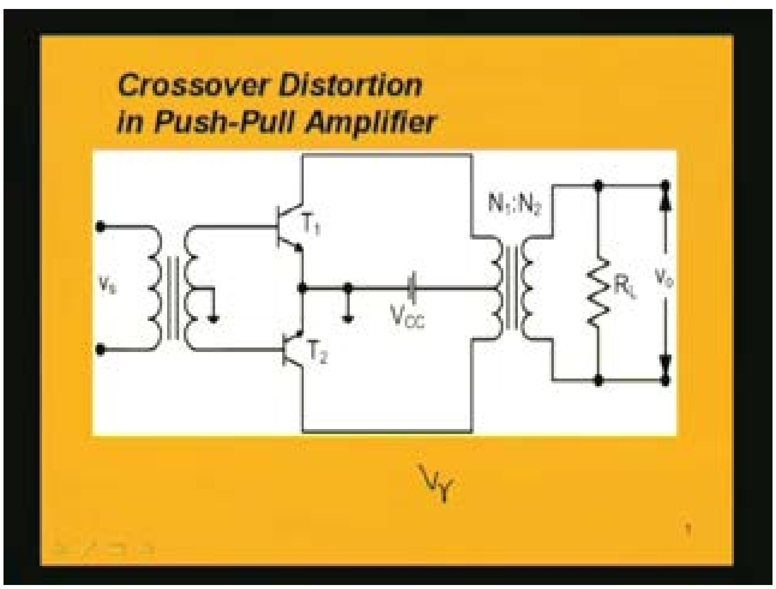
Basic Electronics
Prof. Dr. Chitralekha Mahanta
Department of Electronic and Communication Engineering
Indian Institute of Technology, Guwahati

Module -5
Power Circuits and System
Lecture - 3

Class AB Operations of Power Amplifier

In the last classes we discussed about some types of power amplifiers and these were class A and class B power amplifiers. Depending upon the conduction cycle, the class A or class B power amplifiers were named. We have seen that in class A power amplifier the conduction is for the full 360 degree and in class B amplifier the conduction angle was 180 degree. In the push pull amplifier that we discussed which is an example of class B type of power amplifier, there is one inherent disadvantage which is known as crossover distortion. This distortion is a result of the portion of the input cycle for which the transistors are not forward biased enough to let the base current flow.

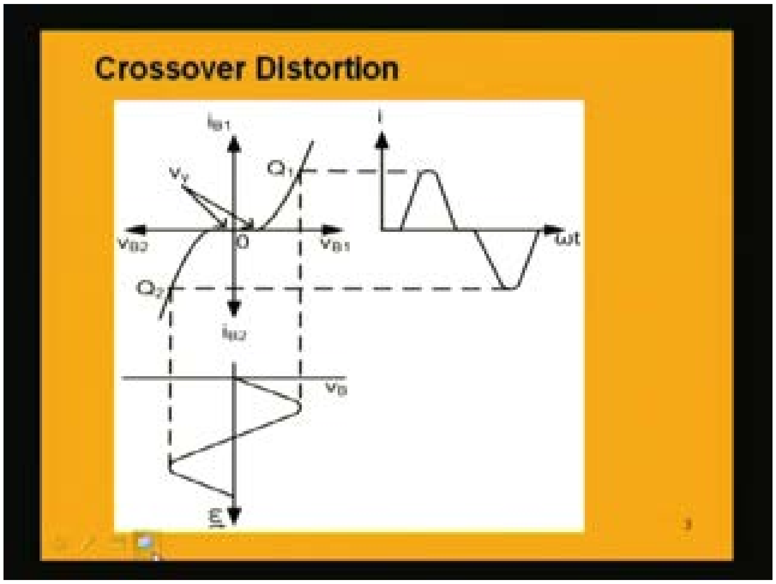
(Refer Slide Time: 2:49)



The input signal which is applied to the primary of this transformer is V_s. In this input cycle for the portion when the input voltage is small and less than the threshold voltage for the transistors which is known as V_{gamma} and this value is 0.7 volt for silicon, we know. In order that the transistor should conduct, the input voltage which is given between emitter and base, we are taking a common emitter transistor here, so this voltage between emitter and base junction should be more than 0.7 for silicon. Otherwise what will happen is that for the portion when the input voltage is less than 0.7 volt the transistors will not conduct and so there will not be any collector current.

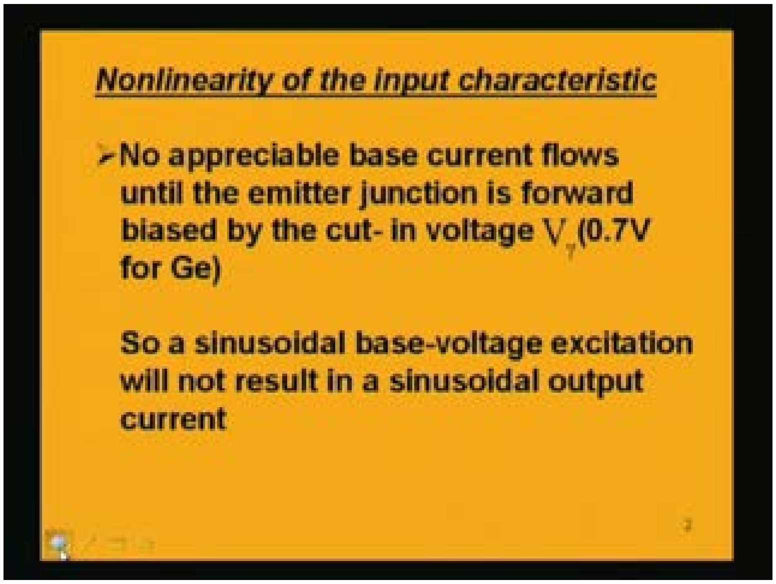
In the load side also there will not be current flowing for this portion and as we have seen that in each of the half cycle of the input voltage one of the transistors either T_1 or T_2 operates. In both the half cycles whether it is positive half cycle or negative half cycle of the input, the corresponding transistor will not conduct for that portion for which the input voltage is less than V threshold. That leads to distortion of the output current because for a portion of this input voltage being less than 0.7 volt we will not get any current in the output side. So that current will be zero.

(Refer Slide Time: 4:58)



That is why we will be getting the output current, i like this. For this portion of the input voltage being less than 0.7 volt, we are not having any current and this is in the transistor T_1. Similarly in the transistor T_2, it will not be forward biased enough initially so the current will be zero.

(Refer Slide Time: 5:25)

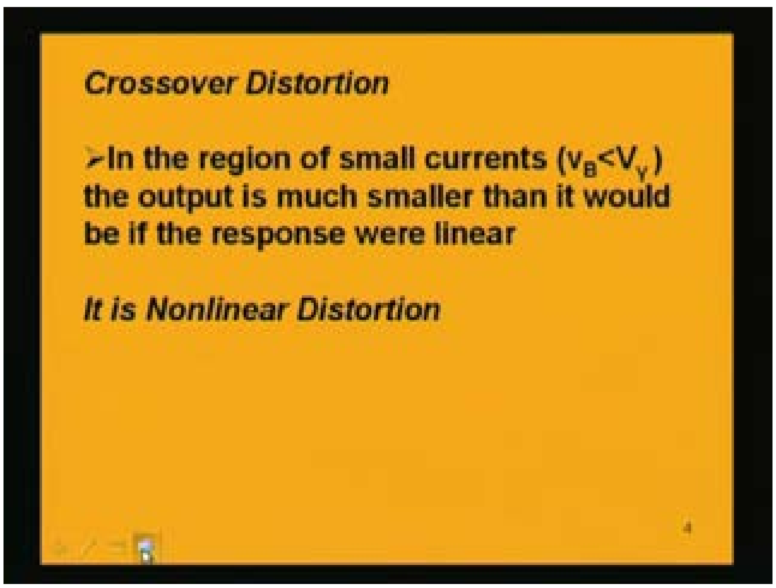


This distortion, which is occurring because of this inherent transistor property, is causing distortion in the output current and that is why we are getting nonlinear output. This nonlinearity causes the output voltage also a wave form which is not linear. So, we have to think about ways to overcome this crossover distortion which is occurring in the push pull amplifier that we discussed earlier.

If we revisit the input characteristic (Refer Slide Time: 6:24) between the base current and the base to emitter voltage of a transistor, here this plot is the input characteristics. For transistor T_1, this is the input characteristic and for the other transistor T_2 it will be operating in the other half cycle or negative half cycle; so, up to this point it will be zero current and then it will increase. The portion where the base current is zero for the transistors is having the voltage less than V_{gamma}. So, V_{gamma} is 0.7 volt here for silicon. The input voltage V_{B1} is named to denote the voltage in the emitter base junction for the transistor T_1. We have the base currents zero and similarly for the other transistor T_2, the portion up to this point this will have the current zero, base current i_{B2} zero because V_{B2} that is the voltage in the emitter base junction for the transistor T_2 is not large enough to overcome the threshold voltage. So, we are having this type of input characteristic in the two transistors T_1 and T_2.

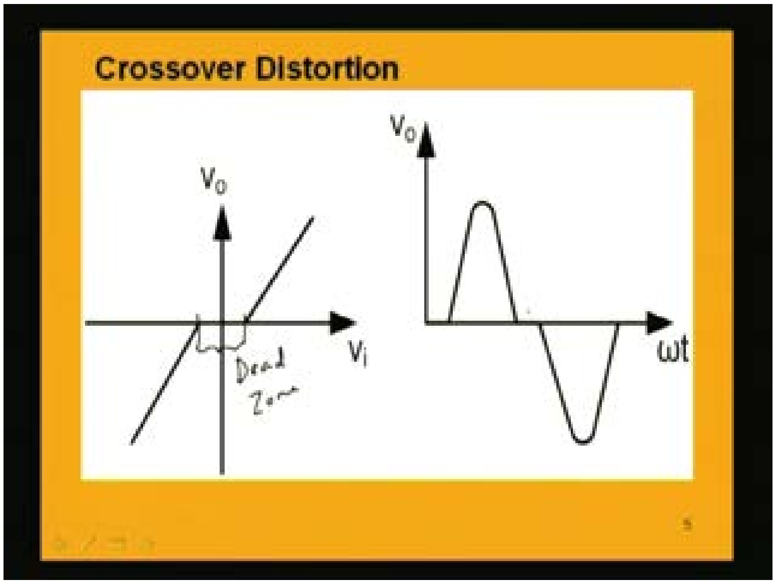
The Q_1 and Q_2 points are denoting the saturating or maximum value of the current. Corresponding to that Q_1 and Q_2 we are having the collector current maximum value and this is denoted by this point. i, current is having this peak value and for this portion you see that there is no current flow. It is zero current and for the other transistor, current that is also having a zero portion; so, that is causing an output voltage in the load which will be also having a very less or almost zero value for this portions and this is called the crossover distortion.

(Refer Slide Time: 9:08)



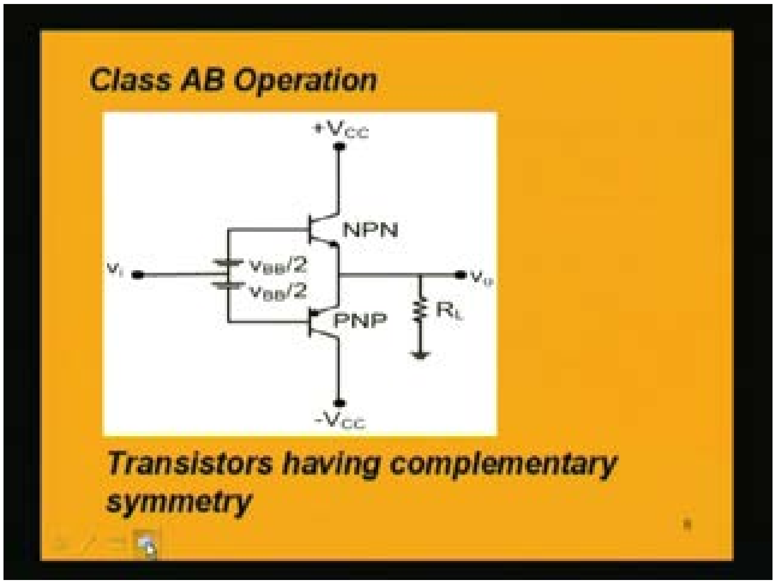
The output is smaller in this portion than it should have been if the response would have been linear. This nonlinear distortion has to be now overcome by some method and due to this crossover distortion what we are getting actually is a dead zone.

(Refer Slide Time: 9:43)



If we consider the transfer characteristic between V_o and V_i, output voltage and input voltage given to the push pull amplifier, we see that there is a zero voltage from this portion to this portion; this point to this point within this portion the output voltage is zero. That is actually called a dead zone and then only it is rising linearly with respect to input voltage V_i. The dead zone which is occurring in the output voltage is causing nonlinearity in the output voltage and that is reflected here. We are not getting a linear characteristic of the output voltage we are having a nonlinear characteristic because of the dead zone introduced by this crossover distortion.

(Refer Slide Time: 10:49)



In order to overcome this crossover distortion we consider now a circuit having a class AB operation and class AB operation means the conduction angle is greater than 180 degree but less than 360 degree. An improvement or a modification of the earlier circuit of push pull amplifier is shown here. Here the transformer part is absent. What is used here is a complementary symmetry of the transistors; we are using NPN and PNP transistor, both are not of the same type. Earlier in push pull amplifier we were using the same type of transistor. (Refer Slide Time: 11:53) NPN transistors were only used, if we look back into the push pull amplifier circuit; T_1 and T_2 were both NPN types. But we can use complimentary symmetry transistor and get rid of the transformer part; so, that is being done. This is one example. Here we are using two transistors having complementary symmetry. That means one is NPN and PNP and also we are using a biasing for the emitter base.

If we look into this V_{BB} by 2 there are two sources which are connected to the two transistors and this is basically to offer biasing for overcoming the threshold voltage. Earlier we did not have any DC biasing. Only we were having in the push pull amplifier the signal. The portion of the signal for which the emitter base junction has a voltage greater than threshold voltage, conducts and that was introducing the crossover distortion.

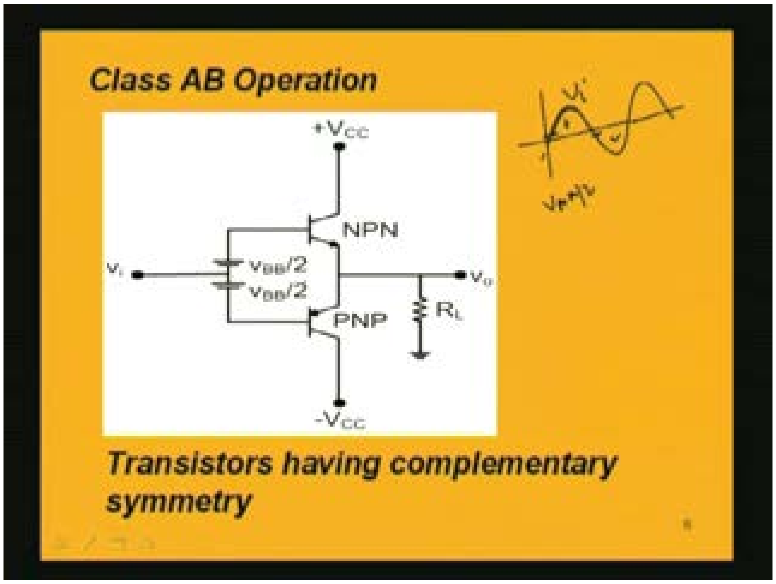
That is why here a DC source having value of V_{BB} by 2 for each of this transistor is used for overcoming the crossover distortion and apart from that this is the input signal V_i which is there and which will have the positive and negative half cycle.

Now what happens is because of the presence of this DC source, both the transistors are already biased for overcoming the V_{gamma} or the threshold voltage. If we consider this emitter base junction it is having a voltage V_{BB} by 2 which is greater than the threshold voltage. The transistor is already conducting. There is a base current even when the input signal is zero. So, there is a current which is already flowing even when the input voltage is zero. Practically what will happen is the current will flow for an angle greater than 180 degree because even if the input voltage is smaller than the threshold voltage V_{gamma}, then also both the transistors will operate or conduct.

(Refer Slide Time: 15:01)

Now as V_i is an AC signal like this, it is increasing. V_i is increasing and as V_i is increased, the NPN transistor here will take over and it will conduct but for the portion when the input voltage, even when it is smaller than V_{gamma} still the transistor was conducting and now when V_i is increased or decreased one of the transistors will take over conduction. So only one will conduct because you can see that V_i is a sinusoidal signal for example we are taking.

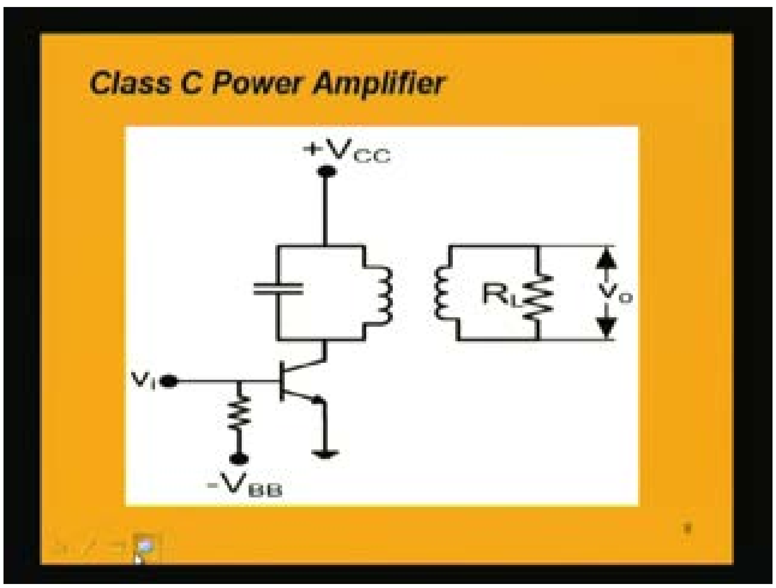
(Refer Slide Time: 15:53)



If you consider the positive half cycle, this V_{BB} by 2 is a small voltage. So, V_i will increase and then it will be greater with respect to V_{BB} by 2 considerably. This transistor NPN will conduct now because it is forward biased and then this PNP will be off because our signal is like this that the PNP transistor will be reverse biased for that portion. But in the negative half, as V_i is going on increasing in the negative half then the transistor which will be taking over for conduction will be the other one that is the PNP transistor. This transistor, lower one transistor will conduct when V_i goes on decreasing and decreasing and that means it is in the negative half because you can see that then it will be in the forward bias. But for the portion when V_i was, say, very small nearing zero even then the transistors were carrying or having a current because of this source V_{BB} by 2.

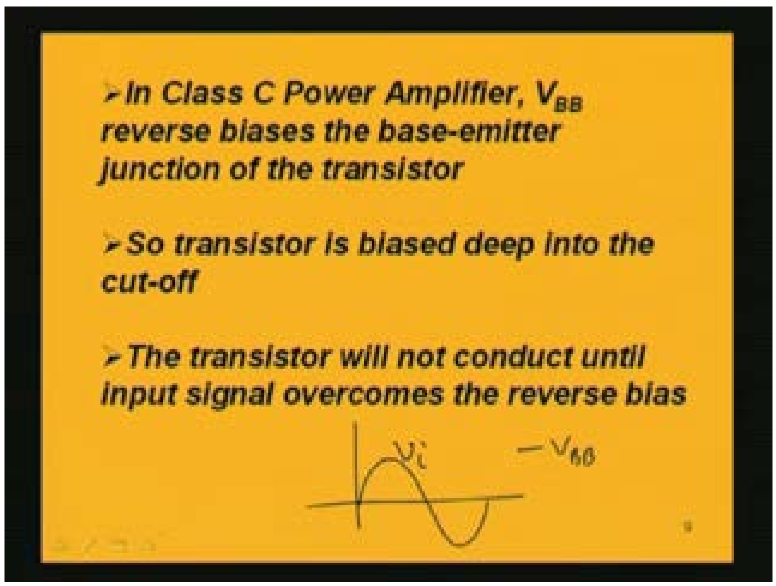
Effectively if we consider a single transistor at a time then we see that it is having a conduction angle greater than 180 degree. Because for the portion of the signal, before it was zero, that means for this portion suppose also it was having conduction the upper one was having conduction as well as the lower one. Even if it is going down, then we can see that the lower one will take over. This one will take over but already it was having a current conducting due to the source V_{BB} by 2. Here we observe that the conduction angle of each of the transistor is more than 180 degree but it is less than 360 degree. There is a disadvantage as far as efficiency is concerned because we can see that there is a stand by current. So there will be power wastage. Efficiency will be less since we have a stand by current flowing even when the V_i signal was zero. There is already wastage of power due to that current; so that leads to lesser efficiency because of this waste of the standby power. Another type of power amplifier is there, which is class C power amplifier.

(Refer Slide Time: 19:08)



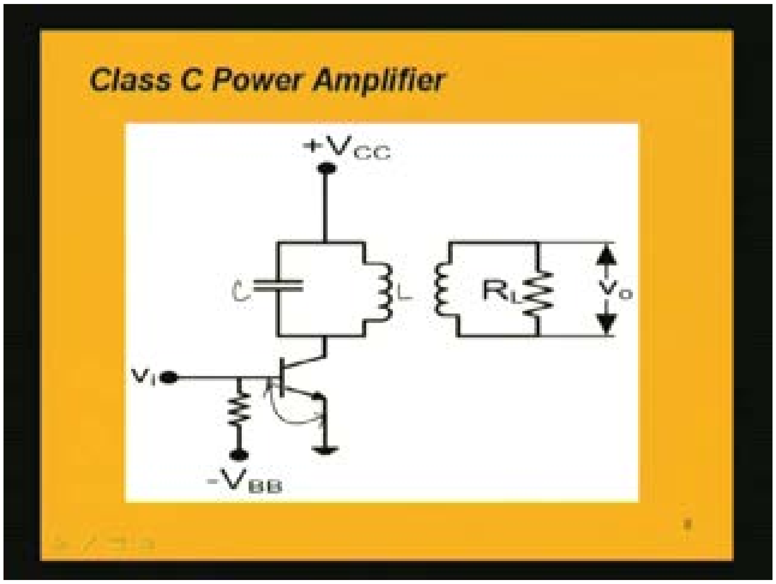
Class C power amplifiers we have earlier already mentioned that it is having conduction angle less than 180 degree. A typical circuit for this class C power amplifier is shown here. Here one point to be noted is that it is already reverse biased, deep into cut off. If we look into the transistor, this is an NPN transistor we are taking in this circuit and there is a voltage V_{BB} negatively or reverse biasing the emitter base junction. It is already reverse biased high enough to cause the transistor deep into cut off; already having gone into the cut off region much deeper, we will have to overcome this V_{BB} reverse biasing voltage to make the transistor conduct. Whenever the input voltage, which is the signal being applied to this amplifier, will be large enough or it will be able to overcome the reverse biasing voltage V_{BB}, then only the transistor will start conducting and there is a tank circuit. This tank circuit which is used by this inductor L and capacitor C that is forming the tank circuit and we are having the load resistance at the output or the secondary side of this transformer; this inductively coupled portion is having this R_L. This R_L is the load resistance when we are having the voltage across this R_L.

(Refer Slide Time: 21:20)



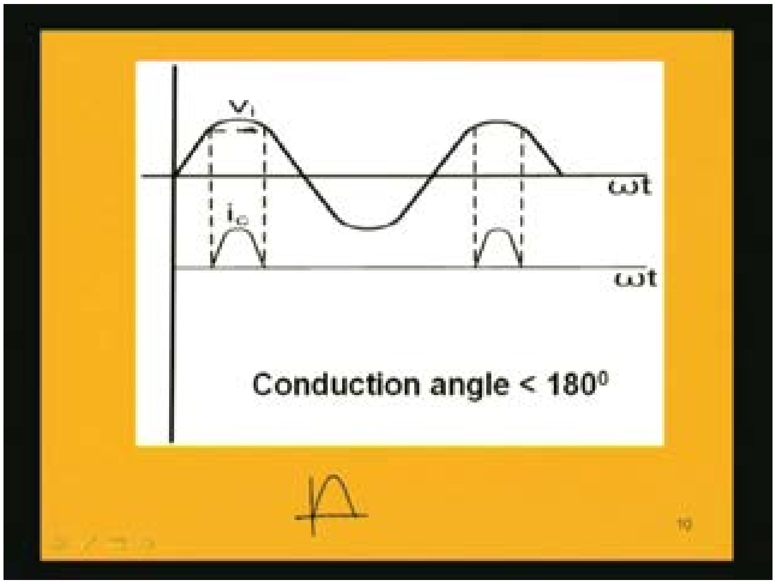
If we look into the operation of this circuit, as the transistor is already being biased deeply into the cut off, the transistor will not conduct until the input signal over comes this reverse biasing voltage. This input signal, which is a sinusoidal signal for example we are taking, is V_i; it is increasing. Already we have a negative biasing voltage present which is reverse biasing the transistor.

(Refer Slide Time: 22:05)



So that voltage across this emitter base junction of the transistor, this voltage must be forward biasing the emitter base junction. Only then the transistor will start conducting. So, V_i minus V_{BB} this quantity must have a value greater than the cut off voltage. It should overcome that V_{BB}.

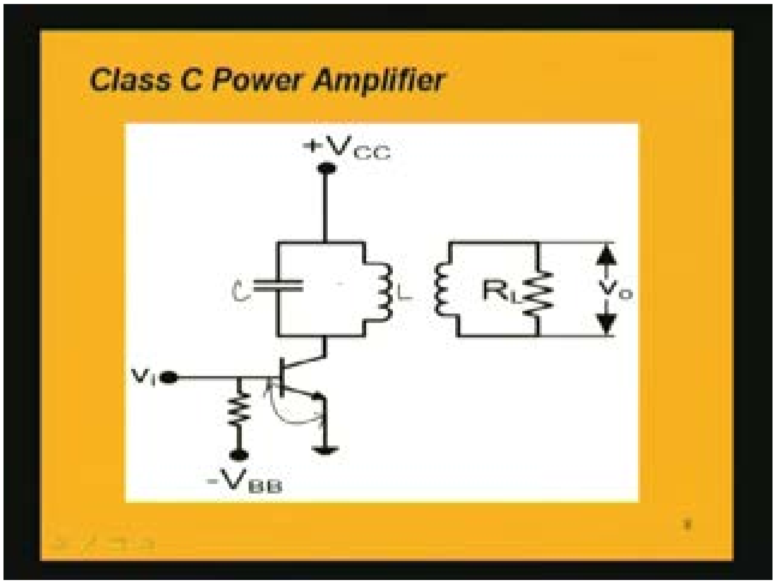
(Refer Slide Time: 22:42)



Then it will start conducting, because of which the current which will be conducting is only for a very small portion in the positive half cycle of the signal. It is obvious that only when the emitter base junction for the transistor will have a forward biasing voltage then only it will start conducting and V_{BB} is a high voltage. It is not a small value. It will have to wait till the point when V_i is greater than V_{BB}. For example we are having here a signal shown by this V_i and practically what happens is that only for a very small portion of the input voltage cycle the transistor will conduct and it is generally even less than 90 degree. That is because only for this portion, from this point to this point, the input voltage is greater than V_{BB}. V_{BB} is sufficiently high that is why the current which flows in the transistor it is only for a very small portion of the input cycle even less than 90 degree.

The current which flows in the transistor will be like a pulse. It will be like a pulse, as shown here. It will increase and then decrease very safely. It is a very steep pulse. We will get the current in the transistor in the form of the pulse. We have to now have a method to convert that pulse into sinusoidal signal because that is the requirement. In the output side we require a sinusoidal voltage because we are amplifying a sinusoidal signal. Whatever we are giving here, we must get at the output same shape and as we are feeding an input voltage which is sinusoidal, the output voltage also must be sinusoidal but what we are getting here is a pulse like voltage. In order to convert this pulse into a sinusoidal voltage here what is done is this provision of this tank circuit.

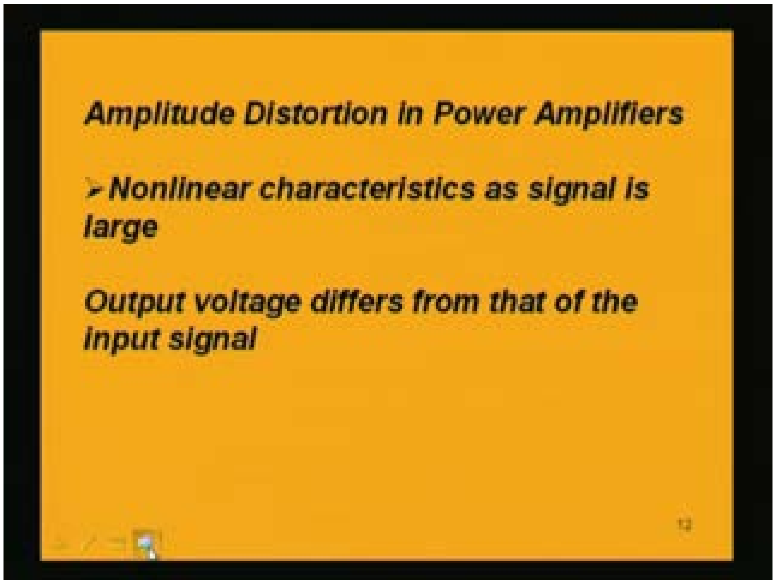
(Refer Slide Time: 25:14)



As this tank circuit is having L and C components, it will be oscillating and that oscillation will be a high frequency oscillation. We will get a sinusoidal voltage; because of the charging and the discharging of this capacitor through this inductor and storing energy in the inductor, we will get a sinusoidal voltage no doubt but that frequency will be high. It is generally used for radio frequency operations, RF operations because frequency is quiet high.

This tank circuit is there to produce sinusoidal signal from this pulse. Because the current in the transistor is in the form of pulse, the tank circuit's presence will convert this pulse type of signal into sinusoidal by charging and discharging of the capacitor as well as storing the energy in the inductor. That is the property of this tank circuit formed by this L and C. This circuit will convert the pulse to a sinusoidal signal. But it is having a radio frequency operation. Here one thing we note is that the conduction angle for the current will be less than 180 degree and almost practically the conduction angle will be around 90 degree only. This is a typical example of a class C amplifier.

(Refer Slide Time: 27:00)

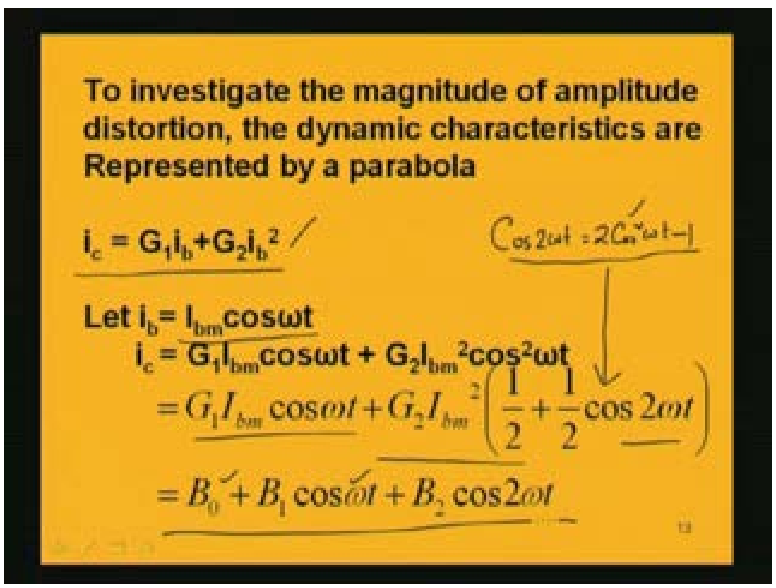


When we are considering the power amplifier, we have to always remember the fact that these signals which are being dealt with they are having high magnitude. Whether it is current or voltage it is a large magnitude; in the order of voltage or amperes we are dealing with and due to this fact the operation of the transistors in this power amplifier go into the nonlinear portion. If we remember, earlier we were discussing about the small signal amplifiers using BJT's. There we were always assuming that the transistor operation is linear and for that we have to be careful to apply the signal which is small such that the transistor is always in the linear operation.

If the input signal is high then that will drive the transistor into nonlinear portions in the characteristic curve either the saturation or cut off but here that guaranty is missing because we are dealing with signal which is large enough and that is why the transistor is driven often into the nonlinear portion like saturation. The effect is that we will have nonlinear characteristics of the signal and the output voltage which we will obtain will be often different from the input signal because of this nonlinearity being introduced by the large amplitude of the signal. There is an amplitude distortion and that causes the distortion in the output signal. We have to have a measure of how much distortion in the output signal is occurring from the input one. That distortion we are going to now discuss.

We are discussing the amplitude distortion in the output signal. To investigate into the magnitude of the amplitude distortion we have to assume the dynamic characteristics of the power amplifier transistor not as a linear one because earlier when we discussed small signal amplifiers using BJT's we were taking the output characteristics in linear way. i_c was beta times of i_b and we were only limiting the study to the linear region; that is for a small portion around the operating point only we were considering. If we consider the relation between the output and input current in a common emitter transistor then i_c is beta times of i_b. But now i_c cannot be simply taken as beta times of i_b or beta means a constant value; it is not a linear relationship. We have to now go beyond that linear study and that is why generally we can represent the current in the transistor as having a relationship of a parabola.

(Refer Slide Time: 31:11)

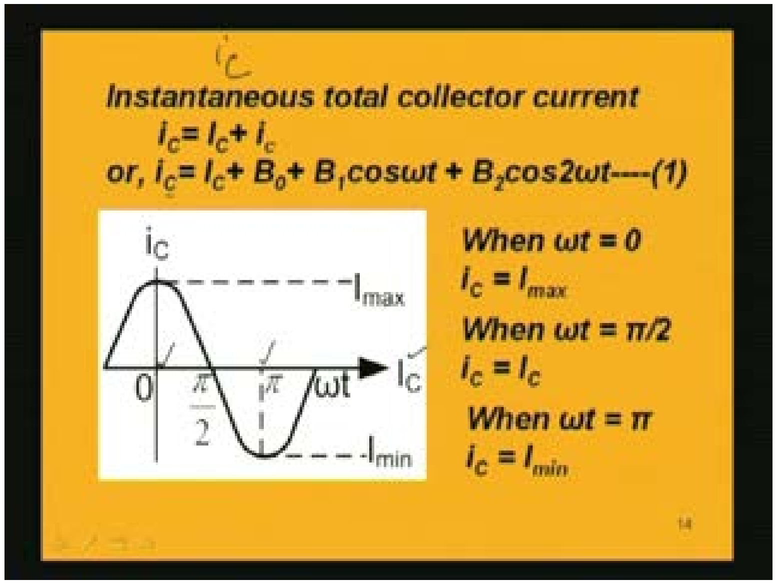


The dynamic characteristics of the transistors are represented by a parabola. We are having an expression of i_c equal to G_1 into i_b plus G_2 into i_b square. This is the equation of parabola. We are basically having the characteristics curve represented by a parabola. Let us take that assumption of taking up to only the second order and we will analyze the relationship of the collector current and the base current by this parabolic relationship G_1 into i_b plus G_2 into i_b square where i_b is the base current, i_c is the collector current.

Let us assume that we are applying a sinusoidal signal and we can then represent i_b as I_{bm} cos omega t. This a sinusoidal signal having the peak value of I_{bm}. If we now replace i_b in this equation by this expression of I_{bm} cos omega t what you will get is i_c equal to G_1 into I_{bm} cos omega t plus G_2 into square of i_b means I_{bm} square cos square omega t. Further simplifying we get that is equal to G_1 into I_{bm} cos omega t plus G_2 I_{bm} square. The cos square omega t can be broken up into having another representation because we know that cos of twice omega t equal to twice cos square omega t minus 1. So, from this relationship we can find out what is cos square omega t? It is half of 1 plus cos twice omega t. Representing in that way just substituting for cos square omega t by this expression of half of cos twice omega t plus 1 term, then we are getting this.

Now if we look into this expression we are having actually the terms which are constant part having a cos omega t part and the other is having a cos twice omega t. Representing that constant G_2 I_{bm} square by 2 by B_o, B_o is a constant to represent this part G_2 into I_{bm} square into half plus G_1 into I_{bm} another constant we are representing by B_1, so, we get B_1 cos omega t plus a third term having G_2 I_{bm} square by 2 representing it by B_2 and there is cos twice omega t term. So, what you get in the current expression is the terms: one is constant B_o; other is having a signal having the frequency of the input signal omega. We are applying the input signal which is I_{bm} cos omega t that is the base current signal. This frequency is seen but another part or third term is having twice of that frequency. That means we are getting twice omega in the frequency.

(Refer Slide Time: 35:40)



This is actually leading to an analysis which will deal with second harmonics; fundamental frequency and second harmonic. We are going to discuss that. But before that let us complete to find out the instantaneous total collector current because the current which we are discussing right now is the AC component. If we consider the instantaneous total collector current there is a DC part, there is an AC part. The DC part is capital I capital C and the AC part is small i small c. This total instantaneous current will be combination of this I_C and small i_c.

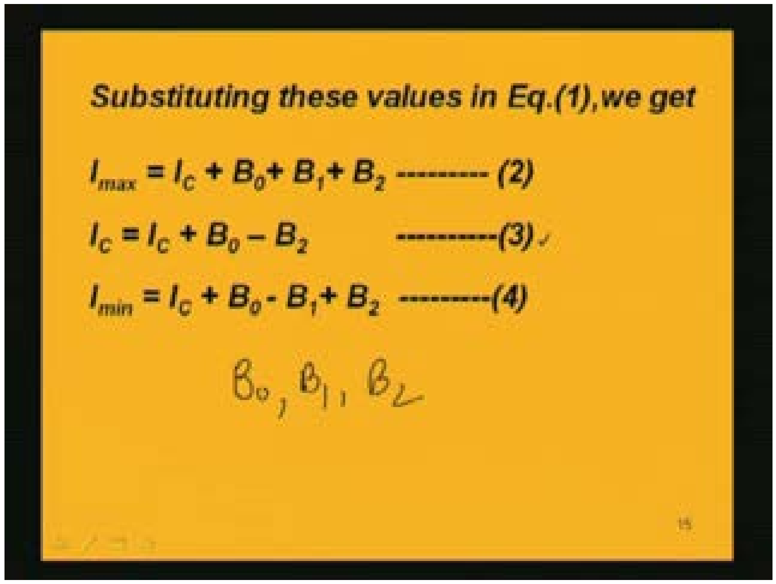
Now we are representing the instantaneous total current by i capital C that means we are writing i small and the subscript capital C and that is equal to capital I capital C that is the DC part plus the signal AC part which is small i small c. We have just now derived what is small i small c. That is equal to B_o plus B_1 cos omega t plus B_2 cos twice omega t. Now we write all this, the whole expression and we get the value of i_C equal to capital I_C plus B_o plus B_1 cos omega t plus B_2 cos twice omega t. This is the instantaneous total current expression and I am naming it as equation 1.

Now we look into the current i_C curve. This is the current. It has a peak value, maximum value and minimum value and these are the denoted as I_{max} and I_{min} and it is symmetrical swing and we are having the DC collector current in between them which is denoted by capital I capital C. Starting from this DC current it will go on increasing and getting the maximum value I_{max} then decreasing it will be having the minimum value I_{min}. Let us consider omega t between this point, take it as zero, and when omega t is equal to pi. Let us consider this portion of omega t; because x axis is having omega t and we are considering these points starting from zero here when it is having the magnitude I_{max} and then when it traverses an angle of pi.

What will be the value of the instantaneous total current small i capital C, as we are denoting by, when omega t is zero at this point. When omega t is zero that value is I_{max}. Because we are starting from this point, this we are assuming as zero. Because this is the whole sinusoidal wave it will be continuing; we can start with any point and we can take a portion of that signal. That is what we are doing. Where we are starting? At this point we are starting when the value of the instantaneous total current is I_{max}. Then we consider when it traverses an angular distance of pi by 2. When omega t is equal to pi by 2, the instantaneous total current is capital I capital C. This is the value which is the DC current.

When it is traversing an angle of pi, the omega t value becomes pi then, the instantaneous total current is I_{min} because here we can see this is getting the negative peak. Now these three points which we are observing in the collector current curve, we will be using to find out the constants in this equation number 1. Because we have three unknowns B_o, B_1 and B_2, so we require three equations to know these three unknowns. For that we will use these conditions to find out constants. This is the normal way we generally solve this equations.

(Refer Slide Time: 40:39)

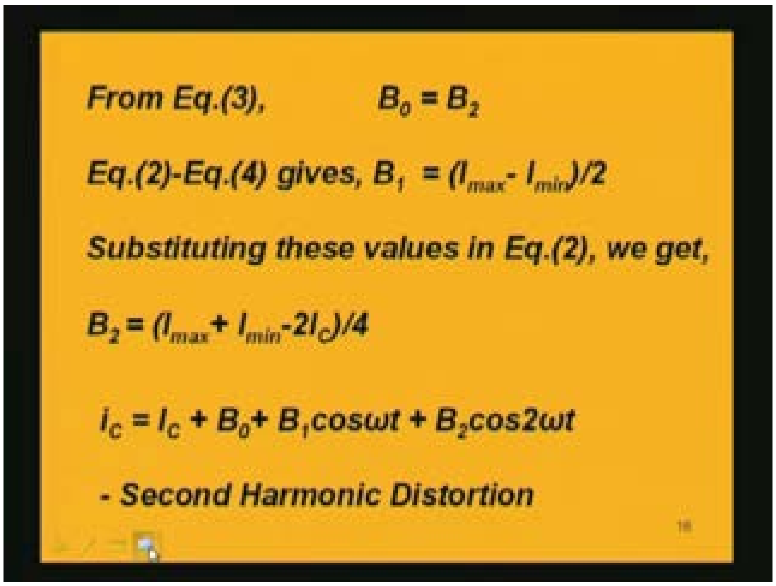


If we look into this equation 1, when we put the omega t value zero what will happen is that I capital C becomes I_{max}, left side will be I_{max}; right side will be capital I capital C plus B_o and omega t zero means plus B_1 plus B_o will be there, cos of omega t when omega t is equal to zero, cos zero is 1, so cos twice omega t is also 1. That will give us this equation number 2 which is I_{max} equal to I_C plus B_o plus B_1 plus B_2. Secondly we will apply when omega t is equal to pi by 2.

From this signal we have seen that when omega t is equal to pi by 2, the instantaneous total current is equal to the DC value capital I capital C. So, put the value omega t is equal to pi by 2. What we will get in this equation is, left side will be capital I capital C; right side will be capital I capital C plus B_o plus B_1 into cos of pi by 2. What will be cos of pi by 2? That will be zero and then B_2 cos twice omega t. Put the value of omega t is equal to pi by 2; cos of 2 into pi by 2 means cos of pi and cos of pi is minus 1. So, it will be minus B_2. That is what is obtained in equation 3. We get capital I capital C equal to capital I capital C plus B_o minus B_2. B_1 becomes zero because cos of pi by 2 is zero. Then in the next equation, equation number 4 is obtained by putting the value of omega t is equal to pi.
So, put the value of omega t is equal to pi in this equation 1. What we will get is the value of instantaneous total current, I_{min}; this point. Left side will be I_{min} and that is equal to

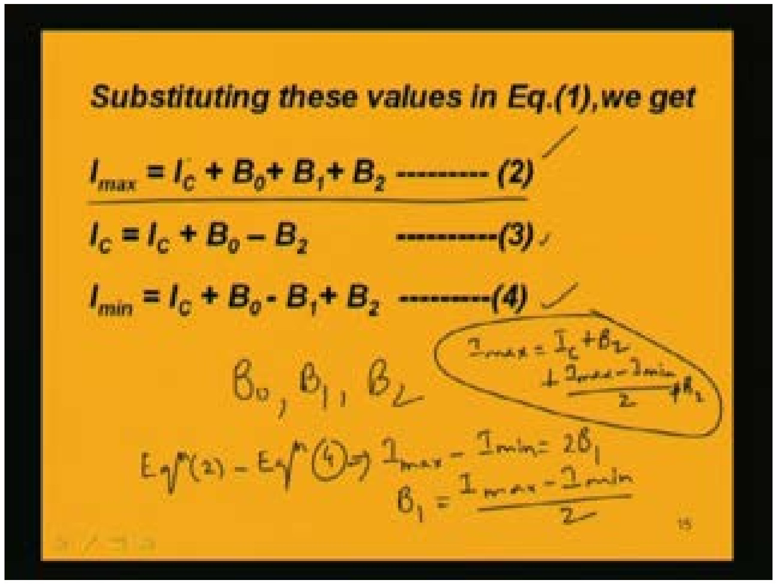
right side equal to capital I capital C plus B_o plus when you put the value of omega t is equal to pi, cos of pi is equal to minus 1; so, minus B_1 and then the next term B_2 cos 2 omega t. Omega t is 2 pi; cos of 2 pi, cos of 2 pi equal to 1, so it will be plus B_2. We have these three equations – 2, 3, 4 and we have to solve for finding out B_o, B_1 and B_2. These three equations are enough to know the three unknowns. The easiest one will be, if we look into the equation number 3, from this equation we see that B_o equal to B_2 will be obtained. I_C, I_C cancels so B_o will be equal to B_2. These two values are equal.

(Refer Slide Time: 44:39)



To find out the values of B_1 etc., we will subtract equation 4 from equation 2.

(Refer Slide Time: 44:42)

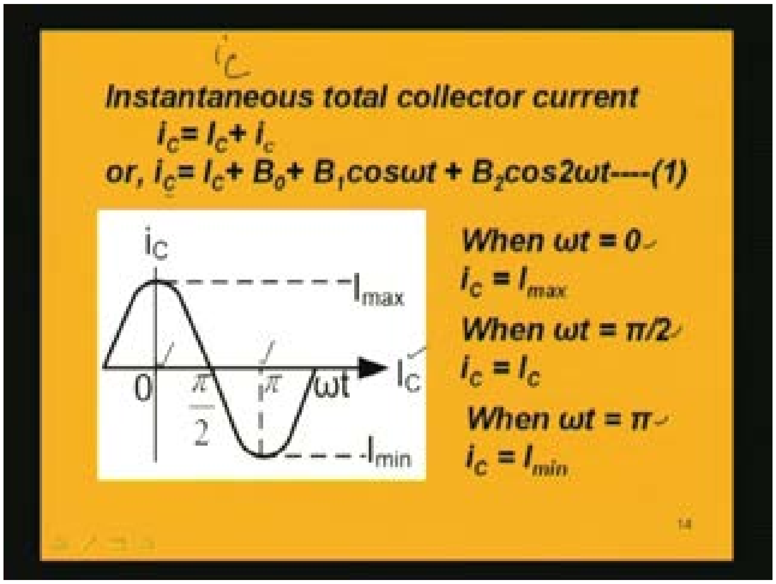


We subtract equation 4 from equation 2; equation 2 minus equation 4 that leads to what? I_{max} minus I_{min}, this left side we are subtracting equal to this equation and this equation. So, right side this two cancel; B_o B_o cancel we are subtracting 4 from 2. So, $2B_1$ plus $2B_2$ and that is giving you again what we have got is B_1 plus B_1; sorry B_2 minus B_2 cancel. That is not right; 2 minus 4 I am doing, B_1 plus B_1 it will be $2B_1$; B_2 B_2 cancel. What we are getting is B_1 that is equal to I_{max} minus I_{min} by 2. This is what we are getting for B_1.

Now, you have to find out what is the value of B_2? That is equal to B_o also. To find that you substitute these values B_o equal to B_2 and B_1 equal to I_{max} minus I_{min} by 2 in equation 2. In Equation 2, if we substitute these values; so, what we get is that I_{max} equal to I_C plus B_o equal to B_2 from third equation we have already got; we can simply write B_2 in place of B_o plus B_1 we have found out. B_1 is equal to I_{max} minus I_{min} by 2. Then the rest of the terms is plus B_2. So, this equation is the governing equation from where we will get the value of B_2 because it becomes twice B_2 plus this portion which is equal to I_{max}. Doing simplification finally we get B_2 equal to I_{max} plus I_{min} minus 2 times I_C by 4. This is obtained and now all these constants Bo, B_1 and B_2 have been found out in terms of the maximum current, minimum current and DC current.

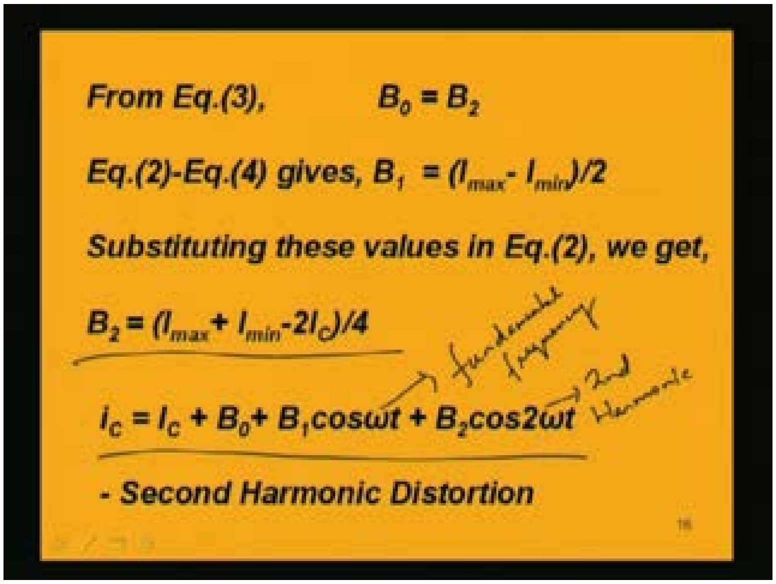
Putting these values of B_o, B_1 and B_2 into the original equation number 1, what we get finally?

(Refer Slide Time: 48:06)



In this equation we substitute these values. The total instantaneous current i capital C equal to capital I capital C plus we will be writing for say B_o plus B_1 cos omega t plus B_2 cos twice omega t.

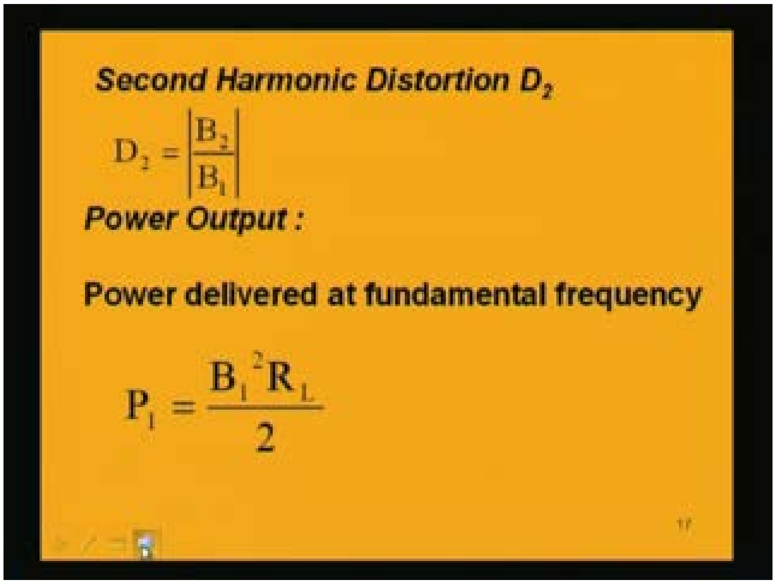
(Refer Slide Time: 48:25)



Here we can substitute all this B_o, B_1 and B_2 values. If we observe closely the equation, this is having a fundamental frequency. This is called the frequency of the input signal is omega and this term is having the same frequency omega. This is a term having the fundamental frequency and the other term B_2 cos twice omega t is having second harmonic component. This is a second harmonic component; this is 2 times. What is the final expression? Basically it is giving an expression which is giving you an idea about the second harmonic distortion that is occurring in the output. This second harmonic distortion we are getting because of the nonlinearity in the characteristics; the dynamic characteristic nonlinearity is giving the amplitude distortion and we are getting a second harmonic term because of that in the output.

There is a measure actually to have an idea about how much distortion is taking place. How much second harmonic distortion is taking place that distortion measure is given by term D_2.

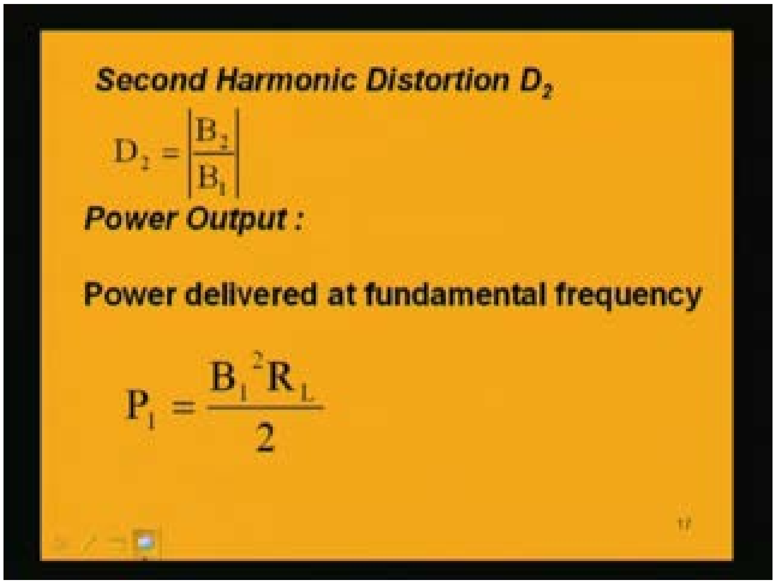
(Refer Slide Time: 50:11)



This is called second harmonic distortion D_2 and it is given by the value modulus of B_2 by B_1. The two terms B_2 and B_1, if we take ratio between them and take the modulus value that will give the second harmonic distortion. It is basically giving you the idea about how much or second harmonic distortion is taking place. If we consider the power output, the power at the output which is delivered at the fundamental frequency is B_1 square R_L by 2 because at the fundamental frequency the term which is associated is B_1; B_1 cos omega t is the term, which is relating to the fundamental frequency.

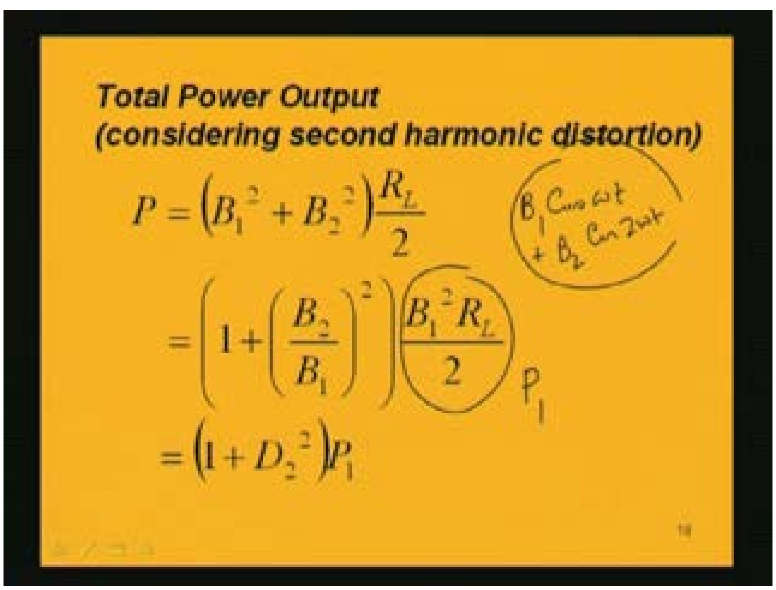
We want to find out the AC output power. We know that AC output power will be the value of peak square by 2. If we are considering the current, this is the current. I square R_L and I square means it will be peak value by root 2 square. RMS average value we will have to consider when we are considering AC. The load resistance is R_L and we have this current component at the fundamental frequency B_1 cos omega t.

(Refer Slide Time: 51:58)



So, it will be B_1 square by 2 into R_L. That will be the power delivered at the fundamental frequency and that is denoted by P_1.

(Refer Slide Time: 52:05)

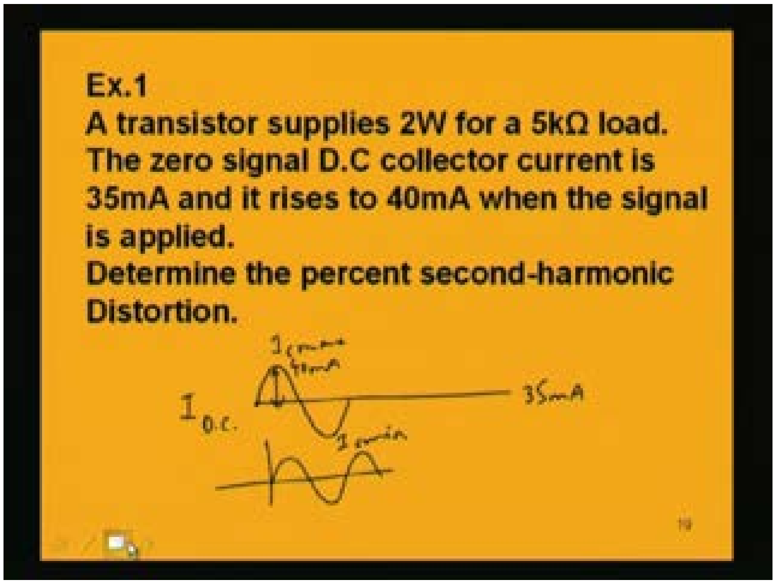


As this is a current having second harmonic distortion term also if we want to find out the total power even considering that second harmonic distortion, the total power output at the load will be summation of the power delivered by the fundamental frequency as well as the second harmonic term. Considering the second harmonic distortion, the total power output will be P; for example we are denoting it by P. It is equal to B_1 square R_L by 2 plus B_2 square R_L by 2. Since B_1 cos omega t and B_2 cos twice omega t are the terms, if we consider those two terms having fundamental frequency and second harmonic term, it is B_1 cos omega t plus B_2 cos twice omega t. These are the terms.

If we want to find out the output power because of these two terms it will be B_1 square by 2 into R_L plus B_2 square by 2 into R_L and that here we are rewriting and we can write in another way taking common B_1 square R_L by 2. That is the power at the fundamental frequency then inside the bracket it will be 1 plus B_2 by B_1 square because we are dividing by B_1 square; B_1 square has been taken out. B_2 square by B_1 square that we are writing by B_2 B_1 whole square. What is this term B_2 by B_1? We have just now denoted it by D_2 that is a second harmonic distortion and that is used to represent this term B_2 by B_1. B_2 by B_1 we are writing by D_2. So, the total power P becomes equal to 1 plus D_2 square and this whole term we are writing by P_1 that is the power delivered at fundamental frequency. The total power P equal to 1 plus D_2 square into P_1.

Here whatever analysis we have been doing is using second harmonics only. We can consider the higher order terms also like up to B_2 square we are considering but there may be B_3, B_4, etc., considering the higher order harmonics. That will lead to the terms inside bracket D_2 square plus D_4 square etc., but we are now limiting up to only second harmonics and we are not going into higher order harmonic. But if we consider those then the analysis will also involve those higher order harmonics.

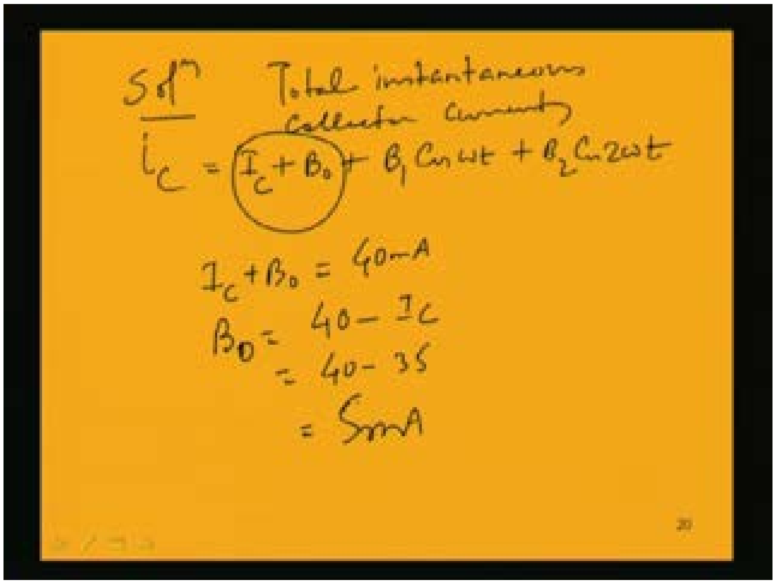
(Refer Slide Time: 55:16)



Let us do one example with all the discussion that we had today. The example is that a transistor supplies 2 watt for a 5 kilo ohm load. The zero signal DC collector current is 35 milli ampere and it rises to 40 milli ampere when the signal is applied. Determine the percent second harmonic distortion. Here we are having an example of a power amplifier and the load is 5 kilo ohm and the transistor is supplying 2 watt to the 5 kilo ohm load. That means the power output is 2 watt and that power output what is actually it is considering here it is to be seen that the power 2 watt is the power output or the power consumed by the load. But we will have to also see the second harmonic distortion as is seen here, as given in this question. Determine the percent second harmonic distortion.

Another information given is that the zero signal DC collector current is 35 milli ampere but it rises to 40 milli ampere when the signal is applied. That means you have DC current, I_{DC} zero signal. When the signal is absent, no signal is applied, only the DC current is flowing. That is 35 milli ampere. 35 milli ampere is the current and it rises to 40 milli ampere when the signal is applied. We are applying a signal assuming it to be sinusoidal. When you have no signal this is the value of the current which is a DC current and it will increase and decrease like this and this is I_C max, I_C min. It increases to 40 milli ampere.

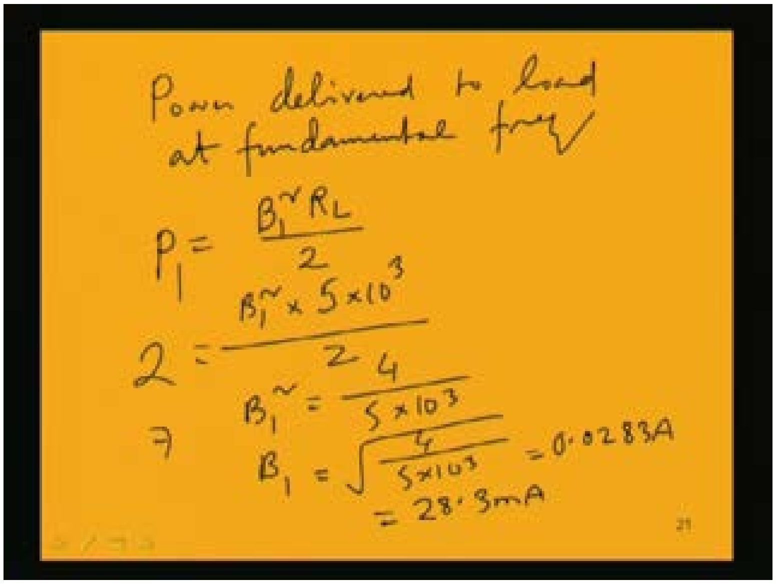
(Refer Slide Time: 57:57)



The DC component we will have to find out because if we consider the total instantaneous collector current i_C, that is equal to this DC component plus B_o plus B_1 cos omega t plus B_2 cos twice omega t. It is said here that the zero signal DC collector current is 35 milli amperes and it rises to 40 milli amperes. That DC component will be what? This I_C plus B_o will be 40 because the total DC component will be rising to 40 milli ampere from 35 milli ampere because we have seen in the earlier analysis that when we were considering this parabolic expression for the collector current we were having those terms B_o plus B_1 cos omega t, all these things. So, that DC part if we consider, this DC component in this whole expression of this collector current we will have to see.

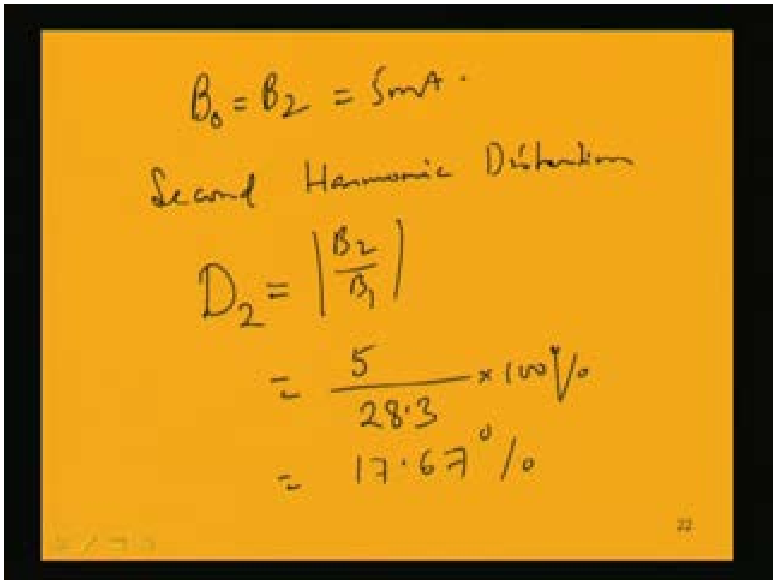
This is the expression; this is the total DC component (Refer Slide Time: 59:48). We will have to keep in mind that total DC component means not I_C only it will be I_C plus B_o when the signal is applied. Without signal it will be only I_C; that part has to be kept in mind. So now I_C plus B_o is equal to 40 milli ampere. What is B_o? B_o is equal to 40 minus I_C that is equal to 40 minus 35 is equal to 5 milli ampere.

(Refer Slide Time: 1:00:26)



If this is the B_o value, again it is given that the power delivered to load is 2 watt for a 5 kilo ohm. The power delivered to load at fundamental frequency is P_1 equal to B_1 square R_L by 2 and that power is 2 watts. So, it is B_1 square; it is a 5 kilo ohm load, so, 5 into 10 to the power 3 by 2. From this we get B_1 square equal to 4 by 5 into 10 to the power 3. So value of B_1 is equal to under root 4 by 5 into 10 to the power 3. That becomes equal to 0.0283 ampere; it is equal to 28.3 milli ampere. That much is the value of D_1 and mind it this is a having a unit 5 milli ampere because it is the current.

(Refer Slide Time: 1:01:52)



Again we know B_o equal to B_2 and B_o we have already found out 5 milli amperes. So, that is 5 milli ampere. The second harmonic distortion which we have to find out is a measure which is given by modulus B_2 by B_1 and we can simply put these values 5 by 28.3 and in percentage we will have to write. So, that gives you 17.67% which is the second harmonic distortion; that is the distortion taking place due to this nonlinearity in the output.

Today we discussed about AB type power amplifier and C type power amplifier. We have used application of complementary symmetric transistors in class AB type of power amplifier. Also we have discussed about the amplitude distortions that takes place due to the nonlinearity in the dynamic characteristics of the power amplifier because of which the second harmonic distortion is taking place and in the output current, we have seen that we got a component having fundamental frequency as well as the second harmonic component. We have also seen the second harmonic distortion measure that is given by D_2 which is an expression relating the B_2 and B_1 values. This second harmonic distortion is one effect that we get in power amplifier which is different from small signal amplifiers because in small signal amplifiers we were using the linear dynamic characteristic which is not the case in power amplifier because it deals with large amplitude of the signals.