Basic Electronics
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Module: 2 Bipolar Junction Transistors
Lecture-8
Frequency Response of BJT Analysis - Part-1

Today we will discuss how the frequency of the applied signal has an effect on the voltage gain of a BJT amplifier. In the last classes we were discussing about the analysis of a BJT amplifier but we were considering that all the capacitances in the amplifier circuit were short circuited. But then this condition is only true for the signal having frequency not very low or not very high; that is in the mid frequency range. But if the frequency of the applied signal is low or high then the voltage gain of the amplifier will not be the same as we discussed earlier because then the analysis has to be done taking into consideration the capacitances which are present in the amplifier circuit. If we recall what we were discussing earlier, the amplifier circuit having capacitances which are coupling capacitors, these capacitors under DC they are open circuit and under signal being applied or under AC condition these were assumed to have a short circuit condition. Because in the frequency at which the signal was applied, at that frequency the capacitive reactance offered by these coupling capacitors were small enough since we have selected high value of the capacitances so that effectively we can very well assume that the capacitive reactance is very, very small and this is like a short circuit part. We revisit the amplifier circuit again and we will consider only the common emitter amplifier circuit.

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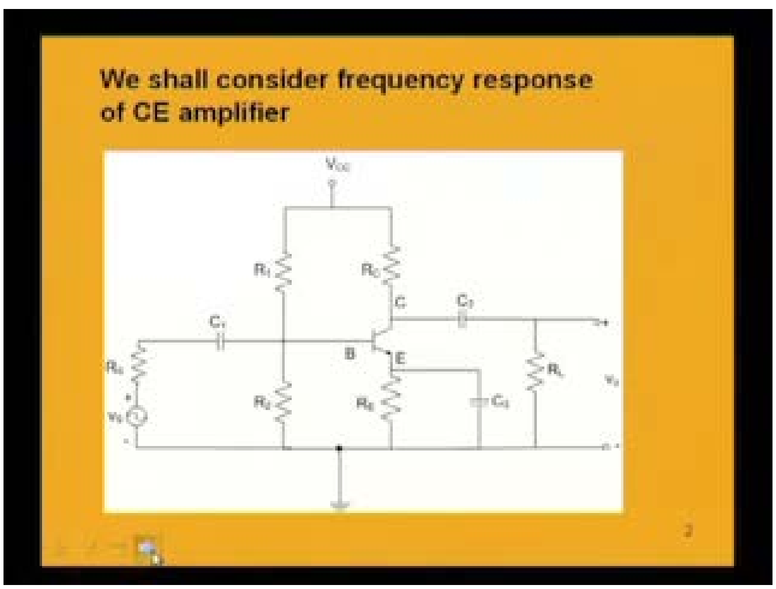

Here in the common emitter amplifier circuit, if we look back, the circuit was having the coupling capacitor C_1, C_2 and there is an emitter bypass capacitor which is C_3. When the small signal equivalent circuit is drawn considering these capacitors also then we will get a circuit where C_1, C_2 and C_E, C_E being the bypass capacitor, are there. But apart from these three capacitors we also have 2 other capacitances which are C_{be} between base and emitter and C_{bc} between base and collector. These two capacitances are coming from the transistor model because when we were discussing the diodes if we remember, the diodes are having a diffusion capacitance in the forward biased condition and a transition capacitance which is prevalent in the reverse biased condition. If we look into the transistor, the transistor is having a forward biased diode and the reverse biased diode, the forward biased diode being between the base and emitter junction and the reverse biased junction is between the collector and base junction.

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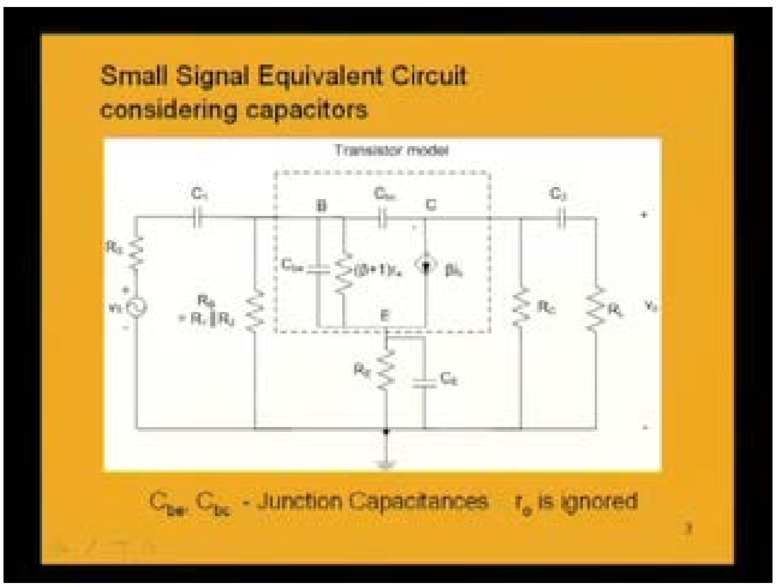

These capacitances will have to be taken into consideration. That is why the transistor model will be having C_{be} that is the diffusion capacitance in the forward biased condition of the diode, which is the emitter base junction and C_{bc} is the junction capacitance which is in the reverse bias diode between collector and base. Taking this into account and considering all these capacitances which are present in the amplifier circuit, the coupling capacitor as well as the emitter by pass capacitor, the whole amplifier circuit will be like this. Here all the others are simply what we considered earlier and the extra are only these capacitances. In this circuit we are having the capacitances. We cannot neglect this capacitances or the effect of this capacitances when the frequency of the applied signal that is V_S is not in the mid frequency range; it is either too small or too high.

What will happen if the signal frequency is in the mid frequency range? What we discussed earlier let us again go into that discussion. We know that typical values of these capacitances are generally C_1 and C_2, the coupling capacitances are a few microfarads and the bypass capacitor which bypasses the emitter resistance r_e is in tens of microfarads, a bit higher than C_1 and C_2 but it is in the microfarad range.

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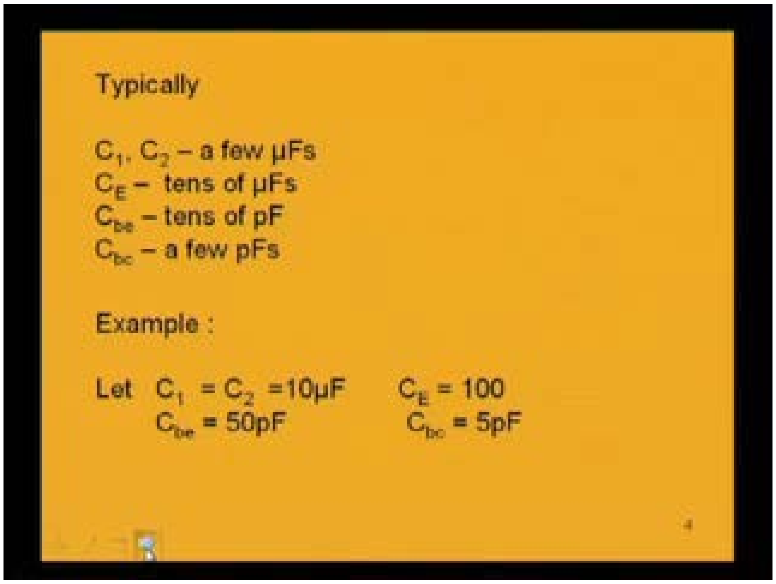

The transistor capacitances C_{be} and C_{bc} these two are in the order of Pico farads. C_{be} is typically tens of Pico farads and C_{bc} is typically a few Pico farads. With this concrete example now let us see the effect of frequency of the applied signal on these values of reactances offered by these capacitances. For example we will take values of C_1 and C_2 to be say 10 microfarad, C_E is 100 microfarad and C_{be} is in the Pico farad range, let us take 50 Pico farad and C_{bc} is 5 Pico farad. With these typical values let us find out what will be the reactances offered by these capacitance when the signal frequency is say 1 kilo hertz that is the mid frequency range; it is neither too small nor too high frequency. 1 kilo hertz is the frequency of the signal which is applied at the input. V_S is having a frequency of 1 kilo hertz. At 1 kilo hertz value of frequency what will be the capacitances offered by each of this? Let us calculate what will be the capacitive reactances offered by each of this capacitance?

Coupling capacitors are offering a capacitive reactance X_{C1} and X_{C2} which are equal because we are taking equal values of C_1 and C_2 which is 10 microfarad. We know that 1 by 2 pi fc is the value of reactance offered by a capacitance. Omega is 2 pi f; 1 by omega C. We are considering the magnitude. Let us not think about the 'j' part. Actually it is having two components. One is the real and other one is imaginary but let us take the value of 1 by 2 pi fc. Plugging in the values of this C_1 and C_2 in this expression, C_1 and C_2 value is 10 microfarad. 1 by 2 pi, f is 1 kilo hertz, so 10 to the power 3. We are bringing in hertz order and 10 into 10 to the power -6 because it is microfarad. We calculate this value and it comes to around 15.9 ohm. This value is quite small value of reactance.

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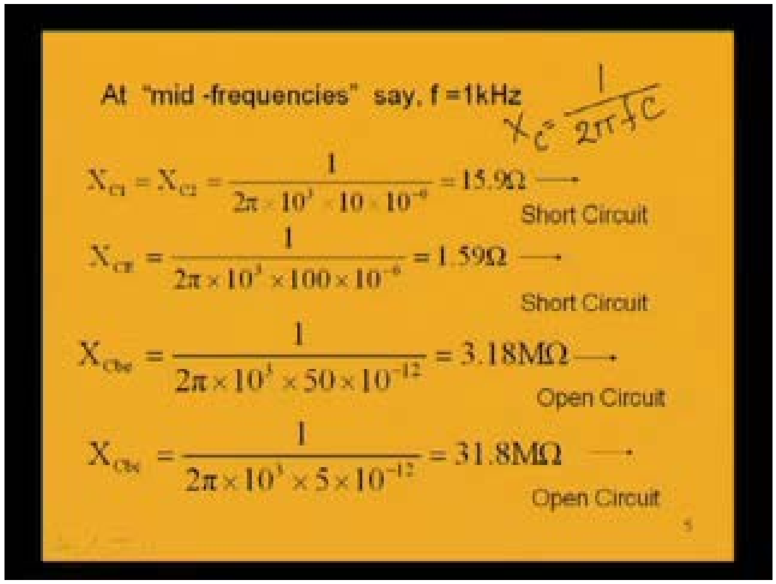

Similarly we calculate this capacitive reactance offered by the emitter bypass capacitor X_{CE}. Calculating 1 by 2 pi into 10 to the power 3 into, it is 100 microfarad; so it is 1.59 ohm. If we look into these values it is almost like short circuiting the part since these are very small. These values being very small we were very legitimate in assuming that the capacitances were like short circuiting when we were considering the amplifier earlier. We were earlier considering that capacitances C_1, C_2 and C_E are such that they are quite large. In the frequency at which we are considering we can very conveniently assume them to short circuit the part and that was what we were doing earlier and now we are clear that our assumption was not wrong because these values are quite small. We can very conveniently assume them to be short circuiting.

What about the transistor capacitances which are present? Let us calculate the reactances they offer. 1 by 2 pi into f 10 to the power 3 hertz and the value of this diffusion capacitance is 50 Pico farads. Pico farad means 10 to the power -12 farad. It is even smaller value in the denominator, so at this frequency of operation the overall value of this capacitive reactance becomes 3.18 mega ohm. Similarly the capacitance in the collector base junction of the transistor which is X_{Cbc}, is equal to 1 by 2 pi into 10 to the power 3, 5 Pico farads is the value we are taking which is the typical value. That comes to 31.8 mega ohm. If we look into these two values of X_{Cbe} and X_{Cbc} that is the reactances offered by the capacitances present in the transistor model, these are very, very large values and they are in the order of mega ohms. Effectively these are like open circuit. If we look back into the circuit these capacitances are offering such a higher value of reactance that they are almost like open circuit. Since the value of this capacitive reactances are very high, they will practically allow no current to flow through them as if they are just like open circuit. That is why these capacitances were nowhere in picture earlier when we were considering the transistor amplifier in the mid frequency range. We were having a very simplified circuit without these capacitances.

Now we consider the frequency of the applied signal not at mid frequencies or 1 kilo hertz range but at lower frequency. When the frequency is low what will happen to X_{C1} and X_{C2}? 1 by 2 pi fc, this frequency is smaller value. If this frequency is small then the value of X_{C1} and X_{C2} will be higher than the earlier mid frequency range. If we consider low frequency signal then the capacitive reactances being offered are significantly high. Similarly the X_{CE} also will be significantly higher now because this frequency is small. So these values will be high. X_{C1}, X_{C2} and X_{CE} values will be higher now. If these values are higher what will happen to the signal in the circuit? Because we are now having a considerable reactance in this capacitance as well as this capacitance and this capacitance, all three will be offering significant reactance. There will be a higher drop in the capacitances. The signal which is applied here will be having a drop here. Similarly the signal which is available here will be having a drop here. The output signal will be having a lesser value because of these drops occurring at these capacitances.

Similarly the capacitance in the bypassing part of this emitter resistance R_E, as this capacitance is no longer short circuit, it will not be effectively short circuiting. It will be lesser effective in providing the short circuit part. That is why we will have a current flow in this resistance R_E also, as a result of which the overall voltage gain of this amplifier will be reduced. The voltage gain of an amplifier is equal to beta times R_C parallel R_L divided by beta plus 1 r_e when this capacitance is short circuiting. But when this capacitance is not short circuiting then this resistance and this resistance will be coming together in series. In the denominator of this voltage gain expression we have this voltage gain minus beta R_C parallel R_L divided by beta plus 1, it will be small r_e plus capital R_E because this R_E is coming in the denominator.

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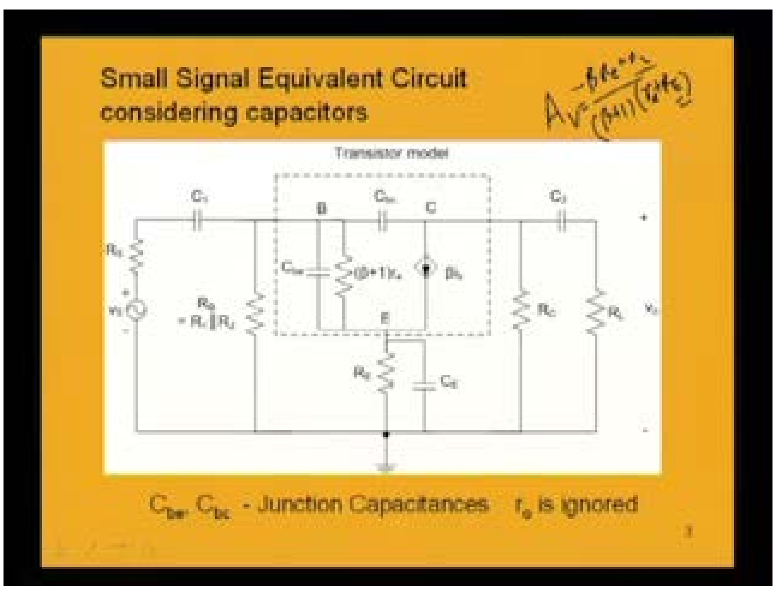

If denominator is higher overall voltage gain will be lesser. Due to these two factors one being that there will be voltage drop here in these two capacitances, your overall voltage gain which is the ratio between output voltage and input voltage or if we consider the overall voltage gain with respect to the signal AV_S it is V_O by V_S. This V_O without this capacitance will be higher than V_O with capacitance. If there is a capacitance there will be voltage drop here. So the output voltage that we will get is less. We will have a lesser voltage gain. So voltage gain reduces when the signal frequency is low.

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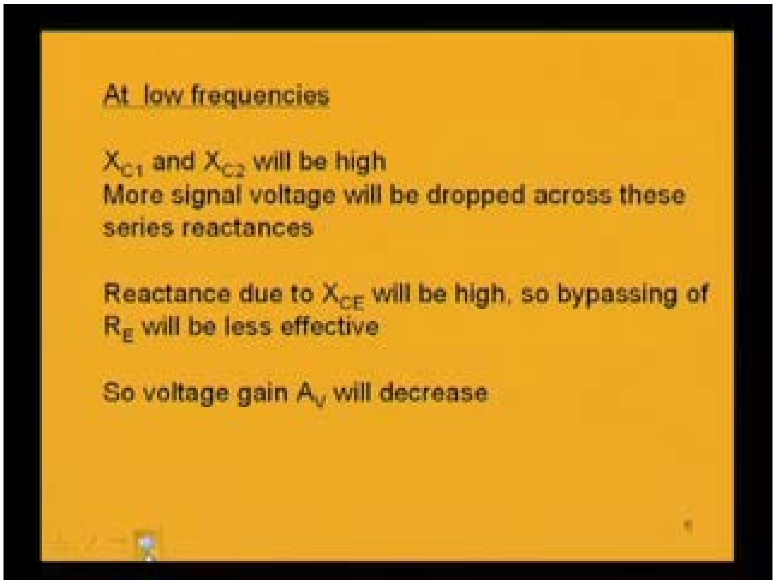

The other capacitances which are present in the transistor, because of this diffusion and transition capacitances this cannot affect because the overall capacitance or the capacitive reactance offered by these capacitances is 1 by 2 pi fc. Frequency is smaller, so the reactance will be even higher. It will be even higher than the mid frequency range. If this capacitive reactance is even higher, they are more and more like open circuit and they will not come into the picture because the current cannot flow through these two capacitances. In the low frequencies the parameters which are going to affect the voltage gain are the capacitances C_1, C_2 and C_E that is the coupling capacitors and the bypass capacitor.

Now let us consider a higher frequency region. At high frequencies what will happen is that the transistor capacitances C_{be} and C_{bc} will offer a lesser reactance. This frequency is higher means the capacitive reactance will now decrease.

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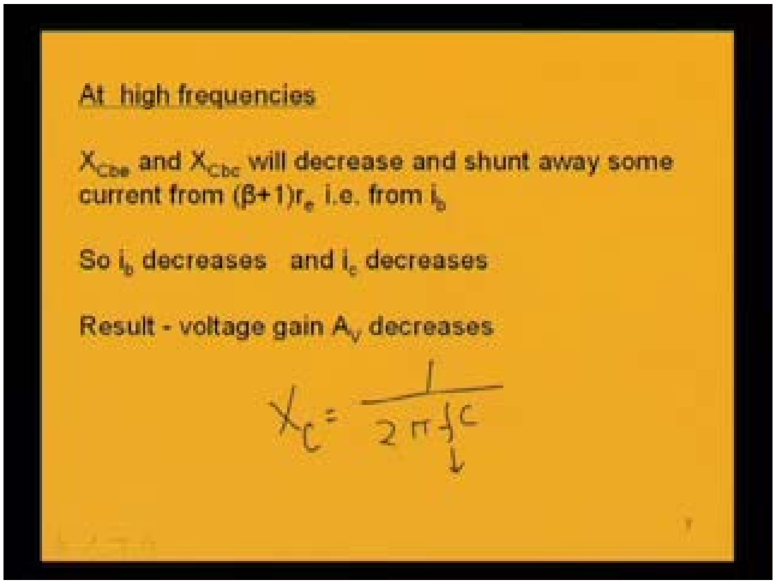

Earlier it was like open circuit, very high. Now it will decrease. When the capacitive reactance is decreasing it will allow more and more current to flow. A part of the current will now flow through the diffusion as well as the transition capacitances and the effect is that they will shunt away a part of the current i_b. If we look into the circuit again they are these two capacitances. The current coming into this point, the base point without these two capacitances, this current would have flown through these resistances beta plus $1r_e$. But now a part of the current is being shunted away by this C_{bc} and C_{be} because their capacitive reactances are now low. Earlier it was almost like open circuit, very high. The reactance was in the order of mega ohm. It was not possible for current to flow through them. But now a part of the base current will be shunted away by these two capacitances because they are offering lesser and lesser reactance as a result of which the base current what would have been there, had there not been these capacitances present is now less. Base current is less means collector current is also less, beta times i_b will be less.

If the collector current is less the voltage gain will be now lesser because the voltage gain will depend upon the output voltage by input voltage. Output voltage is the current through this resistance R_L multiplied by this resistance R_L and this current is coming from this current source which is the dependent current source beta times i_b. If i_b is less then this dependent current source is providing less current; this current will also be less, so overall voltage gain will be less. From this analysis we have seen that in both the cases when the frequency is low as well as high, the voltage gain of the amplifier is lowered. We cannot ignore the effect of frequency of the signal being applied at the input on the overall voltage gain of the amplifier.

Today we will discuss the frequency response of an amplifier. We will analyze how the gain is reduced with frequency being low or frequency being high and once again at high frequencies the coupling and bypass capacitors will not affect because if the frequency is higher then their values will be smaller and smaller. It will be more and more short circuiting type because of this fact that it is 1 by 2 pi fc. If f is high, the overall capacitance offered by this coupling as well as bypass capacitor will be lesser and lesser and that does not harm our voltage gain. If we consider low frequency the capacitances which will be responsible for the lowering of the voltage gain are C_1, C_2 and C_E and when we consider high frequency of the signal the capacitances which will be responsible for lowering of the overall voltage gain of the amplifier are the junction capacitances of the transistor C_{bc} and C_{be}. We can very conveniently divide our analysis into two parts one is when the frequency is low that is at low frequency and then at high frequency, we can consider the response of the amplifier separately. That's what we are going do now.

If we now plot the voltage gain of an amplifier verses frequency we get a curve like this. We focus on this curve in the mid frequency range that is the flat portion of the curve. We are plotting the gain verses frequency. Frequency is varied from zero onwards and in the y-axis we are plotting the voltage gain A_{VS}. A_{VS} customarily is that voltage gain with respect to the source. A_{VS} is V_O by V_S overall gain of the amplifier with respect to the signal being applied and within bracket 'f' is written because we are now considering the gain as a function of frequency. That is why the parameter or the arguement inside the bracket will be f. If gain is plotted verses frequency then during this portion, mid frequency the voltage gain is constant which is denoted by A_O. A_O is the mid frequency voltage gain that is the same voltage gain which we were discussing taking into account the capacitors C_1, C_2 and C_{be} short.

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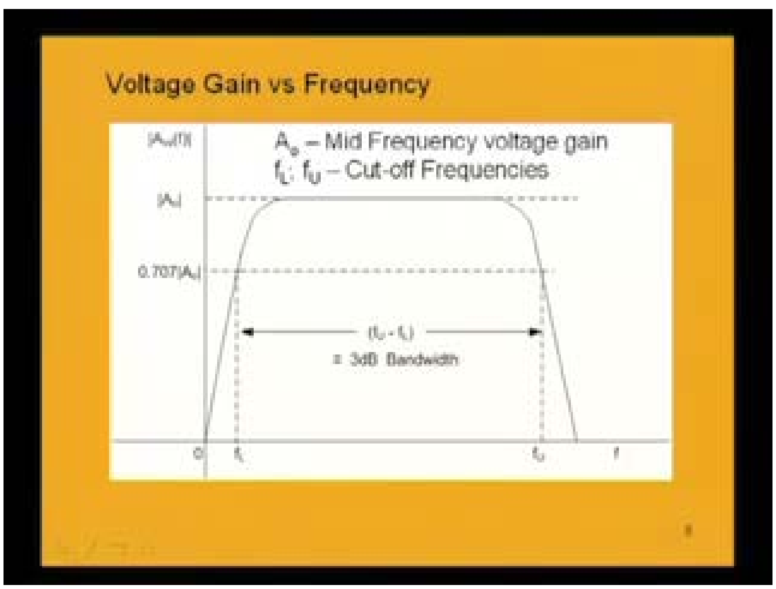

If the frequency is lowered we will get the voltage gain being drooping off. That it is going to be lesser and lesser as well as when frequency is higher then also the gain will be lowering from the value of A_O as seen here. The lowering of the gain occurs because of the reasons just now explained. One point to be noted in this graph is that we are marking two frequencies f_L and f_U; f_L and f_U are called cut off frequencies where the gain of the amplifier drops off to 1 by root 2 times the gain of the mid frequency region. 1 by root 2 means 0.707. The values of the frequencies at which the gain drops off to 0.707 times the constant gain A_O, which is obtained at mid frequency range, are called cut off frequencies. Basically one is lower cut off frequency one is upper cut off frequency. Lower cut off frequency is the cut off frequency in the low frequency region and upper cut off frequency is the cut off frequency in the higher frequency region. What is the significance of this 0.707 or 1 by root 2 times? It comes actually from practical considerations because generally we apply an amplifier for audio purposes.

If it is an audio amplifier practically what happen is that the gain of the audio amplifier even if it drops off up to 1 by root 2 times the gain then also our ears are not able to percept that change in the gain and we hear almost same gain or we hear the audio signal as having the same amplification. That is there is no distortion perceived by the ears. All ears are naturally immune to the audio signal gain mean dropped off to maximum of 0.707 times the peak value and from that considerations actually this 1 by root 2 times or 0.707 times that value has a particular significance. Even if that voltage gain drops up to that level still it is tolerable and that is why this distance between the upper cut off frequency and lower cut off frequency is called the bandwidth, 3 dB bandwidth. It has to be seen where the 3 dB bandwidth comes from? We are writing in decibel and this is the particular unit which is obtained from a ratio and taking its logarithm to the base 10 multiplied by 20. That is 20 log to the base 10 of the ratio between the gain and the gain at mid frequency. As shown here this 20 log 10 magnitude of $A_{VS}(f)$ to A_O value is in dB unit and this is customarily done to normalize this $A_{VS}(f)$ gain with respect to the value of gain A_O and then express this magnitude of frequency response in dB and that is done practically. In the books also we see that the plot is in dB that is in decibel. So that decibel unit we have to take in this way. The voltage gain in the mid frequency range A_{VS} is conventionally V_O by Vs; in the mid frequency means where there is no effect of frequency of the signal.

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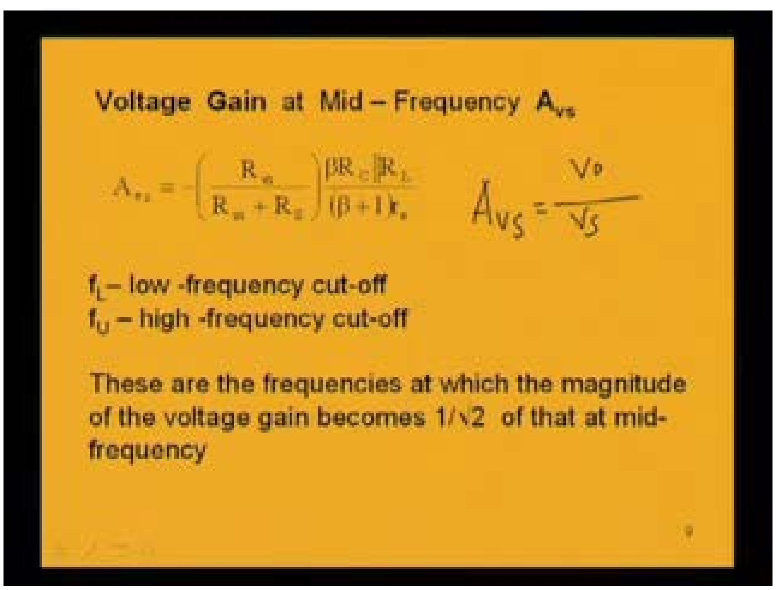

This is a constant and that value, if we recall our earlier analysis, is minus R_{in} by R_{in} plus R_s into beta times of R_C parallel R_L divided by beta plus 1 small r_e. These we are familiar with from our earlier analysis. This is the overall gain of the amplifier in the mid frequency range. Because it is not having any frequency component it is constant. As we have shown in the plot the lower frequency cut off and the upper frequency cut off or higher frequency cut off are two frequencies and we can find out basically from these two frequencies what will be the value of lower cut off frequency and what will be the value of upper cut off frequency for a particular amplifier given the parameters values, because we know that at those frequencies the value of the voltage gain will be 1 by root 2 times or 0.707 times the value in the mid frequency range; that is this value. As it is customary to write it in decibel, the decibel scale if you write then at f_L and f_U that is at the lower cut off and upper cut off frequencies the value of the voltage gain A_{VS}, magnitude of this value will be 1 by root 2 times of A_O.

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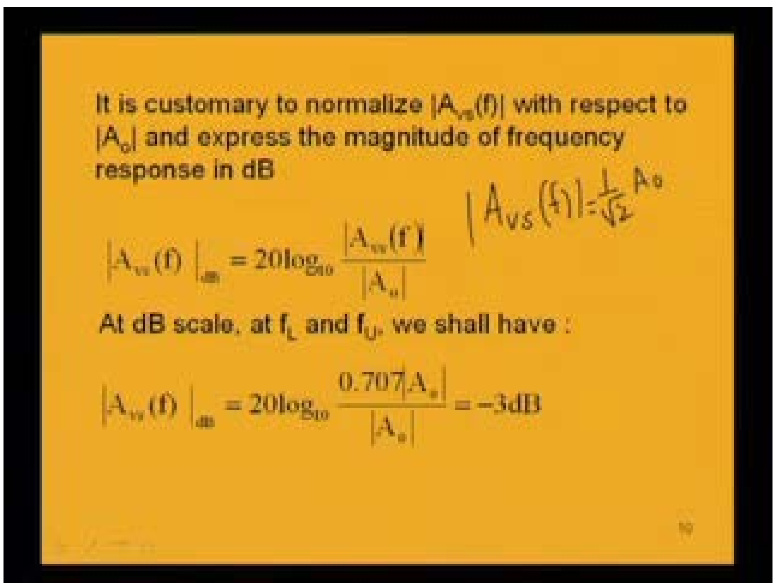

If we put that then we will get 20 log 10 of $A_{VS}(f)$ is 0.707 times A_O by A_O and this value is the dB value. If we calculate, this A_O, A_O cancel; 20 log 10 of 0.707 becomes -3. The overall quantity becomes -3 dB. That is why this -3 dB is very important as far as amplifiers are concerned. This is the bandwidth and that signifies the distance between the lower cut off and upper cut off frequencies because at those frequencies the gain becomes 1 by root 2 times the maximum gain which is A_O. This is the dB scale, -3 dB bandwidth we are going to find out. We will find out the lower cut off frequency and upper cut off frequency which are known as 3 dB cut off frequencies. 3 dB cut off frequencies means immediately we know that the gain has reduced to 1 by root 2 times of A_O.

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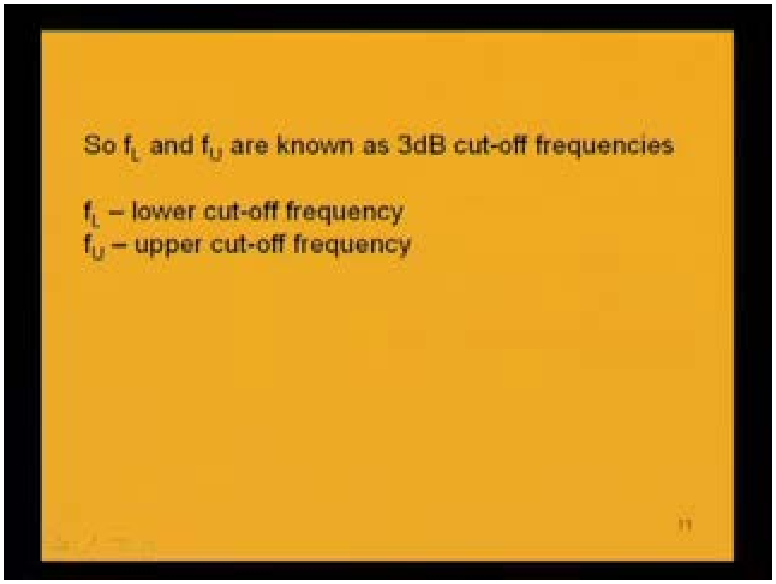

Using this analysis we can now proceed to find out what is the lower cut off frequency? When considering the low frequency region the capacitances which will be there will be C_1, C_2 and C_E. In order to find out the lower cut off frequency we will consider each capacitance separately; we will consider C_1 and neglect the other two and similarly for the others also we will do like that and find out the lower cut off frequency due to each of the capacitances and finally we will find out the overall lower cut off frequency considering all the three. Let us first find out the lower cut off frequency due to C_1. We are assuming that the other two are short circuited; C_2 and C_E will be short circuited and C_1 has a significant capacitance.

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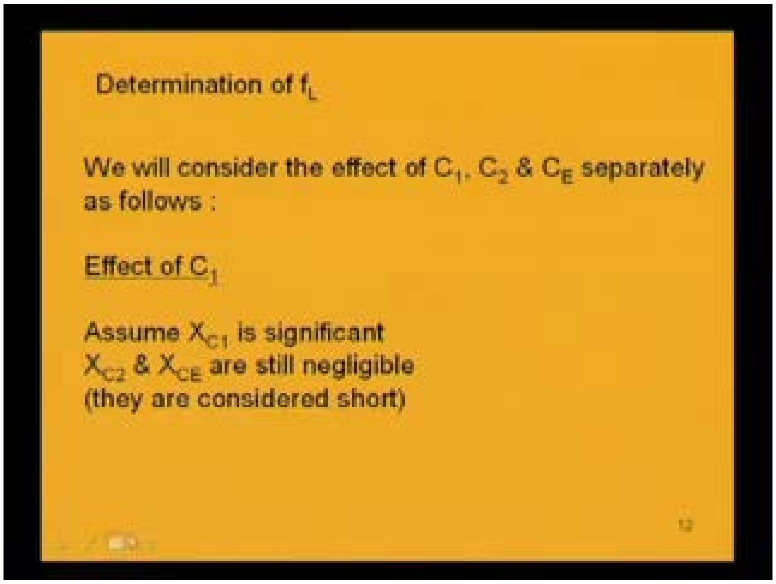

The circuit of the amplifier will have C_1 and there will be no other capacitances.

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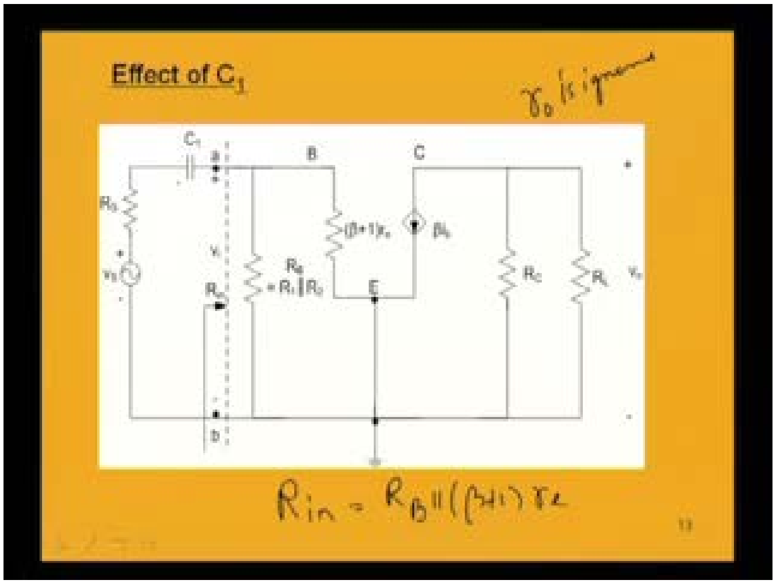

If we look into this circuit, it is very familiar to us because earlier also we discussed the same circuit in the mid frequency region. Only in that case this C_1 was not there. We find out what will be the input resistance of this amplifier? Input resistance, R_{in} can be found out by looking into the input circuit at the terminals AB. R_{in} is nothing but these 2 resistances in parallel that is R_B parallel beta plus 1 r_e. If I consider this R_{in} and consider the circuit to the left of R_{in}, we get this circuit where we can see that the input voltage V_i is across this R_{in} which is equal to V_S into R_{in} by R_{in} plus this whole series impedance and that is nothing but R_s plus 1 by j omega C_1.

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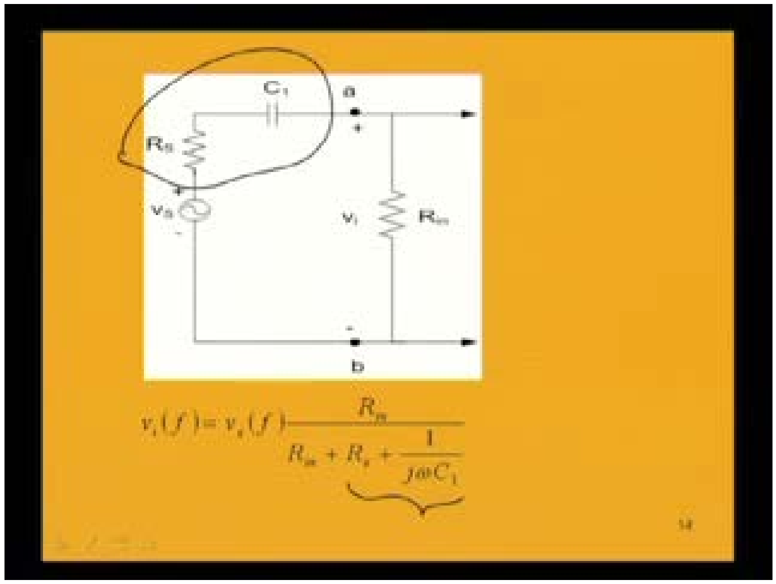

Simplifying this expression a little further we get V_i equal to V_s into R_{in} by R_{in} plus R_s plus 1 by j omega C_1 can be written as rationalizing by multiplying numerator and denominator both by j, in the numerator j will come and in the denominator j square. We know j square is equal to -1. So minus j by omega C_1 and again omega we know it is 2 pi fC_1 for this circuit. Just replacing this I get the expression of this ratio of V_i by V_s equal to R_{in} by R_{in} plus R_s minus j into 1 by 2 pi f C_1 where f is the frequency at which we are operating the input signal. That can be further reduced to another expression by writing common R_{in} plus R_s; taking this common in the denominator it will be 1 minus j into 1 by 2 pi f into R_{in} plus R_s into C_1.

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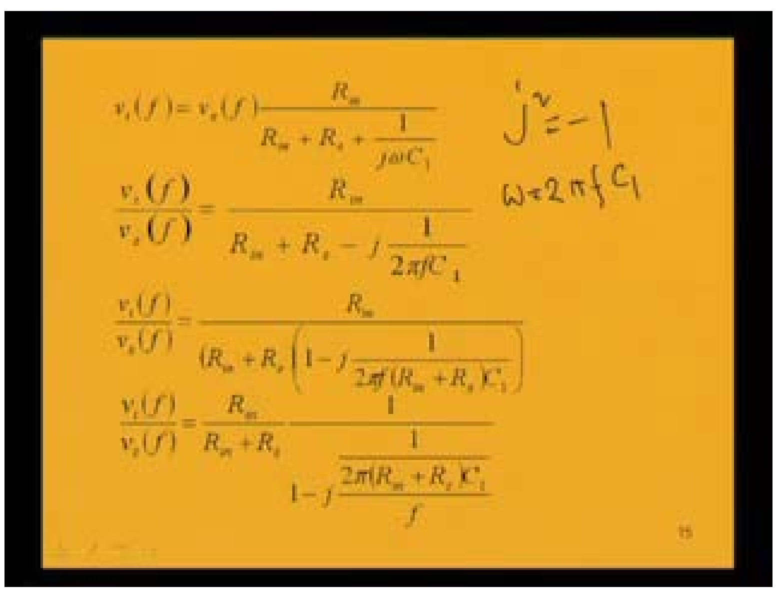

That can be further written as R_{in} by R_{in} plus R_s into 1 by 1 minus j; I write 1 by 2 pi f R_{in} plus R_s, whole term is in the numerator and in the denominator keeping this into C_1 in the numerator and keeping only f in the denominator, this f is in the denominator only. I can write this one as this one. Look into this term 1 by 2 pi into R_{in} plus R_s into C_1. That term let us write it is as f_{LC1} because this is 2 pi into a resistance into a capacitance. R_C basically is nothing but a time constant of the circuit and that intention we are keeping in mind. So we are expressing f_{LC1} as 1 by 2 pi into R_{in} plus R_s into C_1. We consider only the magnitude of this ratio because there is a j term. Both the angle as well as magnitude are associated with this. But we forget about the angle because we are interested in finding out the overall voltage gain which is having the magnitude of the voltage gain.

We are writing only the amplitude or magnitude v_i by v_s that is equal to R_{in} by R_{in} plus R_s into 1 by taking the magnitude of this part. It is a complex quantity of 1 minus j theta. If I want to find out the magnitude of this component, this whole expression will be 1 plus theta square under root. That is what is done; 1 plus f_{LC1} by f whole square under root to the power half. This is the ratio between v_i and v_s. When the frequency, f becomes the frequency f_{LC1}, the value of a $v_i(t)$ and $v_s(t)$, this magnitude or amplitude of this ratio becomes R_{in} by R_s plus R_{in} into 1; when these two are equal it will be 1. So 1 by 1 plus 1 means 2; square into half will go. In the denominator it will be 1 by 1 plus 1; 1 square means 1 to the power half; 1 by root 2 that means 0.707 R_{in} by R_s plus R_{in}. That we get at frequency f is equal to f_{LC1}.

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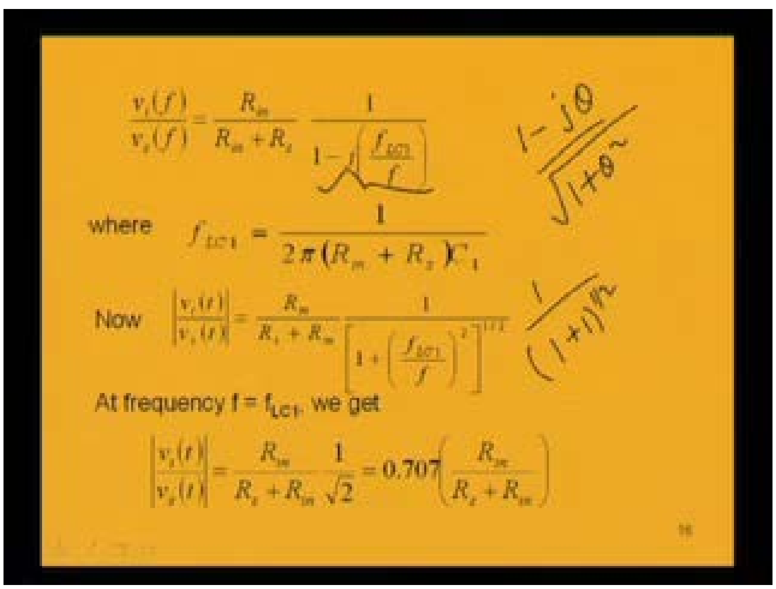

If we consider the overall voltage gain A_{VS} because this was the ratio between v_i and v_s. For the amplifier let us consider the voltage gain v_o by v_i. If we look into this amplifier circuit again v_o is here, this is v_i. In between v_o and v_i there is nothing, no capacitance. The circuit is similar to the mid frequency region circuit. v_o and v_i this ratio is same as the voltage gain v_o by v_i for the amplifier in the mid frequency region and that is having the relation which is known to us. We know that we can replace that v_o by v_i which is A_v that means the voltage gain which is nothing but, if we consider the magnitude only minus sign we are not writing, beta into R_C parallel R_L by beta plus 1 r_e that is the voltage gain between output terminals and input terminals.

Let us consider the overall voltage gain v_o by v_s. By a chain rule I can write it as v_o by v_i into v_i by v_s. v_s by v_i is equal to this expression A_v into R_{in} by R_s plus R_{in}. This is v_o by v_i which is A_v and this part is equal to v_i by v_s. We can also replace A_v. But keeping it as it is, we are getting A_v which is the voltage gain v_o by v_i. This A_v is nothing but v_o by v_i. Similarly v_i by v_s that was just now found out which is from this R_{in} by R_s plus R_{in} into this part. That is what we are expressing and we are considering magnitude that is why I am writing only the magnitude part or I can write this v_o by v_s as $A_{vs}(f)$ considering the frequency. You can write it as A_O into 1 by 1 plus f_{LC1} by f whole square to the power half because A_v into R_{in} by R_{in} plus R_s is nothing but A_{vs} that is the mid frequency range overall voltage gain without considering capacitance. That is nothing but again A_O in the mid frequency region. Mid frequency region voltage gain if it is A_O, magnitude we are considering; another part is there which is 1 by 1 plus f_{LC1} by f whole square to the power half or under root.

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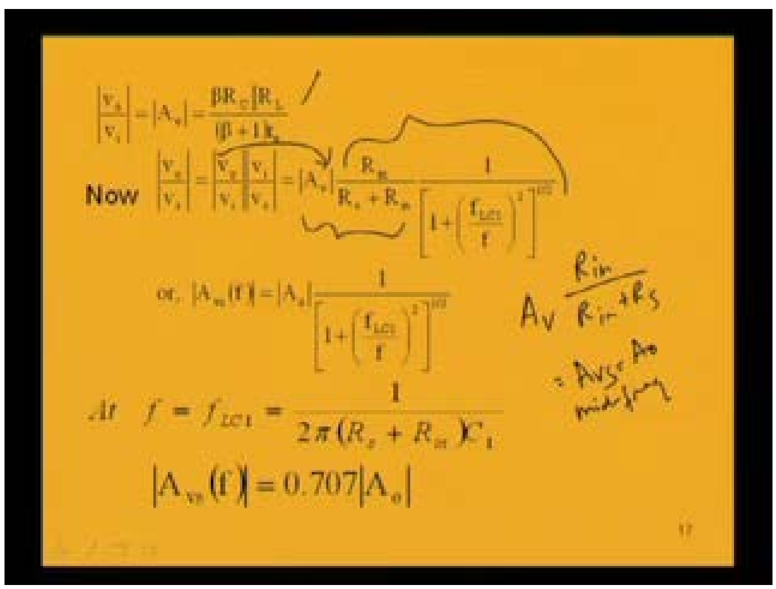

At frequency f_{LC1} when this f is equal to f_{LC1}, this part becomes root 2. Overall voltage gain $A_{vs}(f)$ is equal to 0.707 A_O and that is the lower cut off frequency f_{LC1} at which this happens. The lower cut off frequency due to C_1 is equal to 1 by 2 pi R_s plus R_{in} into C_1 because at that frequency when you substitute f is f_{LC1} by this one and make f is equal to f_{LC1}, then we get our required criterion that the voltage gain roughs up to 0.707 times the mid frequency gain. This f $_{LC1}$ or the lower cut off frequency due to C_1 is equal to 1 by 2 pi into R_s plus R_{in} into C_1. This lower cut off frequency can be found out easily.

We look into the circuit having this capacitance C_1. Look from this input side across this C_1. If I find out what is the effective resistance, it is equal to R_s plus R_{in}. R_s plus R_{in} is the effective resistance looking from the capacitor C_1 by making V_S zero when you find out effective resistance and R effective into C_1, actually this whole term will be determining the time constant of this circuit having capacitance and from that we can find out what is the frequency by 1 by 2 pi into R effective into C_1. This is actually the lower cut off frequency.

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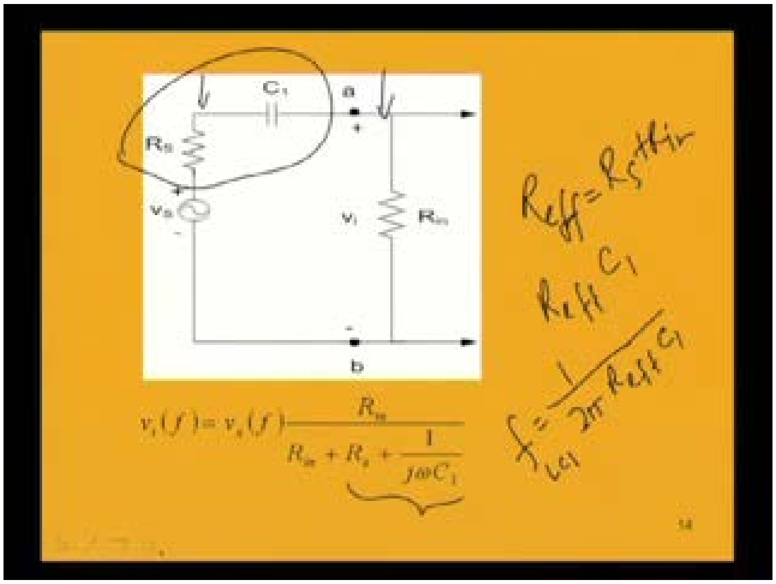

Let us try one problem for finding out the lower cut off frequency due to the capacitance C_S alone as shown in this figure. In this example we will find out the lower cut off frequency due to the capacitor C_S alone.

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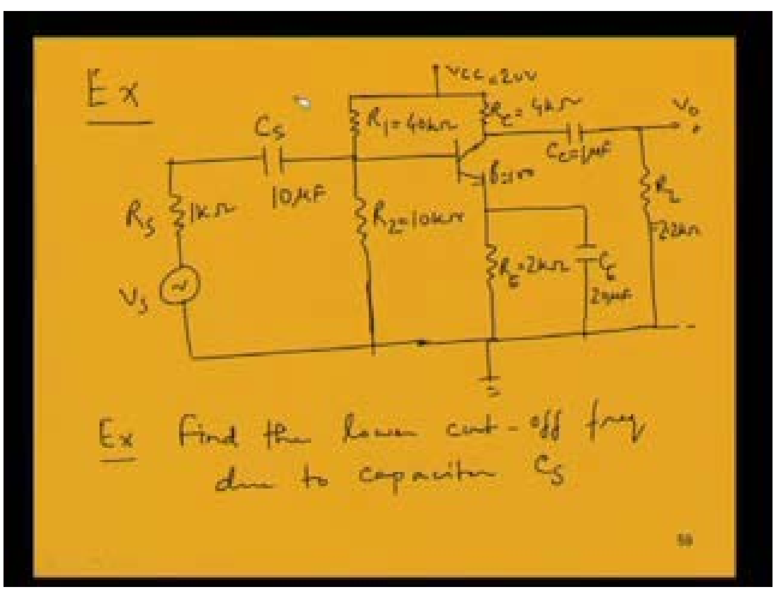

For solving this example we have to first draw the small signal model for this transistor amplifier. The small signal model as we discussed earlier will have the capacitance in the high frequency and the low frequency region also. Let us draw the small signal model including the capacitances because we are concerned with the frequency response and as is the method for drawing the small signal model which we discussed earlier let us proceed. This circuit is having R_s, V_S is the source, C_S is the series capacitor with the source and in the small signal model we know that the parallel combination of the biasing resistance R_1 and R_2 let us equivalently express it as R_B and this is beta plus 1 r_e and R_E the capital R capital E, is the emitter resistance, C_E is the emitter bypass capacitor and here the current source beta ib and the collector resistance R_C and the collector capacitance, load resistance R_L will be here. Here in this model due to this C_S alone we will be finding out the lower cut off frequency.

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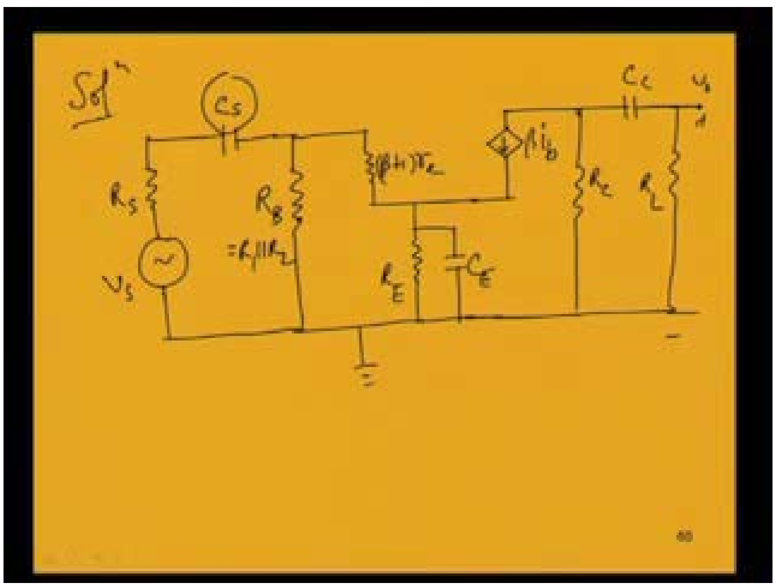

Replacing these values we have to first of all find out what is r_e? That we do not know. In order to know r_e we have to be concerned about the DC equivalent circuit. DC equivalent circuit if we draw then it will be having this R_1 and R_2 parallel. This is R_C and this is the transistor emitter resistance R_1 R_2; V_{CC}, 20 volt, R_C is equal to 4 kilo ohm and for this transistor beta value is given as 100. In this example actually beta is given by 100. We have to note beta value in order to find out the parameter R_s. R_E value is 2 kilo ohm, R_2 is 10 kilo ohm, R_1 is 40 kilo ohm. What will be this R_1 parallel R_2? Let us write that as R_B. It is R_1 R_2 by R_1 plus R_2 and putting the values 40 into 10 by 40 plus 10, we get 8 kilo ohm.

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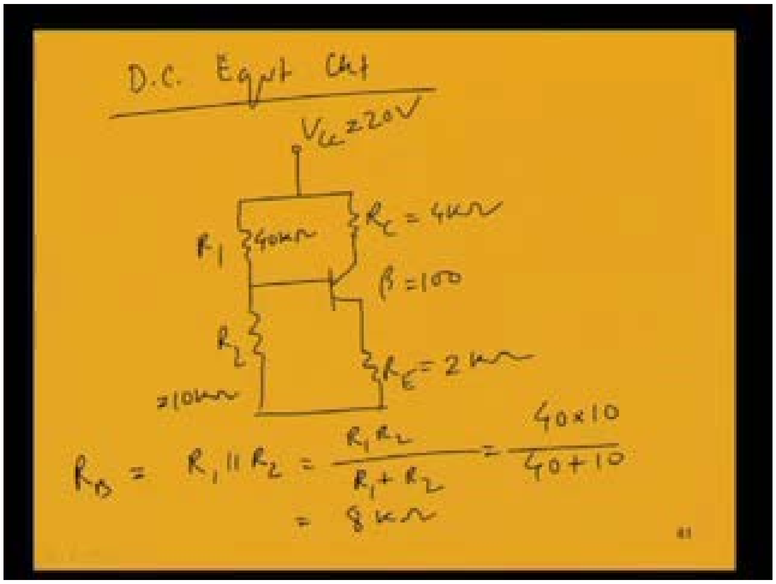

This is the value of the parallel equivalent resistance. The Thevenin's equivalent circuit will give us the value of R_E. We draw the Thevenin's equivalent circuit replacing this R_B by whatever we have got which is 8 kilo ohm. This is V_{CC}, R_C is 4 kilo ohm; V_{CC} is equal to 20 volt, R_E is equal to 2 kilo ohm and we need to know the Thevenin's equivalent voltage. Thevenin's equivalent voltage can be found out from this; V Thevenin equal to V_{CC} into R_2 by R_1 plus R_2; 20 into 10 by 10 plus 40. This is equal to 4 volt. We can now replace here 4 volt. Now we can find out what is R_E? This is I_B base current. In this circuit V Thevenin minus I_B R_B minus V_{BE} minus beta plus 1 I_B into R_E that is equal to zero. Replacing the values 4 minus I_B, we do not know; R_B is 8 minus 0.7 minus 100 plus 1 into I_B into R_E is 2 is equal to zero. This equation will give the value of I_B.

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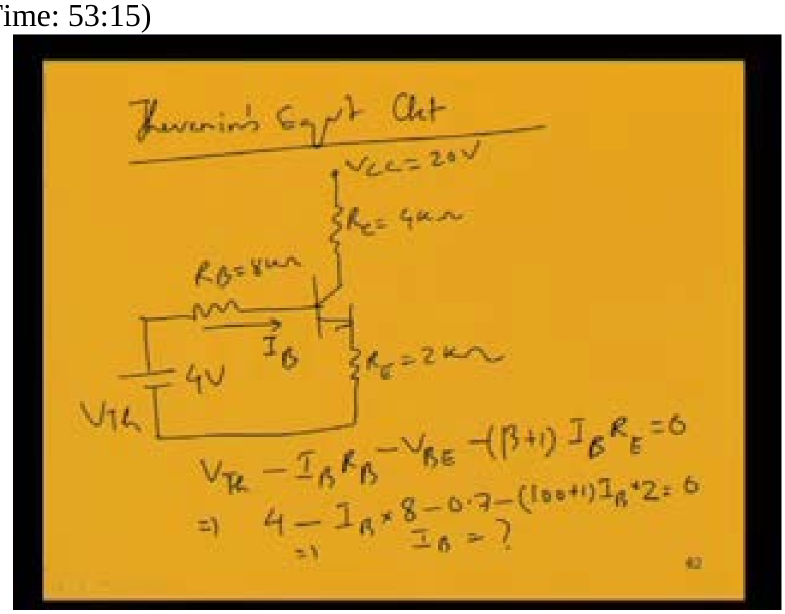

If we do this we will get the value of I_B. You should check and get a value of 0.0157 milli ampere. This is the value of I_B which we get from this equation. Solving this equation we get a value of I_B which is equal to this much. If we know I_B we can also know I_E which is nothing but beta plus 1 into I_B. Beta value is 100; 100 plus 1 into I_B is 0.0157. This is in milli ampere. What we will get is 1.586 milli ampere. Knowing the value of I_E, we can now find out what is the value of small r_e; 26 milli volt by capital I capital E, I_E. Putting these values we get 26 milli volt by 1.586 milli ampere and that is equal to 16.39 ohm. Because this order is milli volt by milli ampere, it will be in ohm. 16.39 ohm is small r small e, r_e. Beta plus 1 r_e equal to 100 plus 1; that is 101 into 16.39 and that comes to 1.655 kilo ohm.

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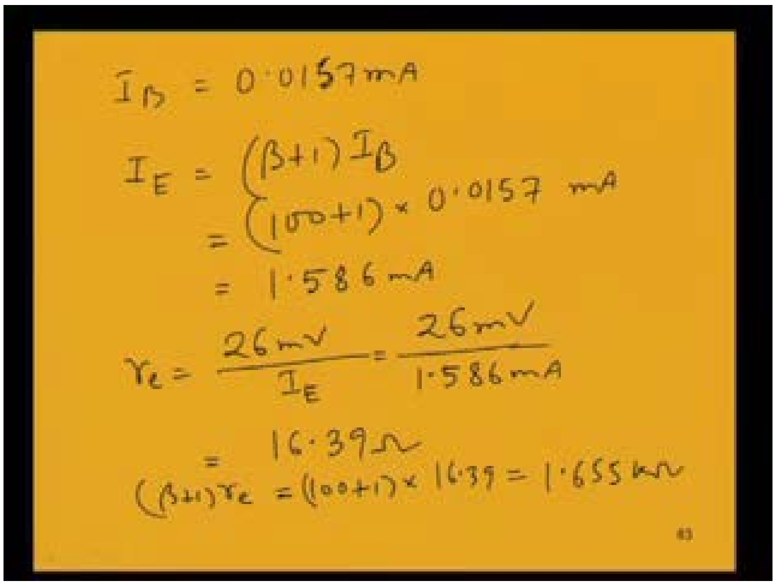

This is ohm. But in kilo ohm we will get 1.655 kilo ohm. We now know this beta plus one r_e. We look into the small signal model and find out what is the input resistance R_{in}? We can find this out and that is equal to R_B parallel beta plus 1 r_e. In the mid band region, that is when we ignored the effect of this capacitance, that R_{in} the input resistance we have to find out. In the mid band that R_{in} is equal to R_B parallel beta plus 1 r_e. Replacing the values R_B is equal to 8 kilo ohm and beta plus 1 r_e we have found out to be 1.655; so 8 into 1.655 by 8 plus 1.655 is equal to 1.371 kilo ohm. We know this R_{in} that is the input resistance for the mid band frequency region. Then in order to find out the lower cut off frequency we know that, we have just now found out the lower cut off frequency due to C_S alone. Individually we are finding out the lower cut off frequency and that we know. f_{LCS} if we denote that is 1 by 2 pi into effective resistance as looked by this capacitance C_S and that is nothing but R_S plus R_{in} into C_S, because the effective resistance is as looked by capacitor C_S.

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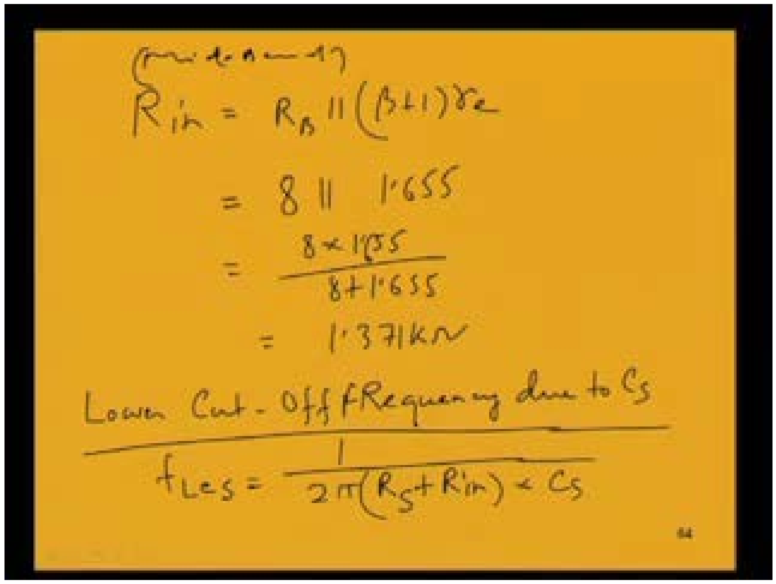

This is the capacitors C_S. What will be the effective resistance? That is R_{in} plus R_S. From this side we will look into; so it will be R_S plus this R_{in}. What will be this value? That value we can find out; f_{LCS} is equal to 1 by 2 pi into R_S, series resistance here with the source is 1 kilo ohm, so 1 plus 1.371 that we have found out, into the capacitance C_S which is 10 microfarad. But this is in kilo ohm. So into 10 to the power 3, we will have to do into 10 to the power -6 into 10; that is 10 microfarad is the capacitance C_S. If we do this calculation then we will get the value of f_{LCS} to be 6.71 Hertz. 5851 This capacitance C_S is offering a lower cut off frequency of 6.71 Hertz. In order to know the lower cut off frequency due to this capacitance we have seen that we have to find out the effective resistance which is looking from the capacitor what effective resistance is there and for finding that out we have seen that we have to find out the input resistance is in the mid band region and that input resistance is found out by considering the small signal model and after finding out that R_{in} we found out the effective resistance because it is simply the series resistance between R_{in} and the R_S. This effective resistance due to the C_S only that has been obtained which is equal to 1.371 kilo ohm and then it will give you the value of the lower cut off frequency.

In this discussion we have today analysed the transistor amplifier in the common emitter configuration. We are considering first the low frequency and then we will be also considering the high frequency analysis. But today we have discussed the lower cut off and upper cut off frequencies and we are trying to find out what is the cut off frequency value for both the lower and upper frequency regions and for the lower frequency regions we have found out the lower cut off frequency considering one coupling capacitor C_1. Also we will be finding out next the lower cut off frequency due to the other two capacitances and then we will be also finding out the overall cut off frequency in the low frequency region and then we will also find out the higher or upper cut off frequency.