Power Amplifier

The device which converts d.c power to a.c power and ~~con~~ whose action is controlled by the input signal. The power amplifier raise the low level power to high level power.

The d.c power is distributed as —

d.c power = a.c power + losses.

Voltage Amplifier

The device which is used to raise the voltage level of input signal is called voltage amplifier. The voltage amplification is given below in common emitter configuration —

$$A_V = \frac{V_o}{V_{in}} = \frac{I_C R_C}{I_B R_{in}} = \frac{\beta I_B R_C}{I_B R_{in}}$$

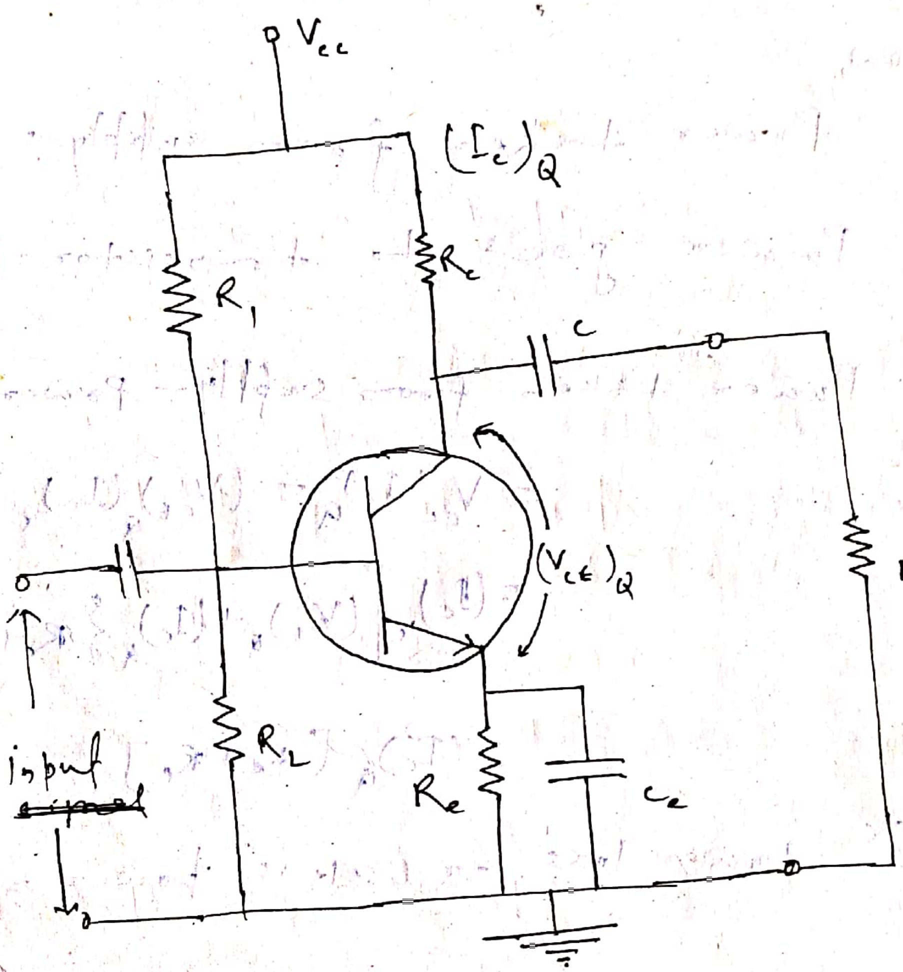
$$\therefore \boxed{A_V = \beta \cdot R_C / R_{in}}$$

Comparasion bet^n voltage Amp. & power amplifier

Voltage Amplifier	Power Amplifier
i) $\because A_v = \beta \cdot \frac{R_c}{R_{in}}$. In voltage Amplifier the transistor is used with high $\beta (= \frac{I_c}{I_B})$ i.e. for this base should be thin.	i) while, in power amplification, comparatively β, the base of transistor used should be thicker to handle large current.
ii) ~~Current~~ collector resistance (R_c) should be high ~~greater~~ than the input resistance R_{in} i.e R_{in} is low than R_c	ii) In this case collector resistance should be low.
iii) Input voltage is low	iii) while, input voltage is high.
iv) In voltage amplification RC coupling is used	iv) while, here transformer coupling is used.
v) Output impedance is high	v) Output impedance is low.
vi) Output power is low	vi) Output power is high.

Voltage Amplifier can not be used as power amplifier :-

For the discussion we consider the following voltage amplifier (CE) circuit —



Let, $(I_c)_Q$ is quiescent collector current and $(V_{CE})_Q$ is the quiescent voltage in betn collector and emitter then for collector emitter ckt —

$$V_{cc} = (I_c)_Q R_c + (V_{CE})_Q + (I_c)_Q R_e$$; for d.c case $C_e \to \infty$

$$= (V_{CE})_Q + (I_c)_Q [R_c + R_e]$$

where

R_c = Collector resistance

R_e = Emitter resistance.

$\therefore \quad V_{cc} = (V_{CE})_Q + (I_c)_Q [R_c + R_e]$ ——— (i)

Now,

Power taken from supply = $V_{cc}(I_c)_Q$

Power goes to transistor = $(V_{CE})_Q (I_c)_Q$.

$\therefore$ Power taken from supply − Power goes to transistor

$$= V_{cc}(I_c)_Q - (V_{CE})_Q (I_c)_Q$$

$$= (I_c)_Q \left[(V_{CE})_Q + (I_c)_Q \{ R_c + R_e \} \right] - (V_{CE})_Q (I_c)_Q$$

$$= (I_c^2)_Q [R_c + R_e]$$

i.e. Power loss or useless power $= (I_c^2)_Q [R_c + R_e] > 0$. ——— (ii)

Equation (ii) shows that power which is wasted unnecessarily heating the resistor. Due to this fact a voltage amplifier can not be used as a power amplifier.

To reduce this wastage, we can short circuited R_c and R_e. But, R_e can not be short circuited because this is a part of biasing network and if R_c is short circuited then R_L will be short circuited. Here there is a best possibility that the R_c is replaced by a chock coil (in which d.c resistance is almost zero). That is why in a power amplifier transformed coupling is used.

Types of power amplifier :-

i) Audio power amplifier :- The power amplifier which raise the power level of the signal that having frequency range from 20Hz to 20kHz. since this frequency is small, hence it is also called small signal amplifier.

ii) RF power amplifier :- The power amplifier which raise the power level of the signal (RF signal) that having frequency range 20kHz to 30 MHz, is called RF power amplifier or tunned power amplifier. This is also called large signal power amplifier.

On the basis of operation, there are following type of power amplifier —

i) Class A power amplifier
ii) Class B " "
iii) Class C " "

i> **Class A power** amplifier :- The power amplifier in which the collector current flows at all time during the full cycle of input signal is called class A power amplifier.

ii> **Class B power** amplifier :- The power amplifier in which collector current flows only for the half cycle of input signal is called class B power amplifier.

iii> **Class C power** amplifier :- The power amplifier in which collector current flows only during the less then the half cycle of input signal is called class C power amplifier.

The transistor used in power amplifier is called power transistor.

iv) Class AB power amplifier :- A power amplifier may be biased at a d.c level above the zero-base-current of class B and above one-half cycle of class A power amplifier. In this condn amplifier is called class AB power amplifier. In class AB power amplifier the output signal swing in betn 180° and 360° i.e swings in greater than one-half cycle and less than full cycle. Class AB power amplifier requires a push-pull connection.

v) Class D power amplifier :- The power amplifier which operation is doing on pulse [digitaly] and 'on' for short time and off for long interval is called class D power amplifier. (Used in digital modulation).

Push-Pull operation :- As we know that, in class B power amplifier, collector current flows only during the one-half cycle of input signal i.e for 180° swing.

When ~~at~~ the Two class B operation in which one provide the output on +ve-half ~~of +ve~~ cycle and other to provide ~~output on -ve half cycle~~ on -ve-output-half cycle are combined then it provide an output for full 360° operation. This operation is this operation is called Push-pull operation. And, such a combination of two class B amplifier is termed as push-pull connection.

Some terms.

i> Power dissipation capacity :- The ability of power transistor by which a power amplifier dissipate the heat developed in it, is called power dissipation capacity.

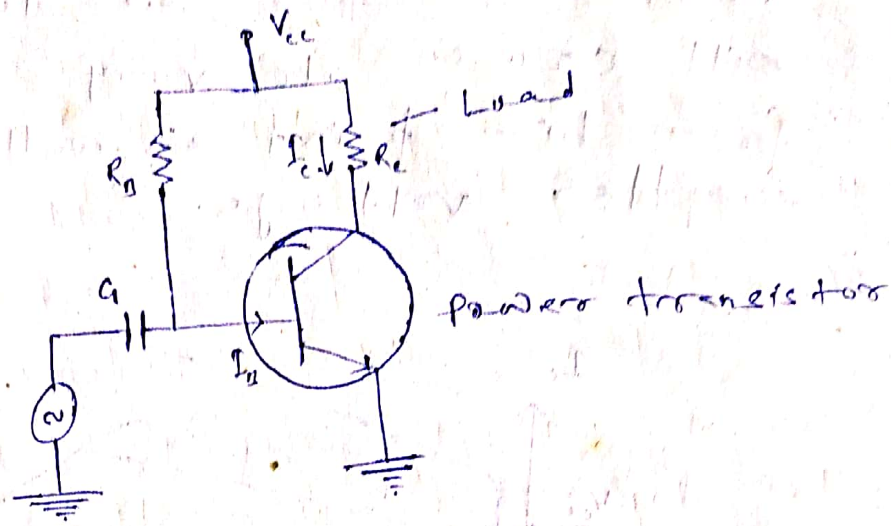
ii> Distortion :- The change in shape of output signal in comparision with input signal is called distortion. Distortion occurs due to the non-linear behavior of transistor, i.e transistor is a non-linear device, hence distortion occurs. For small (voltage amplifier) signal, there is no problem of distortion but for large signal amplifier, distortion is produced.

Efficiency of power amplifier —

$$\eta = \frac{\text{Average a.c power output}}{\text{d.c power input to transistor}}$$

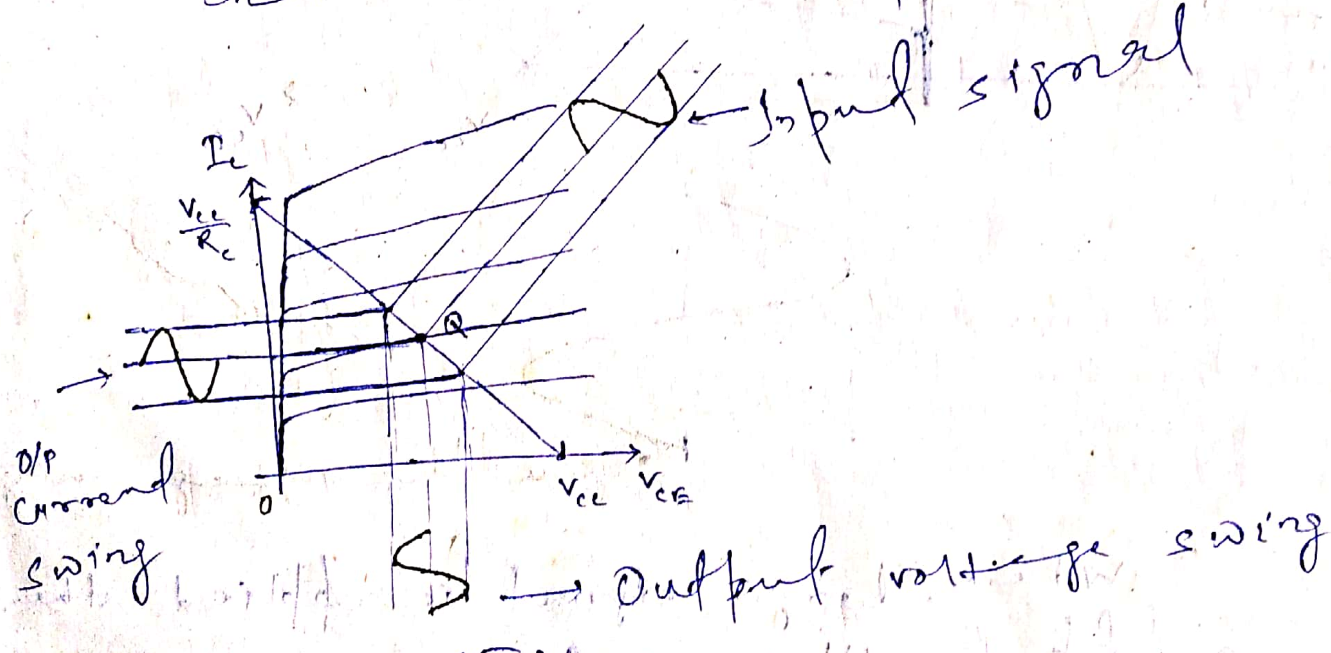
Power Amp.	class A	class B	class AB	class C	class D
operation cycle	360°	180°	180° to 360°	Less than 180°	Pulse operation
Efficiency	25% to 50%	78.5%	betn 25% (or 50%) to 78.5%		Typically over 90%

Class A Amplifier.



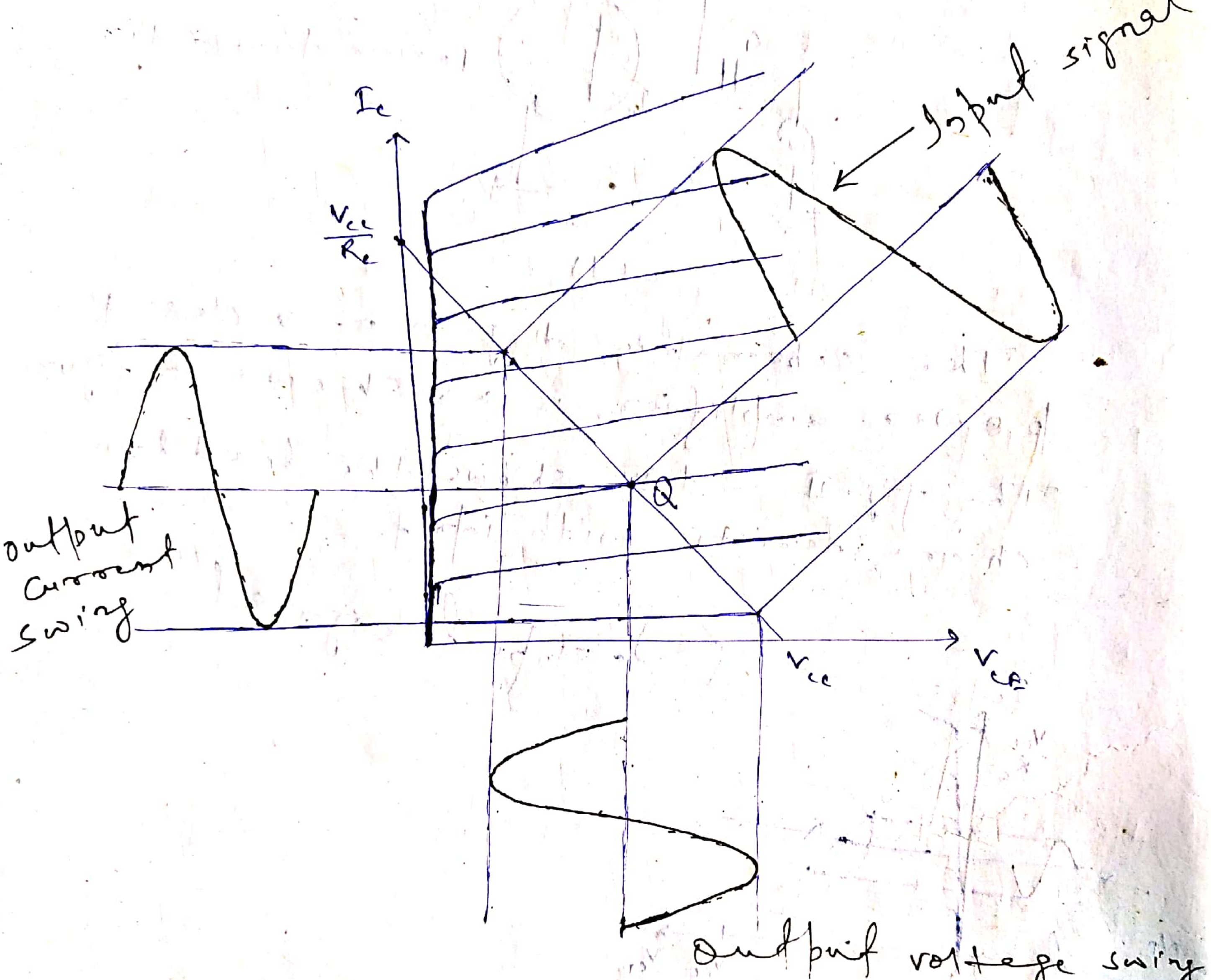
(I)

The schematic diagram of a class A power amplifier is as shown in figure. The fig-II and III shows the load line characteristic with input.



(II)

As, when input signal is applied, output will vary from its d.c biasing point or operating point above and below. When, a small signal is applied then base current vary above and below the d.c bias point which will cause to vary collector current from bias point as well as collector-emitter voltage.



When, large signal is applied then output will vary further ~~around~~ around d.c bias point untill collector current or collector-emitter voltage reache to a limiting condition. For the current this limit is either zero-current at low end or V_{cc}/R_c at high end as cleared from load-line characteristic shown in fig-III. And, the limiting condition for collector-emitter voltage is either zero at high end ~~and~~ or supply voltage V_{cc} at low end as shown in figure.

Q is taken so that the transistor works in the linear region.

Now, if $(I_c)_Q$ and $(V_{CE})_Q$ are collector current and collector-emitter voltage, when no signal is applied then,

D.C power drawn from battery $V_{cc} = V_{cc}(I_c)_Q$

This power drawn is used in following two parts —

i) Power dissipated in collector ~~as~~ load heat $P_c = \cancel{V_{CE}}(I_c^2)_Q R_c$.

$P_c = (I_c^2)_Q R_c$.

ii) Power given to the transistor

$P_{tr} = P_{in} - P_c = V_{cc}(I_c)_Q - (I_c^2)_Q R_c = (V_{CE})_Q (I_c)_Q$.

Now,

output a.c power developed in load resistor R_c

$(P_o)_{ac} = I_{rms}^2 R_c = (I_c^2)_{rms} R_c$

$\Rightarrow (P_o)_{ac} = \frac{(V_{CE}^2)_{rms} R_c}{R_c^2} = \frac{(V_{CE}^2)_{rms}}{R_c}$.

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$$\Rightarrow (P_o)_{ac} = \frac{\left(\frac{V_m}{\sqrt{2}}\right)^2 \cancel{R}}{R_c} = \frac{V_m^2}{2R_c}$$

$$\boxed{(P_o)_{ac} = \frac{V_m^2}{2R_c}}$$

OR,

$$\boxed{(P_o)_{ac} = (V_{CE})_{rms}(I_c)_{rms}}$$

OR, $$\boxed{(P_o)_{ac} = \frac{V_m I_m}{2}}$$

Hence the power flow diagram —

$(P_{in})_{dc}$

- P_{RC} = Power dissipate in collector load ~~resistor~~ as heat $= (I_c^2)_Q R_c$
- $(P_t)_{dc}$ = Power given to transistor
  - $(P_c)_{dc}$ = Power dissipated by transistor in collector region as heat.
  - $(P_o)_{ac}$

Efficiency :-

$$\eta_{overall} = \frac{\text{a.c power delivered to load}}{\text{Total power delivered by d.c supply}}$$

$$= \frac{(P_o)_{ac}}{(P_{in})_{dc}} \times 100\,\%$$

For over all efficiency —

$$(P_{oc})_{ac} = V_{rms} I_{rms} = \frac{1}{\sqrt{2}} \frac{[V_{max} - V_{min}]}{2} \cdot \frac{1}{\sqrt{2}} \cdot \frac{[I_{max} - I_{min}]}{2}$$

$$= \frac{[V_{CE}(P-P)][I_C(P-P)]}{8}.$$

$$\therefore \eta_{overall} = \frac{(P_o)_{ac}}{(P_{in})_{dc}} \times 100\,\% = \frac{[V_{CE}(P-P)][I_C(P-P)]}{8\, V_{CC} (I_C)_Q}$$

Max^n efficiency :- Max^n efficiency can be determined by using max^n collector current and max^n voltage swing.

For current swing this will be

$$\cancel{(I_C)_{P-P}}\; I_C(P-P) = \frac{V_{CC}}{R_C}$$

and, voltage swing is

$$V_{CE}(P-P) = V_{CC}$$

$$\therefore (P_o)_{ac} = \frac{V_{CE}(P-P) \times I_C(P-P)}{8} = \frac{V_{CC}^2}{8R_C}.$$

And,

Maxm power input can be calculated by using d.c bias current set to one-half of maxm value —

$$\therefore (P_{in})_{dc} = V_{CC}\left(\frac{Max^m \cdot I_C}{2}\right) = V_{CC} \times \frac{V_{CC}/R_C}{2}$$

$$= \frac{V_{CC}^2}{2R_C}$$

$$\therefore \eta_{max} = \frac{\text{a.c power delivered to load}}{\text{Total power input by load}}$$

$$= \frac{V_{CC}^2/8R_C}{V_{CC}^2/2R_C} \times 100 = \frac{1}{4} \times 100 = 25\%$$

$$\eta_{max} = 25\%$$

This efficiency is achieved at ideal condn. But, in practice, efficiency will be less than 25%.

~~Example~~

Collector Efficiency

The collector efficiency is defined as —

$$\eta_{collector} = \frac{(P_o)_{ac}}{(P_t)_{dc}} \times 100\%$$

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