Basic Electronics
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Module -5
Power Circuits and System
Lecture - 2
Transformer Couple Power Amplifier

Today we will discuss about other type of class A power amplifier which is transformer couple class A power amplifier. In the last class we discussed about one type of class A power amplifier which is series fed and today we will discuss transformer couple large signal power amplifier. The transformer coupling, as the name suggests, there will be a transformer which will be used for coupling the load to the amplifier. Here let us consider a resistive load; for example when we have to use an audio power amplifier we have to drive a loudspeaker. We have to transfer power to a load having resistance around 5 to 15 ohm. This resistance is very small but here we are transferring power from the large signal amplifier using a transistor and we know that the output resistance of a transistor is quite high. So, here to transfer power from a device having high resistance to a load having very low resistance that mismatching of the impedance causes lesser transfer of power because the load is having a very small resistance and the device that is a transistor amplifier is having a high resistance.

It cannot transfer the whole amount of power because of mismatch in the impedances. We know from maximum power transfer theorem that if the load resistance as well as the resistance of the device from where we are transferring the power, these two impedances match. That is ideally when they are equal that is source resistance and load resistance are equal, then maximum power can be transferred. Here in view of that we are going to use a transformer at the output side. That is we are going to couple the load to the device or the amplifier through a transformer.

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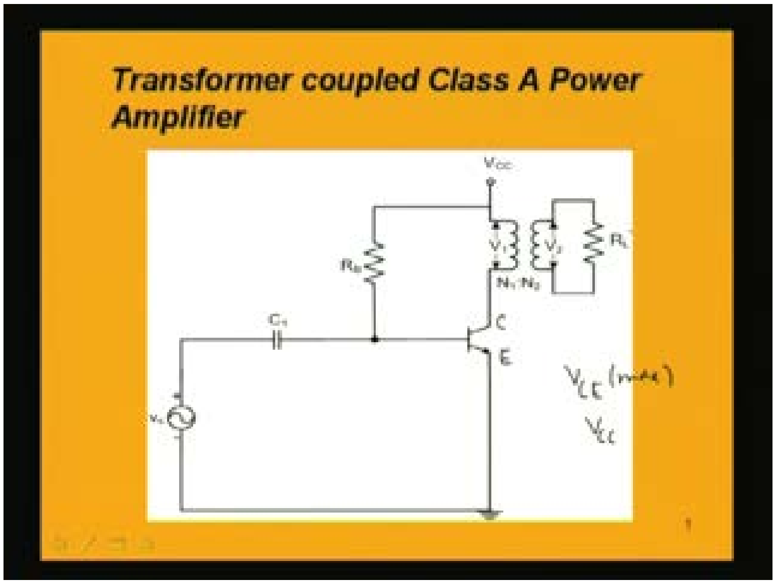

That type of circuit is shown here where we are having a transformer having the turns ratio between the primary winding and the secondary winding; N_1 is to N_2. A transformer, as we know, has two windings. One is the primary winding, other is the secondary winding and the primary winding is where we connect the supply and by induction we get an induced voltage in the secondary side. Here we are showing a transformer having number of turns in the primary N_1 and number of turns in the secondary N_2. So, N_1 is to N_2 is the turns ratio.

The resistance R_L is a load resistance which is connected across the secondary of the transformer and we are using a fixed bias scheme given by this resistance R_B; similar to that we discussed earlier in series fed class A power amplifier. Here the primary is having voltage V_1 and the secondary of the transformer is having the voltage V_2.

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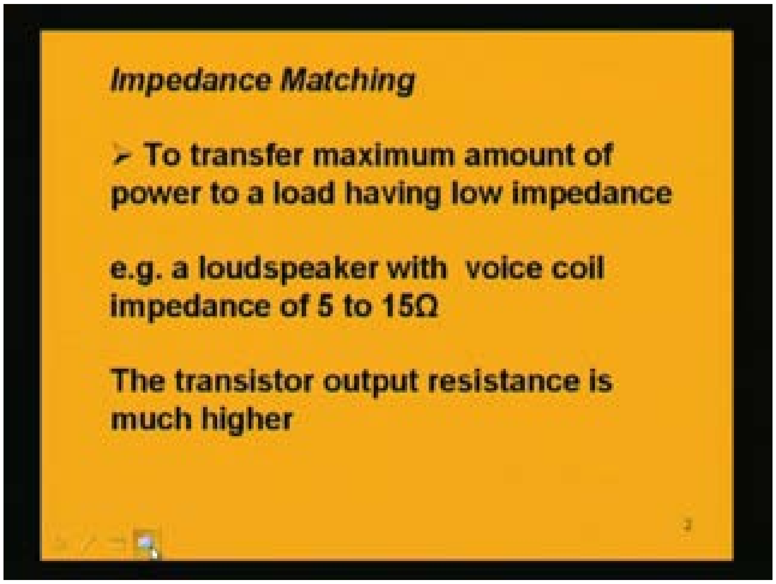

As I have mentioned this is to transfer maximum amount of power to the load having low impedance; for example in a loudspeaker where the voice coil impendence is only around 5 to 15 ohm. But the transistor output resistance used in the large signal amplifier is quite high; that is much higher than the loudspeaker voice coil impedance. So, we have to go through a transformer coupling.

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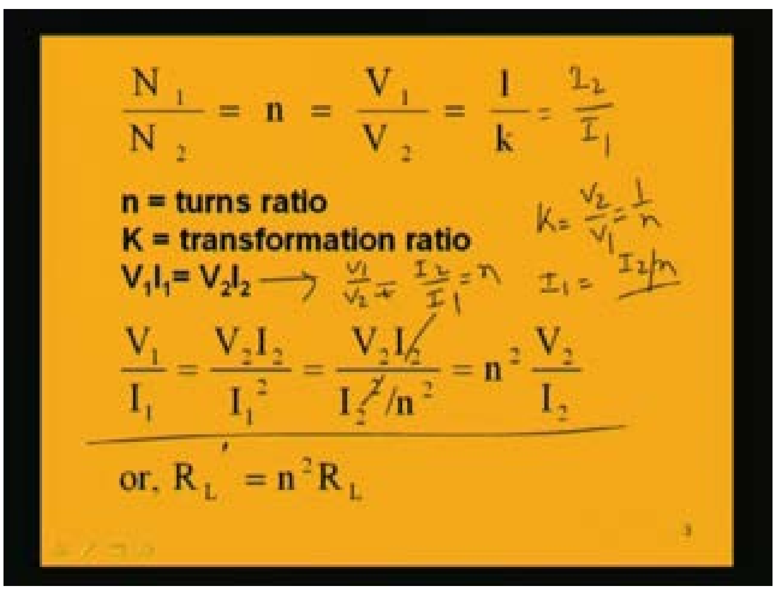

In this transformer as I have noted N_1 is the number of turns in the primary winding and N_2 is the number of turns in the secondary winding. The ratio between N_1 and N_2 is given by turns ratio and it is denoted by a small letter n and that is equal to V_1 by V_2. That is the ratio between the windings of the primary and secondary determines at what ratio the supply voltage will be transferred to the secondary winding side. So, V_1 is to V_2 is given by the turns ratio n and that turns ratio n is actually 1 by K where K is the transformation ratio. That K which is transformation ratio is a term that is used in transformer to denote the ratio between V_2 and V_1. So, actually K, the transformation ratio is V_2 by V_1. It is equal to 1 by n.

Transformation ratio is 1 by turns ratio and assuming ideal transformer where the input power and output power are equal, V_1 I_1 is equal to V_2 I_2. That is the assumption we will use for ideal transformer and from that we can get that V_1 by I_1 is equal to, right side also if we divide by I_1 square that means both left hand side and right hand side if we divide by I_1 square what we get is V_1 by I_1 equal to V_2 I_2 by I_1 square. That can be written as V_2 I_2 by I_2 square by n square because from V_1 I_1 is equal to V_2 I_2 we get that V_1 by V_2 equal to I_2 by I_1. As V_1 by V_2 is equal to n that is equal to I_2 by I_1 is equal to n. So, we can write I_1 as I_2 by n. Using that relation, here in place of I_1 we are substituting I_2 by n and as it is square, we get I_2 square by n square. This n square will come to the numerator. If we simplify it will be equal to n square into, one I_2 will cancel with one I_2. So, what will remain is n square into V_2 by I_2.

If we look into this expression that V_1 by I_1 equal to n square into V_2 by I_2. Now V_1 by I_1 means, the resistance in the primary side if we look, the resistance which will be obtained in the primary side is nothing but the resistance R_L transferred to the primary side. The resistance which is actually in the secondary winding that is R_L, if we transfer this resistance from the secondary to the primary side then, we get the value as R_L dash which is equal to n square into R_L. The value of the resistance in the secondary winding that has to be multiplied by square of the turns ratio so that we can transfer that secondary winding load resistance R_L to the primary side and that value is denoted by R_L dash.

It is equivalently expressing that. We are having in the transformer primary resistance R_L dash which is nothing but the secondary resistance or load resistance transferred to the primary side. This is done in order to easily draw the load line which will be required in further analysis. Because it is a transistor which is being employed for this power amplifier or large signal amplifier, we will find out the efficiency that means the ratio between the output AC power to the input DC power and that requires the currents and voltages in the AC as well as the DC conditions and we have to draw load line for the transistor to see how the signal changes.

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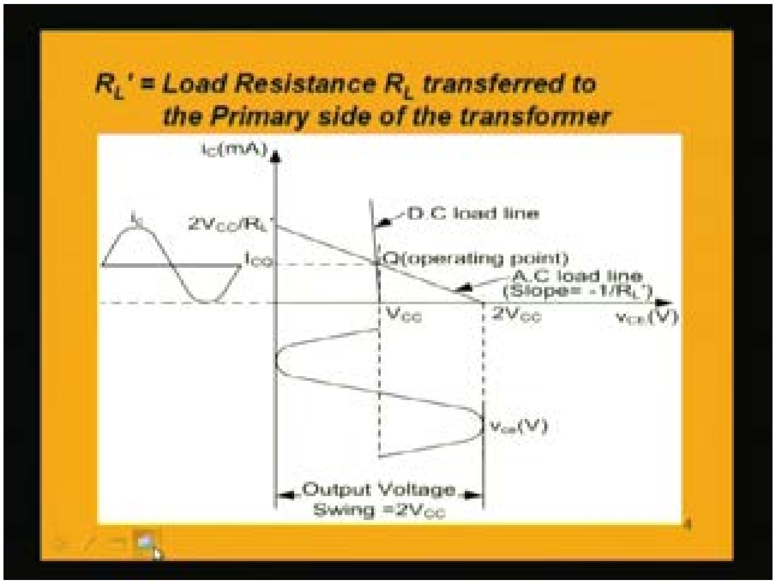

If we now consider the load line for this transistor, then we have two load lines. One is the DC load line which is the load line for the prevailing DC conditions and under DC condition we will not have the R_L dash because the R_L dash that is the load resistance transferred from the secondary to the primary side will be only effective when we consider AC power because the load R_L dash or R_L is getting AC power. We are concerned about the AC power being transferred to the transformer secondary side load. If we consider the DC load line, we can draw the DC load line by noting down the maximum value of the DC collector current and the maximum value of the DC voltage.

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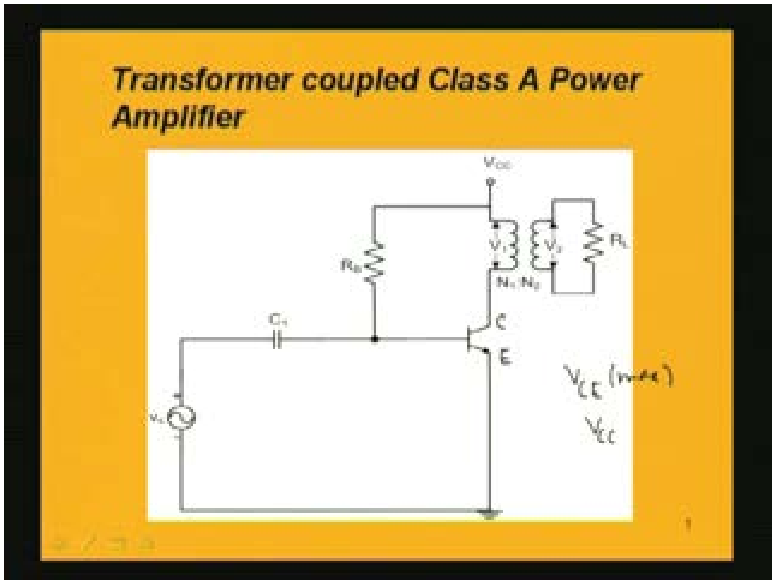

If we look into the circuit again, when the DC condition prevails, if we are only interested in the DC condition then in this circuit if we consider from V_{CC} to ground this transformer primary is having very negligible resistance. It can be assumed to be almost zero. That is the transformer primary winding is having almost zero resistance. That is why in this part, the DC current which will flow will have no resistance and the current which will flow is almost infinite. The current which will flow, almost it will be like a short circuit current. If we consider this collector current then as there is no resistance, the current will be almost infinite and the voltage is V_{CC}.

Collector to emitter we consider because, we have to know the maximum values of the collector to emitter voltage and the maximum value of the collector current to draw the DC load line. If we now consider this circuit in the collector side of the transistor, V_{CE} maximum value can be the value which is the supply voltage V_{CC}. So, under DC conditions the maximum collector to emitter voltage will be V_{CC} and maximum collector current will be infinite. It is infinitely large.

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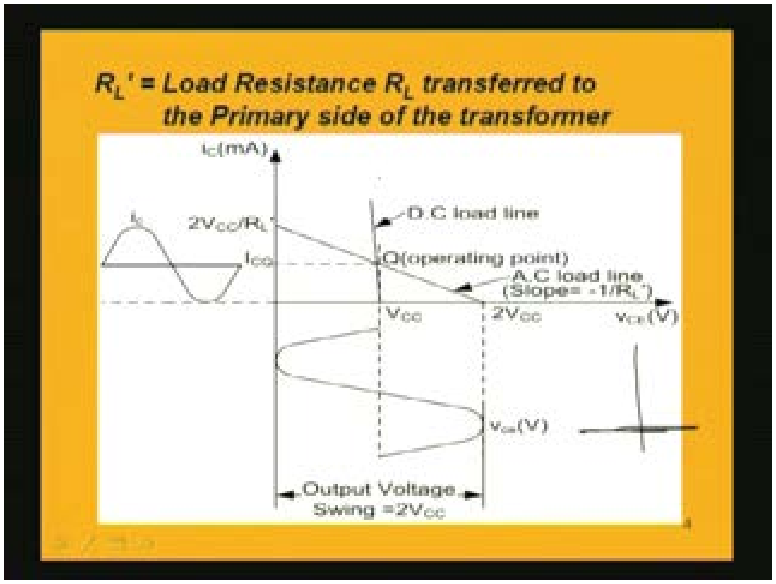

The DC load line if we draw it is almost like a vertical line because current is reaching around infinite value and the collector to emitter voltage under DC is V_{CC}. Joining two points actually we get a vertical line and there is a very small resistance in the primary winding. Considering that exactly it will be not vertical but it will have a little slope; very small slope. This is the DC load line. To draw the AC load line, we consider the AC conditions prevailing and we have already seen that the primary of the transformer will have this R_L transferred to it by the value R_L dash.

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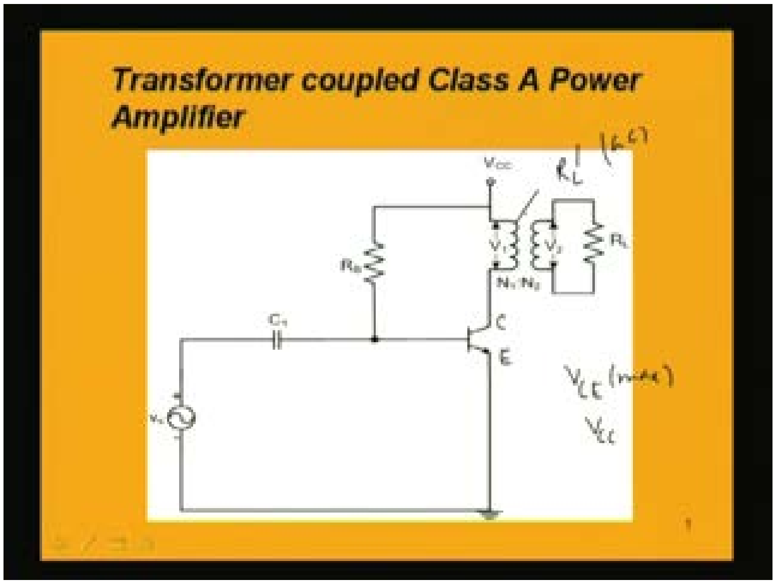

That is in the primary winding we will have a resistance R_L dash. So, here will be a resistance R_L dash in the AC condition. As this transformer primary winding is having R_L dash which is equal to n square into R_L and the load line if we want to draw for AC, when there is no signal then, the voltage of the collector to emitter will be simply V_{CC}. That is the DC source V_{CC}.

When you apply the signal, this is the signal V_s which we are applying and we are applying a sinusoidal voltage, the current in the collector will be sinusoidally increasing and decreasing; it will be a sinusoidal wave. Starting from DC value it will increase and decrease. So, that point is Q point which is the DC point or quiescent point. We know that at that point the value of the collector to emitter voltage was V_{CC} and the collector current was say I_{CQ}. If we now apply the signal then the collector current will increase and decrease like this and when the collector current increases the collector to emitter voltage will decrease from V_{CC} and it will go down and the maximum collector current that can flow is at this point where the collector to emitter voltage will be zero.

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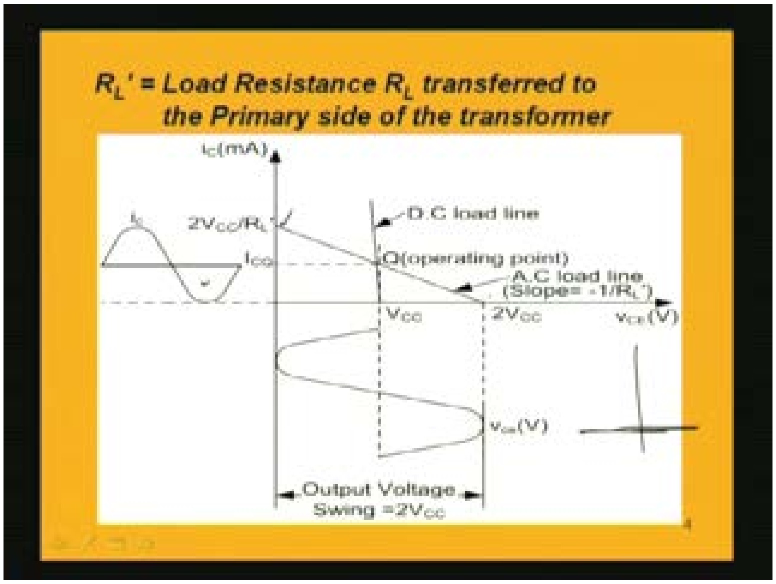

Then it will again increase and in this half cycle, when the collector current goes down to the negative half, the AC collector current goes to the negative half, then the collector to emitter voltage will increase beyond V_{CC} and the increment will be to this point. That is the maximum point on the load line and that point has the voltage of 2 times V_{CC}. When this maximum voltage between collector to emitter becomes 2 times V_{CC}, to understand that we have to see about the circuit; what is it having in the circuit? We are having a transformer. Transformer winding carries a current. When this current is in the negative half cycle, if we see the circuit again (Refer Slide Time: 19:27), the collector current which is flowing in the primary of the transformer if it goes down, as soon as it starts falling or decreasing then the collector current is that factor which estaplishes the flux in the core. If the flux goes down, then due to the Lenz law there will be an EMF which will be opposing the very cause behind it. That means it will not let the collector current to collapse and for encountering or for over coming that it will be actually aiding the voltage by increasing it to 2 times V_{CC}. It will aid the voltage V_{CC}. It will prevent the fall or collapse of the collector current. Due to the Lenz law it will not allow the collector current to fall and it will oppose the very cause behind the fall of the current. So, it will try to over come it and it will aid it by the voltage which will make it equal to V_{CC} and that is why total voltage at that point when the collector current goes down to the valley will be 2 times V_{CC} total.

The maximum value of the collector current if we consider the signal then this is 2 times V_{CC} by R_L dash. R_L dash is the resistance in the primary winding. This 2 times V_{CC} by R_L dash will be this peak value of the collector current and this is equal to this portion. V_{CC} by R_L dash was here and the total will be twice V_{CC} by R_L dash; the maximum or the peak of the collector current. AC load line is having a slope of 1 by R_L dash. But it is in the negative direction because you can see from the AC load line, the slope is negative. This is the load line analysis and what is the maximum swing of the output voltage or collector to emitter voltage? From one peak to the other peak the total swing is 2 times V_{CC}.

With this knowledge of the load line analysis, we can proceed to find out what will be the output AC power. The AC power if we consider we know that the AC power is equal to the voltage and current multiplied but that voltage and current is the RMS voltage and RMS current. We are finding out the average power and average AC power is given by i_c peak to peak into V_{CE} peak to peak by 8.

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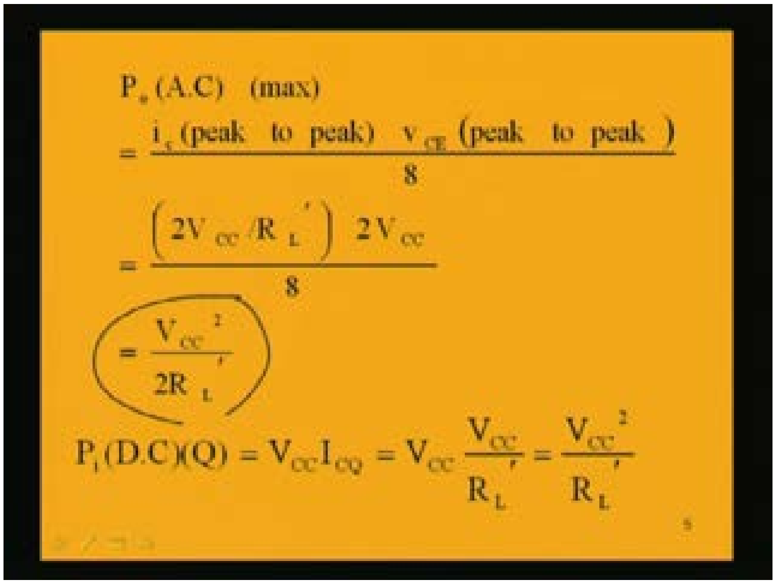

That we have earlier found in the class A series fed power amplifier also and we have deduced that. Putting down the value of i_c peak to peak and V_{CE} peak to peak, i_c peak to peak means this point to this point is twice V_{CC} by R_L dash and V_{CE} total swing peak to peak is 2 times V_{CC} divided by 8. Simplifying this expression we get, V_{CC} square divided by R_L dash into 2. This is the expression for the AC power output, maximum. We are considering the maximum AC power output; maximum because we are considering from this point to this point. The maximum value of this current it can have is 2 times V_{CC} by R_L dash.

This is the output power and the input power, which is a DC power, is provided by the source or battery V_{CC} and we know that the DC power is equal to V_{CC} into I_{CQ} and that can be written as V_{CC} into V_{CC} by R_L dash is equal I_{CQ}. Because this current I_{CQ} at this point (Refer Slide Time: 25:16) is the DC collector current, which is the Q point collector current. Q point is the quiescent point and at that quiescent point the collector current is I_{CQ} that is the DC collector current and that value is equal V_{CC} by R_L dash. Putting down this value V_{CC} by R_L dash multiplying with V_{CC} we get V_{CC} square by R_L dash. This is the DC input.

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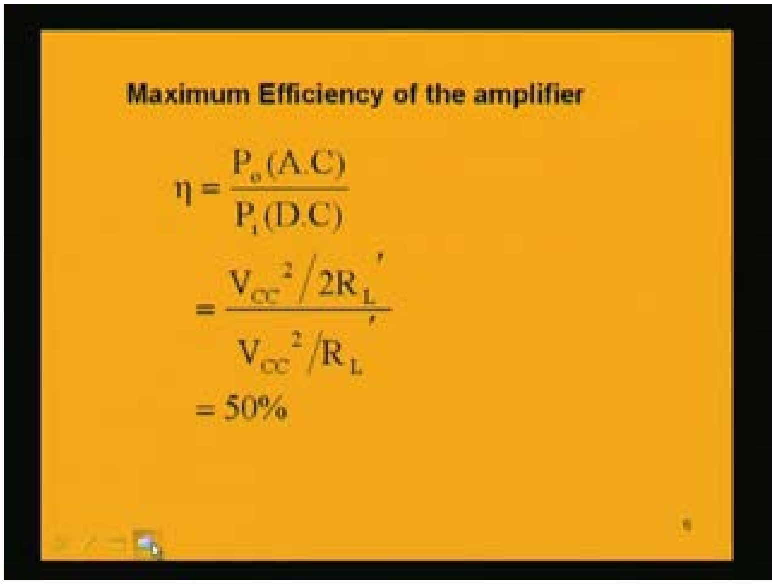

If we want to find out the maximum efficiency of this transformer couple amplifier, we have to take the ratio. We have to find the ratio between the output AC power and the DC input. Output AC power P_o AC we have found out to be V_{CC} square by twice R_L dash and V_{CC} square by R_L dash is the DC input. Putting down these values if we find out the maximum efficiency it boils down to half or 50%. So, here in the transformer couple amplifier we achieve a higher efficiency than the series fed class A power amplifier which we discussed earlier. We get 50% maximum efficiency in the transformer couple power amplifier.

The operation of this amplifier both series fed which we discussed earlier and the transformer couple power amplifier that we discussed today, they are both in class A operation. Because if we look into the output characteristic, I mean the collector current then we see that the current is flowing for whole cycle because it is not going down to either saturation or cut off. So, it is in class A operation; the conduction angle is 360 degree.

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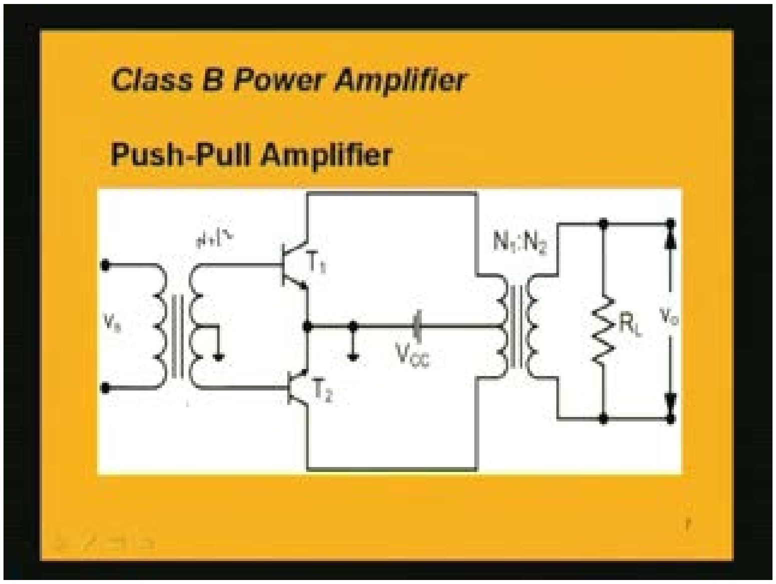

We consider another type of power amplifier. Depending upon the conduction angle we have another type of power amplifier which is class B power amplifier. In class B power amplifier, we know that the conduction angle is 180 degree. The quiescent point is located in such a way that it does not allow one half of the current cycle to flow. For example we have a push pull amplifier which is an example of a class B operation. What is there in this class B push pull type of amplifier? We have 2 transistors. They are shown as T_1 and T_2 and we are having transformer stages both at the input and the output. One example we are showing where we are having a transformer at this input stage and we are having another transformer at the output stage and the resistance R_L is connected to the secondary of the output stage transformer and the voltage across this R_L is V_o which is the output voltage we considered for driving any load and here given an AC input V_s, supply voltage at the input, this is a transformer which is having a center tap secondary.

The meaning of this center tap secondary is that actually we are having the same number of turns here from the upper half of this point and the lower half of this point. Suppose we have N_1 here, N_2 here in the secondary set then N_2 by 2 will be in this half; number of windings and N_2 by 2 will be in the lower half. That means exactly equal voltages will be induced in the two halves and we are considering N_1 is to N_2 that is the turns ratio in this output stage transformer and here also we are using a center tap transformer. So, here if this total is N_1, this will be N_1 by 2, this will be N_1 by 2.

We note here that we are having two transistors T_1 and T_2, which are npn transistors. Both are similar type of transistors and V_{CC} is the source DC supply. As we are applying an input voltage which is sinusoidal what will happen in the positive half of the input? Let us consider when we have V_s in this positive half wave. Let us consider what will happen? How the operation of the transistor will proceed for the positive half of the input voltage cycle? In the positive half cycle this point is positive, this point is negative.

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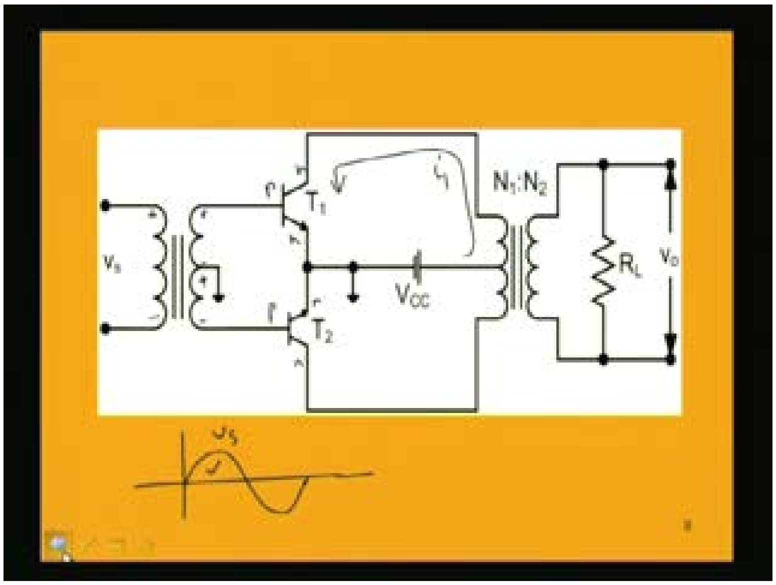

Here also we will have induced voltage like this. That is this point, the center point is ground. With respect to ground, the upper point will be positive and with respect to ground the lower point will be negative. Equal voltages will be induced here in both the halves. This is the case of transistor T_1; it is forward biased. If we look into the transistor base, this is npn transistor. So, we have this forward biasing for the transistor T_1 in the emitter base junction. The transistor T_1 will now conduct and so, collector current will flow in the transistor T_1 in this direction. Let us consider this is i_1. But what about the other transistor T_2? If we look into the other transistor T_2, this is also an npn transistor, but look at the biasing. This p is connected to negative. So, it will be reverse biased. There is no conduction taking place in the transistor T_2. The transistor T_1 will only conduct and the current flowing in the winding will be i_1 and so there will be a current flow in the secondary of the transformer and this current as it flows, it will produce an output voltage V_o.

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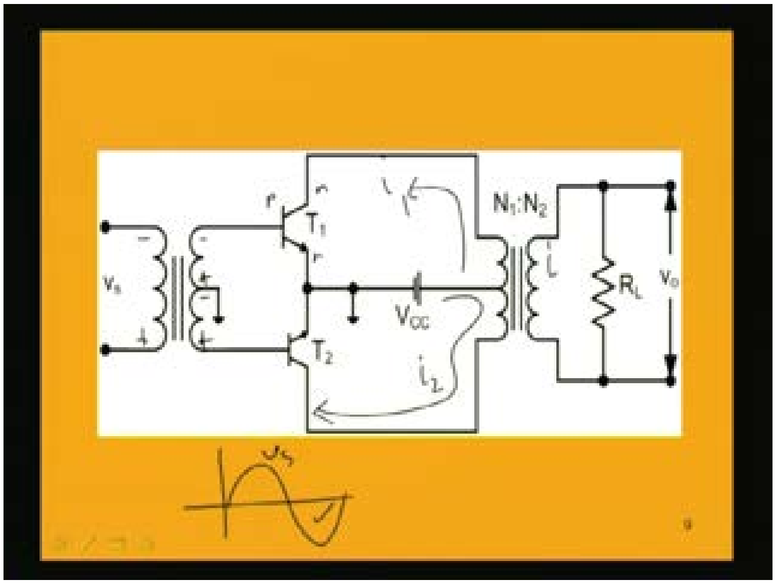

In the other half of the input cycle that is in the lower half if we consider, in the negative half cycle what will happen is that we get this point positive. The induced EMF will have these polarities so that now the transistor T_2 is forward biased in the emitter base junction. Because P is connected to positive, it will be forward biased and other transistor T_1 will be reverse biased. That is clear from this polarity of the induced EMF here in the secondary upper part. This is P at this npn transistor. P is connected to negative. So, it will be forward biased. There is no conduction in the transistor T_1 but conduction will take place in the transistor T_2 and so we will have a collector current in the transistor T_2 flowing in this direction.

So, through this transformer primary winding we see the direction of the current, i_1 and i_2. This is i_1 and this is i_2. Earlier i_1 was in this direction. So, one is in this direction, one is in other direction. These two directions are opposite. The current which will flow by induction in the secondary, which is say i in the secondary of the transformer in the output stage, will be the difference between these two currents because these are opposite. It will depend upon the current directions of i_1 and i_2. So, their difference will flow in the secondary of this transformer i. This type of push pull amplifier is named as push pull because in one half cycle the current is pushed up and in the other half cycle it is pushed down.

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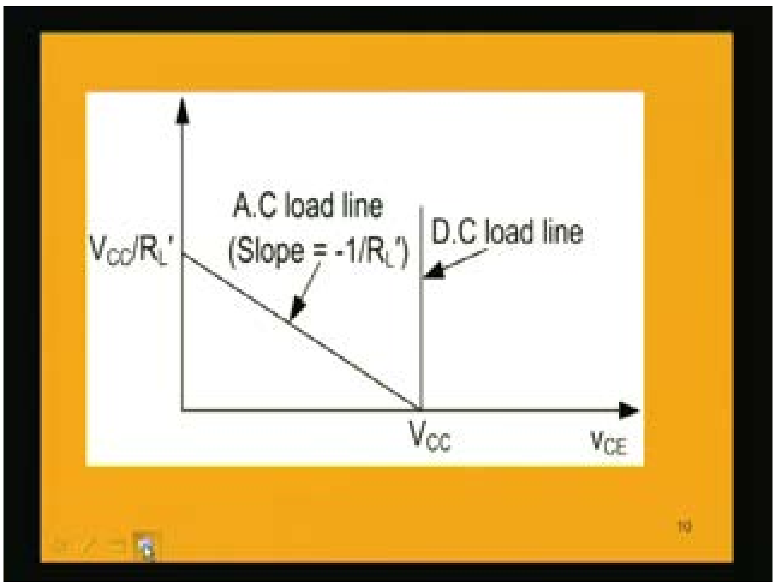

In the load line characteristics if we see, DC load line as we have earlier mentioned will be almost vertical and that is because the primary windings are assumed to be ideal having no parasitic resistance and that is why in the DC condition, the current will be infinitely high. That is why we are showing a DC load line by a vertical line and V_{CC} is the DC voltage because the source is V_{CC} source. In this type of push pull amplifier what we have seen is that one transistor is operating at a time. So, we are combining the operations of two transistors and finally we are finding out the output voltage by combining these two voltages which are induced individually by the two transistors in each half cycle. At a time only one transistor is conducting. The AC load line for one transistor if we consider, then the load line will be like this. The V_{CC} is the DC voltage.

When you do not have any signal when we do not have this V_s, suppose V_s is zero then, it will only have the V_{CC} voltage that is the DC voltage. That is why the DC voltage is here which is the voltage across collector to emitter when there is no signal.

When there is one transistor conducting say T_1, then we will have increase of the collector current and the collector current will increase up to the maximum value V_{CC} by R_L dash. Suppose upper one transistor is conducting, so ignoring the transistor drop which is very negligible we can have only the V_{CC} voltage maximum up to which the collector current can go is V_{CC} by R_L dash. R_L transferred to this primary side will be R_L dash and will be n square into R_L; n being the turns ratio between primary and secondary winding. If we now consider the AC load line we are having one point here and the other point, starting point is here. This AC load line will have a slope of minus 1 by R_L dash. This picture is only for one transistor, mind it.

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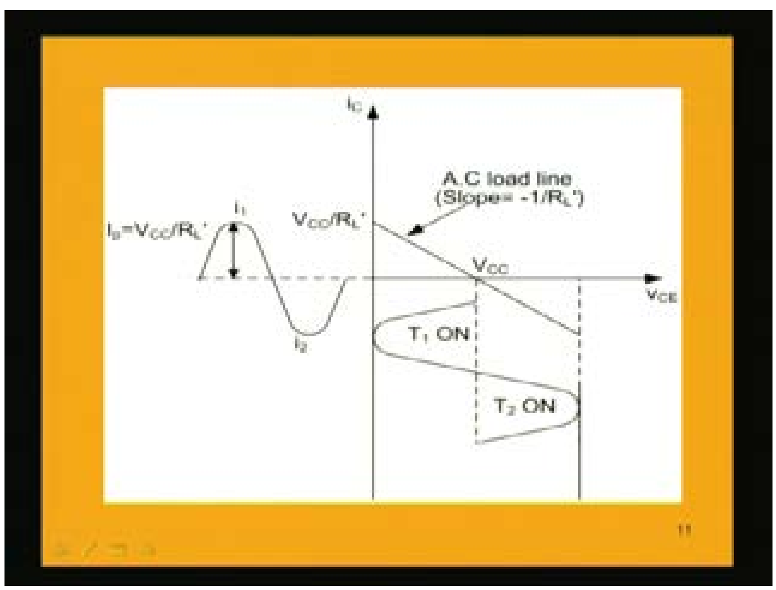

If we now combine both the transistors and try to draw the voltage and current swings, then for upper portion when the transistor current i_1 is increasing that means the upper transistor T_1 is conducting then current is rising. i_1 the sinusoidal current; peak value can be V_{CC} by R_L dash starting from zero. This is the AC current that we are considering and in the other half when T_2 is conducting, the current is i_2; the other sinusoidal current in the other half when T_2 is ON. So, the load line will extend to this point; starting from this it will come down to here. That means we are having the T_2 ON; T_1 ON, the voltage will be reducing. This is the combination of the two transistors load lines and we now find out the DC current which is flowing.

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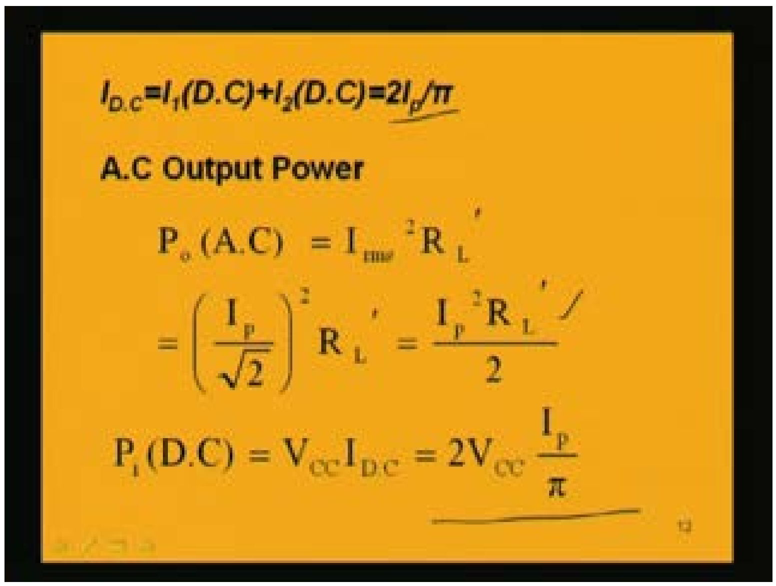

You have to be careful about this point because we are having a sinusoidal waveform and this is having two halves. One is this I_1 and the other is I_2. That is why if we find out the total DC current that will be I_1 DC plus I_2 DC and we can find that out which is nothing but 2 by pi into I peak. If the peak value of this current is say, I_P then the DC current that will flow, the DC value of this sinusoidal current will be 2 times I_P by pi; 2 by pi into I_P, I_P being the peak value of the current. Now we find out the AC output power. We know that the AC power can be found out if we consider the average AC value. That is obtained by considering RMS, root mean square value. The output voltage is obtained across this load resistance R_L because we are interested in this voltage V_o and what is this voltage? It is a resistive load, so, it is current square multiplied by R_L. That current must be the RMS value of the AC current. Whenever we find out the power average value in AC, we take the RMS value. So I square R but that I should be the RMS value of the I.

That is why we are writing I_{rms} square into R_L dash. Here actually we are considering the R_L dash to be transferred to the primary winding. Everything we are considering in the primary side because we are going to compare the output and input; find out the efficiency.

With respect to this input circuit, we will do every thing. That is why we are transferring this R_L from secondary to the primary side. That is nothing but I_{rms} square; I root mean square value into R_L dash and root mean square value is nothing but peak value divided by root 2. That is why we are writing I_P by root 2 square into R_L dash and if we simplify that we get I_P square into R_L dash by 2. This is the AC output power. AC output power is obtained as given by this expression. It depends on the peak value of the current. If we consider the DC input that is the power you are giving as input to the amplifier, then V_{CC} into $I_{D.C}$ that is the power input and that is equal to V_{CC} into $I_{D.C}$; we have seen it is 2 times I_P by pi; so, 2 V_{CC} into I_P by pi that is the DC input.

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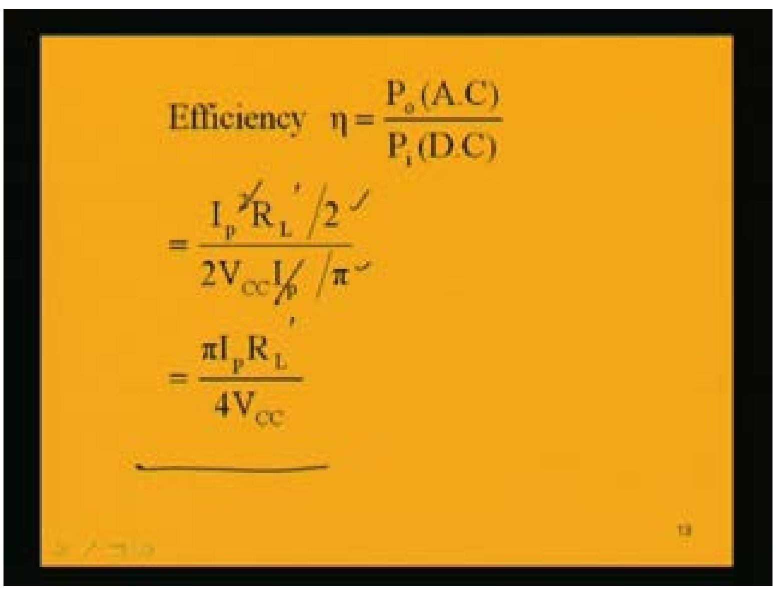

If we find out the efficiency of this amplifier, finding out the ratio between the output and the input, output is the AC output, input is the DC input. What will be the ratio between these two? Just by substiuting the values of this P_o A.C and P_i D.C, P_o A.C is this value I_P

square R_L dash by 2. So, we are replacing here I_P square R_L dash by 2 and P_i D.C we have as twice V_{CC} into I_P by pi. That is why we are replacing here or substituting here 2 times V_{CC} I_P by pi. This calculation gives us pi into, this pi will go up; pi into, one I_P will cancel out with one I_P and finally what will remain is pi times I_P into R_L dash divided by 4; 2 will come down, 4 into V_{CC}. This is the effiency of this push pull amplifier.

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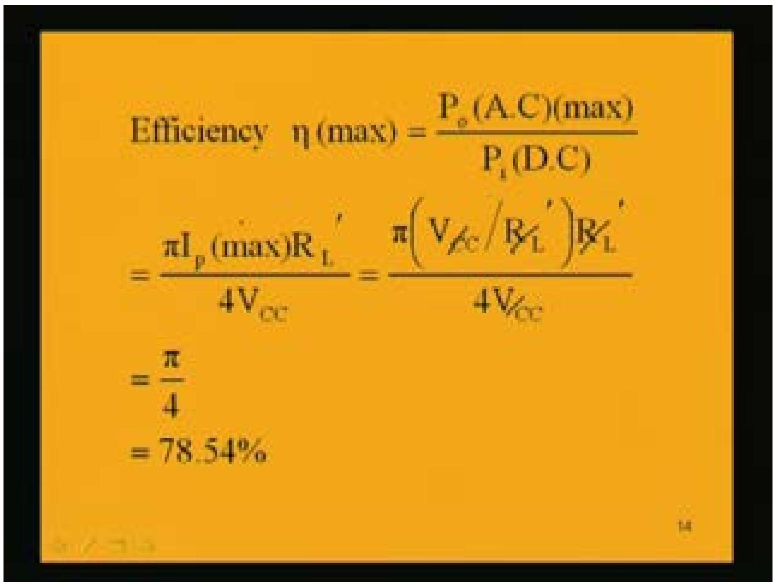

If we now consider the maximum effiency, what will be the maximum efficiency that you can achieve with the push pull amplifier? We have to consider the maximum output power and find out the ratio between the maximum output power which is an AC power, the maximum value of the AC power that can be obtained with the DC input. If we look into this expression, the variable is I_P because for a particular push pull amplifier the value which is the load resistance that we are fixing; we are not going to change the load resistance and also we are having a constant DC source. So, the peak value of the current, actually this value can go upto maximum value is this one, which is V_{CC} by R_L dash. If I put this in this expression, the output power maximum which we obtained as pi I_P R_L dash, so pi I_P (max) R_L dash by 4 V_{CC} if we put, just I am writing this again by taking I_P max which can be written down as V_{CC} by R_L dash. If we now design in such a way that this value I_P which is dependent upon these two, you get the efficiency changing.

The value of I_P if we now substiute, maximum value of the peak current that is given by V_{CC} by R_L dash. What we get is here V_{CC} and V_{CC} cancel, R_L dash and R_L dash also cancel. So, we get pi by 4. pi by 4 means, in percentage value we find 78.54% is the maximum efficiency that we can get for this type of push pull amplifier. We have seen earlier that we were able to get 50% maximum efficiency when we were considering a transformer couple power amplifier. Here in the class B operation an example of which is a push pull amplifier, we are getting an efficiency of 78.54% that is higher than the earlier cases.

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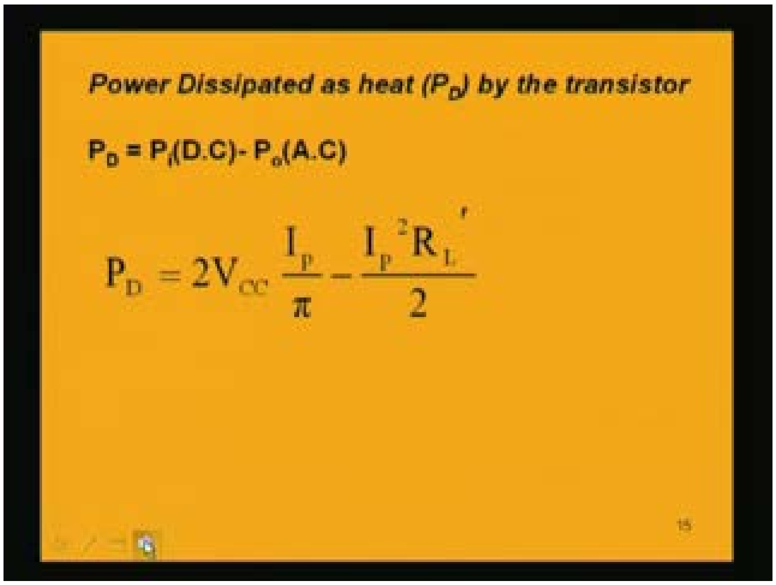

If we want to find out the power dissipated by the transistor as heat, this power dissipation can be found out by subtracting the AC power output from the DC power input, P_i D.C minus P_o A.C. That will give the power dissipation by the transistors. That power which is dissipated as heat can be found out by just subtracting P_o A.C from P_i D.C. Putting down these values, P_i D.C is nothing but 2 V_{CC} I_P by pi minus output AC power is I_P square into R_L dash by 2. If we substitute these values, we get the power dissipated as heat. In this type of push pull amplifier the key point is that we are having class B operation no doubt. That means for a particular transisor it is operating only in one half but we are combining these two transistors to get the overall output current and individually each of the transistor is operating in class B operation. Advantage here is that we can increase the efficiency. It is even higher than the earlier examples which we are taking, like a class A amplifier were only having 25% and 50% efficiency, but here it is more which is 78.54%. If we now compare these three amplifiers which we have discussed that is we have already discussed a class A and now we are discussing class B, then from the efficiency point of view we are having a higher value in push pull amplifier.

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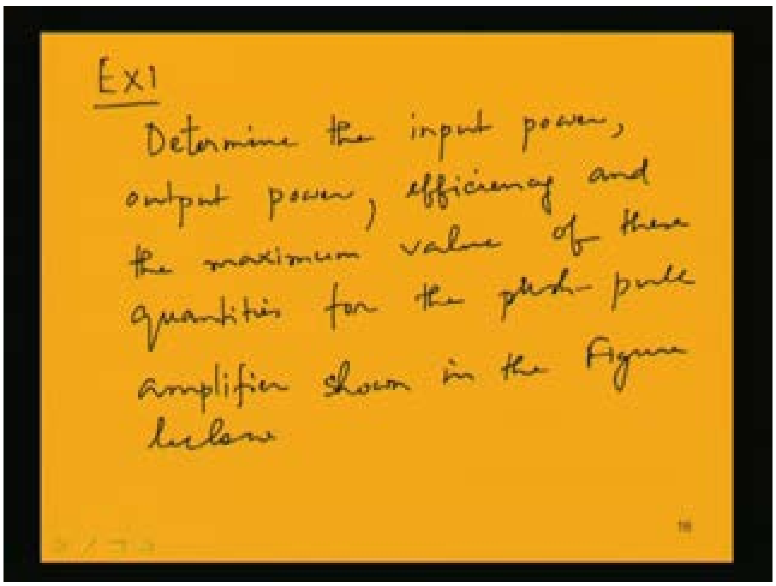

Let us do one example to determine the input power, output power, efficiency and the maximum value of these quantities, for the push pull amplifier shown in the figure below. We have to find out the input and output power, efficiency and the maximum values of this input and output power for a push pull amplifier, which is shown here.

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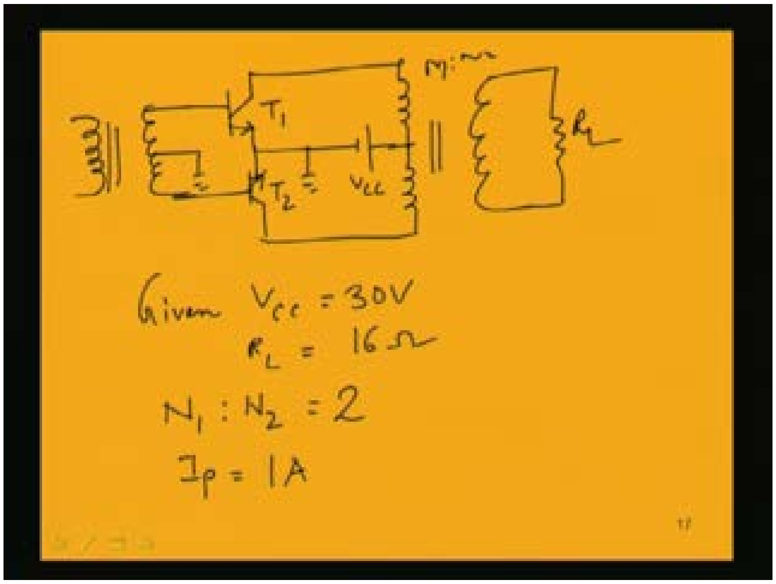

It is a center tap transformer. Actually upper half and lower half are having same number of turns. It is having these transistors and we are having a source like this and at the output side we are having the load R_L. These are the transistors T_1 and T_2. This is the source V_{CC} and this is N_1 is to N_2, transformer turns ratio. You are given that the voltage V_{CC} is equal to 30 volt, this R_L is equal to 16 ohm and the turns ratio between N_1 and N_2, N_1 being the primary winding and N_2 being the secondary winding, is 2 and the peak value of the current is 1 ampere. This is the data given to you.

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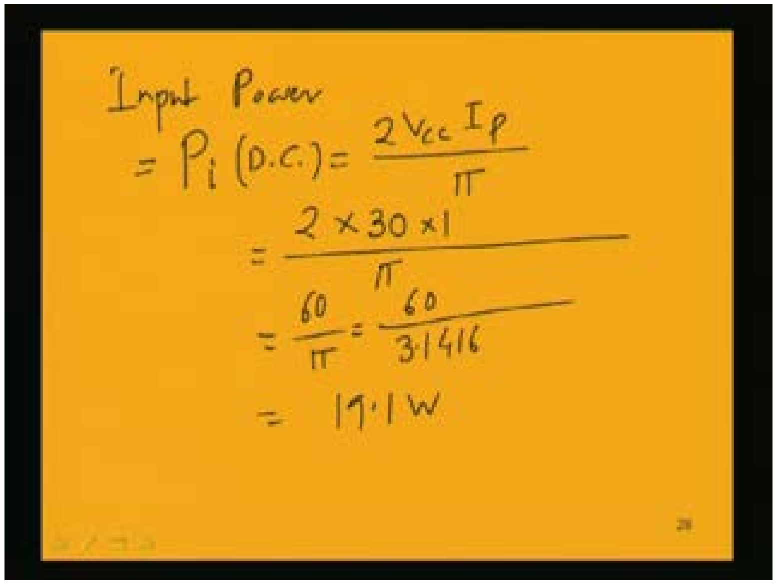

Now if we want to find out what is the input power, we know that input power, say P_i D.C is equal to 2 times V_{CC} into I_P by pi. We substitute these values V_{CC} is equal to 30 volt; peak value of the current which flows in the circuit is given as 1 ampere. This denominator is only having pi. So we get 60 by pi, this much watts and if we calculate 60 by 3.1416 that value will be equal to 19.1 watts.

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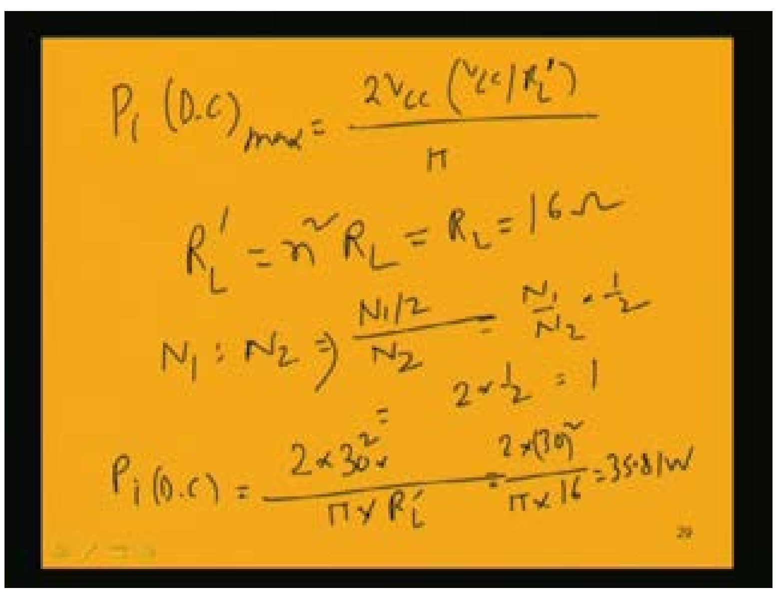

This is the DC input power. If we want to find out what is the DC input maximum then we will put down the I_P maximum value that it can have which is V_{CC} by R_L dash. R_L

dash is the resistance in the secondary; that is the load resistance transferred to the primary side which is given by n square into R_L. Here we are given N_1 is to N_2. This N_1 and N_2 is the ratio between the total primary winding and secondary winding. We have to see this. This N_1 is total primary winding and this is secondary. N_1 is to N_2 for a particular transistor or for a particular conduction we will have to find out. So, that is N_1 by 2 by N_2. That will be N_1 by 2 means N_1 is to N_2 we are given. But we will have to find out N_1 by 2 is to N_2 and if we want to find out, it will be N_1 is to N_2 into half and N_1 is to N_2 is given as 2; so, 2 into half that means 1. R_L dash and R_L are equal and what is the value of R_L? It is 16 ohm.

Now the P_i D.C can be found out to be just by substituting this 2 into 30 square V_{CC} into V_{CC} will be V_{CC} square and divided by R_L dash into pi. So 2 into 30 square divided by pi into R_L dash is 16. If we calculate this value, it is 35.81 watts.

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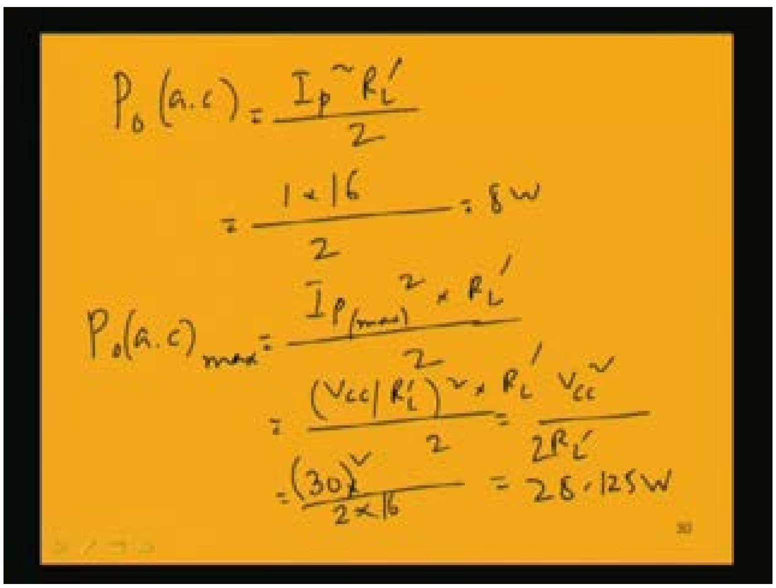

These are the DC input values and maximum value so what will be the AC output that also can be found out. Output power which is I_P square R_L dash by 2; I_P is 1, R_L dash is R_L which is 16 by 2. That means 8 watts and output power maximum can also be found out. The maximum value of this I_P can be found out which is nothing but V_{CC} by R_L dash whole square into R_L dash by 2. It boils down to V_{CC} square by R_L dash and R_L dash - one will go; so, R_L dash into 2. Putting these values 30 square divided by 2 into R_L dash; R_L dash is 16. This gives the value of 28.125 watts.

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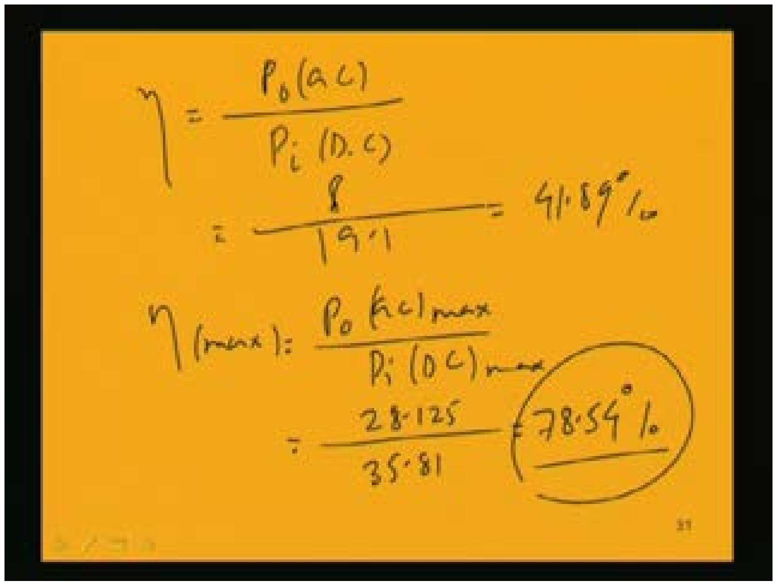

This we have got. Now, we can find out the efficiency P_o A.C by P_i D.C. P_o A.C value is 8 watts and P_i D.C value is equal to, earlier we have found, 19.1. This value will be 8 by 19.1 and that is equal to 41.89% and maximum efficiency if we find P_o A.C maximum by P_i D.C maximum and these values are 28.125 and 35.81. So, that gives 78.54, which is the typical maximum efficiency value. It also has been verified that this value is the maximum value it can have.

In this class today we discussed about two types of power amplifiers. One is the transformer couple power amplifiers which are generally used for audio applications which operates in class A mode of operation. But it is using a transformer to couple the load and second class of power amplifier that we discussed was a push pull amplifier which operates in class B operation and it is having a higher efficiency than class A power amplifier. It has class B operation in each of the transistor that is being operated because we are having two transistors and we are combining the operation of the two transistors in push pull amplifier. Out of all these amplifiers which we discussed till now we have got that efficiency is highest for the last one that we discussed today which is the push pull amplifier and we will observe later other type of amplifier like class AB also we will study later.