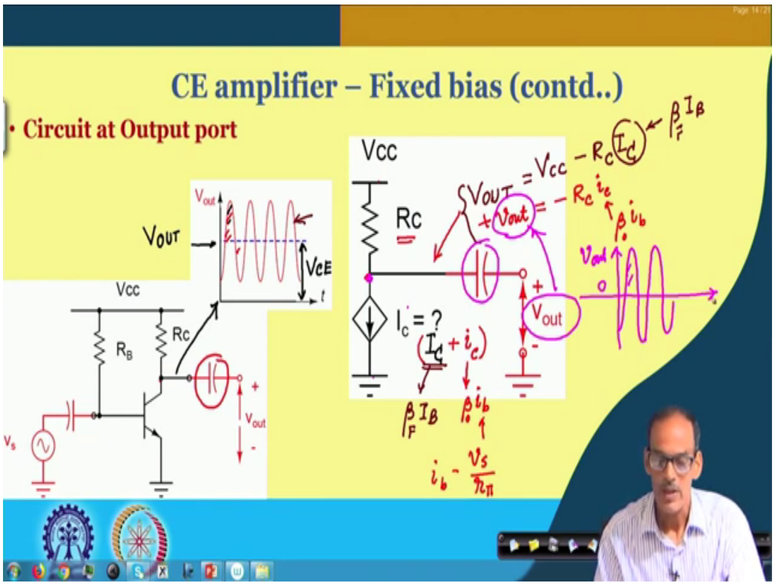

So, at the output port what we are expecting that voltage here it will be like this it is shown here, it is having a DC voltage called say V capital C E incidentally, this is CE or you may call this is V capital out. So, this level we can say capital V capital out on top of that we do have the small signal. So, we do have the small signal here.

So, now this small signal of course, we can extract by as I said by placing this capacitor. So, we will see that part, but initially the DC part, what we have it is we do have R c connected to V cc and then we do have the collector to emitter voltage. So, we do have the sorry collector to emitter current I c. So, this I c it may be having both DC part. So, this I c may be having 2 currents; one is DC part I capital C. And, then also the small signal part, small I c right.

Then this I c capital I c as I said that it is beta times I B whereas, the small signal part here whatever the small signal we are seeing here, this is also beta multiplied by i b. So, this beta it is slightly different from beta F it is called large signal beta in forward direction, this is called a small signal current gain beta, but practically we may consider both are equivalent, but you need to be careful there they are not exactly same. On the other hand the small signal current here it is this beta multiplied by ib and this ib it is essentially it is coming from the v s divided by r pi.

So, we will see this it is shown, but just to see that the current flow here it is having DC component and the small signal component, then we do have if I consider the voltage at this point. So, voltage at this point we do have DC part, it is generated by this DC current R c and V cc. So, we do have this V OUT, just now what we said is V OUT, which is V cc minus R c multiplied by I capital C, which is of course, beta into I capital B. In addition to that we also have ah small signal part so, we may call small v out.

So, what is that it is for that small signal this is ground and so, we can say this is ground and the i c current is flowing here. So, we may say that this is minus R c multiplied by i c and this i c as I said that this is beta times i b and on the other hand this part it is beta F times I B ok.

So, now we do have both the DC part and the AC part together that gives us this signal, so, instantaneous signal. Now, by placing the capacitor here, by placing this capacitor here we are removing this DC part and at the output what we see it is only this part.

So, if you are observing the signal here what we will see that it is a small signal with respect to ground; so, with respect to ground. And, we call this is small v small out right. Now, if I combine this information together we can get the small signal equivalent circuit.

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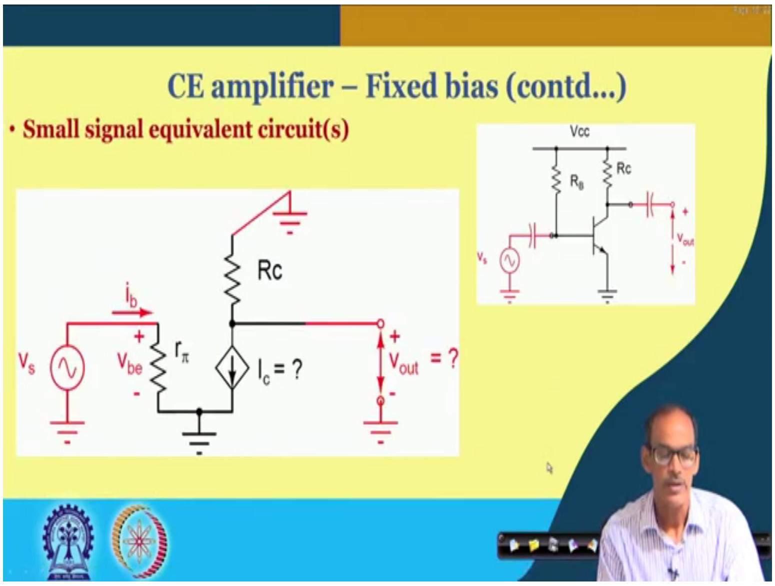

So, in the next slide we can look into the corresponding small signal side equivalent circuit. But let me take a break and then we will be discussing in detail on this one.