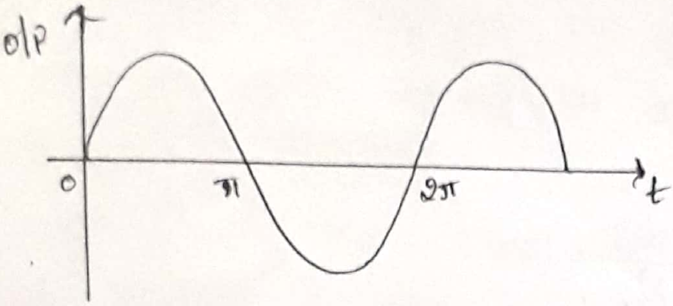
POWER AMPLIFIERS

Amplifier classes (based on conduction angle).

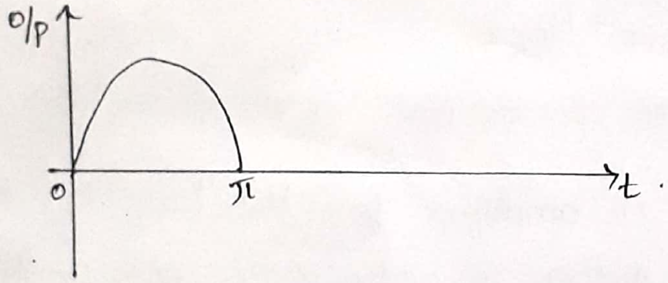
Class-A: o/p transistor biased at quiescent current I_{CQ} and conducts for entire cycle of i/p signal.



If the Q pt and the i/p signal are selected such that the o/p signal is obtained for a full i/p cycle.

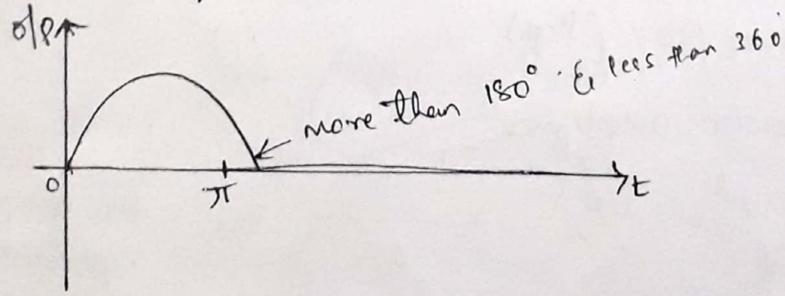
360°

Class-B:- o/p transistor conducts for only half of each sine wave i/p cycle.

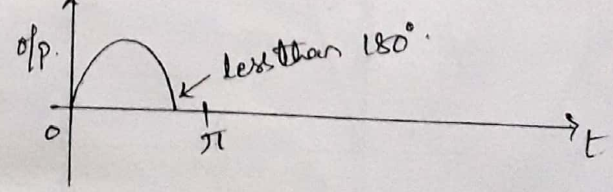


180°

Class-AB:- o/p transistor is biased at a small quiescent current and conducts for slightly more than half a cycle.



Class-C:- o/p transistor conducts slightly less than half a i/p cycle.



* The main feature of a large signal amplifier are the ckt's power efficiency and impedance matching to the o/p device.

Amplifier efficiency :-

Power efficiency of an amplifier is defined as the ratio of power o/p to the power i/p, improves going from class A to D.

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

$$\text{But } P_{in} = P_{out} + P_{losses}$$

$$\% (\eta) = \frac{P_{out}}{P_{out} + P_{losses}} \times 100$$

Where, P_{losses} - is the power lost in the power transistor

* max. η of class A amplifier for the largest o/p voltage and current swing is only 25%. with a direct or series fed load and 50% with a transformer connection to the load.

Class 'B' → 78.5%, Class AB : 50% to 78.5

Class - D → over 90%. (High)

⇒ Class-A of power amplifier

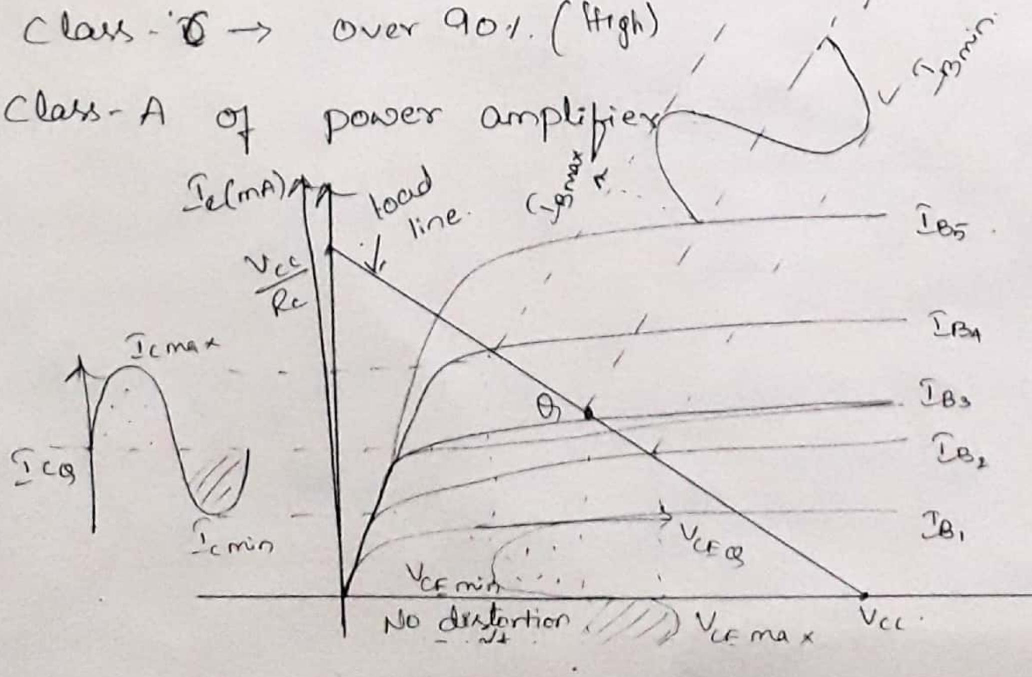
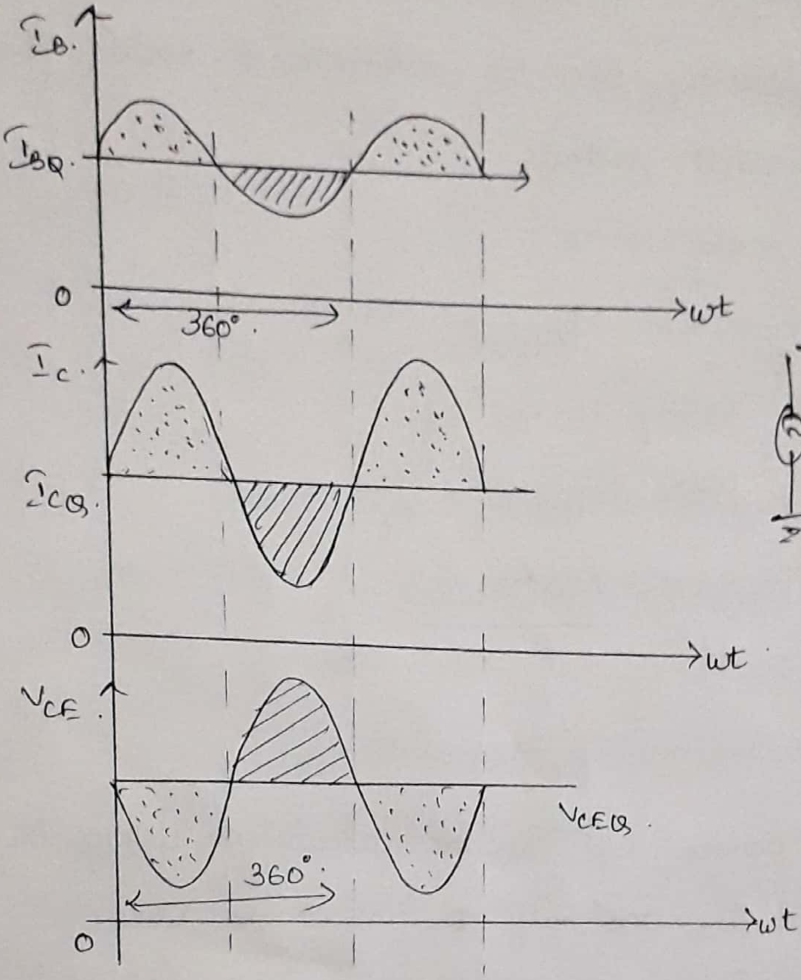
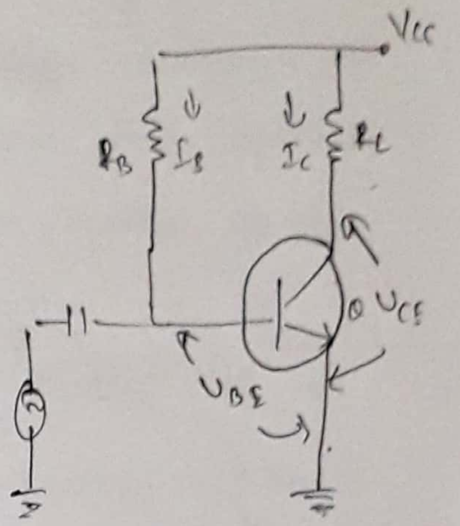


fig: Graphical representation of Class-A. amplifier

Series Fed, Directly coupled class A Amplifier





DC operation

$$I_{BQ} = \frac{V_{CC} - 0.7}{R_B}$$

$$I_{CQ} = \beta I_{BQ}$$

$$V_{CEQ} = V_{CC} - I_{CQ} R_L$$

Power Considerations

I/p power is given by,

$$P_i(dc) = V_{CC} I_{CQ} \longrightarrow (1)$$

The o/p power delivered to the load (R_C) is given by

$$P_o(ac) = V_{CE(rms)} I_{C(rms)}$$

$$P_o(ac) = I_C^2(rms) R_C$$

$$P_o(ac) = \frac{V_C^2(rms)}{R_C}$$

Efficiency (η): It ~~is~~ represents the amount of ac Power delivered from the d.c. source.

$$\% \eta = \frac{P_o(ac)}{P_i(dc)} \times 100\%$$

Maximum efficiency : For the Class-A series fed amplifier the maximum efficiency can be determined using the maximum voltage and current swings.

For the voltage swing it is,

$$\text{maximum } V_{CE(p-p)} = V_{CC}.$$

For the current swing it is,

$$\max I_{C(p-p)} = \frac{V_{CC}}{R_C}.$$

$$\therefore \max P_o(ac) = \frac{V_{CC}(V_{CC}/R_C)}{8}.$$

$$= \frac{V_{CC}^2}{8R_C}.$$

The maximum power i/p can be calculated using the dc bias current set to one-half the maximum value.

$$\text{maximum } P_i(dc) = V_{CC}(\text{maximum } I_C) = V_{CC}\left(\frac{V_{CC}/R_C}{2}\right)$$

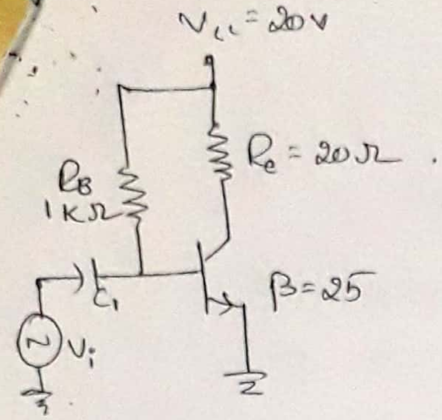
$$P_{i(dc)} = \frac{V_{CC}^2}{2R_C}$$

$$\therefore \%\eta = \frac{P_o(ac)_{max}}{P_i(dc)_{max}} \times 100\%.$$

$$= \frac{\cancel{V_{CC}^2}}{\cancel{8R_C}_{4}} \times \frac{\cancel{2R_C}}{\cancel{V_{CC}^2}} \times 100\%.$$

$$= 25\%.$$

① Calculate the input power, output power and efficiency of the amplifier.



$$I_{BQ} = \frac{V_{cc} - 0.7V}{R_B} = \frac{20V - 0.7V}{1K\Omega} = 19.3mA.$$

$$I_{cQ} = \beta I_B = 25(19.3mA) = 482.5mA \simeq 0.48A.$$

$$V_{CEQ} = V_{cc} - I_c R_c = 20V - (0.48\Omega)(20\Omega) = \underline{10.4V}$$

$$V_{CE} = V_{cc} = 20V, \text{ with } I_c = \frac{V_{cc}}{R_c} = 1000mA = 1A,$$

$$I_{c(p)} = \beta I_{B(p)} = 25 (10mA \text{ peak})$$

$$= 250 \text{ mA peak}.$$

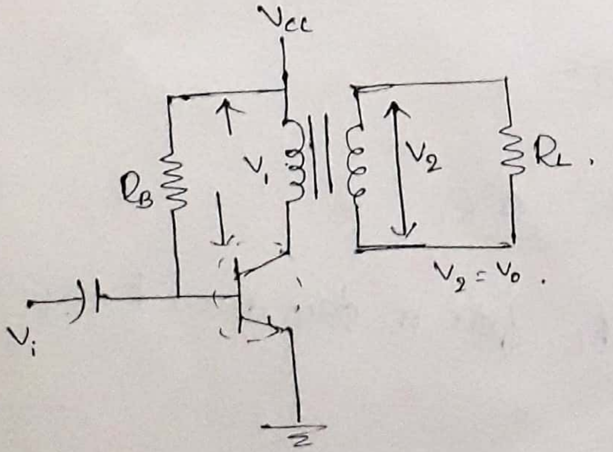
$$P_{o(ac)} = I^2_{c(rms)} R_c = \frac{I_c^2(p) R_c}{2} = \frac{(250 \times 10^{-3} A)^2 (20\Omega)}{2}$$

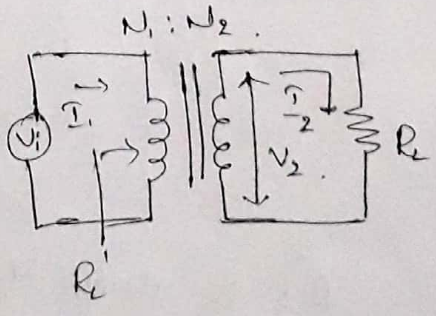
$$\underline{P_o(ac) = 0.625W}$$

$$P_{i(dc)} = V_{cc} I_{cQ} = (20V)(0.48A) = 9.6W$$

$$\eta = \frac{P_o(ac)}{P_i(dc)} \times 100\% = \frac{0.625W}{9.6W} \times 100\% = 6.5\%.$$

<u>Transformer-</u> <u>Coupled</u> <u>Class-A</u> <u>amplifier</u>.





N_1 - no of turns on primary.

N_2 - no of turns on secondary.

V_1 - Vtg applied to primary.

V_2 - Vtg on secondary.

Voltage transformation :-

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

Current transformation :-

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

Impedance matching:

R_L is connected across the transformer secondary. This impedance is changed by the transformer when viewed at the primary side (R_L'). R_L' is reflected impedance at the primary side.

$$\frac{R_L}{R_L'} = \frac{R_2}{R_1} = \frac{V_2/I_2}{V_1/I_1} = \frac{V_2}{V_1} \cdot \frac{I_1}{I_2} = \frac{N_2}{N_1} \frac{N_2}{N_1} = \left(\frac{N_2}{N_1}\right)^2.$$

Let $\frac{N_2}{N_1} = 1/a$.

$$\Rightarrow \frac{R_L'}{R_L} = \frac{R_1}{R_2} = \left(\frac{N_1}{N_2}\right)^2 = a^2.$$

$$\Rightarrow R_1 = a^2 R_2 \quad \text{or} \quad R_L' = a^2 R_L.$$

R_L' is always higher than R_L, for a step down transformer

N_1 - no of turns on primary

N_2 - no of turns on secondary.

V_1 - vtg applied to primary

V_2 - vtg on secondary.

$V_{CEQ} = V_{CC}$.

$P_{DC} = V_{CC} \times I_{CQ}$.

$P_{ac} = \frac{V_{1rms}^2}{R_L'} = \frac{V_{1m}^2}{2R_L'}$ AC o/p Power.

V_{1m} - peak value of primary voltage

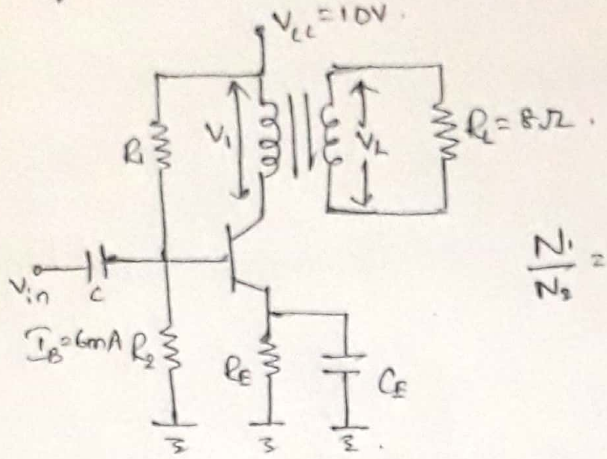
V_{1rms} - rms value of —— 11 ——

$P_{ac} = \frac{V_{2rms}^2}{R_L} = \frac{V_{2m}^2}{2R_L}$.

$\% \eta = \frac{P_{ac}}{P_{dc}} \times 100 \%$

$\% \eta = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 V_{CC} I_{CQ}} \times 100 \%$.

1. For the ckt shown below, calculate the dc input power, Power dissipated by the transistor & efficiency of the circuit for the input current swing of 4mA.



$\frac{N_1}{N_2} = 3:1$

$I_{CQ} = 140mA$

$V_{CEmin} = 1.7V$

$V_{CEmax} = 18.3V$

$I_{cmin} = 25mA$

$I_{cmax} = 255mA$

$$P_i(dc) = V_{cc} I_{CQ} = 10V \times 140 \times mA = 1.4W$$

$$P_Q = P_{in}(dc) - P_o(ac)$$

$$P_o(ac) = \frac{(V_{CEmax} - V_{CEmin})(I_{cmax} - I_{cmin})}{8}$$

$$= \frac{(18.3 - 1.7V)(255mA - 25mA)}{8}$$

$$P_o(ac) = 0.477W$$

$$P_Q = 1.4 - 0.477 = 0.92W$$

$$\% \eta = \frac{P_o(ac)}{P_i(dc)} \times 100\% = \frac{0.477W}{1.4W} \times 100\% = 34.1\%$$

*

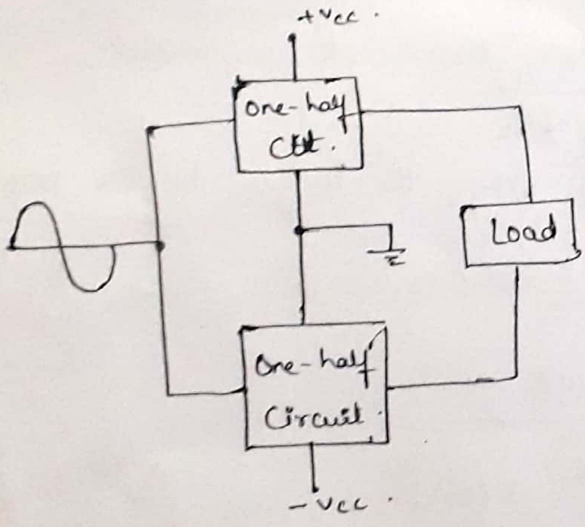
To get a full cycle across the load, a pair of transistors is used in class B operation. The two transistors conduct in alternate half cycles of the i/p signal and full cycle across the load is obtained. The two transistors conduct in alternate half cycles of the input cycle signal of the input signal. & a full cycle across the load is obtained. The two transistors are identical in characteristics and called matched transistors.

a) When both the transistors are of same type i.e. either n-p-n or p-n-p then the ckt is called as push pull class B amplifier ckt.

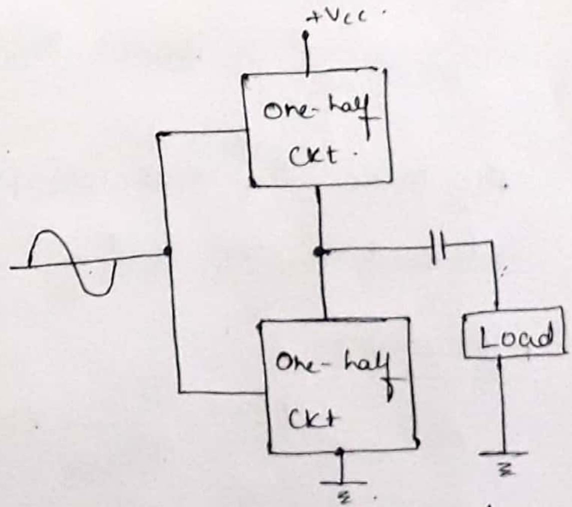
b) Complementary symmetry class B.

Class-B Amplifier

Class-B amplifier provides o/p for the only one-half of the signal cycle. To obtain output for the full cycle of signal, it is necessary to use two transistors and have each conduct on opposite half-cycles, the combined operation providing a full cycle of output signal. Since one part of the ckt pushes the signal high during one half-cycle and the other part pulls the signal low during the other half-cycle, the ckt is referred to as a push-pull ckt. The below fig shows a diagram for push-pull operation. The power transistors used in the push-pull circuit are capable of delivering the desired power to the load. and the class-B operation of these transistors provides greater efficiency than was possible using a single transistor in class-A. operation.



(a) using two vtg supplies.



(b) using one vtg supply.

Input (DC) power:

$$P_{i(dc)} = V_{cc} I_{dc}$$

where I_{dc} is the average (or) dc current drawn from power supplies. In class-B operation, the current drawn from a single power supply has the form of a full-wave rectified signal, whereas that drawn from two power supplies has the form of a half-wave rectified signal from each supply.

In either case, the value of the average current drawn can be expressed as

$$I_{dc} = \frac{2}{\pi} I_{(p)}.$$

$$P_{i(dc)} = V_{cc}\left(\frac{2}{\pi} I_{(p)}\right)$$

$I_{(p)}$ - Peak value of the o/p current w/f.

<u>Output (AC) power:</u>

$$P_{o(ac)} = \frac{V_L^2(rms)}{R_L}.$$

$$P_o(ac) = \frac{V_L^2(p\text{-}p)}{8R_L} = \frac{V_L^2(p)}{2R_L}.$$

The larger the rms (or) peak o/p vtg, the larger is the power delivered to the load.

<u>Efficiency:</u>

$$\%\eta = \frac{P_o(ac)}{P_i(dc)} \times 100\%.$$

$$\left(\frac{V_L(p)}{I(p)} = R_L\right)$$

$$= \frac{V_L^2(p)/2R_L}{V_{cc}\left(\frac{2}{\pi} I_{(p)}\right)} \times 100\% = \frac{\pi}{4}\frac{V_L(p)}{V_{cc}} \times 100\%.$$

The larger the peak voltage, the higher is the ckt efficiency, up to a maximum value when $V_L(p) = V_{cc}$, this maximum efficiency then being maximum efficiency $= \frac{\pi}{4} \times 100\% = 78.5\%$.

Power dissipated by output transistors:

The power dissipated (as heat) by the output power transistors is the difference b/w the input power delivered by the supplies and the o/p power delivered to the load.

$$P_{2Q} = P_i(dc) - P_o(ac).$$

where P_{2Q} is the power dissipated by the two power transistors

The power dissipated by each transistor is,

$$P_Q = \frac{P_{2Q}}{2}.$$

① For a class B amplifier providing a 20-V peak signal to a 16-Ω load (speaker) and a power supply of $V_{CC} = 30V$ determine the input power, output power & ckt efficiency.

$$I_L(p) = \frac{V_L(P)}{R_L} = \frac{20V}{16\Omega} = 1.25A$$

$$P_i(dc) = V_{CC} \times \frac{2}{\pi} I_L(p) = \left(\frac{2}{\pi}(1.25) \times 30\right)$$

$$= 23.9W$$

$$P_o(ac) = \frac{V_L^2(P)}{2R_L} = \frac{(20)^2}{2(16)} = 12.5W$$

$$\%\eta = \frac{P_o(ac)}{P_i(dc)} \times 100\% = \frac{12.5W}{23.9W} \times 100\% = 52.3\%$$

Maximum power considerations

For class B, the maximum output power is delivered to the load when $V_{L(p)} = V_{cc}$.

$$\text{max. } P_{o(ac)} = \frac{V_{cc}^2}{2R_L}.$$

The corresponding peak ac current $I_{(p)}$ is

$$I_{(p)} = \frac{V_{cc}}{R_L}.$$

$$\text{max } I_{dc} = \frac{2}{\pi} I_{(p)} = \frac{2V_{cc}}{\pi R_L}.$$

$$P_{i(dc)} = V_{cc} \times I_{dc\,(max)} = \frac{V_{cc} \times 2V_{cc}}{\pi R_L}.$$

$$\boxed{P_{i(dc)} = \frac{2V_{cc}^2}{\pi R_L}}$$

$$\text{max } \%\eta = \frac{P_{o(ac)}}{P_{i(dc)}} \times 100\% = \frac{V_{cc}^2/2R_L}{\frac{2V_{cc}^2}{\pi R_L}} = \frac{\pi}{4} \times 100\%$$

$\therefore$ maximum $\%\eta = 78.54\%$.

② For a class-B amplifier using a supply of $V_{cc} = 30V$ & driving a load of 16Ω, determine the maximum i/p power output power and transistor dissipation.

$$\text{maxi output power, } P_{o(ac)} = \frac{V_{cc}^2}{2R_L} = \frac{30V^2}{2(16)} = 28.125W.$$

$$\text{max } P_{i(ac)} = \frac{2V_{cc}^2}{\pi R_L} = \frac{2 \times 30^2}{\pi \times 16} = 35.81W.$$

$$\therefore \max \% \eta = \frac{P_o(ac)}{P_i(dc)} \times 100\% = \frac{28.12W}{35.81W} \times 100\% = 78.54\%$$

$$P_Q = \frac{\max P_{2Q}}{2} = \left(\frac{2V_{cc}^2}{\pi^2 R_L}\right)\frac{1}{2} = 5.7W$$

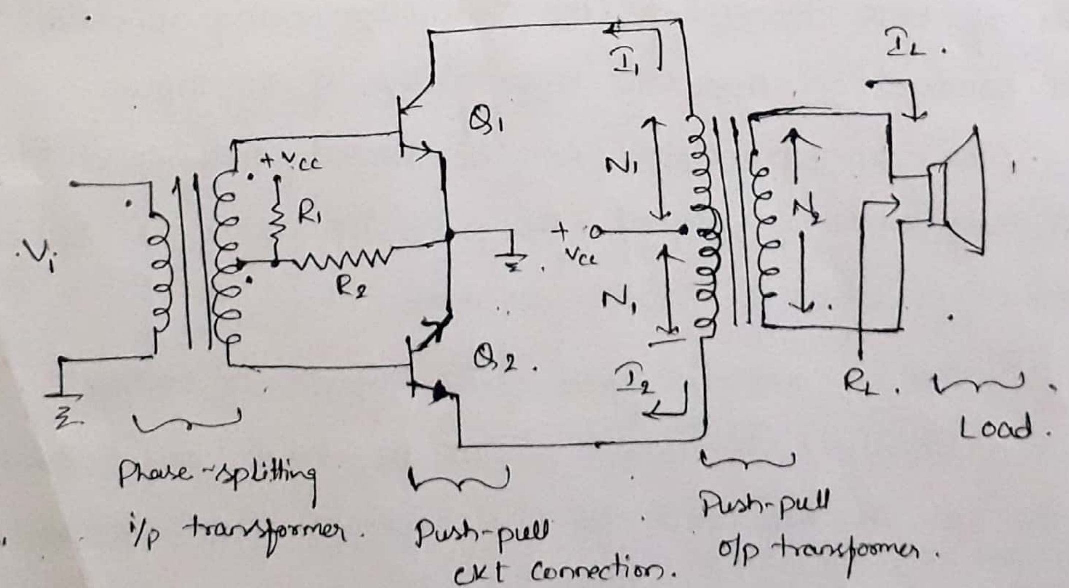
Efficiency is also given by

$$\% \eta = 78.54 \cdot \frac{V_L(P)}{V_{cc}} \%$$

Class-B Amplifier Circuits

1. Transformer- Coupled push-pull ckt.
2. Complementary - Symmetry ckt.
3. Quasi - complementary push-pull amplifier.

Transformer -coupled Push-pull circuits:



The ckt uses a centre-tapped input transformer to produce opposite - polarity signals to the two transistor inputs and an output transformer to drive the load in a push-pull mode of operation.

During the first half-cycle of operation, transistor Q_1 [is] driven in to conduction, whereas transistor Q_2 is driven o[ff].
The current I_1 through the transformer results in the first-ha[lf]
cycle of signal to the load.
During the second half-cycle of the input signal, Q_2 conduc[ts]
where as Q_1 stays off, the current I_2 through the transform[er]
resulting in the second half-cycle to the load. The overall signal developed across the load then varies over the full Cycle of signal operation.

Complementary - Symmetry Circuits

Using complementary transistors i.e. npn & pnp, it is possible to obtain a full cycle o/p across a load using half-cycles of operation from each transistor as shown in fig (a). Where as a single input signal is applied to the base of both transistors, the transistor being opposite type, will conduct on opposite half-cycles of the input.

The npn transistor will be biased into conduction by +ve half cycle of signal, the pnp transistor is biased into conduction when the input goes +ve.

During a complete cycle of the input, a complete cycle of o/p signal is developed across the load. one disadvantage of the ckt is the need for two seperate vtg supplies. and another disadvantage is present of cross-over distortion in the output signal.

Cross-over distortion refers to the fact that during the signal cross-over from positive to negative, there is some non linearity in the output signal. This results from the fact that the ckt doesnot provide exact switching of one transistor off and the other on at the zero-vtg conduction. Both transistors may be partially off so that the o/p vtg doesnot follow the input around the zero-vtg condition.

Biasing the transistors in class AB improves this operation by biasing both transistors to be 'ON' for more than half a cycle.

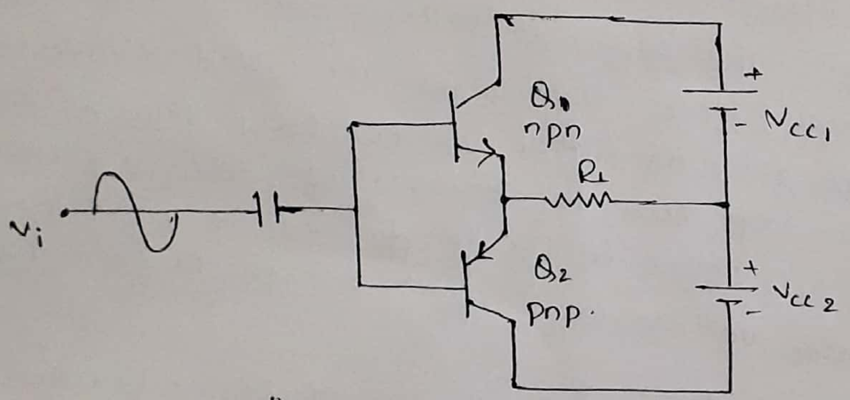
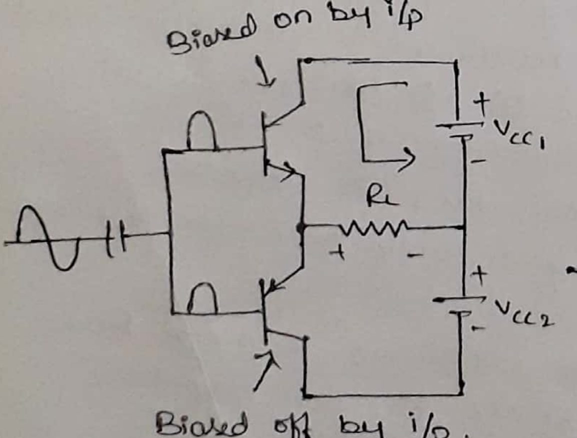


fig (a)



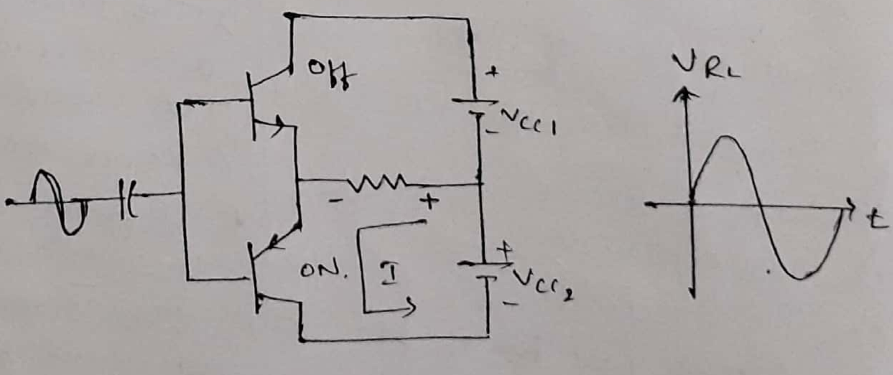
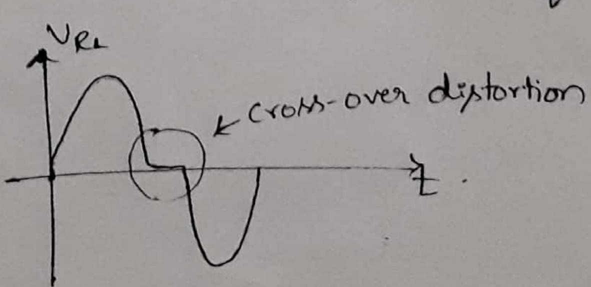


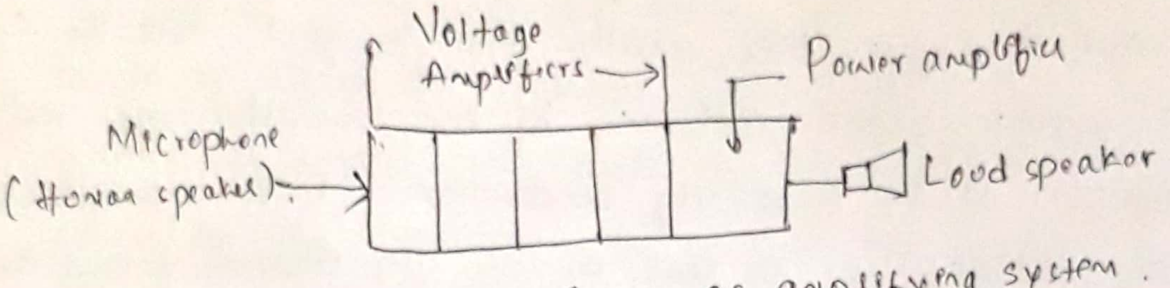
fig (b)

for +ve half cycle.

fig(c) for -ve half cycle.



Concept of large Signal Amplification



Public Address System or amplifying system.

The system consists of many stages connected in cascade. Hence
basically it is a multistage amplifier. The input is sound signal of
a human speaker and the output is given to the loudspeaker which
is an amplified input signal. The input and the intermediate stages
are small signal amplifiers. The sufficient voltage gain is obtained by
all the intermediate stages. Hence these stages are called voltage amplifiers

But the last stage gives an output to the load like a load
speaker. Hence the last stage must be capable of delivering an
appreciable amount of a.c. power to the load. So it must be
capable of handling large voltage or current swings or in other
words large signals.

Applications of PA:

1) Public address systems
2) Radio receivers
3) Tape player etc.
4) T.V receivers.
5) Cathode ray tubes etc.

Disadvantages of Series fed class A amp

1) The load resistance is directly connected and carries the Q collector current. This causes wastage of power
2) Power dissipation is more
3) Efficiency is very poor, due to large dissipation
4) The output impedance is high hence ckt cannot be used for low impedance loads such as loudspeakers

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8.70 lakhs