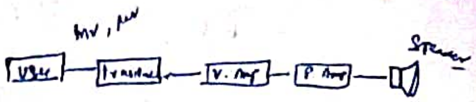
Power Amplifiers



An amplifier receives signal from transducer (e.g :- Microphone) or other i/p source and provides a larger version of the signal to some o/p device or to another amplifier stage

→ I/p (to) transducer signal is generally small (a few millivolt from a Cassette or CD i/p, a few microvolt from antenna) and needs to be amplified sufficiently to operate an o/p device (ex:- Speaker or other power handling device)

→ ~~Voltage amplifier only increase voltage level. They are small signal amplifiers,~~

→ Since the voltage & current level are small in small-signal amplifier, the amount of power-handling capacity & power efficiency is poor. Voltage amplifier only increase the voltage level. They are called small signal amplifier.

→ Power amplifier / large signal amplifier provide sufficient power to the o/p load to drive a speaker or other power device - typically a few watts to tens of watts.

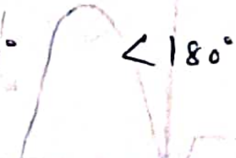
→ Power amplifier ckt handle large voltage signal at moderate to high current levels.

→ The main feature of large-signal amplifier are . ckt's power efficiency, the maxm power the ckt can handle, and impedance matching to the o/p device.

Classification :- (Short - Note - 2011 - BPUT .)

Amplifier classes represent the amount the o/p signal varies over one cycle of operation for a full cycle of i/p signal.

Class →	✓ A	AB	✓ B	C	D
Operating cycle →	360°	180° to 360°	180°	<180°	Pulse operation
Power efficiency →	25 % to 50 %.	25 %. to 78.5 %. or 50 %. to 78.5 %.	78.5 %.	80 %.	90 %.

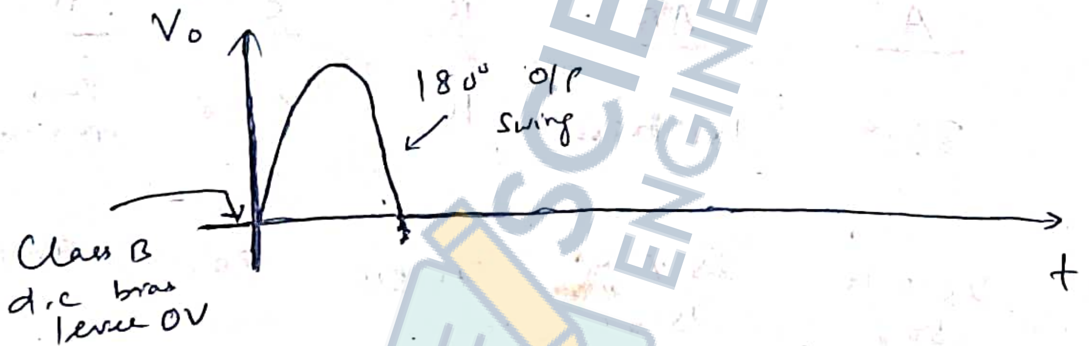


Class A :- The o/p signal varies for a full 360° of the cycle. This requires the Q- point to be biased at a level so that at least half the signal swing of the o/p may vary up & down without going to high enough

Voltage to be limited by the supply voltage ~~ve~~ level or too low to approach the ~~power~~ lower supply level.

Class B :-

A Class B ckt provides an o/p signal varying over one-half the i/p signal cycle or for 180° of signal.



The d.c bias point for class B is therefore at 0V, with the o/p then varying from this bias point for a half-cycle.

Class AB :-

An amplifier may be biased at a d.c level above the zero-base-current level of Class B and above one-half the supply voltage level of Class A.

This bias Congn is Class AB. The O/P signal 320 swing occurs between 180° & 360° and is neither Class A nor Class B operation.

Class C :-

The O/P of a Class 'C' amplifier is biased for operation at less than 180° of the cycle and will operate only with tuned (resonant) circuit.

Appln :- Radio or Communications.

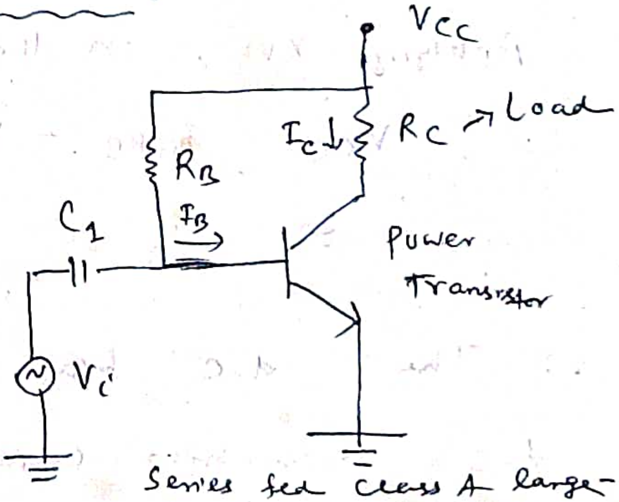
Class D :-

This operating Class is a form of amplifier operation using pulse (digital) signals, which are on for a short interval and off for a long interval. The major advantage of class 'D' operation is that the amplifier is 'on' (using power) only for short intervals and the overall efficiency can be practically be very high.

Class A - Power Amplifier :-

1) Series-fed Class A amplifier :-

A simple fixed-bias ckt Connection can be used as a Class A series-fed amplifier. The only difference between this circuit and the small-signal



Series fed class A large-signal amplifier.

version, is that the signals handled by the large-signal circuit are in the range of volts and the transistor used is a power transistor that is capable of operating in the range of a few to ten of watts.

→ Power transistor is different than the normal transistor.

(i) Base is thicker

(ii) 'β' value is less

(iii) Capable of handling large power.

→ This ckt is not the best to use as large-signal amplifier because of its poor power efficiency.

→ 'β' of power transistor is generally less than '100', overall amplifier ckt using power transistors that are capable of handling large power or current while not providing much voltage gain.

D.C bias operation :-

Applying KVL, in the i/p loop,

$$V_{CC} - I_B R_B - V_{BE} = 0$$

$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

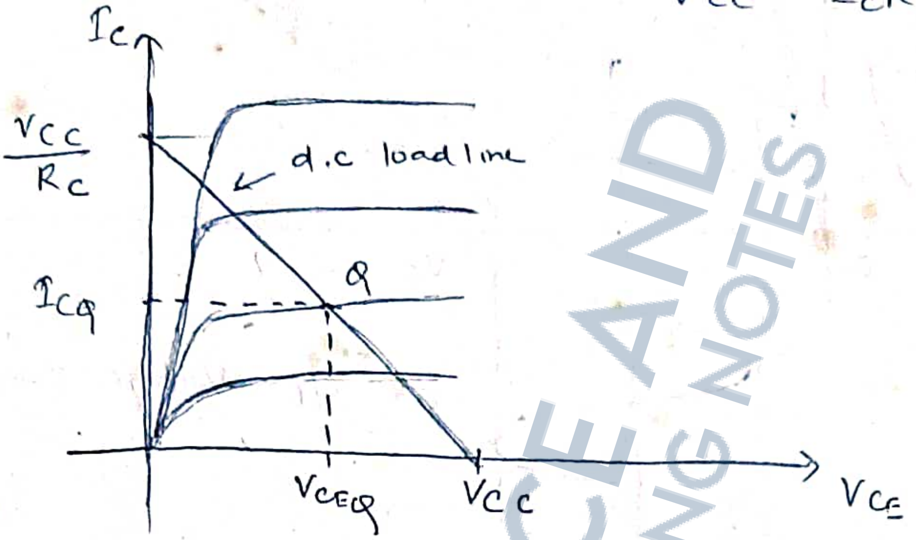
∴ The d.c bias set by Vcc & R_B fixes the d.c base-bias current at

$$I_B = \frac{V_{CC}-0.7}{R_B} \quad — ①$$

with Collector Current $I_C = \beta I_B$ — ②

and Collector - emitter Voltage

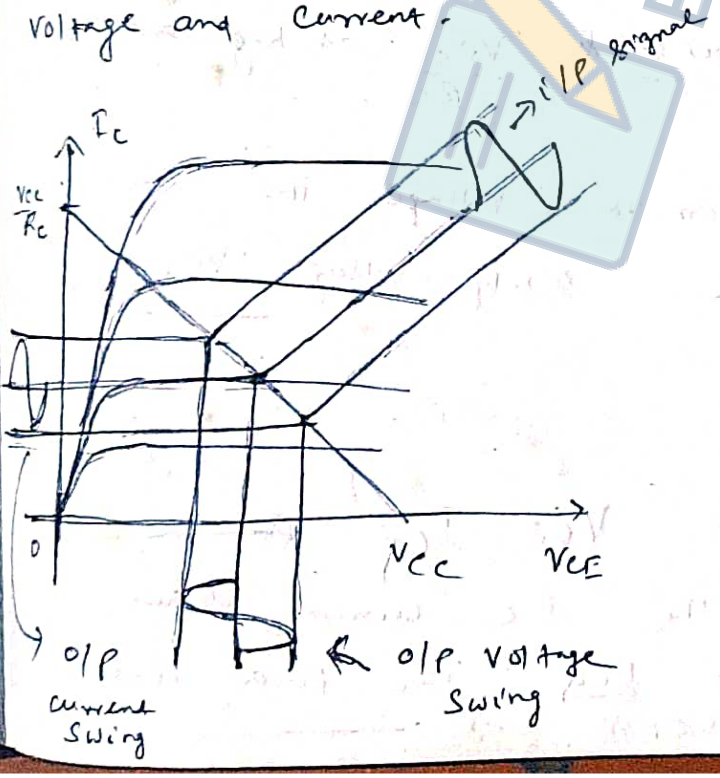
$$V_{CE} = V_{CC} - I_C R_C \quad — ③$$



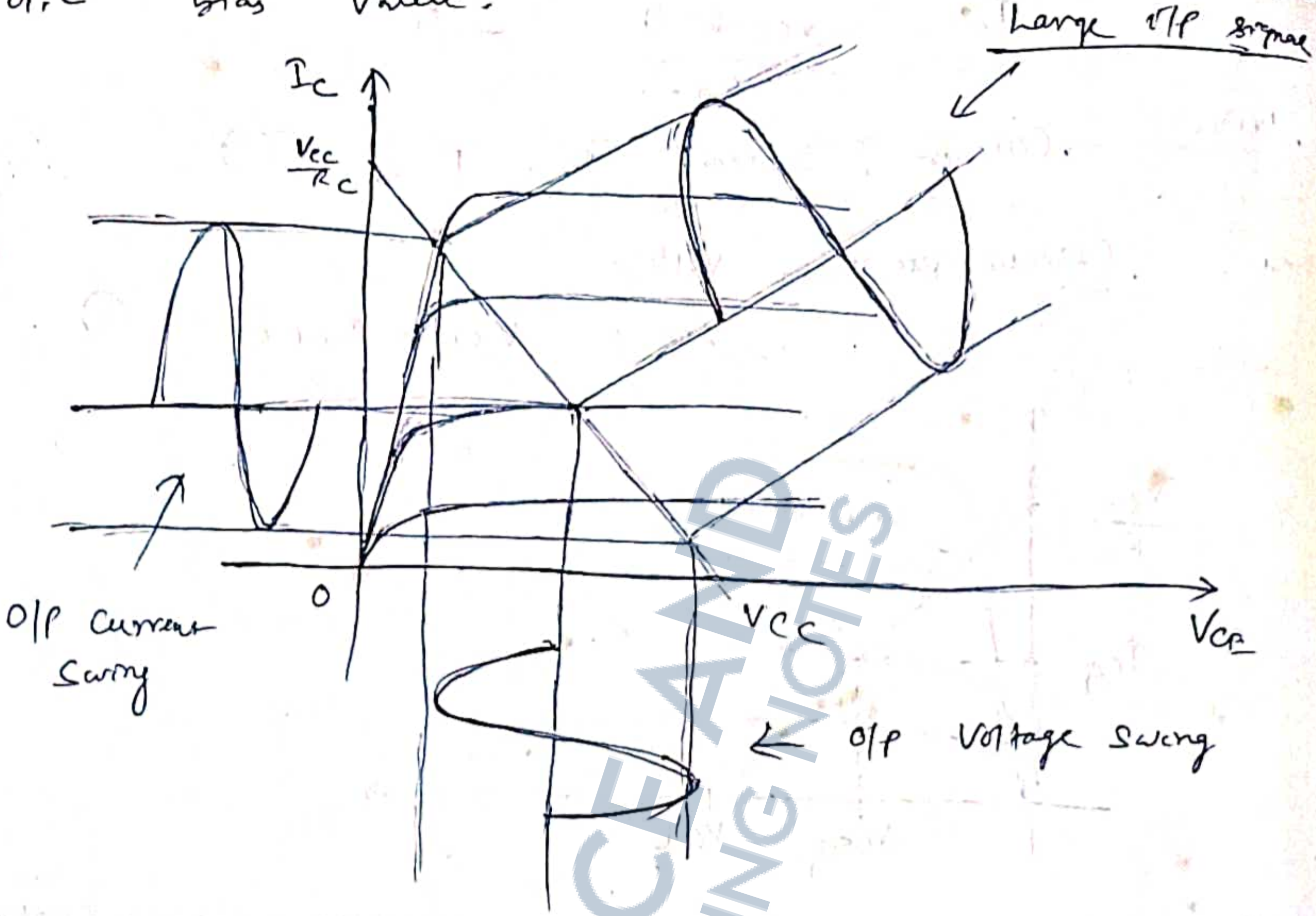
Transistor Characteristics showing load line and Q- Point.

A.C Operation:-

When an i/p ac signal is applied to the amplifier, the o/p will vary from its dc bias operating voltage and current.



A small i/p signal will cause the base current to vary above and below the d.c bias point, which will cause the collector current to vary from the d.c bias point set, as well as the collector - emitter voltage to vary around its d.c bias value.



As the i/p signal is made larger, the o/p will vary further around the established d.c bias point until either the current or the voltage reaches a limiting Condⁿ.

For the current the limiting Condⁿ is Zero Current at low end & $\frac{V_{CC}}{R_C}$ at high end of its swing.

For Collector-emitter voltage the limit is either 0V or the supply voltage V_{CC}.

Power Consideration :-

$$P_i(dc) = \overset{\text{i/p voltage}}{V_{CC}} \cdot I_{CQ} \quad ①$$

With no i/p signal, the d.c current drawn is the collector bias current I_{CQ}. The power drawn from the supply (V_{CC}) is

The a.c i/p signal, results in a.c current & voltage signal. The o/p voltage & current varying around the bias point provide a.c power to the load. (R_C).

∴ The a.c power delivered to the load (R_C) may be expressed using,

$$P_o(ac) = V_{CE}(rms) . I_C(rms) \quad — ②$$

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

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

Efficiency :-

The efficiency of an amplifier represents the amount of ac power delivered (transferred) from the dc source.

The efficiency (η), is calculated using.

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

Max^m efficiency :-

$$P_o(ac) = V_{CE}(rms) . I_C(rms)$$

P → Peak

P-P → Peak to peak

$$= \frac{V_{CE}(P)}{\sqrt{2}} . \frac{I_C(P)}{\sqrt{2}}$$

$$= \frac{1}{2}\left[V_{CE}(P) . I_C(P)\right]$$

$$= \frac{1}{2}\left[\frac{V_{CE}(P\text{-}P)}{2} . \frac{I_C(P\text{-}P)}{2}\right]$$

=) $P_o(ac) = \frac{1}{8}\left[V_{CE}(P-P) . I_C(P-P) \right]$

Max^m $V_{CE}(P-P) = V_{CC}$ (0 to V_{CC})

Max^m $I_C(P-P) = \frac{V_{CC}}{R_C}$. (0 to $\frac{V_{CC}}{R_C}$)

=) $P_o(ac) = \frac{1}{8} \times \left[V_{CC} \times \frac{V_{CC}}{R_C} \right]$

max^m $P_o(ac) = \frac{1}{8} . \frac{V_{CC}^2}{R_C}$ ——— ③

Max^m power i/p can be calculated using d.c bias current set to one-half the max^m value.

$I_{CQ} = \left(\frac{\frac{V_{CC}}{R_C}}{2} \right)$ —— ④

~~$V_{CE} = V_{CC}$~~

From eq^n (1),

$P_i(dc) = V_{CC} . I_{CQ}$

max^m $P_i(dc) = V_{CC} . \left(\frac{V_{CC}}{2R_C} \right)$ —— ⑤
↳ using eq^n (4).

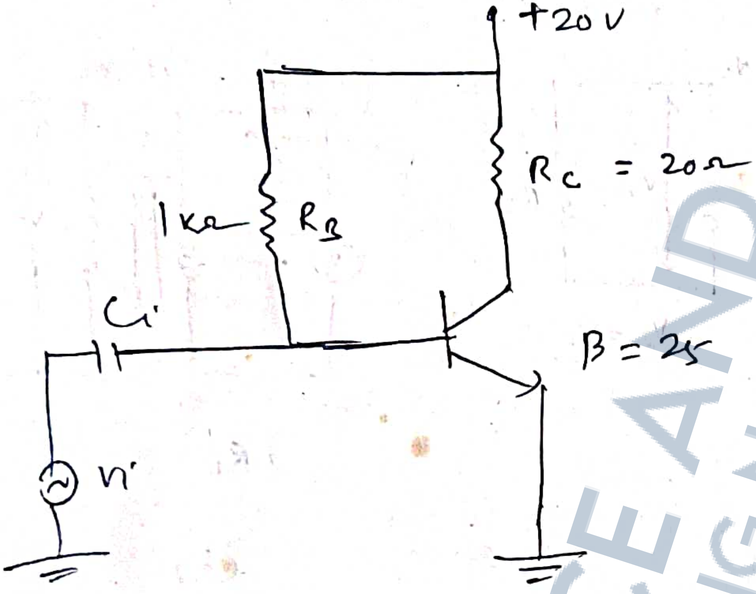
max^m $\% \eta = \frac{\text{max}^m P_o(ac)}{\text{max}^m P_i(dc)} = \frac{\frac{1}{8} . \frac{V_{CC}^2}{R_C}}{\frac{1}{2} . \frac{V_{CC}^2}{R_C}}$ [Dividing eq^n ③ by eq^n ⑤]

$= \frac{1}{8} \times \frac{2}{1} = \frac{1}{4} = 25\%$.

∴ $\boxed{\text{Max}^m \ \% \eta = 25\%}$

→ But practically it provide efficiency much < 25%.

Ex:-29



Calculate

I/P power

O/P power

efficiency.

Given

I_B (Peak) = 10mA.

Ans :- KVL to I/P loop

$$20 - I_B R_B - 0.7 = 0$$

$$\Rightarrow I_{BQ} = \frac{20-0.7}{1k\Omega} = 19.3 \text{ mA}.$$

$$I_{CQ} = \beta I_B = 25 \times 19.3 = 0.48 \text{ Amp}$$

$$V_{CQ} = V_{CC} - I_C R_C = 20 - 0.48 \times 20 = 10.4 \text{ V}.$$

Given I_B (Peak) = 10 mA. [Due to a.c i/p voltage)

$$I_C(P) = \beta I_B(P) = 25 \times 10 = 250 \text{ mA}.$$

$$P_o(ac) = I_{rms}^2 \cdot R_C = \left\{\frac{I_C(P)}{\sqrt{2}}\right\}^2 \cdot R_C = \left\{\frac{250 \times 10^{-3}}{\sqrt{2}}\right\}^2 \times 20\Omega$$

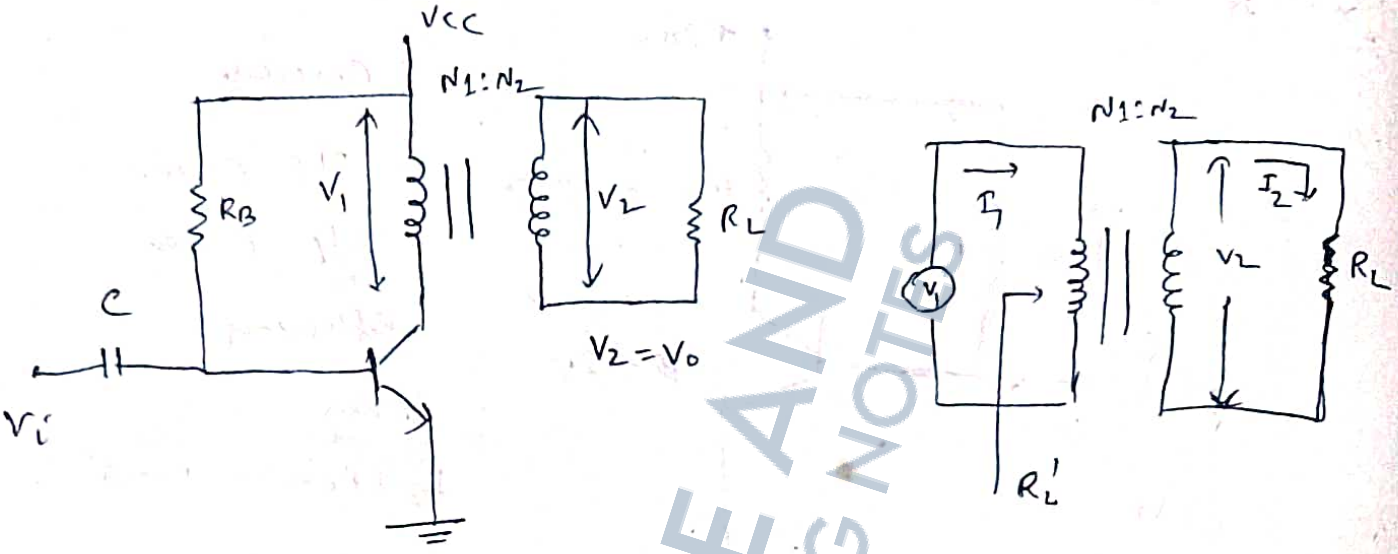
$$= 0.625 \text{ watt}.$$

$$P_o(dc) = V_{CC} \cdot I_{CQ} = 20 \times 0.48 = 9.6 \text{ watt}.$$

$$\eta = \frac{0.625}{9.6} \times 100 = 6.5\%$$ [efficiency]

2) Transformer Coupled Class-A amplifier

It uses a transformer to couple the o/p signal to the load.



(a) (b)

Transformer Coupled audio power amplifier.

Voltage transformation :-

The transformer can step up or step down a voltage applied to one side, depending upon the turns ratio. The voltage transformation is given by

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} \qquad - \textcircled{1}$$

The eqn ① shows that if the number of turns of the wire on the secondary is larger than number ~~of~~ on primary, the voltage at the secondary side is larger than the voltage at the primary side.

Current transformation :- The current in the secondary winding is inversely proportional to the number 328 of turns in the winding.

$$I_2 \propto \frac{1}{N_2}$$

$$I_1 \propto \frac{1}{N_1}$$

$$\frac{I_2}{I_1} = \frac{1}{N_2} \times \frac{N_1}{1}$$

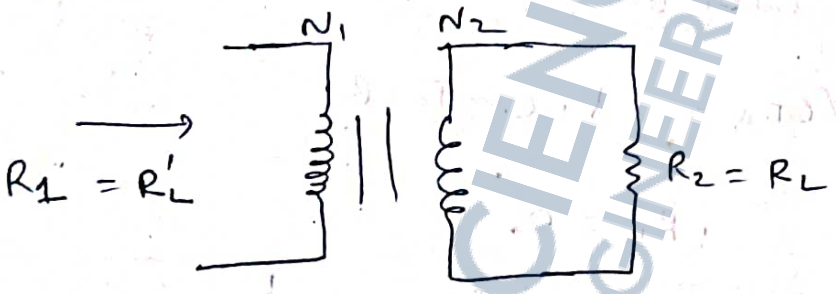
The currents transformation is given by

$$\frac{I_2}{I_1} = \frac{N_1}{N_2} \quad \text{—②}$$

i.e If the number of turns of wire on the secondary is greater than that of the primary, the secondary current will be less than the current in the primary.

Impedance transformation:-

Since the voltage & current can be changed by a transformer, an impedance 'seen' from either side (primary or secondary) can also be changed.



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

$$\therefore \frac{R_L}{R_L'} = \frac{R_2}{R_1} = \frac{V_2/I_2}{V_1/I_1} = \frac{V_2}{I_2} \times \frac{I_1}{V_1} = \left(\frac{V_2}{V_1}\right) \times \left(\frac{I_1}{I_2}\right)$$

$$\frac{R_L}{R_L'} = \frac{N_2}{N_1} \cdot \frac{N_2}{N_1} = \left(\frac{N_2}{N_1}\right)^2 \quad \text{—③}$$

Defining, $a =$ = turns ratio of the transformer,

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

Eqⁿ ③ becomes,

$$\frac{R_L}{R_L'} = \frac{1}{a^2}$$

$$\Rightarrow \boxed{R_L' = a^2 R_L}$$

$$\Rightarrow \boxed{R_1 = a^2 R_2}$$

∴ The Reflected impedance is related directly to the square of the turns ratio.

Operation of amplifier stage :-

The transformer (dc) winding resistance determines the d.c load line. The d.c resistance is small (ideally 0Ω).

$$V_{CEQ} = V_{CC} - I_C \cdot R_C$$

$$R_C = 0$$

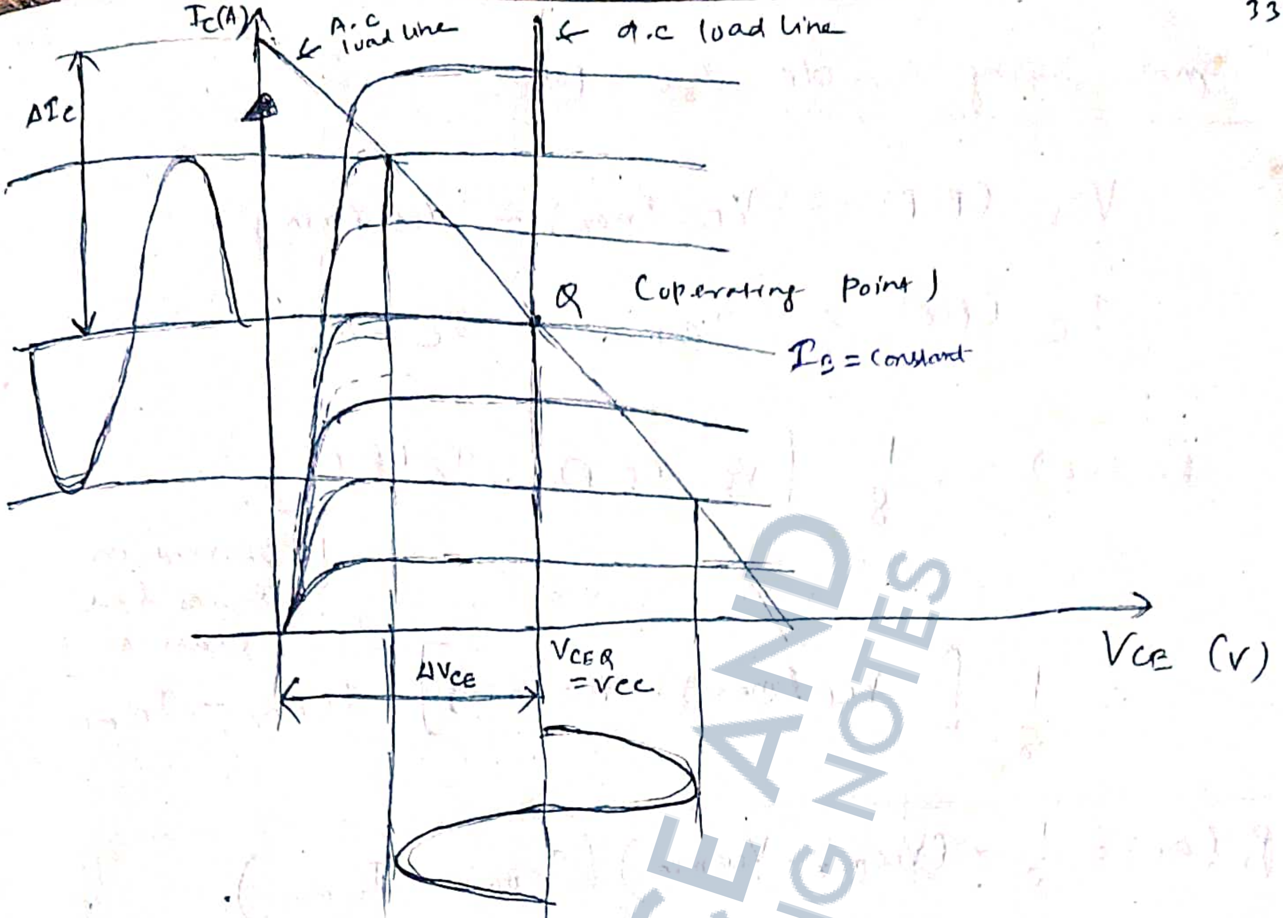
$$\Rightarrow \boxed{V_{CEQ} = V_{CC}}$$

x = constant
Line is // to y-axis.

∴ The 0Ω d.c load line is a straight vertical line, drawn at $V_{CE} = V_{CC}$.

The operating point (Q-point) on the characteristic curve can be obtained graphically at the point of intersection of d.c load line and base current set by the ckt.

To carry out a.c analysis, it is necessary to calculate the ac load resistance



"seen" looking into the primary side of transformer, then draw the a.c load line on the Collector characteristics.

$$R_L' = a^2 R_L \quad \text{—} ①$$

Slope of A-C load line = $-\frac{1}{R_L'}$. ✻ (∵ slope of A-C load line = $-\frac{1}{r_{ac}}$)

A-C load line can be drawn, which has a slope $\left(-\frac{1}{R_L'}\right)$ and it passes through Q-point.

[Hints:- $y - y_1 = m(x - x_1)$ Slope, point form in Co-ordinate geometry]

→ The o/p voltage swing around the d.c bias voltage V_{CC} and the o/p current swing around the d.c bias current I_{CQ}.

✻ A.C Load line $I_C = \left(I_{CQ} + \frac{V_{CQ}}{r_{ac}}\right) - \frac{V_{CE}}{r_{ac}} \Rightarrow y = c + mx$ [Where $c = I_{CQ} + \frac{V_{CQ}}{r_{ac}}$, $m = -\frac{1}{r_{ac}}$, $x = V_{CE}$]

Signal swing & o/p A.C power

$$V_{CE}(p-p) = V_{CE}(max) - V_{CE}(min)$$

$$I_C(p-p) = I_{Cmax} - I_{Cmin}.$$

$$P_o(ac) = \frac{1}{8}\left[V_{CE}(p-p) \cdot I_C(p-p)\right]$$

[Derived in Series fed Class A]

$$= \frac{1}{8}\left[V_{CE}(max) - V_{CE}(min)\right]\left[I_{Cmax} - I_{Cmin}\right]$$

$$\boxed{P_o(ac) = \frac{1}{8} \times (V_{CEmax} - V_{CEmin})(I_{Cmax} - I_{Cmin})}$$

→ Voltage delivered to load,

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

→ Power across the load,

$$P_L = \frac{V_L^2(rms)}{R_L}$$

→ Load Current $I_L = I_2 = \frac{N_1}{N_2} \cdot I_C.$

→ ~~Total~~ o/p A.C power can also be calculated,

$$P_L = I_L^2(rms) \cdot R_L$$

~~→ The~~ Efficiency :-

The i/p (dc) power obtained from the supply is calculated from the supply d.c voltage

∴ Avg. Power ~~supply~~ drawn from supply,

$$P_i(dc) = V_{CC} \cdot I_{CQ}.$$

Max^m efficiency $= \dfrac{\text{max}^m\ P_o(ac)}{\text{Max}^m\ P_i(dc)}$

$$= \frac{\frac{1}{8} \times (V_{CE\,max} - V_{CE\,min})(I_{C\,max} - I_{C\,min})}{V_{CC} \cdot I_{CQ}}$$

$$= \frac{\frac{1}{8} \times (2V_{CC} - 0)(2I_{CQ} - 0)}{V_{CC} \cdot I_{CQ}}$$

$$= \frac{1}{8} \times \frac{2\cancel{V_{CC}} \times 2\cancel{I_{CQ}}}{\cancel{V_{CC}} \times \cancel{I_{CQ}}}$$

$$= \frac{4}{8}$$

$$\boxed{\eta_{max} = 50\%}$$

2nd Method :-

$$\eta = \frac{\frac{1}{8}[V_{CE\,max} - V_{CE\,min}][I_{C\,max} - I_{C\,min}]}{V_{CC} \cdot I_{CQ}}$$

But $V_{CC} = \dfrac{V_{CE\,max} + V_{CE\,min}}{2}$

$$\Rightarrow \eta = \frac{\frac{1}{8} \times [V_{CEmax} - V_{CEmin}][2I_{CQ} - 0]}{\left(\frac{V_{CEmax} + V_{CEmin}}{2}\right) I_{CQ}}$$

$$\% \eta = \frac{1}{\cancel{8}_{2}} \times \frac{(V_{CEmax} - V_{CEmin}) \times \cancel{2} I_{CQ} \times \cancel{2}}{[V_{CEmax} + V_{CEmin}]} \times 100$$

$$\Rightarrow \boxed{\% \eta = 50 \left[\frac{V_{CEmax} - V_{CEmin}}{V_{CEmax} + V_{CEmin}}\right]}$$

$$\text{Max}^m \ \eta = 50 \times \left[\frac{2V_{CC} - 0}{2V_{CC} + 0}\right] = 50\%.$$

→ **Power loss :-**

$$\boxed{P_Q = P_i(d.c) - P_o(ac)}$$

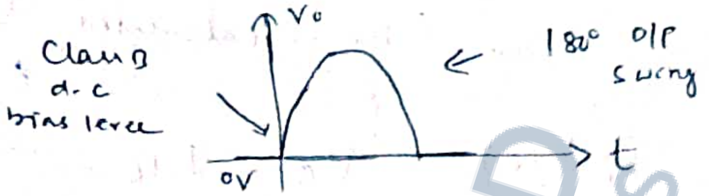
where P_Q = Power dissipated as heat.

Note:- For transformer-coupled amplifier, the power dissipated by the transformer is small (due to the small d.c resistance of a core). Thus the only power loss considered here is that dissipated by the power transistor.

Class-B Amplifier operation :-

Class B operation is provided when the d.c bias leaves the transistor biased just off, the transistor turning on when the a.c signal is applied.

[Note:-



]

→ This is essentially no bias, and the transistor conducts current for only one-half of the signal cycle. To obtain o/p for the full cycle of signal, it is necessary to use two transistors and have each conduct on ~~Opposit~~ opposite half-cycles, the combined operation providing a full-cycle of o/p signal.

→ Since one-part of the ckt pushes the signal high during one half-cycle and other part pulls the signal low during the other half-cycle, the circuit is referred to as a push-pull circuit.

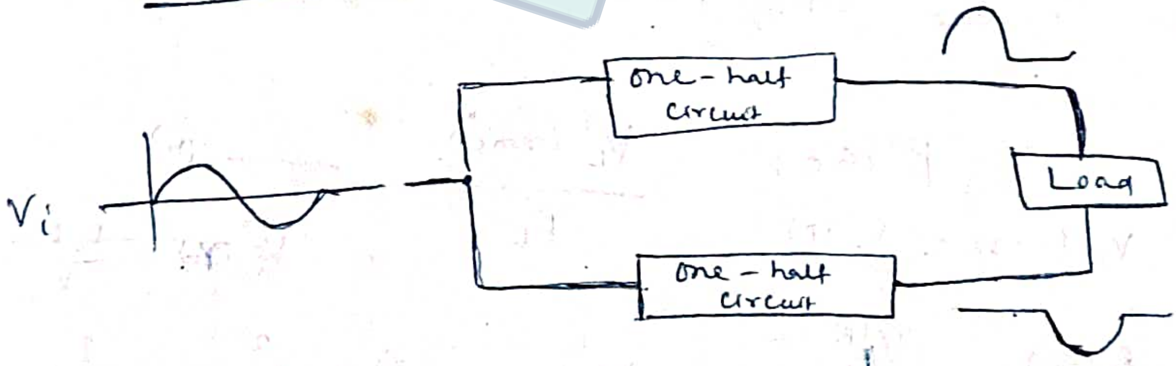


fig:- Block ~~diagram~~ representation of push-pull operation

Efficiency of Class - B amplifier :-

The power supplied to the load by an amplifier is drawn from the power supply that provides the i/p or d.c power. The amount of this i/p power can be calculated using, like ~~rectifier~~ (Full wave Rectifier)

$$P_i(dc) = V_{cc} \cdot I_{dc} \quad \text{——} ①$$

where I_{dc} is the avg. or d.c current drawn from the power supplies.

$$I_{dc} = \frac{2 I(p)}{\pi} \quad \text{——} ②$$

[Note:- In full wave rectifier $I_{dc} = \frac{2 I_m}{\pi}$]

where

$I(p)$ = Peak value of o/p current waveform.

$$\therefore \quad P_i(dc) = V_{cc} \times \frac{2 I(p)}{\pi} \quad \text{——} ③$$

o/p A.C Power :-

The power delivered to the load (usually referred to as a resistance R_L), [using r.m.s value of the voltage]

$$P_o(ac) = \frac{V_L^2(rms)}{R_L} \quad \text{——} ④$$

$$V_L(rms) = \frac{V_L(p)}{\sqrt{2}}$$

~~$V_L(rm) = \frac{V_L(rms)}{V}$~~

Also:-

$$P_o(ac) = \frac{\left(\frac{V_L(p)}{\sqrt{2}}\right)^2}{R_L} = \frac{V_L^2(p)}{2R_L} = \frac{\left(\frac{V_L(p-p)}{2}\right)^2}{2R_L} = \frac{V_L^2(p-p)}{8R_L} \quad \text{—} ⑤$$

Efficiency :-

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

$$= \frac{\left(\frac{V_L^2(rms)}{R_L}\right)}{\left(V_{CC} \times \frac{2I(P)}{\pi}\right)} \times 100$$

Note :-

$$P_o(ac) = \frac{V_L^2(rms)}{R_L}$$

$$= \frac{\left(\frac{V_L(P)}{\sqrt{2}}\right)^2}{R_L}$$

$$\boxed{P_o(ac) = \frac{V_L^2(P)}{2R_L}}$$

$$= \frac{V_L^2(rms)}{R_L} \times \frac{\pi}{V_{CC} \times 2I(P)} \times 100$$

$$= \frac{V_L^2(P)}{2 \times R_L} \times \frac{\pi}{V_{CC} \times 2I(P)} \times 100$$

~~$\left(\because V_L(rms) = \frac{V_L(P)}{\sqrt{2}}\right)$~~

$$\left(\because V_L(rms) = \frac{V_L(P)}{\sqrt{2}}\right)$$

$$= \frac{V_L(P)}{4} \times \cancel{\left(\frac{V_L(P)}{R_L}\right)} \times \frac{\pi}{V_{CC}} \times \frac{1}{\cancel{I(P)}} \times 100$$

$$\left[\because \frac{V_L(P)}{R_L} = I(P)\right]$$

$$= \frac{\pi}{4} \times \frac{V_L(P)}{V_{CC}} \times 100$$

Max^m efficiency, obtained when $V_L(P) = V_{CC}$

$$\% \eta_{max} = \frac{\pi}{4} \times 100$$

$$\boxed{\% \eta_{max} = 78.5\ \%}$$

Power dissipated by o/p transistors :-

The power dissipated (as heat) by the o/p power transistor is the difference between the i/p power delivered by the supplies and the o/p power delivered to the load

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

where P_{2Q} is the power dissipated by two o/p power transistors. The dissipated power handled by each transistor is then

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

Ex:-30 For a class B amplifier providing a 20.V peak signal to a 16Ω load (speaker) and a power suppey of Vcc = 30V, determine the i/p power, o/p power, and ckt efficiency.

Ans :- Given :- $V_L(P) = 20V$

$R_L = 16\Omega$

$$I_L(P) = \frac{V_L(P)}{R_L} = \frac{20V}{16\Omega} = 1.25 \text{ Amp}.$$

$$I_{dc} = \frac{2I(P)}{\pi} = \frac{2}{\pi}\times 1.25 = \frac{2.5}{\pi} = 0.796 \text{ Amp}.$$

$$P_i(dc) = V_{cc}\times I_{dc} = 30\times 0.796 = 23.9 \text{ watt}$$

$$P_o(ac) = V_L^2(P)/2R_L, \quad (20)^2/2\times 16$$

$$P_o(ac) = \frac{\overset{5}{\cancel{20}} \times 205}{2 \times \underset{4}{\cancel{16}}} = 12.5 \text{ watt.}$$

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

Max^m Power Considerations :-

→ Max^m o/p power delivered to the load, when

$$V_L(P) = V_{CC}.$$

$$\boxed{P_o(ac) = \frac{V_{CC}^2}{2R_L}.} \qquad \left[\because P_o(ac) = \frac{V_L^2(P)}{2R_L}\right]$$

Corresponding,

$$\rightarrow \quad I(P) = \frac{V_{CC}}{R_L}.$$

$$\Rightarrow \quad \text{max}^m\ I_{dc} = \frac{2\,I(P)}{\pi} = \frac{2}{\pi} \times \frac{V_{CC}}{R_L} = \frac{2V_{CC}}{\pi R_L}.$$

$$P_i(dc) = V_{CC} \times (\text{max}^m\ I_{dc})$$

$$= V_{CC} \times \frac{2V_{CC}}{\pi R_L} = \frac{2V_{CC}^2}{\pi R_L}$$

$$\boxed{P_i(dc) = \frac{2V_{CC}^2}{\pi R_L}}$$

$$\eta_{max} = \frac{P_o(ac)}{P_i(ac)}$$

$$= \frac{V_{CC}^2}{2R_L} \times \frac{\pi R_L}{2V_{CC}^2} = \frac{\pi}{4} = 78.5\%.$$

→ For class B, operation, max^m power dissipated by the o/p transistor doesn't ~~depend~~ occure as the max^m power i/p or o/p cond^n.

The max^m power dissipated by the two o/p transistor occurs when o/p voltage across load is

$$\boxed{V_L(P) = \frac{2}{\pi} V_{cc}}$$

.'. Max^m transistor power dissipation,

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

$$= V_{cc} \cdot I_{dc} - \frac{V_L^2(P)}{2R_L}$$

$$= V_{cc} \cdot \frac{2}{\pi} I(P) - \frac{V_L^2(P)}{2R_L}$$

$$= V_{cc} \times \frac{2}{\pi} \times \frac{V_L(P)}{R_L} - \frac{V_L^2(P)}{2R_L}$$

$$= \frac{2}{\pi} \times \frac{V_{cc}}{R_L} \times \left(\frac{2}{\pi} V_{cc}\right) - \frac{1}{2R_L} \cdot \left(\frac{2}{\pi} V_{cc}\right)^2$$

(For max^m power dissipation $V_L(P) = \frac{2}{\pi} V_{cc}$)

$$= \frac{4}{\pi^2} \frac{V_{cc}^2}{R_L} - \frac{1}{2}\left[\frac{4}{\pi^2} \frac{V_{cc}^2}{R_L}\right]$$

$$= \frac{1}{\cancel{2}} \times \frac{\overset{2}{\cancel{4}}}{\pi^2} \times \frac{V_{cc}^2}{R_L}$$

$$\boxed{P_{2Q} = \frac{2}{\pi^2} \cdot \frac{V_{cc}^2}{R_L}}$$

For single transistor power dissipated

$$P_Q = \frac{P_{2Q}}{2} = \frac{V_{cc}^2}{\pi^2 R_L}$$

Ex:- 31 For Class B amplifier using supply of $V_{cc} = 30V$, and driving a load of 16Ω. Determine the maxm i/p power, o/p power, & transistor dissipation.

Ans :-

$$P_o(ac)\Big|_{max} = \frac{V_{cc}^2}{2R_L} = \frac{30^2}{2\times 16} = 28.125\,W$$

$$P_o(dc)\Big|_{max} = \frac{2V_{cc}^2}{\pi R_L} = \frac{2\times 30^2}{\pi\times 16} = 35.81 \text{ Watt.}$$

$$\%\eta = \frac{25.125}{35.81} = 78.54\%$$

P_{2Q} = maxm power dissipated by 2 transistor

P_Q = " " " single transistor

$$= \frac{V_{cc}^2}{\pi^2 R_L} \qquad \left[P_Q = \frac{P_{2Q}}{2}\right]$$

$$= \frac{30^2}{\pi^2\times 16}$$

$$\boxed{P_Q = 5.7 \text{ Watt}}$$

Ex:- 32. Calculate the efficiency of a Class B amplifier for a supply voltage of $V_{cc} = 24V$ with peak voltage of

(a) $V_L(P) = 22V$, (b) $V_L(P) = 6V$

Ans :- (a) $\% \eta = 78.54 \times \frac{V_L(P)}{V_{cc}}$

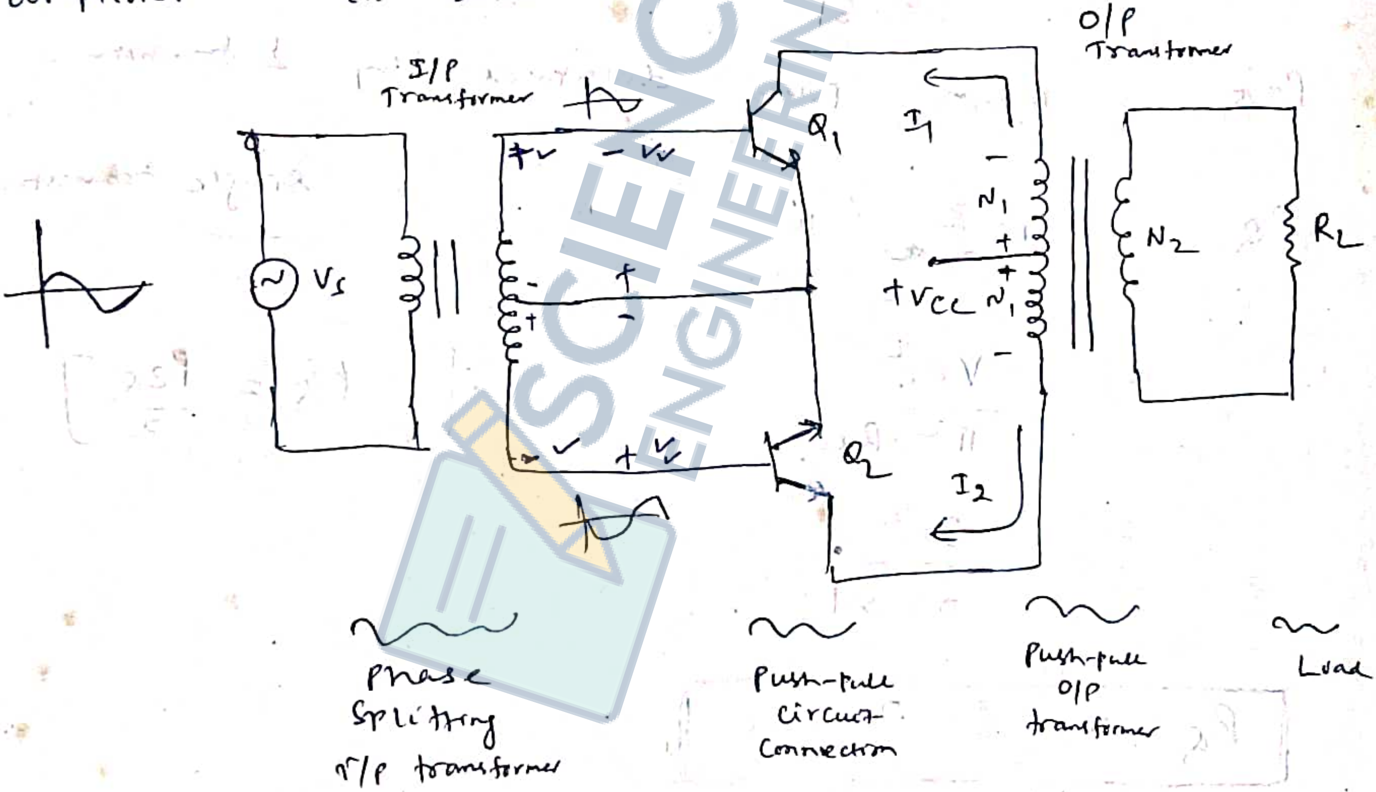
$= 78.54 \times \frac{22}{24} = 72\%.$

(b) $\% \eta = 78.54 \times \frac{6}{24} = 19.6\%.$

Class-B Amplifier ckt :-

1) Transformer - Coupled Push-pull Circuits :-

The circuitry for a class B push-pull amplifier is shown below.



→ When i/p signal is applied, the center-tapped secondary of the i/p transformer develops 2 signals which are identical but opposite in phase.

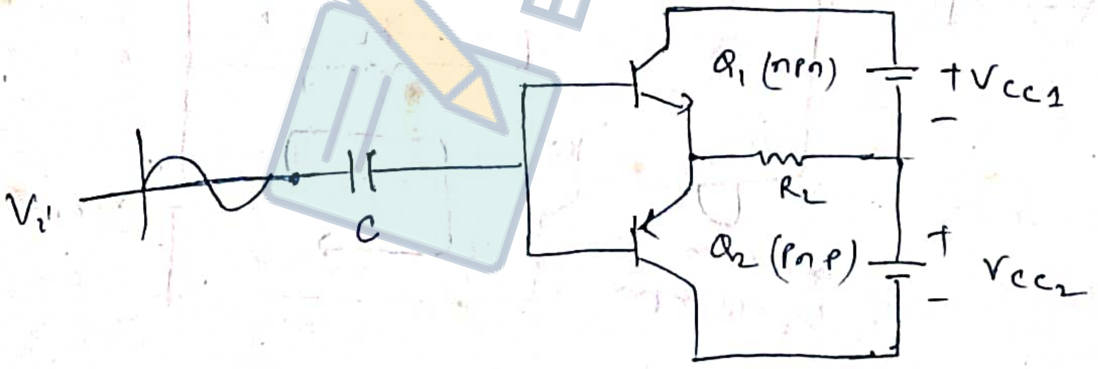
During the first half cycle of operation transistor Q_1 is driven into conduction, where as transistor Q_2 is driven off. The current I_1 through the transformer results in the first half cycle of the signal to the load.

During the second half-cycle of the i/p signal, Q_2 conducts, where as Q_1 stays off; the current I_2 through the transformer 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.

2) Complementary symmetry push pull amplifier :-

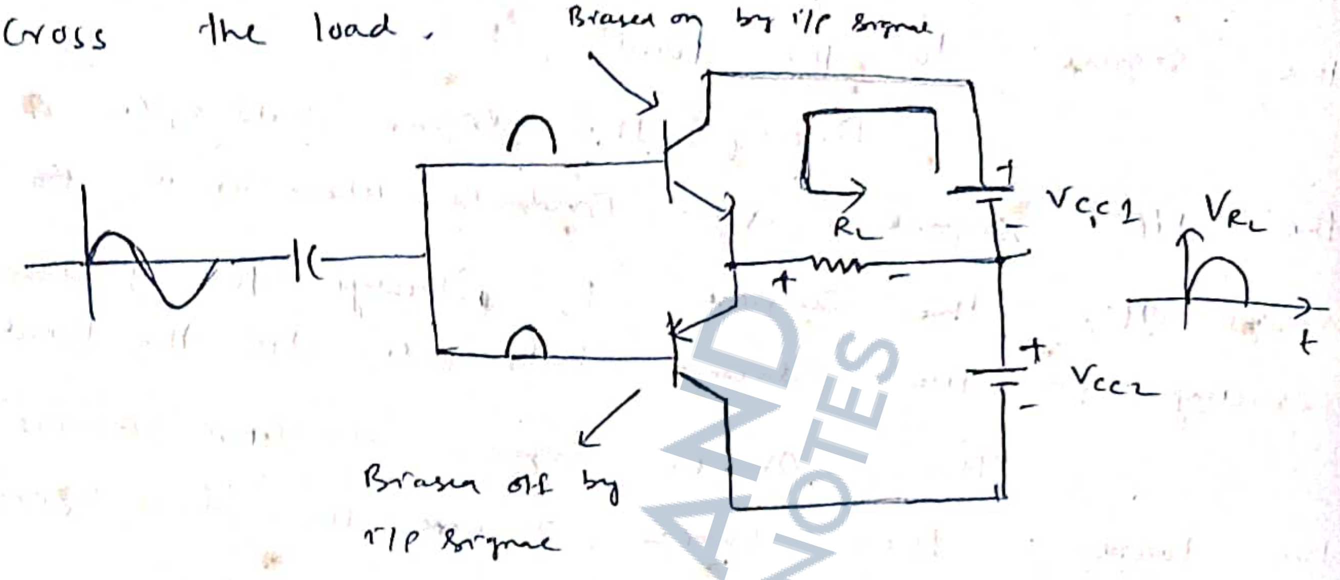
Using complementary transistors (npn & pnp) it is possible to obtain a full cycle o/p across a load using half-cycles of operation from each transistor.



(a)

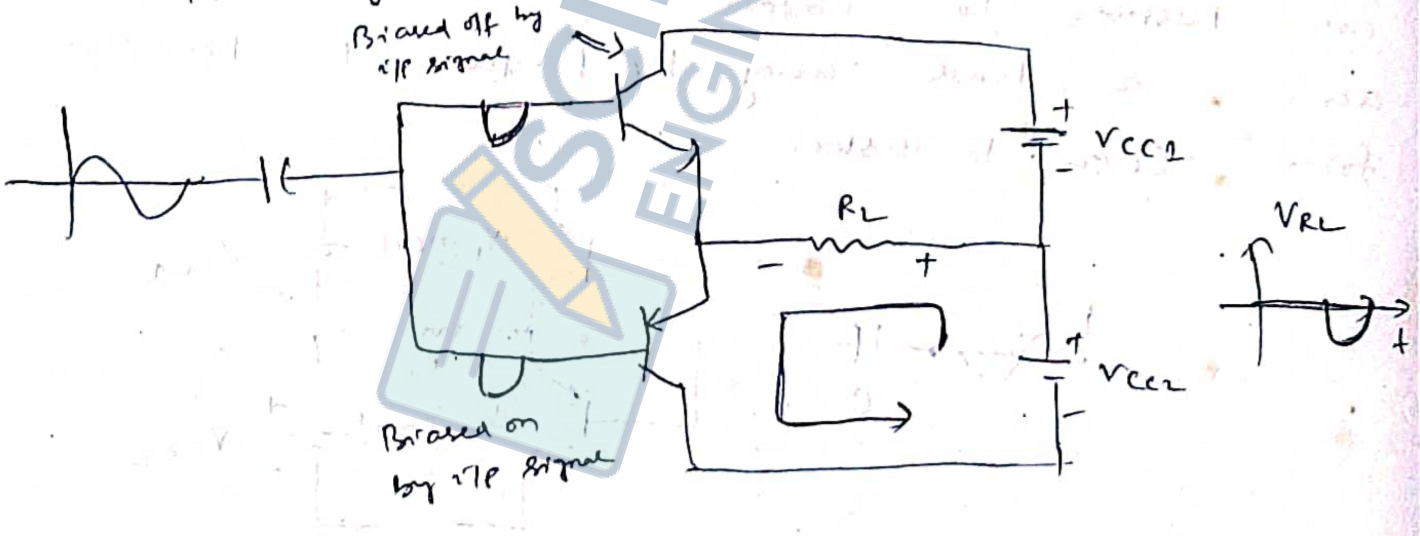
A single i/p signal is applied to the base of both transistors, the transistors, being of opposite type, will conduct on opposite half-cycle of the i/p.

The npn transistor will be biased into conduction by the +ve half cycle of signal, with a resulting half-cycle of signal across the load.



(b) During +ve half cycle.

During -ve half cycle of signal, the pnp transistor is biased into conduction when the i/p goes -ve.

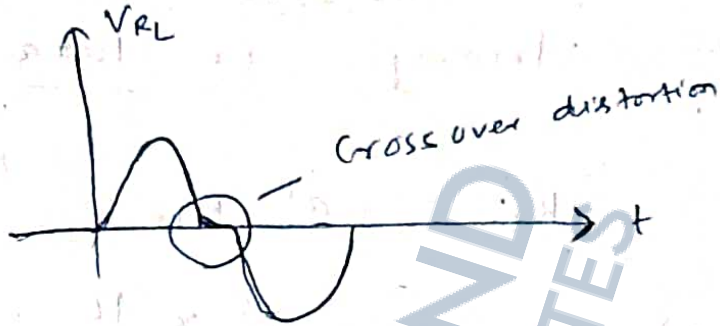


(c) During -ve half cycle.

→ During a complete cycle of i/p, a complete cycle of o/p signal is developed across the load.

→ Disadvantages :- 1) One of disadvantages of the Circuit is the need ~~of~~ for 2 separate voltage supplies.

2) The Complementary circuit resulting in Cross over distortion in the o/p signal.



Cross-over distortion :-

Cross-over distortion refers to the fact that during the signal cross over from +ve to -ve (or vice versa) there is some nonlinearity in the o/p signal. ~~This result~~

This results from the fact that the circuit does not provide exact switching of one transistor off and the other on at zero voltage condition.

Both transistors may be partially off so that the o/p voltage does not follow the i/p around the zero-voltage condition. Biasing the transistors in class AB improves this operation by biasing both transistors to be on for more than half a cycle.

~~Pro~~ EX:-33 :- BPUT 2011

What transformer ~~ra~~ turn ratio is required to match a 16Ω speaker load so that the effective load resistance seen at the primary is 10kΩ?

Ans :-

$$R_L' = a^2 R_L$$

$$\Rightarrow 10k\Omega = a^2 \times 16$$

$$\Rightarrow a^2 = \frac{\cancel{10}^{\,5} \times \cancel{1000}^{\,\cancel{500}\ \cancel{250}\ 125}}{\cancel{16}\ \cancel{8}\ \cancel{4}\ \cancel{2}} = 625$$

$$\Rightarrow \left(\frac{N_1}{N_2}\right)^2 = 625$$

$$\Rightarrow \boxed{\frac{N_1}{N_2} = 25 : 1}$$

Amplifier Distortion :-

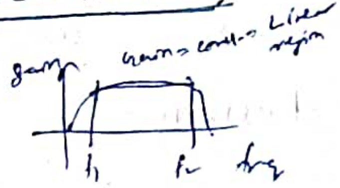
→ A pure sinusoidal signal has a single frequency at which the voltage varies +ve & -ve by equal amount.

→ Any signal varying over less than the full 360° cycle is considered to have distortion.

→ When distortion occures, the o/p will not be an exact duplicate of the i/p signal.

→ Distortion can occure because the device characteristics is not linear, in which case non-linear or amplitude distortion occurs.

→ Distortion can also occurs because the circuit elements & devices respond to the I/P signal differently at various frequencies, this being freq distortion.



● Harmonic distortion :-

Distorted but periodic waveforms can be described using Fourier analysis. The distorted waveform contains fundamental frequency components and frequency components at integer multiples of fundamental freq - these components are called harmonic components or harmonics.

Ex :- A signal that is originally 1000 HZ, could result, after distortion in freq component at 1 KHZ (Fundamental), 2KHZ (2 × 1KHZ), 3 KHZ (3 × 1 KHZ) and so on.

1 KHZ → Fundamental

2K, 3K HZ, → Harmonics.

2KHZ → Second harmonic.

3 KHZ → Third harmonic.

2 mark

Harmonic distortion :-

A signal is considered to have harmonic distortion when there are harmonic freq components [fundamental + integer multiple of fundamental freq].

If the fundamental freq has an amplitude A_1 and nth freq component has an amplitude A_n, a harmonic distortion can be defined as,

% nth harmonic distortion = % D_n

$$\boxed{\% D_n = \frac{|A_n|}{|A_1|} \times 100}$$

Ex-34 :- Calculate the harmonic distortion components for an O/P signal having fundamental amplitude 2.5V, second harmonic amplitude 0.25V and third harmonic amplitude 0.1V and 4th harmonic amplitude 0.05V.

Ans :-

$$\% D_2 = \frac{|A_2|}{|A_1|} = \frac{0.25}{2.5} \times 100 = 10\%.$$

$$\% D_3 = \frac{|A_3|}{|A_1|} = \frac{0.1}{2.5} \times 100 = 4\%$$

$$\% D_4 = \frac{|A_4|}{|A_1|} = \frac{0.05}{2.5} \times 100 = 2\%.$$

Total Harmonic Distortion (THD) :- [% THD]

$$\% \, THD = \sqrt{D_2^2 + D_3^2 + D_4^2 + \cdots} \times 100$$

Ex-35 :-

$$\% \, THD = \sqrt{(0.1)^2 + (.04)^2 + (0.02)^2} \times 100$$

$$\left[\because \frac{.25}{2.5} = 0.1, \quad \frac{0.1}{2.5} = 0.04 \ \& \ 0.02 \right]$$

$$= 0.1095 \times 100$$

$$\boxed{\% \, THD = 10.95 \, \%}$$