**Video Course on Electronics**

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**Module No. # 06**

**Power Amplifiers**

**Lecture No. # 04**

**Power Amplifiers (Contd.)**

We just concluded, the class b operation and we said that in order to take care of crossover distortion the ICQ is not taken as 0, but it is shifted slightly up, so that very small collector current flows even in the absence of the signal and this current is that the trickle current. How to provide the trickle current the biasing schemes, we said about the two schemes, the voltage divider, the bias and diode bias. In diode bias, the diode takes care for the 0.7 volt which is required for forward biasing the emitter base junction of the transistor.

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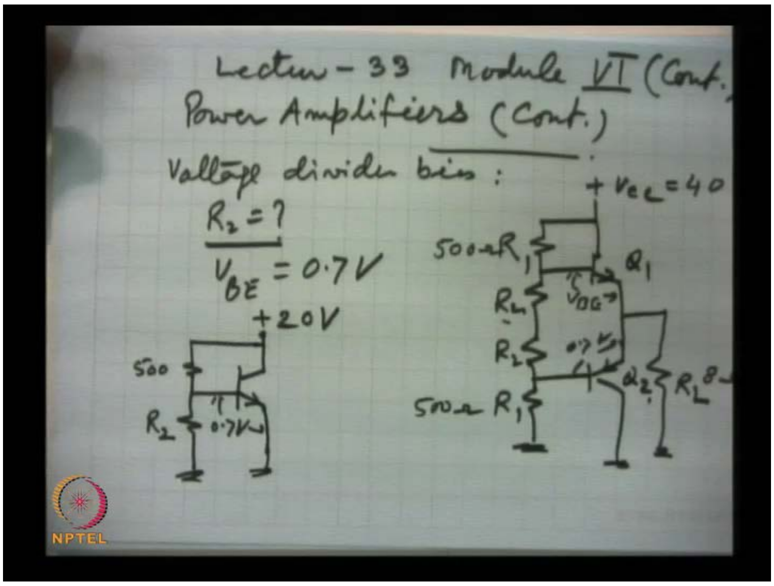


In the voltage divider wise, let us take a very simple example that how to calculate the value of that resistance. The circuit voltage divider, the circuit you will recall was this. (No audio 02:01 to 02:41) This is the voltage divider bias, let us take that this V C C is

40 volt I am taking an illustrative example that how to calculate the value of this resistance R2 to provide 0.7 volts, which will be sufficient to keep these transistors Q 1 and Q 2 into ready to conduct a state so that they start conducting the moment that the input signal is available, no portion of the input signal goes without its representation in the output.

So, this is 40 volts and let this resistance be R 1 be 500 ohms each and this is load resistance is 8 ohms, load speaker, for example, they are of 8 ohms, 4 ohms, 16 ohms like that. And we have to find out the value of R 2 to provide this voltage V B E of V B E equal to 0.7 volts this example, will illustrate several points now this R 2 and this R 2 they are identical, because this voltage drop here is 0.7 volts same as this here also 0.7 volts I made a statement that for the analysis purposes it is sufficient to take the half circuit.

So, I find out the value of this resistance R 2, I will take half part of it and that is this. this is 500 ohms, this is R 2 and now because I am taking half circuit so this from 20 volts this will be this is from 40 volts it will be half of that will be 20 ohms. So, we have to find out the value so that this voltage is 0.7 volts.

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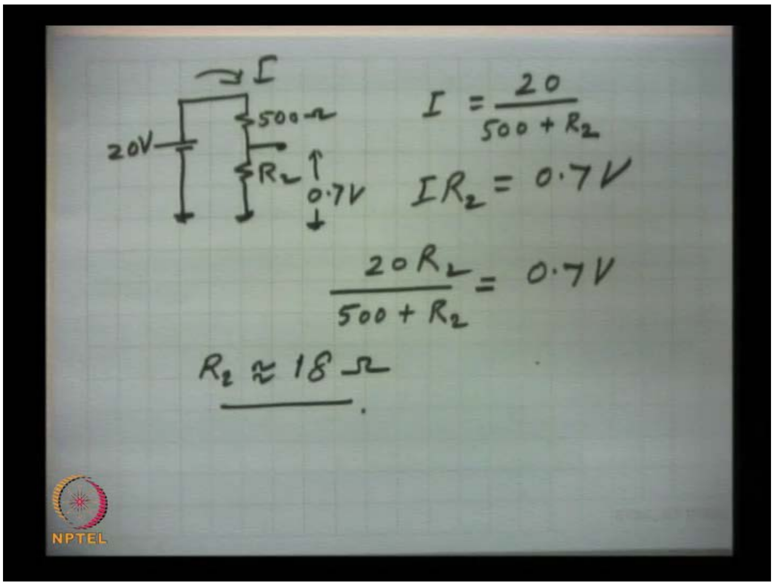


It is very simple that this circuit, We transform in this way this is 500 ohms, this is R 2 and here is that 20 volt battery 20 volts, how to find R 2 such that it produces a voltage 0.7 volts here, I am sure the problem is now clear, how to do that what is the current I through this circuit the current will be currently is by simple ohms law and these two resistance is being in series so 500 ohms, plus R 2, now this current passes through both these resistances.

In series circuit same current flows the voltages will be different in the parallel resistances, the voltages are same, but the different current propagate mind it, so IR2 has to be equal to 0.7 volts now the I R 2 - 0.7. So, we take I R 2, I we substitute I here this become 20R, 500 plus R 2 and this has to be equal to 0.7 volts from here , we find out the value of R 2 just R 2 comes out to be very close to 18 ohms, simple cross multiplication will give the value of R 2 as 18 ohms. So, if 500 ohm resistance here and 18 ohms resistance here 18 ohms, 500 ohms so that completes the circuit and this 18 ohm will provide the trickle current it will forward bias the transistor a emitter base junction so that it is in ready to conduct state as soon as input signal comes and this transmits. This is I wanted to illustrate two points one is that half circuit is sufficient for the analysis of push pull amplifiers how no matter how complicated is the analysis it is always done with half circuit and in the second point was that simple methods are there to calculate these parameters.

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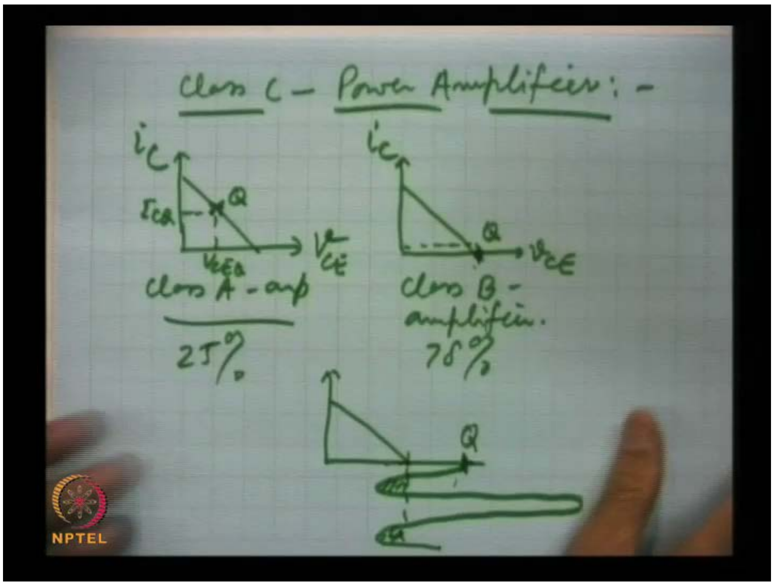


The next power amplifier after A B and A B is class C power amplifiers class C power amplifier all amplifier power amplifier are quite different from each other. In B operation as we have seen that we have to operate it in class push pull amplifier circuit only then we get a useful configuration for practical applications. Class C power amplifiers are very different, here we choose the operating point much below the cut off for example, look here in class A amplifier, this is IC this is V C E this is an AC load line and we choose the operating point in the center to make the maximum use of the maximum swin of the current swing voltages.

This was class A amplifier, class A power amplifier, in B amplifier we shifted this operating points to this point Q is here this is V C E and this is IC so that when there is no signal this was this is one physical reason that why the efficiency of class B operation is high because in this case even, when there is no signal the current ICQ and this voltage V C E Q so 50 percent current continues to flow in this circuit and that is a shear loss, in this case in class B operation, this is class B amplifier when there is no signal ICQ is 0 even in AB operation that is very small current, trickle current is very small but, let us keep the operation pure B operation so there is no current and hence, it is not deriving the collector circuit is not taking any power from the DC source and that is one reason that the efficiency is high in this case when the input signal comes and the transistors will be conducting and hole process is starts and the efficiency here 25 percent, here it was 78 percent 78.5 theoretical, but practically the efficiency is close to 70 percent in well designed circuits. Now this was the cutoff point, in class C operation which are now currently under discussion, we choose the operating point far away from the cutoff region that means here this is the line and we choose the we bias such that this is the operating point we shift it here.

So, that the conduction will occur only when the high pulse, only for this portion the conduction will occur for remaining large part of the input signal the circuit will be dead, non that the collector current will be 0 it will occur only for these pulses which come in this active region a transistor conduct only when it is operating in the cutoff region, in the sorry in the active region. So, this is class C operation and various features we now talk about class C operation.

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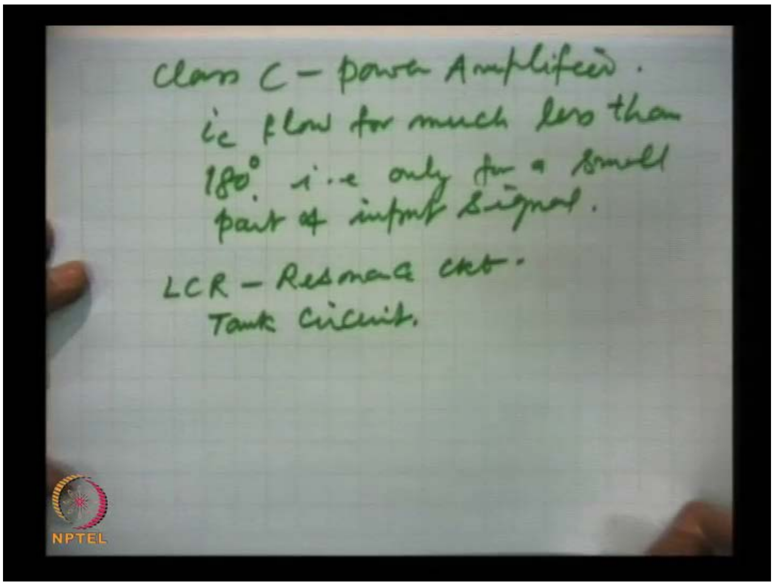


Now, first we take the fact that this is class C power amplifier class C power amplifier this is ic the collector current flows for much less than 180 degrees, of that means only for a small fraction that is only for a small part of the input signal. Now the circuit the most commonly used class C amplifier it makes use of a LCR regional circuit and when it is used the way we are with the collector it is called a Tank Circuit so what is the circuit and how does it work let us talk the basic circuit.

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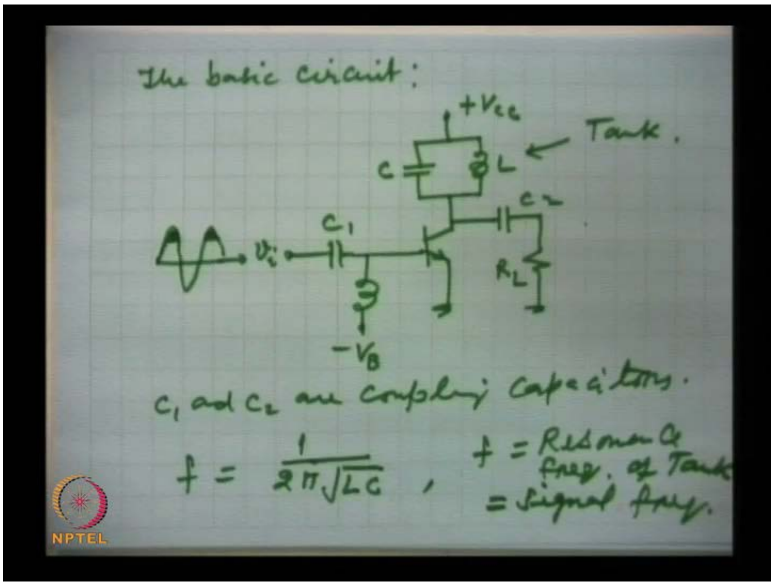

This is the circuit this is commonly used circuit for class C operation. Now here C1 and C2 are coupling capacitors the signal, input signal which for simplicity we will take sinusoidal signal.

And actually in practice also sinusoidal C input signal are used with class C operation and this is coupled to the amplifier here that the power is coupled to the load RL through another capacitor and that is C2 and this is the tank circuit this, is tuned to the signal frequency f, f the resonance frequency for the tank. This is the resonance frequency 1 by 2 pi L into C, here this is a this is the resonance frequency of this tank circuit and this is the same as f is resonance frequency of the tank and also equal as the signal frequency, this is the meaning that the tank circuit is tuned to the signal frequency and the frequency will be given by 1 by 2 pi L C, now this is basically a common emitter circuit and the power we are taking from the collector we are giving as in the case of C amplifier we are giving the input signal at the emitter and base and the important thing here is as I mention that in class C, V bias at much away from the cutoff point it is so negative and that negative bias is provided through this inductance from here by a dc source a negative voltage is applied depending on what are the powers for which we are designing the circuit what will be the input pulse available and according to that the negative bias we will choose and at the output it is to be discussed that because of this negative bias as I discussed here only for a small portions here, a small portions of the positive part the pulse input pulse this circuit will start conducting.

You know the transistor conducts only when it is in the active region and because of this negative bias, first most of this part this will be falling within this negative, this is negative that will be added up so it becomes more negative non conducting. I am talking just of the positive part of the input pulse that for a major portion will be taken up to compensate for this negativity of this biasing, this the emitter base junction of this transistor becomes conducting only for this part and the output so, this tank circuit will get periodic very high powered collector current pulses.

Collector current pulses will be sticking this resonance circuit and this I will soon explain that this circuit is capable of converting, that those pulses into the original sinusoidal; complete sinusoidal signal. In the absence of this we have only this circuit then only this amplified pulses will occur and this pulses will not be of any practical use, we can get back to the sinusoidal cell signal in a amplified much amplified form through this tank circuit, Now let as first graphically see what ever I have said I will explain through this figures.

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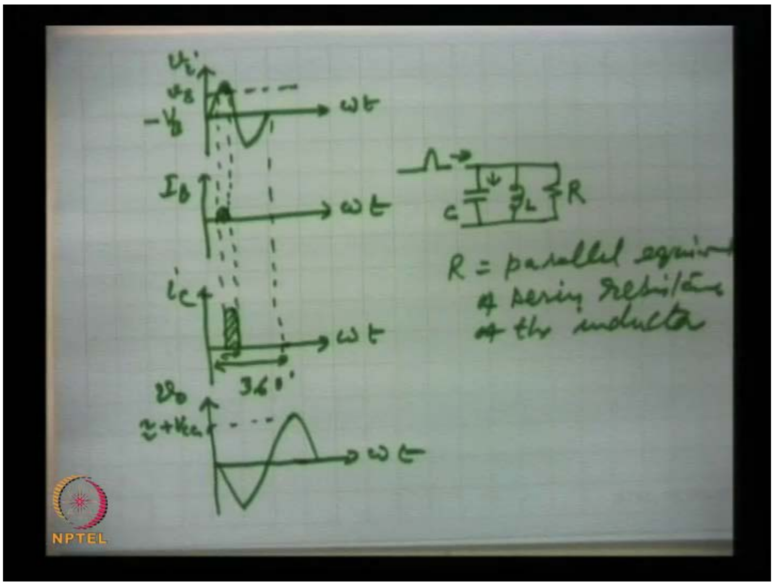


This is the input signal, this is omega t and this is the input voltage, this is where we have biased it and this is Vs, only this portion will make it forward bias the emitter base junction will be forward bias only here this is Vi correspondent this is, let us see IB the base current in this circuit. Base current will flow only when emitter base junction is forward bias and this will be forward bias here. So, only here the base current this is IB, only here it will flow and this will give rise to this is ic, this is the total period or 360 degrees and this the very small fraction few tense of degrees for which the collector amplified, this base current will be amplified and this is the collector current which will be flowing and these high current pulses, they will be striking the tank circuit.

Now tank circuit we can take separately and we can explain that how these pulses will give rise to a completely sinusoidal signal, let us see here that this is the tank circuit this is the tank circuit, this is L this is C and this is the diffractive R and this pulses, they are current pulse is striking this L C R circuit this L C R circuit we are showing here this the inductance the inductor has some series resistance and that series resistance we are representing in as a is equivalent to a series resistance so this R is parallel equivalent of series resistance of the inductor, so this current pulse is strikes, a short current pulse is like a high frequency signal because this time inverse of the time is the frequency so shorter is the pulse higher is the frequency, so for that the capacitor will act as a short circuit and the current will flow through the capacitor and inductor will appear as a large impedance. So, the current will pass through this capacitor and this capacitor will be charged and this will acquire almost the same charge as here V c c, because I will show you that finally, what we are going to have this is the output voltage and this will this is V out omega t then the peak value will be close to V c c.

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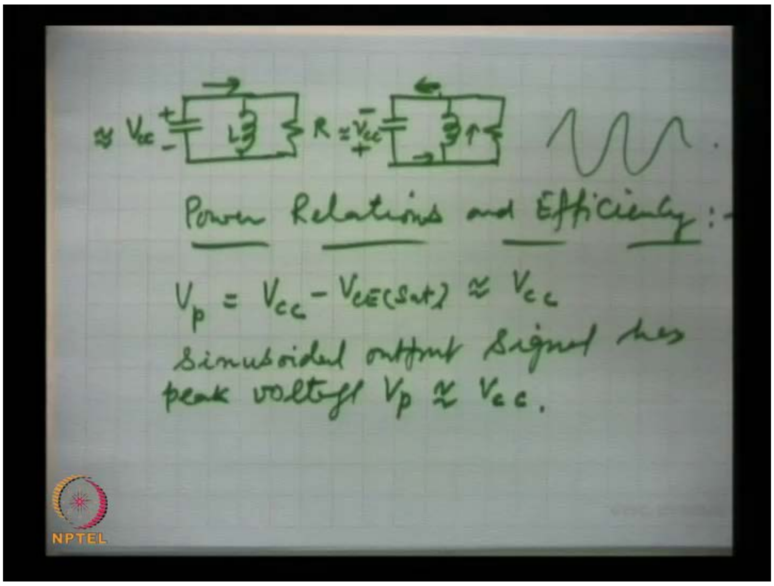


So, the capacitor is charged and we have this situation this is charge to slightly less than V cc because there will be some dissipation in the this resistance which here we have shown and so this will be close to V cc if this is 50 volts this may be initially 48 volts. Now this capacitor is charged and this will get discharge through this resistance and the current will pass through the inductor. In this movement, the electrostatic energy of the capacitor is transformed into the magnetic energy in the coil and so the current this will start discharge till it gets this voltage gets to 0 and then the reverse process will start and this capacitor will be charged from the current flowing through that electromagnetic energy, magnetic energy is stored in to this will be sending current in the opposite direction and this will be charged with the opposite polarity.

The voltage will further be less, but it is still it will be closer to V cc by then the pulse and again because this is all periodic pulses of high frequency, because this we will see that this class C amplifiers are used in radio frequency, kilohertz and megahertz. So, the pulses will keep on repeating after very short timing inverse of the frequency so this process will go on and the sinusoidal output will be continuously available this is like a flywheel that a flywheel if we keep on periodical pushes if we give then it will have almost, not almost it will have a continuous motion.

And the if we do not give continues npush to it then it will start falling in its speed because friction, that friction is equivalent to the resistive part, the losses which will occur that is why I said that this will be charge close to V cc here it will be further falling but, the fall is only few percent of the original V cc value, so this is still close to V cc by then the another clock pulse will come and will charge it again to the same voltage and the process will repeat this way continuously we get a output pulse here like that.You remember that in CE amplifier there was a phase reversal, so a phase reversal is obvious here too, this is a economy circuit I said, because we are feeding the input at the base with respect to the ground and we are taking output at the collector with respect to ground. So, this way the continuous pulses will occur.

Now power relations and efficiency, power relations and efficiency this I have said that the transistor in class C operation is off for a more major portion of the input signal when no signal is present it is totally off and the sinusoidal output of the amplifier has a peak voltage P which will be close to V cc actually V cc minus VCE saturation, the saturation this is fraction of a volt and so this is very close to V cc this is the peak voltage the output of the amplifier, sinusoidal output signal has peak voltage which is VP and which is very close to V cc and in this circuit when the series dc circuit dc resistance is replaced by it is ac equivalent.

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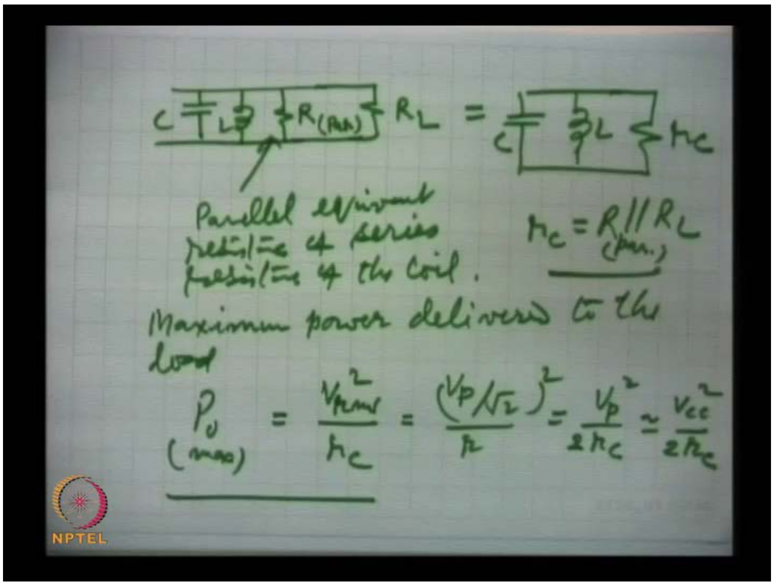


Then the circuit will become this is R L and this is the R which is the parallel equivalent, so we write P rA, this is the parallel equivalent resistance of the series resistance of the coil and this is load when we do the ac analysis then this we have to take as short so when this is shorted this everything will come in parallel and this is what as we shown and here we can replace it by this is C, this is L by this where this is the effective load r c and r c this is L this is C this r c is actually R parallel in parallel R L so this is the ac and the maximum power deliver to the load maximum power delivered to the load P o max P o max this is equal to V r m s square by r c where r c is this effective value of the load and this is equal to V P peak value divided by 2 by r and this is V P squared by 2 r c but, V P is close to V cc so this is actually V cc square by 2 r c, very high power actually because this resistance will be quite low the dc resistance this p r r is a very small resistance as compared to any resistance so this power will be quite high this is the ac power. ac power available from class C amplifier.

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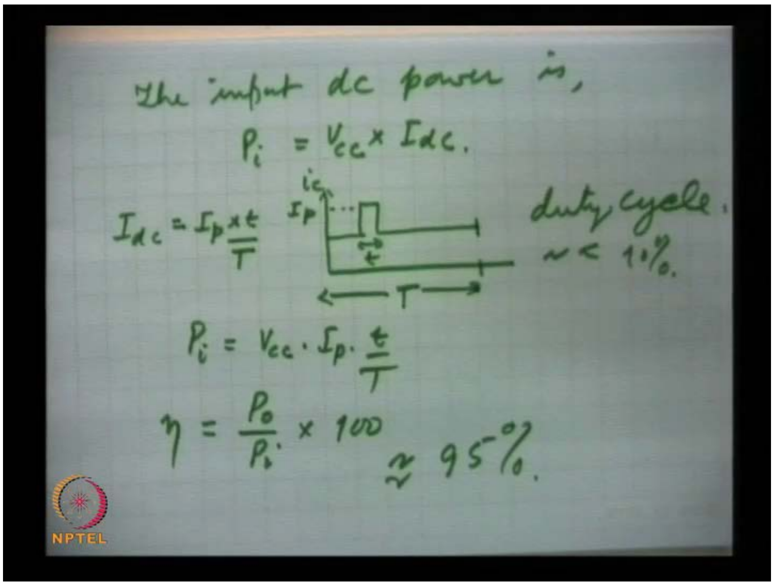


And the input dc power the input d c power is P i equal to V cc into I d c but, I d c does not flow for the hole 360 degrees of the input signal this we have talk several times in class C amplifier it flows only for shorter duration, in fact we can make assumption that the collector pulse is rectangular in shape like this; this is say the total period T and the collector current flows only for this much time t and this is perfectly fine because we have seen that collector current flows only for a very short period of the total signal so this is the total period of the wave and the output this is i c, this is i c and this is the peak value I p peak value.

And then the dc component of this we can write I dc this will be equal to I p peak value into t by T is small as this is 0 suppose this is 0 then I dc drawn will be 0 its very clear the collector current flows for a very short period t in comparison to the period of the wave, so this is the expression which we have to use with this so that P i becomes V dc into this is actually many times talked in terms of duty cycle and for good operation efficient operation duty cycles are around or less than 10 percent, so this is to be replaced I p t by T and then efficiency P 0 by P i into 100 this is the percent efficiency.

And for class C operation it comes close to 95 percent practical efficiencies are also around 90 percent 90 percent that means if we are supplying 1 kilo watt of dc power to a class C amplifier 1 kilo watt, 900 watts will be available as a sinusoidal ac very high power, so that is the reason that we are studying class C operation but, there is a limitation with class C operation in spite of the fact that it is most efficient out of the three but, it can be used only for the generation of sinusoidal signals that means carrier waves. All this television and radio signals are the carrier wave on which the your signal goes so the carrier wave is generated by class C power amplifiers and because carrier is very powerful it is in megawatts.

And so there the efficiency is the biggest consideration and the last thing about so the limitation is only that sinusoidal signals can be generated and as I said that these class C power amplifiers are used for carrier wave generation so they are in kilo hertz and mega hertz are still higher frequencies, so that higher is the frequency smaller is the value of capacitor and it conductance required here this expression I wrote the resonance frequency f is 1 by 2 pi under root L C, so very high frequencies very small values of capacitance in resistance will be required in the circuit so very high q tank circuits are possible with such small values. Now after efficiency the last thing is power dissipation that is also very low in this circuit.

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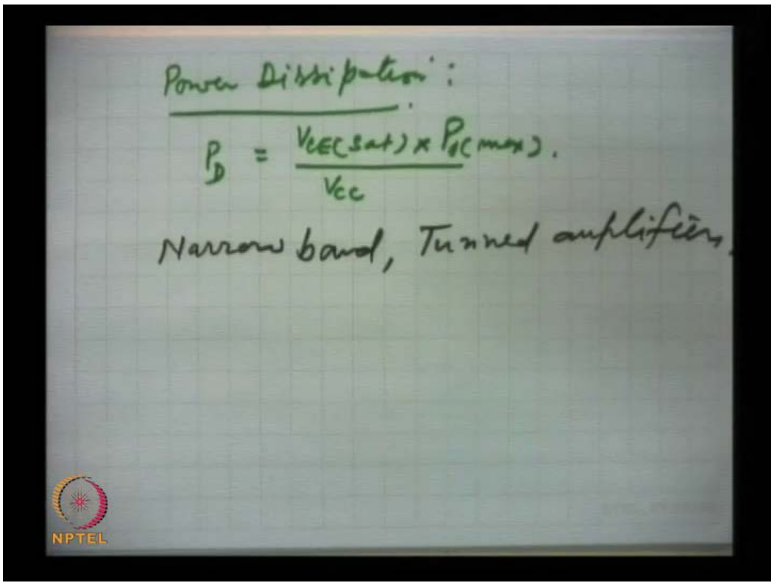


Power dissipation in that is P D this can be shown to be equal to V CE set by V CC, this is P o max, so this is also very small because this V C set is very small so but, one can calculate we have the data for these voltages and this power then power dissipation can be calculated so that finishes our class C operation and in fact this module on power amplifiers is complete, what we have is studied I am now going to summarize, we started with the effect that concept of ac load line that proves very useful in this in the analysis of this power amplifiers. Power amplifiers are analyzed graphically.

And the reason for graphical analysis the reasons are a major reason is that because the in power amplifier large swings of currents and voltages are involved, power is current into voltage the so the swings have to be very high in power amplifiers. A large swings are going to use a major portion and in fact the total active region and we have seen that the curves are non-linear and hence the parameters will vary from point to point, so the analysis as we have done for a small signal amplifiers will not be very accurate the power amplifiers are analyzed graphically and for graphical analysis this ac load line helps it is a great tool and helps in our investigation

So we got the two expression one for current, one for voltage as the two major that the two intersections on the two axis for the load line, then we studied the classification. Classification the small signal classification is done like C common emitter, common base, common collector, power amplifier and this mosfets and facts they are also classified like common source common drain and common gate circuits.

This classification power amplifier is entirely different it is based on the fact that output current is available that means the transistor is put to conduction to what fraction of the input signal, if it conduct for the hole 350, 360 degrees, it is class a operation and in class a operation efficiency is 25 percent which can be increase to 50 percent if instead of using a capacitor coupled load if we use if we replace that R C the resistance by the primary of the transformer then transformer coupling can be used to couple the load and then the efficiency goes up to 50 percent and the reason for this exhauster efficiency is that we saved the power which goes as a waste class a operation in the absence of the signal the half the current half, of the maximum current is still is used in the circuit I C q is in the half of the maximum current that we saved and the efficiency can be raised to 50 percent but, again the use of transformer couple load is selective it has some limitations in the sense that transformer are bulky and the frequency response is if it has to be good the transformers are expansive but, many times they are used.

In class B operation the conduction the transistor is put to conduction for half the cycle half the cycle, so the upper half appear from one transistor in push pull case and the half will appear from the other transistor there is a common load, so at the load the complete signal is available. The efficiency is very high this is a theoretical value is a 78.5 percent but, practical efficiencies are also are close to 70 percent but, normally in class B to use push pull amplifier and in class then we took class C operation, in class C operation the conduction is for a very short time as compare to the period of wave, that means the duty cycle is close is kept close to 10 percent or less, so we discussed the circuit what is the basic circuit of the class C amplifier and how does it work, how do we bias the emitter base junction much below more much more negative then the cutoff and the circuit remains in active non conducting for a major portion of the period of the wave but, it conducts with high efficiencies only for short time. So, the high current pulses at the collector they excite the L C R resonance circuit which is called a tank circuit and we can get a the sinusoidal signal back from these sharp collector current pulses because collector pulses as such are not of any practical use, if we are using for any other purpose than most of the information which will be contained in the for which the circuit is not conducting that that information will not be available.

So, this is a the sinusoidal signal can be obtained by the use a high resonance tank circuit and that puts a limitation on the class C operation, that class c amplifiers are narrow band tuned amplifiers so they have one single biggest application and that is of generation of a carrier signal and so it is very efficient, the efficiencies we have seen they are close to 95 percent and which is very high and that is why they are efficient circuits and the power dissipation is also very low. This I said in the beginning that every system makes use of a power stages the systems are multi stage systems in which the signal processing is done at a small signal level by using the properties of a the small signal amplifier and a small signal circuits which we studied.

But the final, we require power for example, to drive the printer or some motor or speaker so the large power is required at the output stage. So, the last one or two stages are the power amplifier stages and out of that depending on the application these amplifiers which we have studied they are used and that finished our module on power amplifiers. The next we will be the last module that is next lectures will be on differential and operational amplifiers, these amplifiers are very different operational amplifiers popularly are known as op amps and they are very important today they are almost everywhere, they are the op amps in analog circuits in digital circuits they are very widely used so we will be studying of differential and operational amplifiers.