2/5/2073

start

age, particularly in old age.

6) Impedence matching is poor.

5 marks

Chapter - 2

Large Signal Amplifier (Power Amplifiers)

Large Signal Amplifier:-

Large Signal Amplifier are the amplifier that provide sufficient powers to an output load. A power amplifier convert dc power into ac power in presence of input ac signal inorder to achieve high power amplification the following features are incorporated in such transistor.

i) The size of power transistor is made considerable large in order to dissipated the heat produce in transistor during operation.

ii) The base is made thicker to handle larger current.

iii)

Analysis of large signal model:-

A power amplifier is required to produce large voltage and current in load. So, it is designate to operate from cutoff ~~requ~~ reason from it'. of it's output characteristic. These mode of operation is called large signal operation is B.J.T.

In large signal operation, the device parameter may change considerable at different output voltages. There are two important consequence of large signal operation is BJT.

a) Signal distortion occurs due to the non-linear characteristic of an amplifier.

b) Many equations developed for analysis of small signal amplifier are no longer valid.

Classification of Power Amplifiers :-

Basically amplifier classes represents the amount ~~among~~ of output signal varies over one cycle of operation for a full cycle of input signal. On the basis of, the position of operating point power amplifiers are classifies as :-

1) Class A
   i) Direct coupled load.
   ii) Capacitor coupled load (not necessary)
   iii) Transformer coupled.

2) Class B
   i) Tranformer coupled load push pull.
   ii) Complementary symmetry push pull.

3) Class AB

4) Class C

5) Class D

Pushpa

NP

43 copies

Class A Power Amplifier:

→ In class A amplifier, the transistor is biased in such a way that the operating point or Q-point lies at the center of the active region.

→ There is no distortion in the output of the signal, however amplitude distortion may occur if the input signal is very large.

→ The dc load line is the input and output characteristics of class 'A' power amplifiers are shown in figure below:

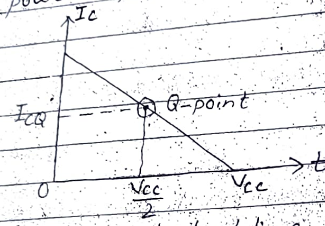


Fig a: dc load line

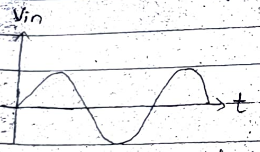


Fig b: input signal (voltage)

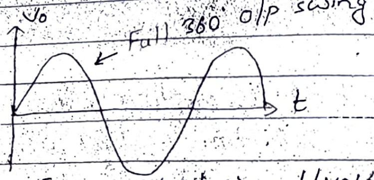


Fig c: output signal (voltage)

There are three types of class A amplifiers:

i) Class A amplifier - direct coupled load

ii) Class A amplifier - capacitor coupled load

iii) Class A amplifier - transformer coupled load

→ The maximum possible efficiency of directly coupled load and transformer coupled load A-amplifier is 25% and 50% respectively.

Class B power amplifier:

→ In class-B amplifier, the transistor is biased in such a wa that Q-point lies at the cut-off region of the transistor. It doesn't need any biasing circuit.

→ The Q-point, the input and the output curves of the class (amplifier is shown below:

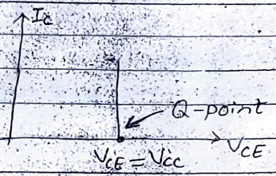


Fig a: Q-point of class B amplifier

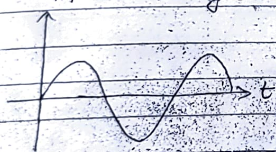


Fig b: input voltage

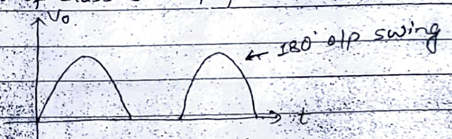


Fig c: output voltage

→ In class B amplifier, the current flows for the half cycle only. the distortion is high. The maximum possible efficiency of th class B amplifier is 78.5%.

→ To obtain the full cycle in output, two transistor operating in cutoff region are connected in the push-pull manner.

→ There are two types of push-pull amplifiers:

a) Transformer coupled load class B push pull amplifier.

b) Complementary symmetry class B push pull amplifier.

→ A cross over distortion occurs in both types of class B push amplifier.

Class A-B amplifier:

To minimize the cross-over distortion of class B push-pull operations, both transistors are slightly forward biased so that their Q-point lie just above the cut-off region.

The current flow for slightly more than a half cycle. The efficiency of class AB amplifier is less than of class B power amplifiers and more than that of class A amplifier.

The Q-point, input curve and output curves of the class AB power amplifiers is shown in figure below:

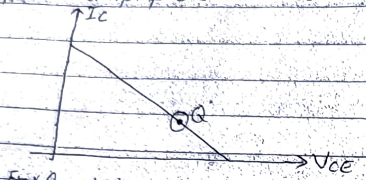


Fig: Q-point of class AB

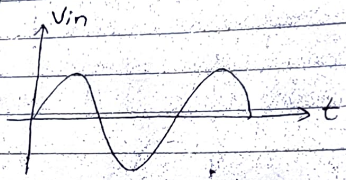


Fig: input voltage

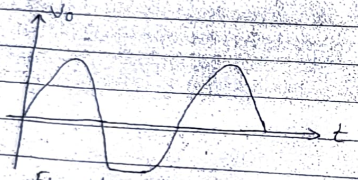


Fig: o/p voltage

Class C power amplifier:

In class C power amplifier, the transistor is biased in such a way that the current flows for less than half cycle of the input sine-wave. The conduction angle is less than 180° in class C amplifier.

→ In class C amplifier, the output is highly distorted so it canno be used in application requiring high fidelity such as audio amplifier.

→ However class C amplifiers are primarily used in high power high frequency application such as radio transmitter.

→ The input and output current waveforms for the class C amplifiers is shown in figure below:

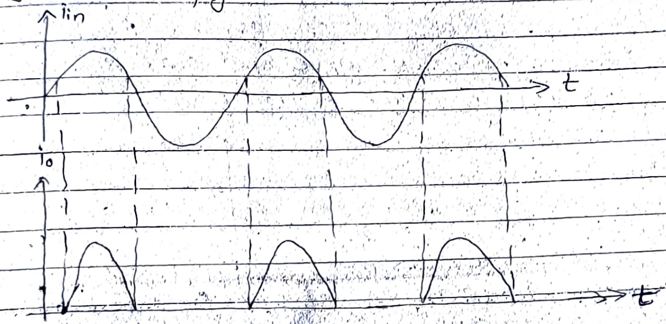
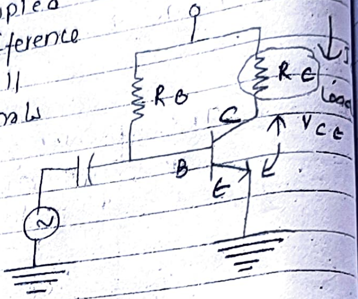


Fig: Input and output current of class C amplifier

Nipesh Prasai

Direct Coupled Load Class A amplifier :-

Figure shows a direct coupled load class A amplifier. The only difference between the circuit and the small signal version is that the signals handelled by the large signal circuits are in the range of volts.



Now,

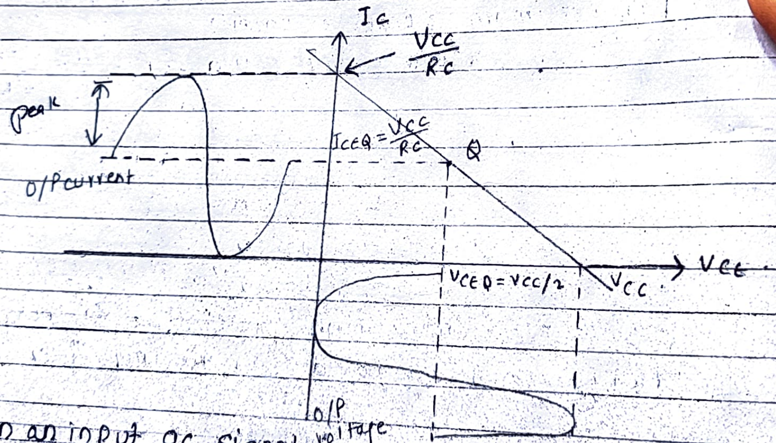
$$V_{CC} = I_C R_C + V_{CE}$$

or, $V_{CC} - I_C R_C - V_{CE} = 0$ —— (I)

Put $V_{CE} = 0$, $V_{CC} = I_C R_C$

$\therefore I_C = V_{CC} / R_C$.

Put $I_C = 0$, $V_{CE} = V_{CC}$



When an input ac signal is applied to the amplifier, shown in figure, the output will vary from it's dc bias operating voltage and current.

$\therefore$ Power drawn from the supply $P_i(dc) = V_{CC} I_{CQ}$ — (II)

The ac power delivered to the load, $P_o(ac)$
$= V_{CE}(rms) \cdot I_C(rms)$ — (III)

The efficiency of the amplifier is given by :-

$$\eta = \frac{\text{~~Voltage~~ average (ac) Power delivered by load}}{\text{average dc power drawn from dc source}} \times 100\%$$

$$\eta = \frac{V_{CE}(rms) \cdot I_C(rms)}{V_{CC} \cdot I_{CQ}} \times 100\%$$

$$= \frac{(V_{CEP}/\sqrt{2}) \times (I_{CP}/\sqrt{2})}{V_{CC} \cdot I_{CQ}} \times 100\%$$

$$\eta = \frac{V_{CEP} \times I_{CP}}{2 V_{CC} \times I_{CQ}} \times 100\%$$

For maximum possible cases,

$V_{CEP} = V_{CEQ} = \frac{V_{CC}}{2}$ and $I_{CP} = I_{CQ} = \frac{V_{CC}}{2R_C}$

$$\therefore \eta = \frac{\frac{\cancel{V_{CC}}}{2} \times \cancel{I_{CQ}}}{2 \cancel{V_{CC}} \times \cancel{I_{CQ}}} \times 100\%$$

$$\therefore \eta = 100/4$$

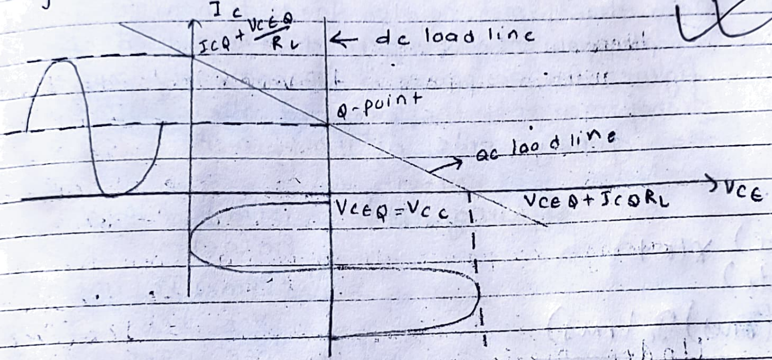
$$\therefore \eta = 25\%$$

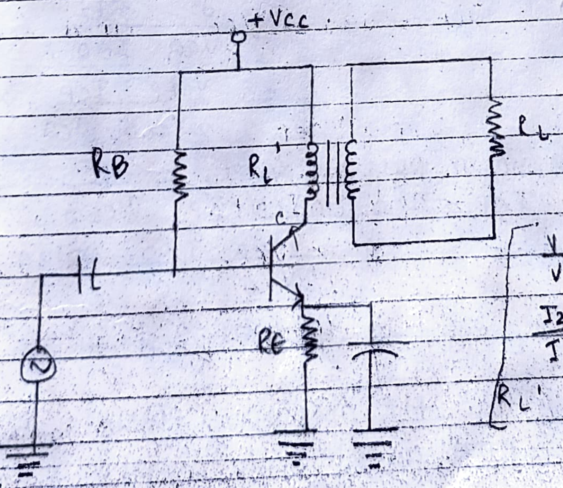
Thus, maximum possible efficiency of a directly coupled load class A amplifier is 25%.

Thus, maximum possible collector efficiency of a direct coupled load class A amplifier is 50%.

IMP

Transformer Coupled Load Class A amplifier :-





Transformer

$$\frac{V_2}{V_1}=\frac{N_2}{N_1}$$

$$\frac{I_2}{I_1}=\frac{N_1}{N_2}$$

$$R_L'=\left(\frac{N_1}{N_2}\right)^2 R_L$$

Fig - Transformer coupled load class A amplifier

A large power is wasted across the collector resistance R_C when current flows through it in a direct coupled load class A power amplifier. wasted ac power in R_C does not contribute to the useful ac output power. In a transformer coupled load, transformer is used to couple power amplifiers to their load as shown in figure. An ac power is magnetically coupled across the transformer into the load and there is no dc loss in the primary side of transformer.

Now,

$$\text{efficiency } (\eta) = \frac{P_o(ac)}{P_{in}(dc)} \times 100\%$$

$$= \frac{V_{CC}(rms)\, I_C(rms)}{V_{CQ}\, I_{CQ}} \times 100$$

$$= \frac{\frac{V_{CEP}}{\sqrt{2}} \cdot \frac{I_{CP}}{\sqrt{2}}}{V_{CEQ} \cdot I_{CQ}} \times 100$$

$$= \frac{V_{CEP} \cdot I_{CP}}{2 V_{CEQ} \cdot I_{CQ}} \times 100\%$$

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

$$= \frac{V_{CC}(rms)\, I_C(rms)}{I_{CQ} \cdot V_{CEQ}}$$

$$= \frac{\frac{V_{CEP}}{\sqrt{2}} \cdot \frac{I_{CP}}{\sqrt{2}}}{I_{CQ}\, V_{CEQ}}$$

$$= \frac{1}{2}$$

For maximum possible cases,

$$I_{CP} = I_{CQ} \text{ and } V_{CEP} = V_{CEQ}$$

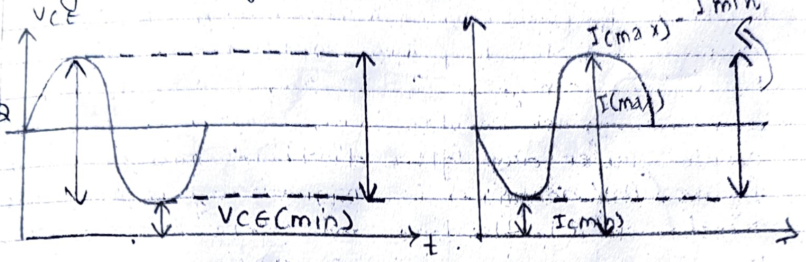
$$\therefore \eta = \frac{V_{CEQ} \cdot I_{CQ}}{2 V_{CEQ} \cdot I_{CQ}} \times 100$$

$$\therefore \eta = 50\%$$

Thus, the maximum possible efficiency of the transformer coupled load class A amplifier is 50%.

IMP

Signal swing and output ac power :-



The ac power developed across the transformer primary is given by :-

$V_{p\text{-}p} = 2V_{peak}$

$V_{peak} = \frac{V_{p\text{-}p}}{2}$

$$P_{O(ac)} = V_{rms} \cdot I_{rms} = \frac{V_{peak}}{\sqrt{2}} \times \frac{I_{peak}}{\sqrt{2}}$$

$$= \frac{V_{CE}(p-p)}{2\sqrt{2}} \times \frac{I_C(p-p)}{2\sqrt{2}}$$ peak to peak.

$$= \frac{(V_{CE\,max} - V_{CE\,min})(I_{max} - I_{min})}{8}$$

For ideal transformer, the voltage delivered to the load is :- $\frac{V_1}{V_2} = \frac{N_2}{N_1}$

$$V_L = V_2 = \frac{N_1}{N_2} V_1 \quad \text{—— (II)}$$

The power across load $P_L = \frac{V_L^2 (rms)}{R_L}$ —— (III)

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

$= \frac{I_c(rms) \cdot V_{ce}(rms)}{V_{CEQ} \cdot I_{CQ}} \times 100\%$

$= \frac{V_{CEP}}{}$

$\frac{V_{CEP} \cdot I_{CP}}{2\, V_{CEQ}\, I_{CQ}} \times 100$

49

$= \frac{1}{4} I_{CP} V_{CC}$ — (II) $\left[\because V_{CEP} = \frac{V_{CC}}{2}\right]$

Also,

$P_{in}(dc) = V_{CC} \cdot I_{dc} = \frac{V_{CC} \cdot I_{CP}}{\pi}$ — (III)

Thus,

$$\eta = \frac{\frac{1}{4} I_{CP} \cdot V_{CC}}{\frac{V_{CC} \cdot I_{CP}}{\pi}} \times 100\%$$

$$= \frac{\pi}{4} \times 100 = 78.5\%$$

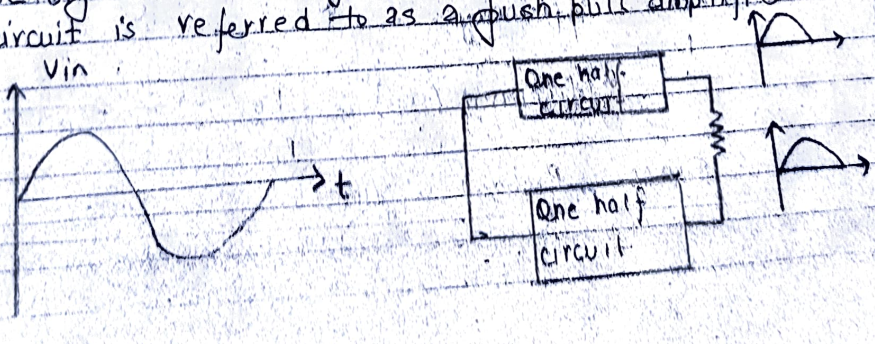
$$\therefore \eta = 78.5\%$$

Thus, the maximum possible efficiency of class is amplifier is 78.5%.

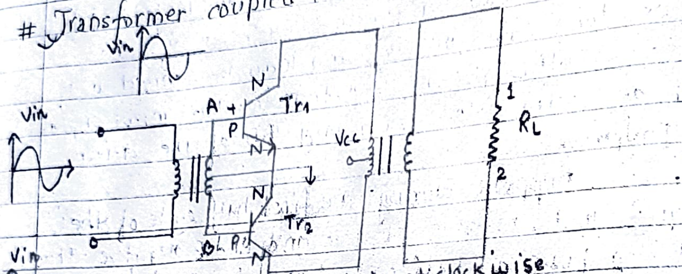
IMP for 2 mark!

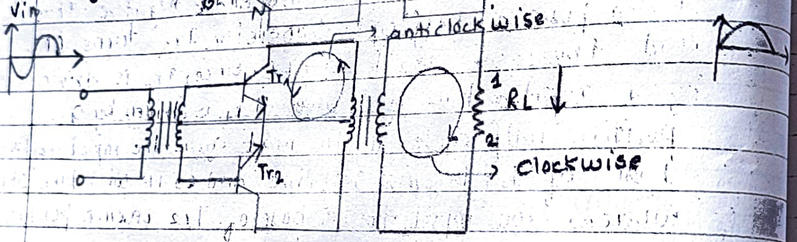
Push-Pull Amplifier:

Push-Pull amplifier is a power amplifier where two transistor operating in class B operation are employed. Each transistor conducts an opposite half-cycle. Since one part of the circuit pushes the signal high during one half cycle and the other part pulls the signal low during the other half cycle. The circuit is referred to as a push pull amplifier.



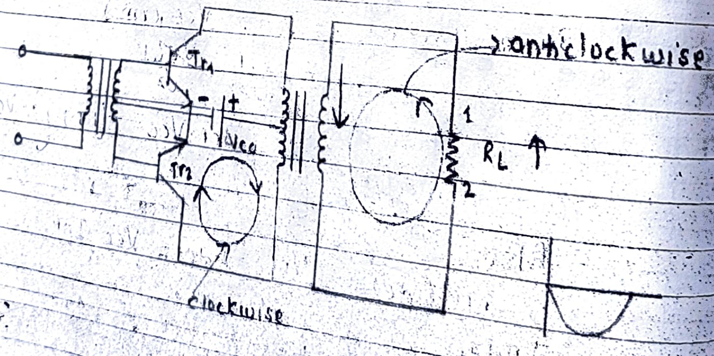
Transformer coupled load class B push pull amplifiers:





During +ve half cycle, Tr_1 ON, Tr_2 OFF.

For -ve cycle.



The transformer coupled load class B push pull amplifier is shown in figure. It consist of two transistor Tr_1 and Tr_2 and load is connected to the circuit through a transformer. The input signal appear across the secondary AB of the driver transformer.

Suppose during the first half cycle of the signal in A becomes positive and end B negative. Thus during positive half cycle transistor Tr_1 turns ON and transistor Tr_2 turns OFF. Since, Tr_2 is driven by a negative half cycle when Tr_1 is driven by a positive half cycle, in the next cycle the input to the base of Tr_1 becomes negative and so it will turn 'OFF' whereas the input to the base of Tr_2 becomes positive and so it will turn 'ON'.

Now,

$$\text{Efficiency } (\eta) = \frac{P_o(ac)}{P_{in}(dc)} \times 100\% \quad \text{——(1)}$$

Since, $P_o(ac) = I_{rms} \cdot V_{CE(rms)}$

$$= \frac{I_{CP}}{\sqrt{2}} \cdot \frac{V_{CEP}}{\sqrt{2}}$$

$$= \frac{1}{4} I_{CP} \cdot V_{CC} \quad \text{——(II)} \quad \left(\because V_{CEP} = \frac{V_{CC}}{2}\right)$$

Also,

$$P_{in}(dc) = V_{CC} \cdot I_{dc} = \frac{V_{CC} \cdot I_{CP}}{\pi} \quad \text{——(III)}$$

Thus,

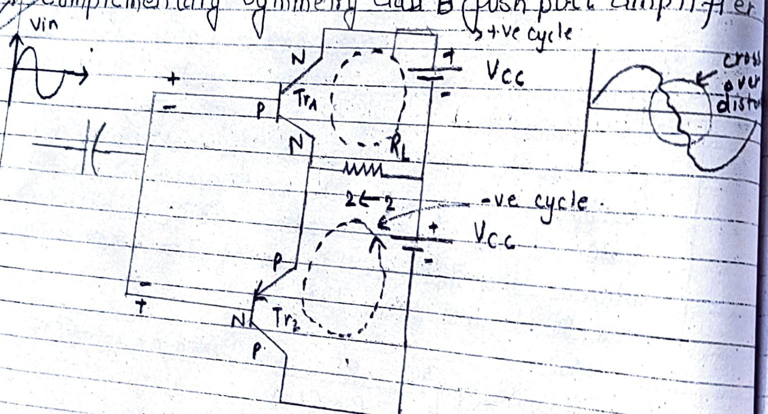
$$\eta = \frac{\frac{1}{4} I_{CP} \cdot V_{CC}}{\frac{V_{CC} \cdot I_{CP}}{\pi}} \times 100$$

$= \frac{\pi}{4} \times 100 = 78.5\%$

$\therefore \eta = 78.5\%$

Thus, the maximum possible efficiency of class B amplifier is 78.5%.

Complementary Symmetry Class B push pull amplifier



The need of an output transformer in push pull operation is eliminated in this amplifiers. It employees one npn and one pnp transistor as shown in figure.

During positive half of input signals transistor Tr_1 (npn) conducts current while transistor Tr_2 (pnp) is cut off.

During negative half of the input signal transistor Tr_2 conduct current while transistor Tr_1 is cut off.

During +ve half cycle.

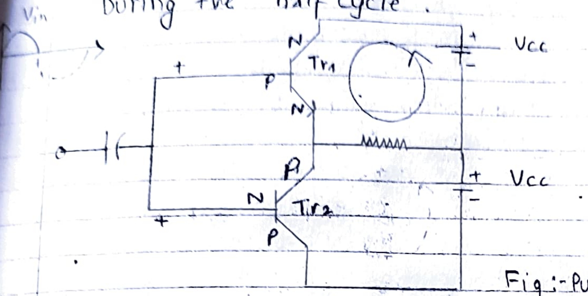
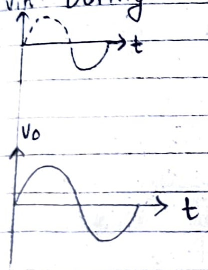


Fig:- Push Pull amplifier during +ve cycle.

During -ve half cycle.



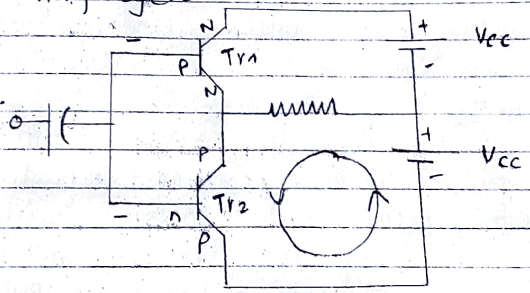
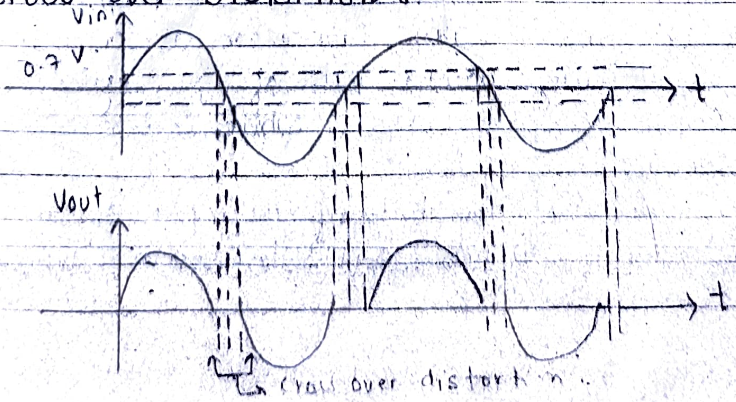


Fig: Output.

Fig: Push pull amplifier during -ve half cycle

Cross over Distortion :-



In class B push pull operation. There is severe distortion at very low signal level because bases of transistor donot turn 'ON' at 0 volt but at 0.3V for Ge and 0.7V for Si. During the period until transistor turns on there will be not output. This result that the output waveform will not be a pure sine wave but a distorted form. This type of distortion is called cross over distortion. Crossover Distortion occurs as a result of one transistor cutting off before the other being conducting. The distortion so introduced is called crossover distortion because it occur during the time operation cross over from the transistor to the other in the push-pull amplifiers.

Crossover distortion can be eliminated by applying slight forward bias to each emitter diode so that Q-point (operating point) each transistor will be located slightly above cut-off. Therefore, one transistor operate for more than one half cycle. Since each transistor operates slightly above more than half cycle, it results in class AB operation.

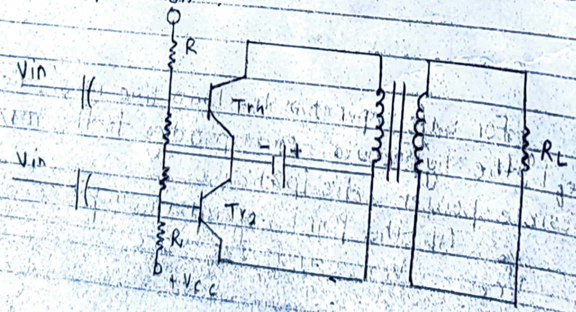


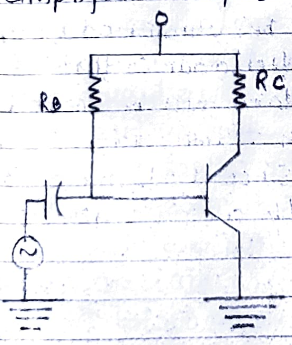
Fig: Class AB operation

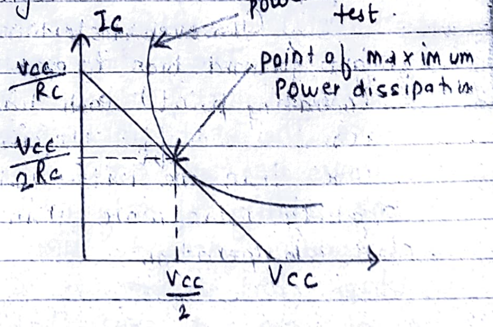
Power dissipation and Heat sink :-

When the transistor is in operation power dissipation takes place at two junction that is collector Base Junction and base emitter junction. This power dissipation causes the junction temperature to rises. The total power dissipation at the junction is given by :-

$$P_d = V_{CB} I_C + V_{BE} I_E$$
$$= (V_{CB} + V_{BE}) I_C \quad [\because I_C \simeq I_E]$$
$$\therefore P_d = V_{CE} I_C \quad \text{(I)}$$

For fixed P_d, the power dissipation curve is hyperbola. The power dissipation varies as the amplifiers output changes.





For safe operation the load line must lie below and left of the hyperbola corresponding to the maximum permissible power dissipation.

At the point of maximum power dissipation

$$V_{CE} = \frac{V_{CC}}{2} \quad \text{and} \quad I_C = \frac{V_{CC}}{2R_C}$$

∴ The maximum power dissipation, $P_{d\,max} = V_{CE} I_C$

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

$$\therefore P_{d(max)} = \frac{V_{CC}^2}{4R_C} \quad \text{———} \quad (II)$$

To ensure that the load line lies below the hyperbola of maximum dissipation, it is required that $\frac{V_{CC}^2}{4R_C} < P_{d\,max}$.

where, $P_{d\,max}$ is the manufacturer's specified maximum dissipation at a specified ambient temperature.

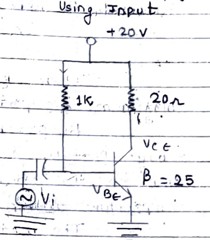
As power transistor handle large currents they always heat up during operations. This heat generated must be dissipated to the surrounding in order to keep the temperature within permission limit.

The metal sheets that serve to dissipate the additional heat from power transistor is known as heat sinks. The heat sinks increase the surface area and allows heat to escape from the collector junction easily. The ability of any heat sink to transfer heat to the surrounding depends upon it's material, volume, area, shape contact between case and sink and movement of air around sink. Heat is conducted from a junction through the semiconductor material, through the case into the surrounding air.

Chapter-2

Numericals :-

1) Calculate the input power, output power, power loss in transistor, the collector efficiency and the overall efficiency of the circuit given in the figure. Assume $I_{BP} = 10mA$.



Here,

$V_{CC} = 20V$

$R_C = 20\Omega$, $R_B = 1K\Omega$,

$\beta = 25$

$I_{BP} = 10mA$

(Base current at peak).

Now,

Input power $= P_{in}(dc) = V_{CC} I_{CQ}$ — (I)

KVL in input loop,

$$V_{CC} - I_{BQ} R_B - V_{BE} = 0$$

Or, $\cancel{V_{CC}}\ I_{BQ} = \cancel{V_{BE} - V_{CC}}\ \frac{V_{CC} - V_{BE}}{R_B}$

$$= \frac{20 - 0.7}{1000}$$

$$\therefore I_{BQ} = 0.0193 = 19.3mA.$$

We know,

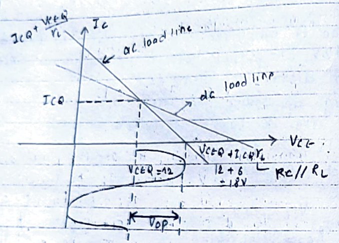
$$I_C = \beta I_B$$

$$I_{CQ} = \beta I_{BQ} = 25 \times 19.3\,mA$$

$$\therefore I_{CQ} = 482.5mA = 0.48A$$

Now,

$$P_{in(dc)} = V_{CC} I_{CQ} = 20 \times 0.48 = 9.6W,$$



$r_L = \frac{R_C \times R_L}{R_C + R_L} = \frac{50 \times 50}{50+50} = \frac{2500}{100} = 25\ \Omega$.

$I_{CQ} = 0.24A$

So,

$I_{CQ} r_L = 25 \times 0.24 = 6V$.

The peak output voltage $(V_{OP}) = 6V$

So, $P_o\ (ac) = \frac{6^2}{2 \times 50} = 0.36\ W$.

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

$= \frac{0.36}{5.76} \times 100\% = 6.25\%$.

iv) $\eta_C = \frac{\text{avg. ac power delivered to load}}{\text{avg. dc power } \cancel{\text{deliver}} \text{ dissipated to collector}} \times 100\%$

Avg dc power dissipated at collector $= V_{CEQ} I_{CQ}$ ($V_{CC}I_{CQ} - I_{CQ}^2 R_C$)

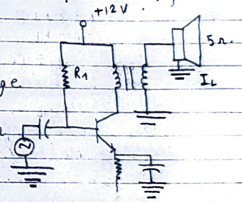
$= 12 \times 0.24 = 2.88W$

So,

$\eta_c = \frac{0.36}{2.88} \times 100\% = 12.5\%$.

3). A power transistor working in class A operation is supplied from a 12V battery. If the maximum collector current change is 100mA. Find the power transferred to 5Ω loudspeaker if it is transformer coupled for maximum power transformer.

Here,



Maximum collector current change

$\Delta I_C = 100mA$.

maximum collector emitter voltage change $\Delta V_{CE} = 12V$.

loudspeaker resistance $(R_L) = 5\Omega$

i) Power transferred to load = ?

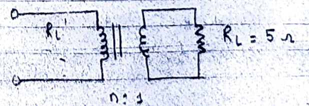
ii) Turn ratio = ?

For maximum power transference, $R_{th} = R_L$

So,

Resistance of transistor $(R_{th}) = \frac{\Delta V_{CE}}{\Delta I_C} = \frac{12}{100 \times 10^{-3}}$

$= 120\Omega = R_L'$



Let, the turn ratio be $n:1$

$$I^2R_L = I_1^2R_L'$$ $$\left[\frac{N_1}{N_2} = \frac{I_2}{I_1} = \frac{V_1}{V_2}\right]$$

$$R_L' = \left(\frac{I_2}{I_1}\right)^2 R_L$$

$$\text{or, } R_L' = \left(\frac{N_1}{N_2}\right)^2 R_L$$

$$\text{or, } R_L' = n^2 R_L \quad \left[\because n = \frac{N_1}{N_2}\right]$$

↳ turn ratio.

$$n^2 = \frac{R_L'}{R_L} = \frac{120}{5}.$$

$$n = \sqrt{\frac{120}{5}}$$

$\therefore n = 4.9$.

$\therefore$ Turn ratio $= 4.9$

Again,

Primary voltage(V_1) = 12V

Secondary voltage V_2 = ?

Now,

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = n.$$

$$V_2 = \frac{V_1}{n} = \frac{12}{4.9} = 2.44\,V.$$

Now,

Load current $(I_L) = \frac{V_2}{R_L} = \frac{2.44}{5} = 0.48A.$

Power transfered to load $= I_L^2 R_L$

$$= (0.48)^2 \times 5$$

$$= 1.19\,W$$

Theodore F. Bogart

8 marks

3.b) Page - 667, example 16-7

For a class B amplifier providing a 20V peak signal to the 16Ω load and a power supply of $V_{CC} = 30V$, determine the input power, output power and efficiency

Here,

$V_{CP} = 20V$, $R_L = 16\Omega$, $V_{CC} = 30\Omega$

i) input power, $P_{in}(dc) = V_{CC} \times I_{dc} = V_{CC} \times \frac{I_{CP}}{\pi}$

$$= V_{CC} \times \frac{V_{CP}}{\pi R_L} \quad \left[\because I_{CP} = \frac{V_{LP}}{R_L}\right]$$

$$= \frac{30 \times 20}{\pi \times 16} = 11.93$$

ii) Output power, $P_o(ac) = \frac{1}{4} I_{CP} V_{CC} = \frac{1}{4} \times \frac{V_{LP}}{R_L} \times V_{CC}$

$$= \frac{1}{4} \times \frac{20}{16} \times 30$$

$$= 9.375.$$

iii) $$\eta = \frac{P_o(ac)}{P_{in}(dc)} \times 100 = \frac{9.375}{11.93} \times 100$$

$$= 78.58\%.$$