Hands out on Large Signal amplifier

A- Difference between voltage and power amplifiers :

⇨ The primary function of a voltage amplifier is to raise voltage level of the input signal whereas a power amplifier is required to feed large amount of power to the load.

⇨ The main difference between these two amplifiers is illustrated below:

Basis of comparison	Voltage amplifier	Power Amplifier
Coupling	Usually R-c Coupling is used.	Invariably Transformer Coupling is used.
Output Power	Low.	Very High .
Collector current	Low (in the range of 1mA)	High (More Than 100mA)
Type Of Transistor	Transistor used has a thin base.	Transistor used has a thick base .
Output Impedance	Very high, about 10-12 KΩ .	Very low nearly 100 to 200 Ω .
Size Of Transistor	The physical size of transistor used is usually small & is known as low or medium power transistor.	The physical size of transistor used is usually large and is known as power transistor.
Transistor Heat Dissipation	The transistor used can dissipate less heat produced during its operation.	The transistor used can dissipate more heat produced during its operation.
Collector Load	High resistance, typically 5to 10 KΩ.	Low resistance, typically 5 to 25 Ω.
Application	Voltage amplifier is used for small signal voltage.	Power amplifier is used for high voltage signals.
Current gain β	Value of current gain is very high(more Than 100).	Value of current gain is Low(Of the order of 25 to 50) .

B- Importance of impedance matching in Power amplifiers :

⇨ Power Amplifier is the last stage of any multistage amplifier & is required to feed large amount of power to the load.

⇨As per the requirement of maximum power transfer theorem , Impedance matching is a required feature for transferring maximum power to load.

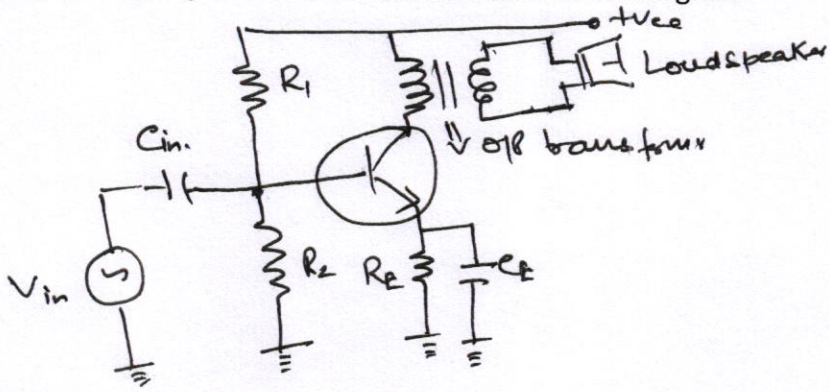
⇨To achieve impedance matching , transformer coupling is required in which turns ratio of the output transformer is designed in such a way that the load resistance looking at the primary side is ,

$$R_1 = \left(\frac{N_P}{N_S}\right)^2 \cdot R_L$$

Where N_P/N_S = Turns ratio of transformer
R_L = Load Resistance

C- Classification of Power Amplifiers (Class A, Class B, Class AB, and Class C amplifiers)

⇨ Basically a power amplifier is a transformer coupled cascaded amplifier in which output is taken across secondary coupling of a transformer as shown in the diagram



⇨ On the basis of mode of operation, such Power amplifiers can be classified as below:

1- Class A Power Amplifier : The amplifier conducts through full 360^0 of the Input, Q Point is set near the middle of the load line.

⇨ **Adv**: This amplifier has least distortion & therefore output wave shape obtained is a replica of input wave shape.

⇨ **Disadv :** Output power is low & Collector efficiency is below 50%(approx. 35%)

2- Class B Power Amplifier : The amplifier conducts through 180^0 of the Input, Q Point is set at the cut off.

⇨ **Adv**: Output power is Higher & Collector efficiency is higher (approx. 50 to 60%)

⇨ **Disadv :** This amplifier suffers from reverse distortion.

3- Class AB Power Amplifier : This is a compromise between class A & Class B Power amplifier in which amplifier conducts in between 180^0 to 360^0 of the Input, Q Point is located between middle of load line to cut off.

⇨ **Adv**: This amplifier has low distortion & has linear behaviour.

⇨ **Disadv : Low** Collector efficiency and high power dissipation.

4- Class C Power Amplifier : The amplifier conducts below 180^0 of the Input, Q Point is set below the cut off.

⇨ **Adv**: High Collector efficiency (approx. 80 %)

⇨ **Disadv :** This amplifier suffers severe distortion.

D-Collector efficiency and Distortion in class A,B,C Amplifiers

⇨ An amplifier is basically an active device that converts dc power from the source to ac signal power in the load.

⇨ The degree to which the amplifier is successful in converting this is measured by conversion efficiency

⇨ This is also called as collector efficiency as output is obtained across collector of the transistor. This Collector efficiency is defined as :

η = ac signal power delivered to load/ dc input power to the collector circuit

⇨ Maximum theoretical value for η depends on

-- The way in which load is coupled to the active device

-- The class of operation of the amplifier.

⇨ Value of η may differ from 25% to 90%

Harmonic Distortion in class A,B,AB & C amplifiers :

⇨ An ideal amplifier should not only produce an enlarged version at the output but also provide a faithful reproduction of the input wave form.

⇨ At times the wave form obtained at the output is not in conformity with the input waveform. This is due to nonlinearity of the active device used for amplification. In other words, it occurs when a transistor is driven beyond the linear range of its characteristics.

⇨ This deformation is known as amplitude distortion or harmonic distortion.

⇨ The harmonic distortion is the rms value of v expressed as a percentage of the rms value of v

where v stands for

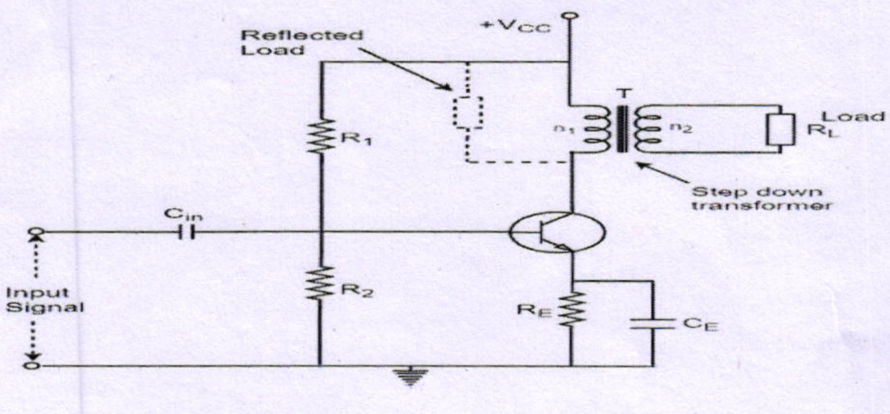
⇨ Harmonic distortion can be reduced by using negative feedback .

E- Single ended power amplifiers : Graphical method of calculation (without derivation) of output power :

⇨ Basically last stage of a multistage audio amplifier with foremost duty of transferring maximum power to the output device.

⇨ A Power amplifier is known as single ended when the output is obtained with respect to one end permanent grounded.

⇨ In such situation either one or several power transistors are connected in parallel to drive the load . Basic circuit of a single ended power amplifier is shown below:

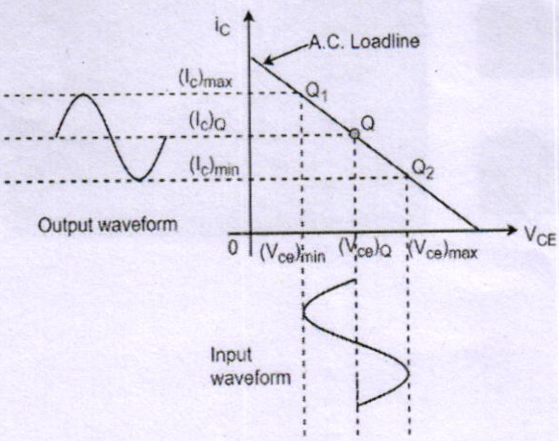
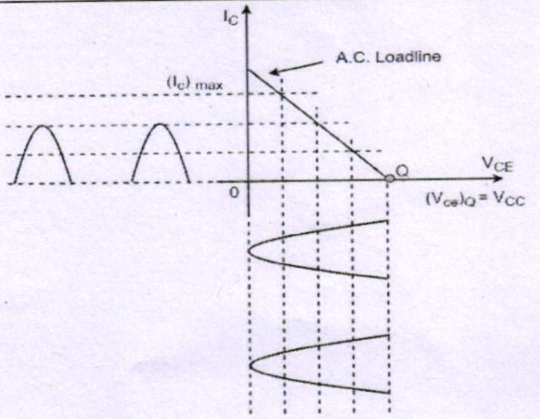
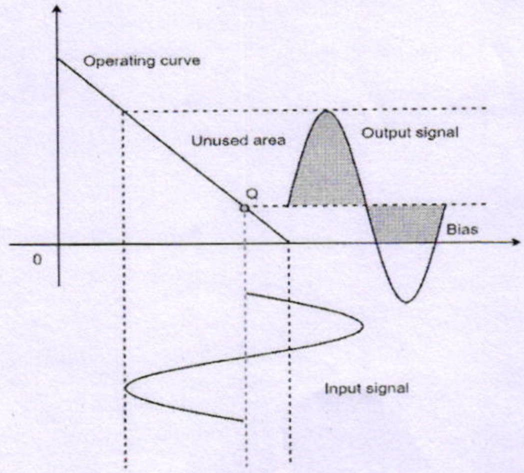


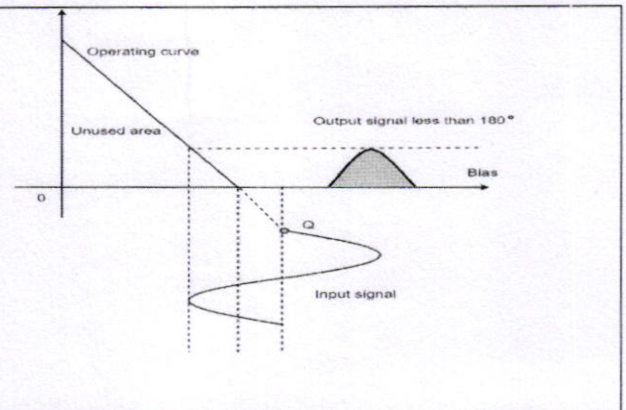
⇨A single ended power amplifier suffers from poor collector efficiency & high harmonic distortion.

⇨This problem of single ended amplifier is overcome by using two transistors in push pull mode which is then called a double ended power amplifier.

Graphical method of calculation of output power :

⇨ Below is illustrated calculation of output power in different single ended amplifiers with help of graphics:

⇨ In a class A power amplifier, values of biasing resistances such as R_1 , R_2 & R_E are adjusted in such a way that the Q point lies in the middle of load line as shown in the adjacent graph : ⇨ Here Collector current flows throughout the whole cycle so that no part of signal is cut off . ⇨ Due to this arrangement, this amplifier has least distortion & output wave shape obtained is a replica of input wave shape. ⇨ The **o**utput power is low & Collector efficiency is below 50%(approx. 35%)	
⇨ In class B power amplifier, biasing circuit is so adjusted that the Q point lies at collector cut off voltage as shown in adjacent diagram. . ⇨As result of this, input circuit is forward biased during positive half cycle when collector current flows but input circuit is reverse biased during negative half cycle when there is no collector current flow. ⇨ Due to this the amplifier has high distortion but at the same time has a higher power output & Collector efficiency.	
⇨In class AB Power amplifier, the biasing circuit is so adjusted that the Q point lies near the cut off voltage as depicted in adjacent diagram. ⇨ In this circuit configuration, the input circuit is forward biased during a small portion of negative half cycle & for complete positive half cycle of the signal, as a result collector current flows for this span. ⇨ During rest of the cycle of signal, the input circuit is reverse biased & during this period no collector current flows. ⇨Such amplifier has low distortion, Low Collector efficiency &high power dissipation.	

⇨ In a class C Power amplifier , biasing is adjusted in such a way that collector current flows for less than positive half cycle as shown in adjacent diagram. ⇨ Such type of amplifier circuit provides High Collector efficiency but they suffer from severe distortion. ⇨ Therefore such circuit is not used for amplification purpose, rather they are used as tuned amplifiers.	

F- Heat dissipation curve and importance of heat sinks.

⇨ As we know, collector current depends on collector leakage current to some extent .At load collector current produces heat within the transistor & this heat tends to increase collector leakage current.

⇨ Since Collector current depends on collector leakage current, therefore with increase in collector leakage current, Collector current also increases.

⇨ The increase in Collector current produces an increase in power dissipated at the collector, which in turn further makes an increase in junction temperature.

⇨ If certain stabilization technique is not adopted, the process is cumulative & in case the process continues, this may lead to destruction of transistor.

⇨ The destruction of a transistor by the cumulative effect of rise in temperature is known as

G- Concept of Thermal Runaway & its protection.

⇨ In case of power transistors, since the heat produced at collector junction is large, it is very much susceptible to thermal runaway. To prevent this thermal runaway in power transistors, certain means s needed to be adopted to dissipate the heat developed at the junction.

⇨ A Very popular device for such purpose is heat sink.

⇨ Heat sink is a sheet of metal used to dissipate heat developed at the collector junction of a power transistor.

⇨ Normally used heat sink is either a fin type or a diamond shaped TO-3 & TO-66 type.

⇨ Heat dissipation curve :

⇨ If a transistor is operating in open air, heat dissipated in junction will conduct away in two ways:

1- Junction to transistor case

2- From Transistor case to air .

⇨ The dissipated power raises the junction temperature . The junction temperature with respect to air can be expressed as :

$$T_{j} - T_{A} = P_{C} \cdot \theta_{jA}$$

Where θ_{jA} = thermal resistance between junction & air having unit $^{0}C/W$ & indicates increase in temperature over ambient per watt dissipated power.

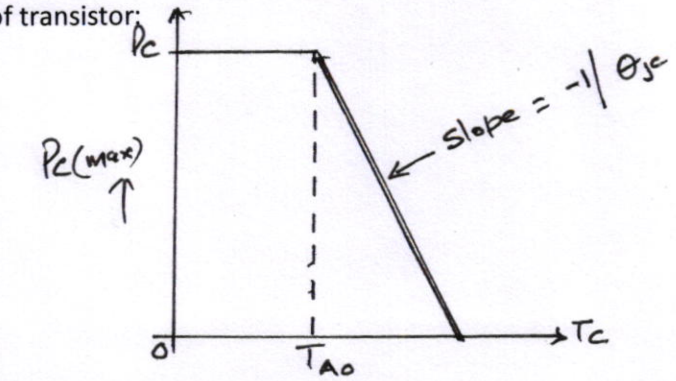
T_{j} = Junction Temperature

T_{A} = Ambient Temperature

⇨ This indicates that smaller the value of thermal resistance, lesser increase in temperature over air will take place.

⇨ In free air, thermal resistance depends primarily on the type of packaging used for power transistor.

⇨ The variation in maximum collector dissipation with case temperature is an important characteristic for any transistor. This variation is indicated by the following curve which is called derating curve of transistor:



⇨It is clear from the curve that transistor can safely dissipate rated maximum power (P_{Cmax}) below temperature T_{A0}.

⇨ However, maximum allowable power decreases with increasing value of temperature higher than T_{A0}. This phenomenon is called derating of power curve.

⇨ The slope of derating curve can be obtained as

$$\text{Slope } \theta_{jA} = T_{jmax} - T_{A0} / 0 - P_{Cmax} = - T_{jmax} - T_{A0} / P_{Cmax}$$

From this equation, Power dissipation at any ambient temperature T_A can be obtained as

$$P_{Cmax} = T_{jmax} - T_{A0} / \theta_{jA}$$

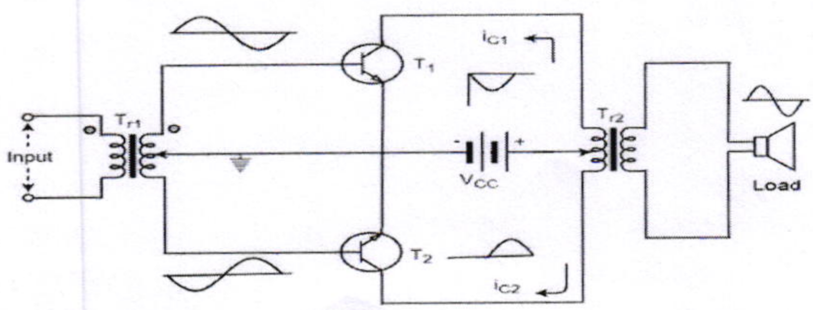
At $T_{jmax} = T_{A0}$, no power can be dissipated as no heat can be removed from the junction.

H- Push-pull amplifier:

⇨ Comparative study of different power amplifiers shows that class B power amplifier when used in such a way that both cycles of its Input signal are utilized, will serve the best purpose.

⇨ In order to compensate the problems of class B power amplifier, push-pull configuration is introduced in which two power transistors are used in such a way that when one works for positive half cycle of input signal, the other works for negative half cycle of input signal.

⇨ The circuit of push-pull class B power amplifier consists of two identical transistors T_1 and T_2 whose bases are connected to the secondary of the centre-tapped input transformer T_{r1}. The emitters are shorted and the collectors are given the V_{CC} supply through the primary of the output transformer T_{r2} as shown in the circuit diagram:

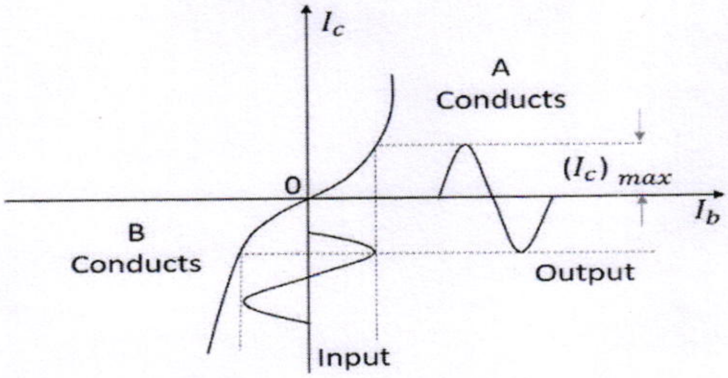


⇨ The two transformers used in circuit of class B push-pull amplifier are centre-tapped.

⇨ When no signal is applied at the input, the transistors T_1 and T_2 are in cut off condition and hence no collector currents flow. As no current is drawn from V_{CC}, no power is wasted.

⇨ When input signal is applied to input transformer T_{r1} which splits the signal into two signals that are 180° out of phase with each other. These two signals are fed to bases of two identical transistors T_1 and T_2.

⇨ As is clear for the positive half cycle of input, the base of the transistor T_1 becomes positive and collector current flows. At the same time, the transistor T_2 has negative half cycle, which throws the transistor T_2 into cut off condition and hence no collector current flows.



⇨ For the next half cycle, the transistor T_1 gets into cut off condition and the transistor T_2 gets into conduction, to contribute to the output.

⇨ In this way, output is obtained for both cycles of input & this way output waveshape is almost replica of wave shape of Input signal .

⇨Since for both the cycles of Input signal ,each transistor conducts alternately, therefore the operation called as push pull operation.

⇨ The output transformer T_{r3} serves to join the two currents producing an almost undistorted output waveform.

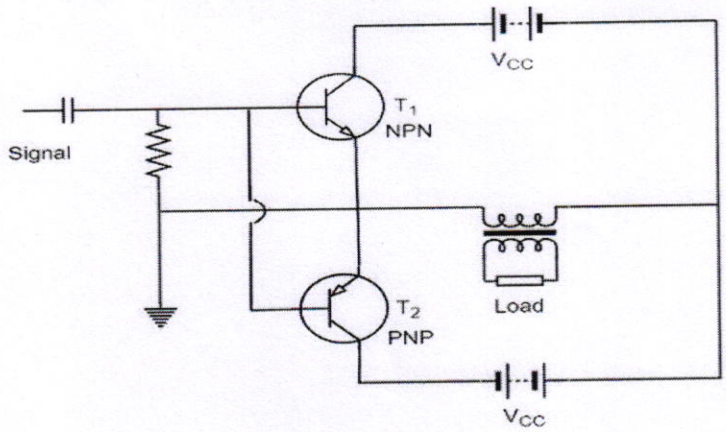
⇨ Power Efficiency of Class B Push-Pull Amplifier is almost 78% & Harmonic Distortion is low.

I- Complementary symmetry push-pull amplifier

⇨ It is same as push pull amplifier with the difference that the two identical transistors used in push pull amplifier are now complemented. Means a pair of identical NPN & PNP Transistor is now used in complementary symmetry push Pull amplifier.

⇨ This arrangement eliminates the need of using a centre-tapped transformers which otherwise makes the circuit bulky, heavy and costly. To make the circuit simple and to improve the efficiency, the transistors used can be complemented, as shown in below circuit diagram.

⇨ This circuit employs a NPN transistor and a PNP transistor connected in push pull configuration. When the input signal is applied, during the positive half cycle of the input signal, the NPN transistor conducts and the PNP transistor cuts off. During the negative half cycle, the NPN transistor cuts off and the PNP transistor conducts.



⇨ As a consequence, the NPN transistor amplifies during positive half cycle of the input, while PNP transistor amplifies during negative half cycle of the input. The transistors used are though complement to each other, yet act symmetrically while connected in push pull configuration of class B. That's why the circuit is termed as **Complementary symmetry push pull class B amplifier**.

Advantages :

1- The weight and cost is reduced because there is no need of centre tapped transformers.

2. Equal and opposite input signal voltage requirement is not mandatory.

Disadvantage .

1- At times, it is difficult to get a pair of complementary transistors with similar characteristics.

2- Two different power supply voltages are required .