Basic Electronics
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Module - 5
Power Circuits and Systems
Lecture - 1
Large Signal Amplifiers

Earlier in last class we discussed about small signal amplifiers. These amplifiers are used to amplify a weak signal and actually what is the procedure for amplifying signals for practical use is that we have a number of stages for amplifiers connected in series. Initially we have to amplify a weak signal whose small voltage will be amplified and this output voltage will be again amplified by using other stages in between and finally what will be driven by this output voltage is that practically we have to use number of devices like loudspeakers, cathode ray tubes, etc., but these require a large amount of power to drive them. So, the amplification which we have done using the small signal amplifiers is not enough to drive these devices because they require large amount of power.

These small signal amplifiers which are typically used for voltage amplification, they are in the initial or intermediate stages of the whole amplification but at the final stage we require power amplifiers. These power amplifiers are basically large signal amplifiers which can handle large amount of power and this power is finally used for driving the devices like loudspeakers, etc. So, we have to know about the large signal amplification. That is the topic we are going to take up today.

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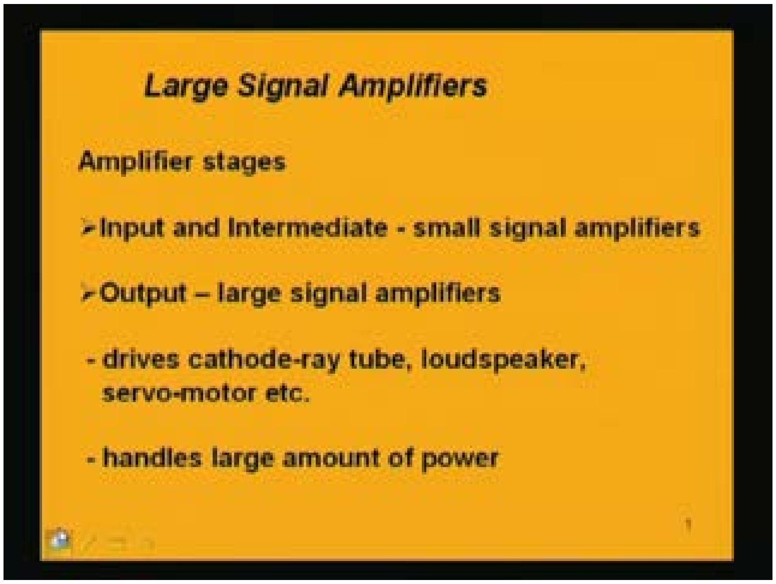

The devices like cathode ray tubes, loudspeakers, servo-motors, etc., they require large power to drive them and that is why we have to use a large signal amplifier.

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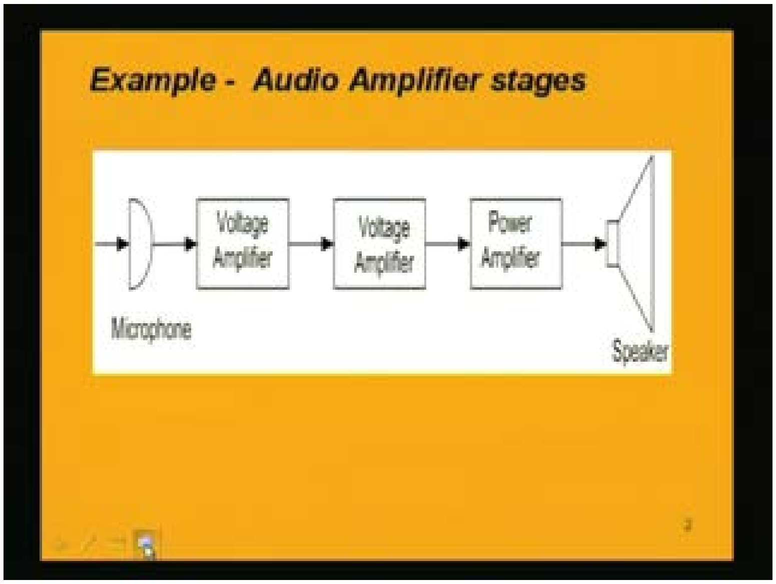

As the large signal is the name that is used to indicate that the signal which is handled will have a high magnitude. That means the amplifier which is the large signal amplifier will use currents or voltages which are higher in magnitude. Earlier we discussed the amplifiers which were linear because we were using a small signal so that the amplifier is still in the linear operation range. Now we will be using large signal amplifiers and that is why the transistor which is used in the amplifier must be power transistor. That means this transistor is a special type of transistor which can handle large amount of powering watts. The power transistor has to be used to handle such high power which is used in the large signal amplifier or power amplifier.

We now discuss or see an audio amplifier having the different stages. We see that the final device which we will be using is a speaker that is loudspeaker. But initially we give the audio signal to a microphone. Microphone will convert an audio signal to an electrical signal and that electrical signal will be first amplified. That means the voltage of this signal will be amplified by this voltage amplifier. This is a small signal amplifier because the microphone produces the voltage of order of millivolt only so that has to be first of all amplified to have a higher magnitude of the voltage. One voltage amplifier may not be sufficient. So, we will use number of voltage amplifiers in series. That is why here for example two voltage amplifiers in cascade are shown.

After voltage being amplified, the final stage is having a power amplifier. This amplifier will be used finally whose output will be given to the speaker or the loudspeaker because loudspeaker requires a high power to drive it. At the last stage, the amplifier which is being used is a power amplifier or a large scale amplifier. So, that amplifier has a higher amount of voltage and current because the multiplication of voltage and current gives you the power. We have in that amplifier a power transistor. If we typically consider a transistor amplifier, that will use a power transistor which can handle a large amount of power or dissipate a large amount of power.

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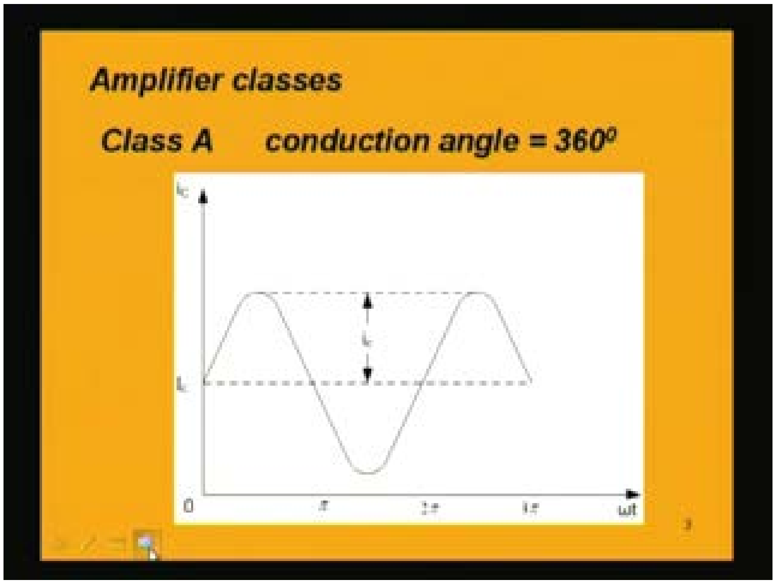

The power amplifier which is used is of different types depending upon the time for which the amplifier operates, means the time of conduction of current, the amplifiers can be divided into four types. These are class A, class B, class AB and class C amplifiers. The conduction angle that is the time or the angle for which the collector current will be flowing that differentiates between the different types of the power amplifier. For example in class A amplifier the conduction angle is 360 degree. If we look into the collector current then for the whole 360 degree angle, the current will flow. At no point there will be any portion where the current is zero. We can see that the whole cycle will be there from 0 to 2 pi or 0 to 360 degree and this is a typical linear amplifier which we earlier discussed when discussing the small signal amplifier.

If we recall when discussing about the small signal amplifiers in the linear operation range, if we bias the transistor properly then we get the output collector current flowing throughout the circle from 0 to 360 degree and at no point of time there was any cut off or a saturation occurring; that idea is still applicable in the class A amplifier. Here it is linearly operating. That is why we can see that the collector current is flowing for the whole cycle from 0 to 360 degree and that is because the DC collector current or the quiescent collector current is positioned in a very proper way so that during the operation at no time the collector current either goes to saturation or cut off. Here we can see that the DC collector current which is the Q point is properly positioned so that during positive and negative half cycle, the collector current rises and falls but it does not enter into cut off or the saturation. This is a typical linear operation of amplifier and this is the class A type of amplifier.

Apart from this class A type of amplifier there are other types of power amplifiers also which are used because in the class A type of amplifier what happens is that there is a huge power loss because of the DC collector current flowing throughout the cycle and we will discuss later how the power loss can be minimized by using other type of amplifiers than class A amplifier.

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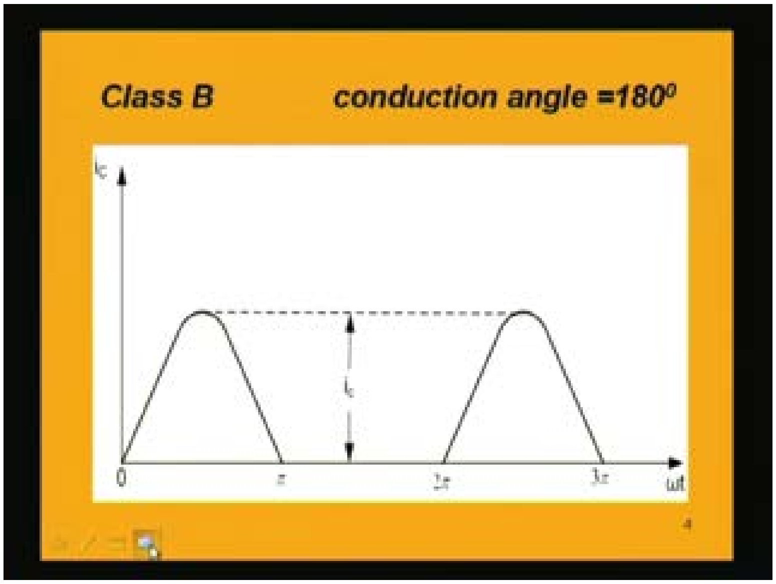

In class B amplifier what happens is that during the negative portion of the cycle, collector current is not flowing. Here we can see that only in one half cycle from 0 to 180 degree, the collector current flows. This is class B amplifier and here the conduction angle is exactly 180 degree. From 0 to pi the conduction takes place and from pi to 2 pi the conduction does not take place. This is a typical example of an amplifier where you are locating basically the quiescent current at the cut off. That is if we are placing the quiescent current here then in the negative half cycle we are entering the cut off region. So, there cannot be any current flow.

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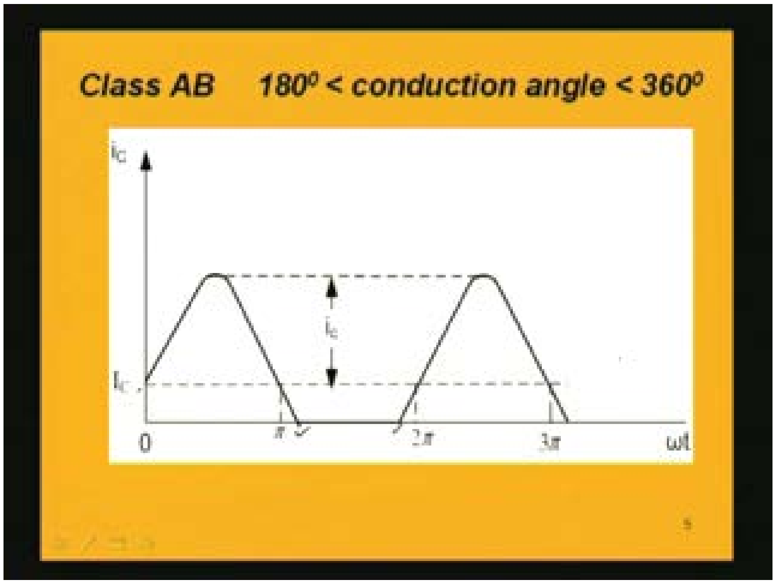

Another type of amplifier is class AB type of amplifier. In class AB type of amplifier, the conduction takes place which is greater than 180 degree but less than 360 degree. Here you can see that in class AB amplifier, the collector current is flowing beyond this pi or if the conduction angle is greater than 180 degree there is current but not throughout from pi to 2 pi. That means it crosses this pi. Beyond pi also there is conduction but then it stops conducting and that is why the conduction angle is between pi and 2 pi. It is greater then pi but less than 2 pi. Here we can see that the DC collector current or the quiescent current, capital I capital C is placed here at this position and that is why during the positive half cycle we can see that the collector current is flowing. Again, it also flows when the angle is greater than pi but at this point the collector current enters into cut off. So, from this point to up to this point, this portion, the collector current is zero. Again it will be flowing and rising; so, this will continue.

Because of the position of the DC quiescent point or the DC collector current, the conduction is taking place in this fashion and that is why we get conduction up to an angle which is greater than 180 degree but it is less than 360 degree. That means this AB type of power amplifier is in between A and B. It is not A, because the conduction angle is not from 0 to 360 degree whole. Neither is it B, because in B type of power amplifier the conduction angle is 180 degree. But it is in between.

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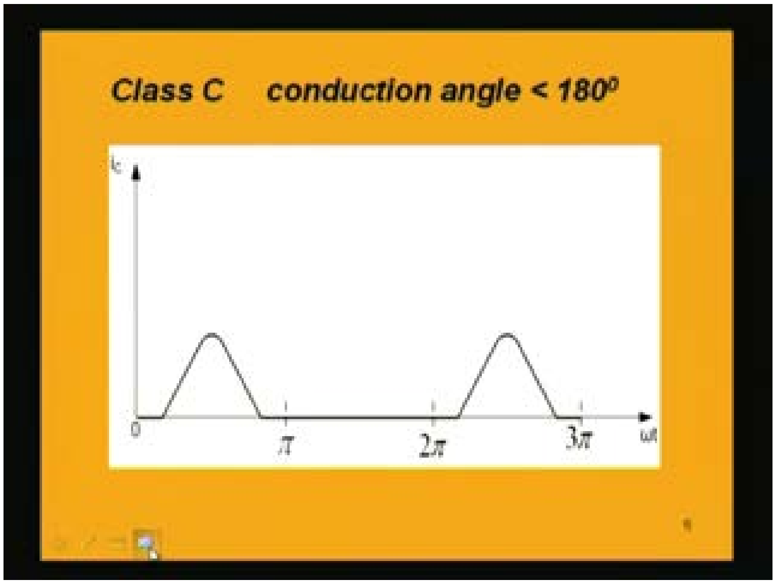

Another type of amplifier is there which is known as class C type of power amplifier. In this class C type of power amplifier, the conduction angle is even less than 180 degree. That means it is even less than the class B type. Here we can see that the collector current which is flowing is not even 180 degree or pi; for a lesser portion it is flowing and that means it is basically not flowing even for one half cycle of the whole cycle. That is only less than one half cycle the collector current is flowing. It is even worse than class B type of amplifier.

Broadly we are having these four types of power amplifiers class A, class B, class AB and class C depending upon the conduction angle that is for the time for which the collector current is flowing. That means whether it is flowing for the whole cycle from 0 to 360 degree or is it flowing for only one half cycle or is it flowing for a conduction angle between pi and 2 pi or even less than pi, we classify the power amplifier.

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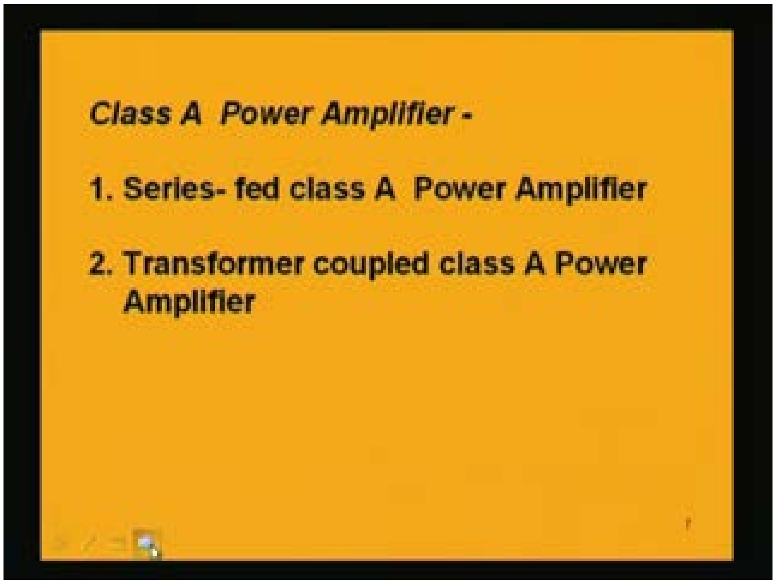

We will now discuss the amplifiers which are classified in these four ways one by one. Let us take for example class A type of power amplifier first. We will discuss the class A type of power amplifier first. The class A type of power amplifier can be classified into two broad classes. One is the series-fed class A power amplifier and the other is the transformer coupled class A power amplifier. Depending upon what device is used in the amplifier, these two classes are made. For example in series-fed class A power amplifier, we will observe that we use a transistor amplifier that was used in small signal amplifiers using BJT. Similar type of circuits will be used for class A power amplifier where transistors are used and in transformer coupled we will find that a transformer is used for coupling the device to the amplifier. That means at the output stage we will feed the output power through a transformer to the device which we are going to use.

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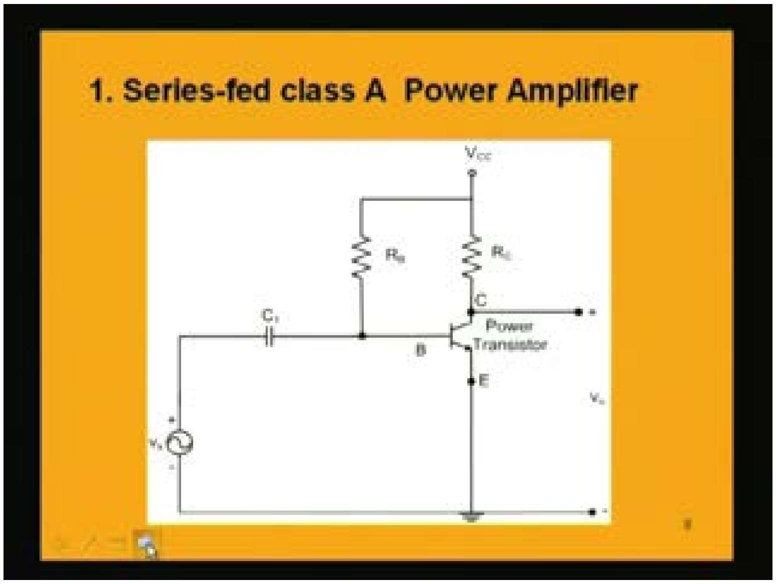

In series-fed class A power amplifier, the transistor which will be used will be a power transistor which can handle large amount of power and there are facilities for handling large amount of power in such type of transistors and the circuit which is used we can see that this is a familiar fixed bias circuit where biasing is done through a resistance R_B and this type of fixed bias circuit earlier we got. This is an example of a fixed bias circuit. There can be potential divider biasing scheme also but we are taking here for example a simple series-fed class A power amplifier where a fixed bias is used and the power transistor is used for amplification. The signal which is to be amplified is V_s and there is this capacitance C_1 to couple the voltage V_s. We all know the reason for the capacitance C_1 being used. It is a capacitor to block the DC component because capacitor is like an open circuit to DC and the output is say V_0 that is going to be used finally.

We now consider this circuit and try to analyze the efficiency of this power amplifier. By efficiency we mean the ratio between the output power to input power. This power amplifier is drawing power from where? It is using a V_{CC} that is the DC voltage is used and the power being drawn is the DC power which is supplied through this V_{CC} and the power which is drawn is V_{CC} into I_C where V_{CC} is the DC supply and I_C is the DC collector current. This much amount of power is used or it is being supplied and to get an idea about how much efficient is this power amplifier that means how much output it is producing that we must know. Then we can get the efficiency of the power amplifier by finding the ratio between the output AC power, which it is developing to the input DC power.

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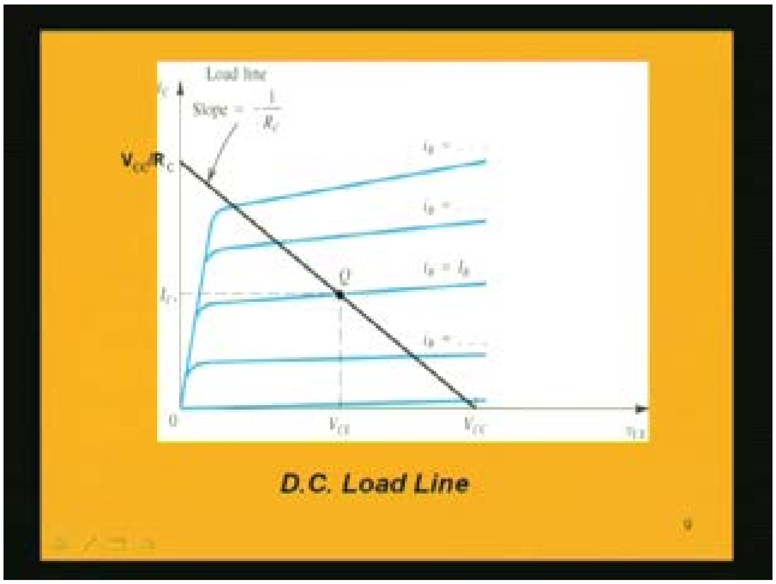

In this circuit if we look into the characteristic curves and the load line, which we already know how to draw the load line, the extreme conditions of the voltage V_{CE} and the current i_C those two points have to be connected on the characteristic; that is the output characteristic of the transistor. We get a load line which is defined by these two extreme points and this load line if we draw on the characteristic curves that is the output characteristic that is the characteristic between the output voltage and output current V_{CE} and i_C then we know the intersecting points of the load line with the characteristic curves where the characteristic is that one which is giving you the DC base current. We recall that the Q point can be determined by finding out the point where the load line is intersecting the output characteristic curve for that particular value of the DC base current.

In this plot we are having the output characteristics of this transistor amplifier and it is the general characteristic. We are not defining exact values because it depends on what V_{CC} you are using? What is the resistance, R_C, you are using? Even without defining all those values we are just plotting the general characteristic curve and here these are the two points V_{CC} and V_{CC} by R_C these are the two extreme points. Joining these we get this DC load line which has a slope of 1 by R_C but it is a negative slope. So minus 1 by R_C is the slope of this DC load line and the point where it is intersecting the particular characteristic curve for the value of i_B, because this i_B is the DC base current flowing in the circuit, this gives the Q point. This Q point is giving the DC values of the collector to emitter voltage V_{CE} and collector current I_C. This is the load line for this particular transistor amplifier which is in class A type of operation.

Here one thing to notice is that the quiescent point, Q is positioned almost at the middle of the load line and that is required condition for class A operation. If Q is not located around the middle of the load line and suppose it is shifted either to the saturation side or to the cut off side then we will not be getting a class A type of operation because in power amplifiers, the base current will be high. It is not in the order of micro ampere range as we earlier got for the small signal amplifiers; it may be in the order of milli ampere range. The swing of this base current will be high and that is why corresponding values of the collector current will also be high. In order to get a symmetrical swing of the collector current, we must position the Q point around the middle of the load line. That is the foremost condition for the class A operation or linear operation.

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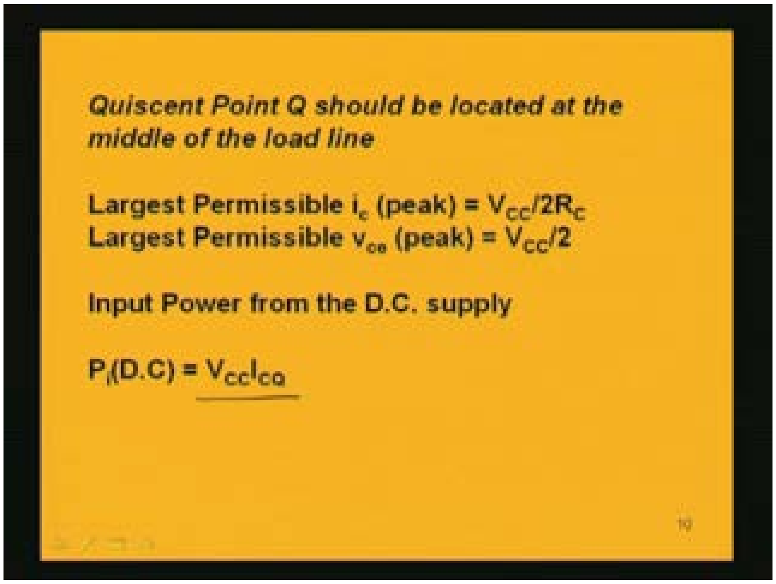

The largest possible or permissible value of the collector current that is the peak value of the collector current, if we see in the load line again, the collector current can swing from the DC collector current to a value given by the value of the maximum. That can be found out because if we consider the maximum value of this V_{CE} that is V_{CC}, the Q point is located here, in the collector current we will be getting from the DC value a swing like this.

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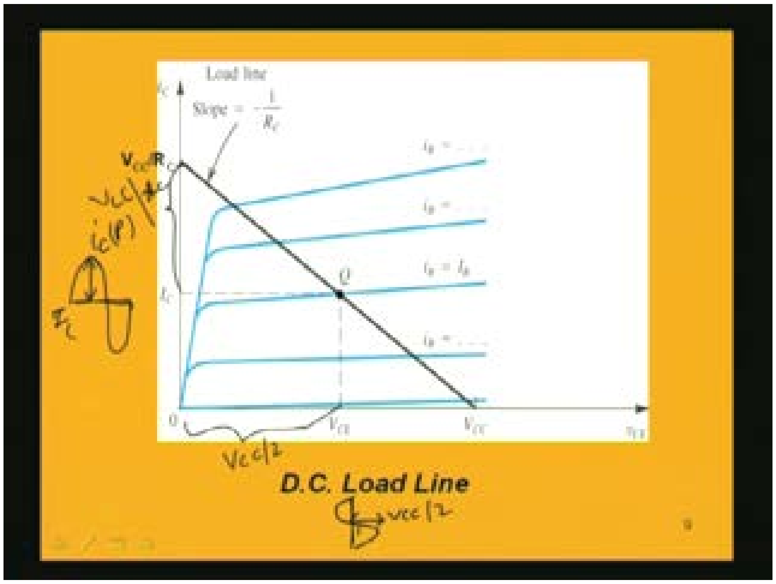

This is the DC collector current. This is the peak value of the i_c peak and this will be the maximum allowable peak of the collector current and that will be how much value? This is half of V_{CC}. This point is V_{CC} by 2. This is V_{CC} by 2. This whole is V_{CC}. So, this is V_{CC} by 2, this is V_{CC} by 2 and so the maximum it can go on either side from the DC value is V_{CC} by 2 R_C. That is we get this swing and that should be V_{CC} by 2 R_C and similarly towards the lower side also V_{CC} by $2R_C$ because the total value is V_{CC} by R_C.

The allowable peak of the collector current in class A operation will be V_{CC} by 2 R_C and the largest permissible collector to emitter voltage peak is V_{CC} by 2 and that is very evident here. The largest swing that the V_{CC} can have will be like this. This value if you want to find out, this will be V_{CC} by 2 and we know that the input DC power is V_{CC} into I_C that is the DC collector current and this is denoted by V_{CC} into I_{CQ}.

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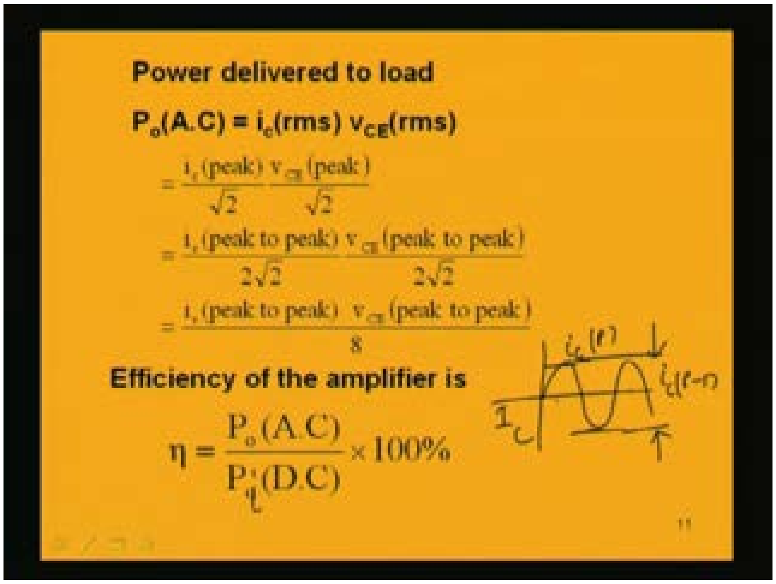

The power which will be delivered to the load that means the output power, we have to find out; the output power is AC. In order to find out the output power, we have to find out the power which is the multiplication or the product of the current and voltage and the current is the collector current i_c. But that value is rms value, root mean square value, we will be taking. Because we are finding out the output power that is AC, so the value that we should consider is the root mean square value and that value is nothing but the peak value by root 2. So, i_c rms into V_{CE} rms this product will give you the output power, the output AC power and that we are finding out by finding the rms value by i_c peak by root 2 and the V_{CE} rms value can be obtained by V_{CE} peak by root 2. We know what is i_c peak? That is the whole swing divided by 2.

The whole swing the i_c has is, this is the I_C capital and it will have this type of wave form. This is i_c peak and this is i_c negative peak. The whole is the i_c. This value if we consider this is i_c peak to peak. i_c peak to peak is the whole swing of the collector current and that whole swing peak to peak divided by 2 will give you the one peak of the collector current and that we are using here i_c peak to peak by 2. That is the one peak value divided by root 2 and similarly V_{CE} peak to peak by 2 divided by root 2 that is the rms value of the V_{CE} and that gives us i_c peak to peak into V_{CE} peak to peak by 8.

In order to find out the efficiency of the power amplifier in class A operation, we find out the ratio between the output power and the DC input because we are feeding a DC input and how much power at the output we are getting that ratio between the output to input will give you the efficiency. We find out this P_o AC by P_{in} DC, into 100%; by substituting these values, we can find out the efficiency; that we will find out.

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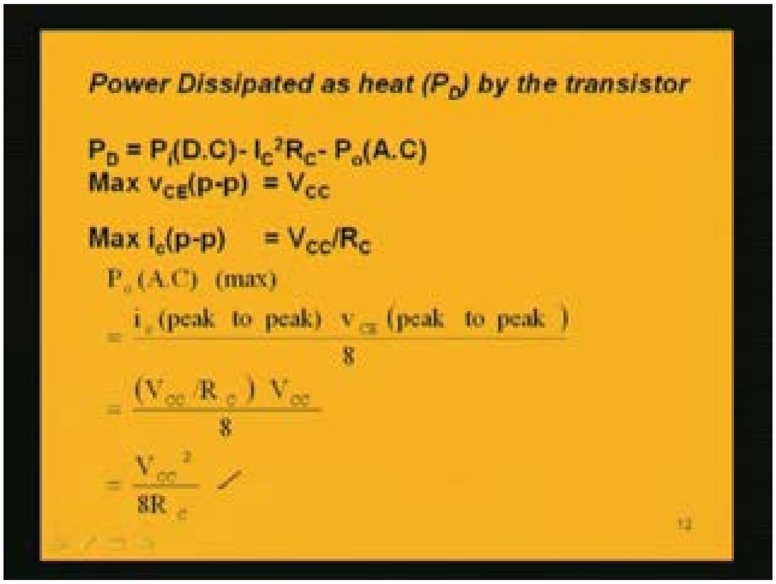

But one thing we must also consider here. One important aspect is that how much power is dissipated by the transistor. Because we are feeding an input power which is V_{CC} into I_CQ that is the DC values and out of this input power we are getting a portion at the output as AC. That is the output power in AC which is the i_c rms into V_{CE} rms. Now some portion of the input power is also wasted. The portions which are wasted one due to the collector resistance R_C. Their, there will be a power wastage because I_C square into R_C. I_C square means square of the DC collector current; because the DC collector current is always flowing that will cause a power loss because a power is absorbed by the resistance in the collector.

So I_C square R_C will be that power absorbed by this resistance R_C and the power which is dissipated by the transistor as heat if you want to find out, we can find it out. P_D is the power dissipated as heat which is dissipated or wasted by the transistor as heat. Handling of large amount of power means it will cause considerable heat. That is the wastage of power and that can be found out subtracting the output power and the power absorbed by this R_C from the input. That is P input DC minus I_C square R_C minus P output AC. That will give you the power dissipated by the transistor as heat.

Now if we consider the maximum collector to emitter voltage swing, peak to peak maximum swing can be V_{CC}.

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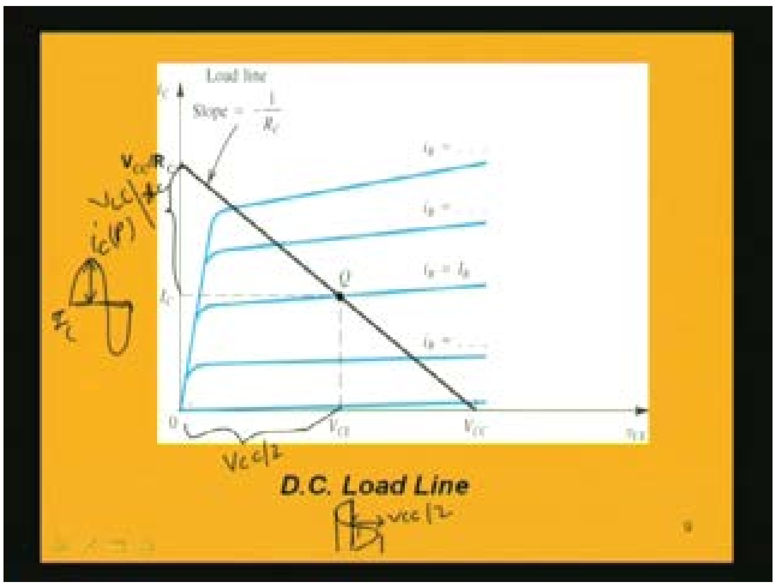

That is obvious here in this plot. We see that as the DC point or the quiescent point is located at the middle, the maximum swing can be only up to V_{CC}. That means zero to V_{CC} can be the swing of V_{CE}. It can swing from DC value to this point and then it can come in the negative half cycle after this point. So, the total peak to peak swing, this peak to peak swing, if we consider that is V_{CC} and peak to peak swing of the collector current that if we consider that will be V_{CC} by R_C. If we consider the maximum output power, considering these maximum cases of the peak to peak swings then P_o AC maximum can be i_c peak to peak into V_{CE} peak to peak by 8 because we have seen already that the output power is i_c peak to peak into V_{CE} peak to peak by 8 and what is this i_c peak to peak? It is V_{CC} by R_C and V_{CE} peak to peak is V_{CC} divided by 8. We get V_{CC} square by 8 R_C is the power output; that is the maximum power output possible.

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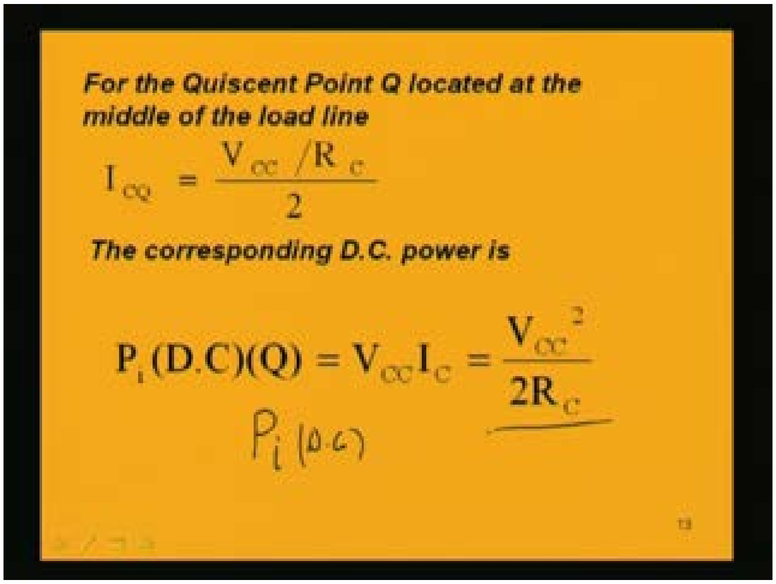

The efficiency of this amplifier can be found out by dividing this output power by input power. What is input power? P_i; it is a DC power that is V_{CC} into I_C and what is the I_C at the quiescent point. This quiescent point has I_C, which is equal to V_{CC} by $2R_C$. Putting it here V_{CC} by $2R_C$ is the collector current, DC collector current; that means the current at the quiescent point. We get the input power P input DC. This is a DC power, mind it; we are feeding it by means of this battery or the source which is the DC source. This is V_{CC}. P input DC is V_{CC} into I_C. Substituting I_C by V_{CC} by 2 R_C, we get the expression as V_{CC} square by 2 R_C. Now we know what is the output power and we know what is the input power? So, we can find out the efficiency.

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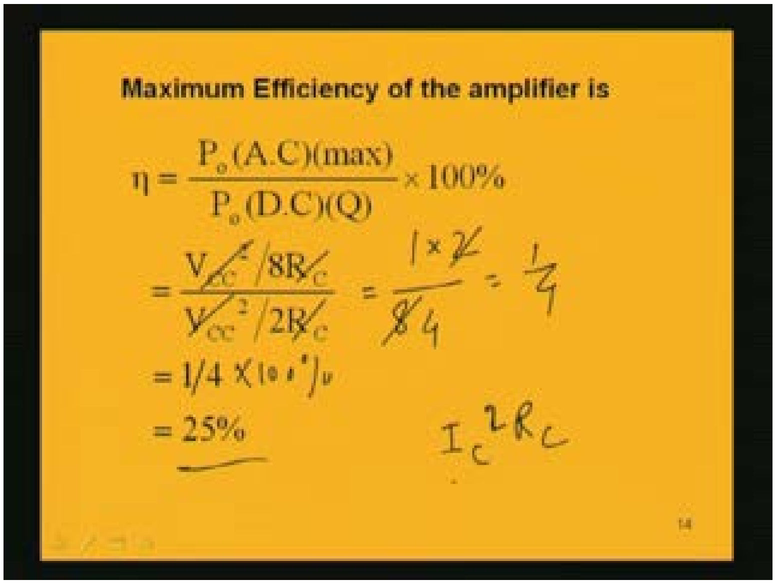

Maximum efficiency of this power amplifier is given by V_{CC} square by 8 R_C by V_{CC} square by 2 R_C, just substituting the values for output power and input power multiplying by 100%, because efficiency is always given as percentage value, we get finally 1 by 4. Because this cancels, only remaining is 1 by 8 and this 2 will go up, so 1 by 4 means in 100% it will be 25%. From this value of efficiency, what we can conclude is that efficiency of this class A power amplifier is very low; it is only 25%. You are feeding a DC power and only 25% of this DC power we are getting as the output. So much wastage is now occurring in the amplifier.

One wastage, which is very obvious, is the heat. The heat is generated but that is not very easy to avoid. Another point to be noted in this type of class A amplifier is that I_C square R_C, this power loss is also a wastage of power because of the flowing of the DC current always or throughout the operation a constant DC current I_C is always flowing in this transistor for the whole cycle. I_C square R_C is the loss that is occurring in the resistance which is connected in the collector of this transistor amplifier.

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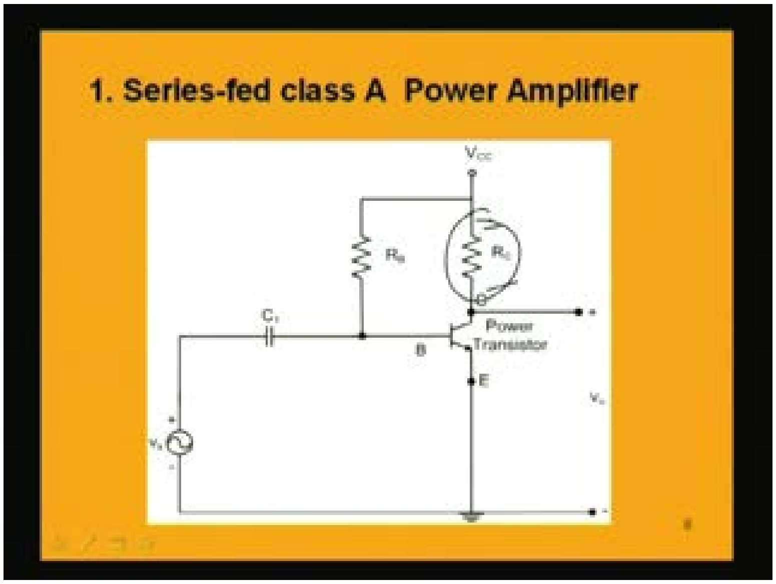

Here this R_C is causing a power wastage and we have to devise some means to reduce or decrease that power loss which is occurring in the R_C. In order to increase the efficiency of the amplifier, class A type of amplifier what is done is that transformer coupled amplifier is used. Because of much wastage of power occurring in this R_C which is connected in the collector, what is done is that a transformer is used to couple the output device to the amplifier. Instead of R_C what we will have is an inductive coil and that will be in the primary side and the secondary side will have the load or the device which is connected. Instead of this R_C next we will have a transformer winding in this and that will reduce the loss occurring by this resistance; that we will discuss next.

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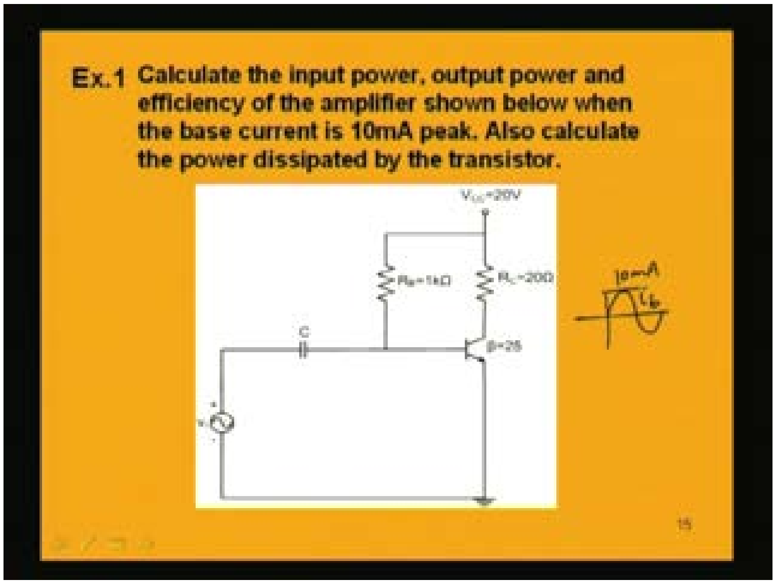

Before going to transformer coupled amplifier now let us try one example dealing with this class A series-fed type of power amplifier. In this example we are having this class A series-fed power amplifier and the value of the beta or the transistor gain is 25. R_B is equal to 1 k ohm, R_C is equal to 20 ohm. V_{CC} the supply voltage is 20 volt. Now you have to calculate the input power, output power and efficiency of the amplifier when the base current is 10 milli ampere peak. Because of the supply V_i, a base current, AC current will flow and that has a peak value of 10 milli ampere. This peak is 10 milli ampere. This is the small i_b and also calculate the power dissipated by the transistor.

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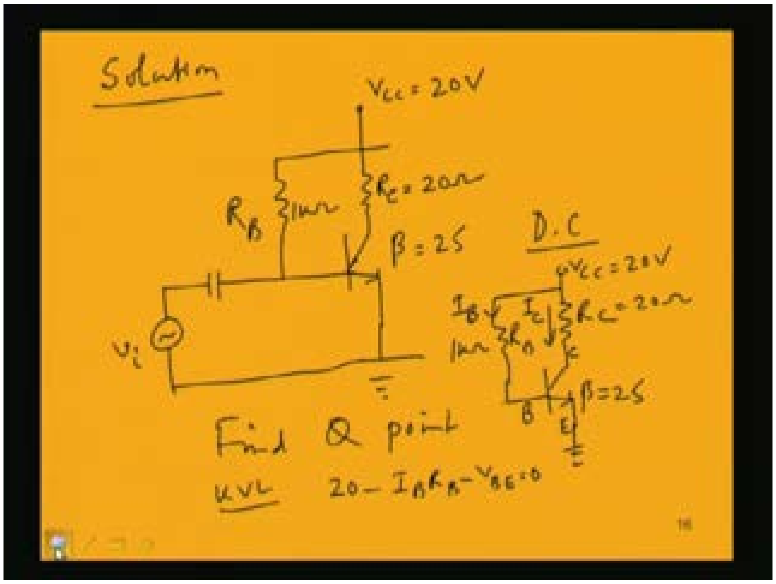

In order to solve this, let us to the analysis. Draw this circuit again. This is a fixed bias circuit. It is a simple circuit using only a fixed resistance R_B in the base and that value is 1 kilo ohm. V_{CC} is given as 20 volt, R_C is 20 ohm and ammeter is directly connected to ground and we have a DC blocking capacitor and the input say V_i; a signal Vi is used. Beta value of this transistor is 25. In this circuit, first we have to find out the Q point because we have to know the DC power input. In order to know the Q point, we will consider only the DC circuit because this capacitor will be open circuiting in DC.

So, under DC condition we will have only these values R_B, R_C; this is the transistor. This portion will be open. So, there will not be any use for this. We are just ignoring this portion and this is the circuit. Here V_{CC} is equal to 20 volt. R_C is equal to 20 ohm, R_B is 1 k ohm. The current which will flow is capital I capital C; in the DC condition we are considering and this current is capital I capital B, base current DC. In order to know this DC base current what we have to do is that we consider the circuit and we apply Kirchhoff’s voltage low.

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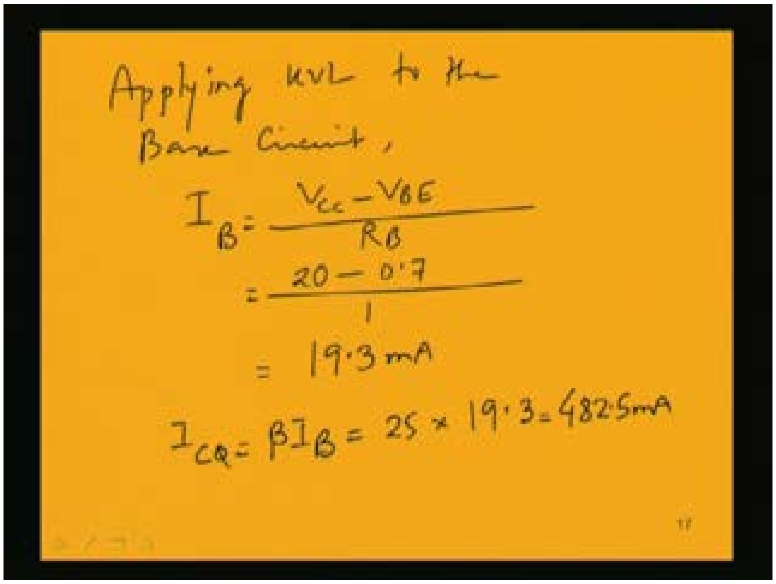

Applying KVL to the base circuit what we get? If we apply KVL, V_{CC} minus I_B into R_B minus V_{BE} this drop we have to remember. This is the base point, this is the emitter and this is the collector. This V_{BE} as usual we will be taking 0.7 volt. Even though it is not specified we will be considering 0.7 volt drop for this transistor from B to E. Putting these values, this is nothing but 20 minus I_BR_B minus V_{BE} is equal to 0. This is the KVL, Kirchhoff's voltage law applied to the base circuit. What will be base current? Base current is equal to V_{CC} minus V_{BE} divided by R_B. Substituting the values V_{CC} is equal to 20 and the value of V_{BE} is 0.7, R_B for this circuit is 1 k and we are keeping kilo ohm. So, the result will be in milli amperes; that unit you have to remember. That is 20 minus 0.7 is 19.3. So 19.3 milli ampere; this is the DC base current flowing in this circuit.

If I_B is equal to 19.3 milli ampere flowing, what is the DC collector current I_{CQ}? That can be found out because we know the value of beta. Beta times of base current is the collector current. Beta value is 25; 25 into 19.3, this many milli amperes will flow as the DC collector current. If we do this multiplication we get a value of 482.5 milli ampere. That means it is 0.4825 ampere. So, almost 0.5 ampere collector current is flowing; DC collector current.

We can see or we can observe that the order of the current flowing in the base also is 19.3 milli amperes. It is not in micro ampere as earlier we were getting. That is the large signal. Why it is called a large signal? It is a large current. In the order of milli ampere it is flowing in the base and in the collector in the order of ampere and you will find that the voltages, collector to emitter voltage which is obtained is in the order of volts. Volt into ampere gives watts. The power is in the order of watts. It is handling such a large amount of power.

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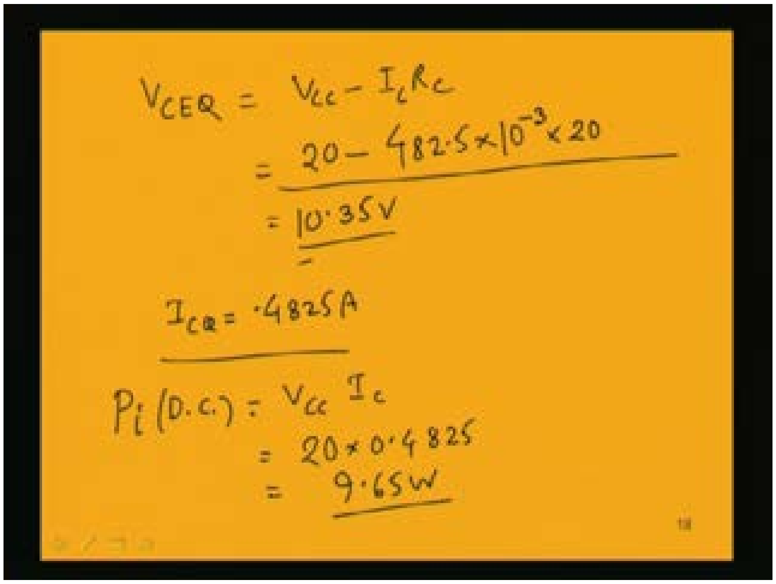

To complete this, what will be now the DC value of this collector to emitter voltage? That means we need to find out the quiescent point. What is the V_{CEQ}? This is V_{CE} (Refer Slide Time: 48:19). That is V_{CC} minus $I_C R_C$ will give you the V_{CE}. So, V_{CEQ} is equal to V_{CC} minus $I_C R_C$. V_{CC} is 20 volt, I_C we have found to be 482.5 milli ampere and R_C value is 20 ohm. We keep it in order of ampere; ampere into ohm will give you volt; multiplied by 10 to the power minus 3. So, this many ampere and 20 ohm is the resistance R_C. The calculation of this will give the value of V_{CEQ} to be 10.35 volt. You see that this is a very high value of voltage and the high value of current, DC value of I_C flowing is 0.4825 ampere.

The DC power we know now. What will be the DC power input? Voltage into current will give you the input power. We again immediately find out what is the P_i DC? It is V_{CC} I_C. V_{CC} is 20 volt, I_C is 0.4825 ampere. This will give you in watts and that value is 9.65. If I multiply it, we get this value. 9.65 watt is the input power you are feeding into this amplifier. Now what about the output?

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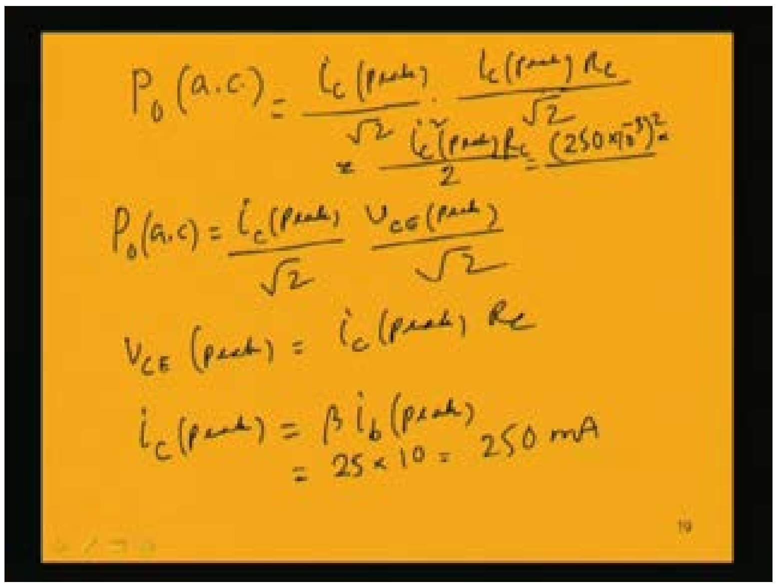

In order to know the output power P_o ac output, we know that it is the RMS value we are finding out. Since we are handling AC, we must consider RMS value. That is the RMS value of the collector current is I_C peak by root 2 and RMS value of the collector to emitter voltage V_{CE} and V_{CE} is nothing but if you look into this circuit (Refer Slide Time: 50:55), this is the V_{CE}. V_{CE} is small i_c into R_C. That is the collector to emitter voltage because we are considering only the AC. We apply Kirchhoff's voltage law, V_{CC} minus $I_C R_C$ minus V_{CE} equal to 0. But this V_{CC} is a DC value, so we will consider only the AC voltage. It is nothing but i_C into R_C and we will have to divide by root 2 because i_C peak into R_C will give you the peak value of the collector to emitter voltage.

We are basically using P_o (a.c) equal to the i_c peak by root 2 into V_{CE} peak by root 2 and V_{CE} peak is nothing but i_c peak into R_C. That is what we are using here. Therefore we need to know what is i_c peak? What is i_c peak? We know what is the value of the base current peak? That is given as 10 milli ampere multiplied by beta. That will give you the i_c peak. So, 25 into 10, 250 milli ampere is the peak value of the i_c current. If we know this, we can put it here. This is nothing but it is 2 in the denominator i_c peak square in the numerator multiplied by R_C. This will give you the value of the output power.

We now replace i_c peak by 250; so, 250, but this is milli ampere. So, we will convert to ampere by multiplying by 10 to the power minus 3 and R_C value we know it is 20 ohm. Now our units are in confirmative; we will get the output in watts.

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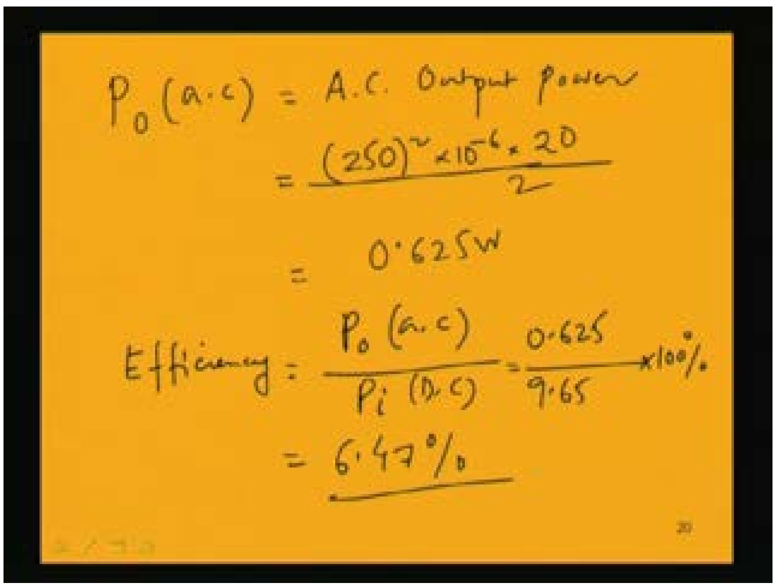

So, we get finally the P_o ac output power that is the AC output power. Finally we will get the values as 250 square into 10 to the power minus 6. Here you just look out; 250 square into 10 to the power of minus 6 into 20 divided by 2. Do this calculation; you should get a value of 0.625 watts. Now you see that we are getting an output power, which is only 0.625 watts but we were feeding an input which is the DC power 9.65 watt. This much of wastage is happening in the amplifier. If we find out the efficiency of this amplifier which is in class A operation that is P_o (a.c) by P_i (D.C), putting the value of output 0.625, input power is 9.65 and find it in percentage. So, it will be 6.47% only. This is only the efficiency. It is very very less; much of the wastage is happening in the transistor.

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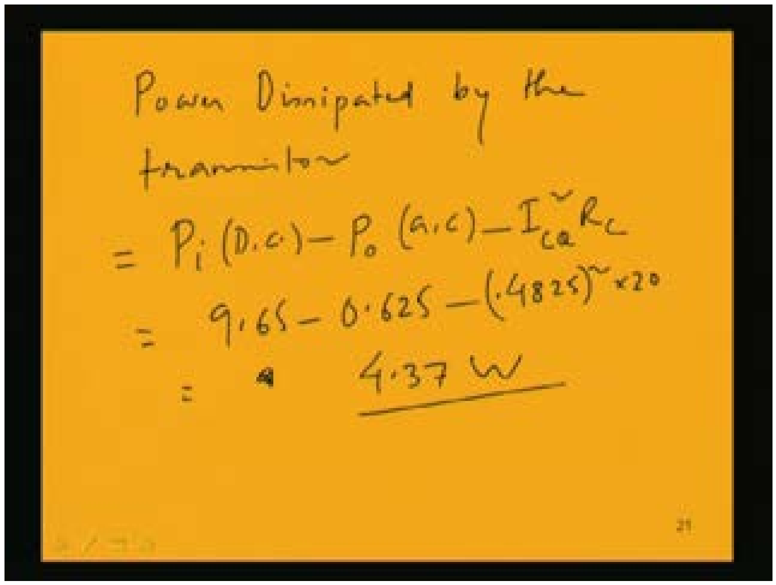

What is the power dissipated by the transistor? If we find out power dissipated by the transistor by subtracting the output power from the input power, we get the total power loss and from that power loss if we subtract the power absorbed by the R_C value that is i_c square R_C, then we get the power dissipated by the transistor as a heat. Power dissipated by the transistor equal to input, which is DC power minus output power, ac power minus the power which is dissipated in the R_C and that is I_{CQ} square R_C. Because if you look into this transistor circuit again, here the DC power is lost as I_C square into R_C. That is a loss which is actually causing the efficiency to be so low. Now DC input is 9.65. AC power, what we will get finally is 0.625 watts only and this if we find, this is 0.4825 square into 20. This value will come to 4.37 watts; you just check this value.

That means power dissipated by the transistor as heat is 4.37 watts and it is not a small value. Quite a high power is dissipated by the transistor and that is why in order to handle such high power wastage or the high heat generated these types of power transistors have a particular sinks which is there in transistor. The sinks are used for handling such high heat being generated by this power dissipation.

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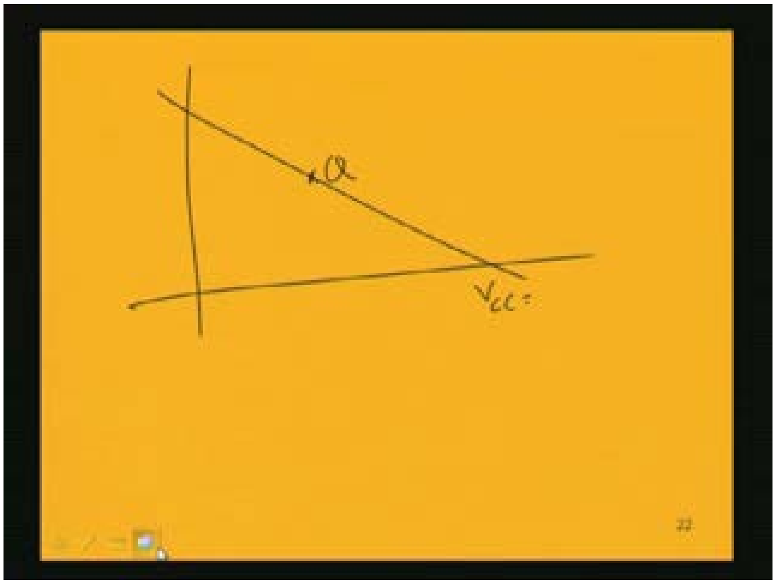

In this class A series-fed power amplifier what we have seen is that no doubt we are getting class A operation; that is the quiescent point is almost at the middle of the load line. We have found the quiescent point here

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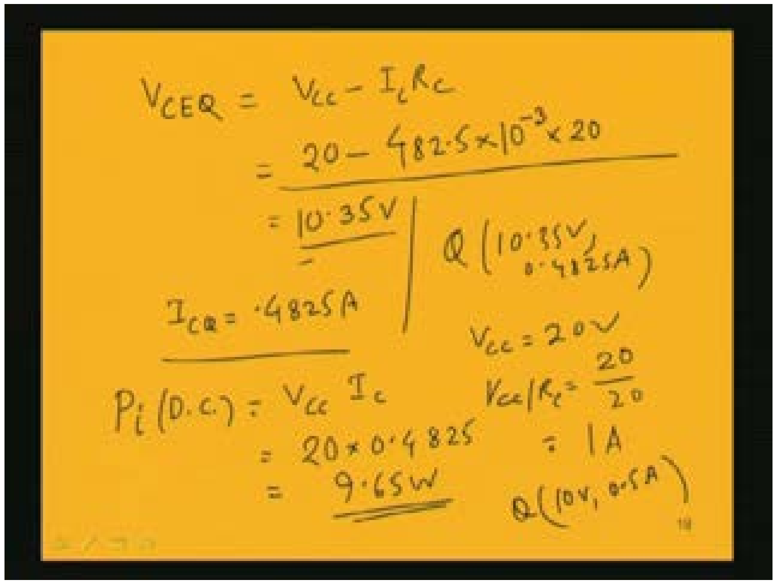

In this particular example we have a got a quiescent point given by 10.35 volt, 0.4825 ampere and we are using V_{CC} to be 20 volt and V_{CC} by R_C is equal to 20 by R_C is 20 that is 1 ampere.

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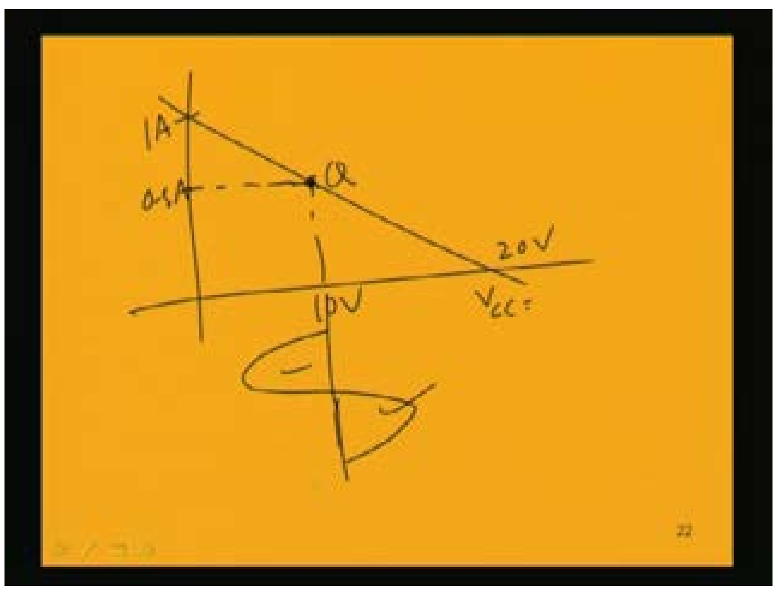

If we consider this Q point this is 1 ampere, this is 20 volt and the Q point is placed at 10.35; almost 10 volt and 0.5 ampere. This is Q roughly. What does it mean actually? We are getting the Q point around the middle of the load line. In this particular example we have now verified that the Q point is located at the middle of the load line. That means we are getting a symmetrical swing. These two halves equal. This drawing should be proper. The two halves of the swing are equal basically. This type of signal we are getting no doubt; we are getting a very fine symmetrical swing of the collector current as well as the V_{CE}. But where we are suffering using this type of class A power amplifier is that a huge amount of power is lost or efficiency of the power amplifier is very, very low.

In this case we are getting an efficiency of only 6%. So, a tremendous amount of power is lost which we are feeding. We are getting only a very small portion and that is not good. So, although the operation is linear, although we are getting very symmetrical swing of the collector as well as the collector to emitter voltage but the disadvantage of this type of power amplifier which is operating in class A operation is the low efficiency. Maximum efficiency can be only 25%; that we have seen. So, we have to go for other types of class A amplifier and in that type of class A amplifier we will not be using the resistance R_C in the collector. Instead, it will be using a transformer coupled power amplifier where the R_C will be replaced by a winding of the transformer.

In this class today, we have seen that the power amplification which is done by power amplifiers can have various operation characteristics like class A, class B, class AB and class C. Depending upon the position of the Q point or the quiescent point we get this different operations and one type of class A amplifier we have discussed today but that is series-fed class A amplifier but that was giving very, very low efficiency and large amount of power was wasted in this type of power amplifier. In the next classes we will discuss better types of class A power amplifiers and also we will discuss about the other types. Class A we are discussing but we will also discuss about the class B and the other types and how we can increase the efficiency of the class A amplifier that we will be taking up in the next classes.