Unit - IV

Output Stages & Power Amplifiers

Power amplifiers :- provide sufficient power to an o/p load to drive a speaker or other power device.

Features of power amplifiers

1) Power efficiency
2) Maximum amount of power that the circuit is capable of handling
3) Impedance matching to the o/p device.

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

Class A Power Amplifier

The o/p signal varies for a full 360° of the cycle. The Q point should be placed such that at least half the signal swing of the o/p may vary up & down without going to a high voltage enough to be limited by the supply voltage.

Class B Power Amplifier

provides an O/P signal varying over one half the i/p signal cycle or for 180° of the signal.

* dc bias point is at 0V.

Class AB

* The O/P swing occurs between 180° & 360°, and is neither class A nor class B operation.
* bias level is above the zero base current level of class B and above one half the supply voltage level of class A.

Class C

* biased for operation at less than 180° of the cycle & will operate only with a tuned circuit, which provides a full cycle of operation for the tuned frequency.

Class D :

* form of amplifier operation using pulse signals.

Series Fed Class A Amplifier

Fixed bias connection

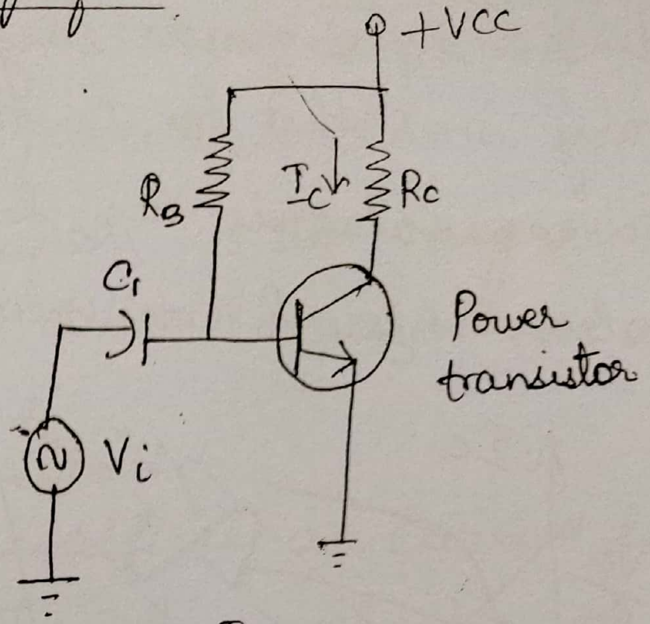
* I/P is of volts range.
* $\beta = 100$.

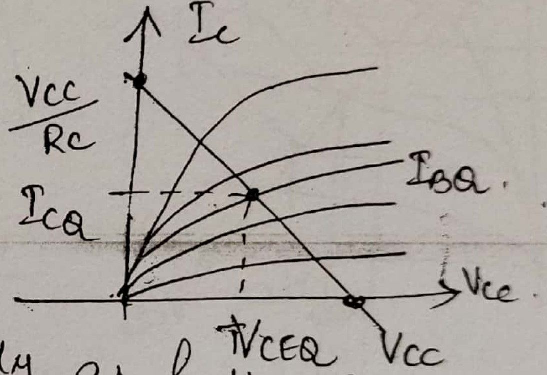
DC Bias Operation

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

$$I_C = \beta I_B$$

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



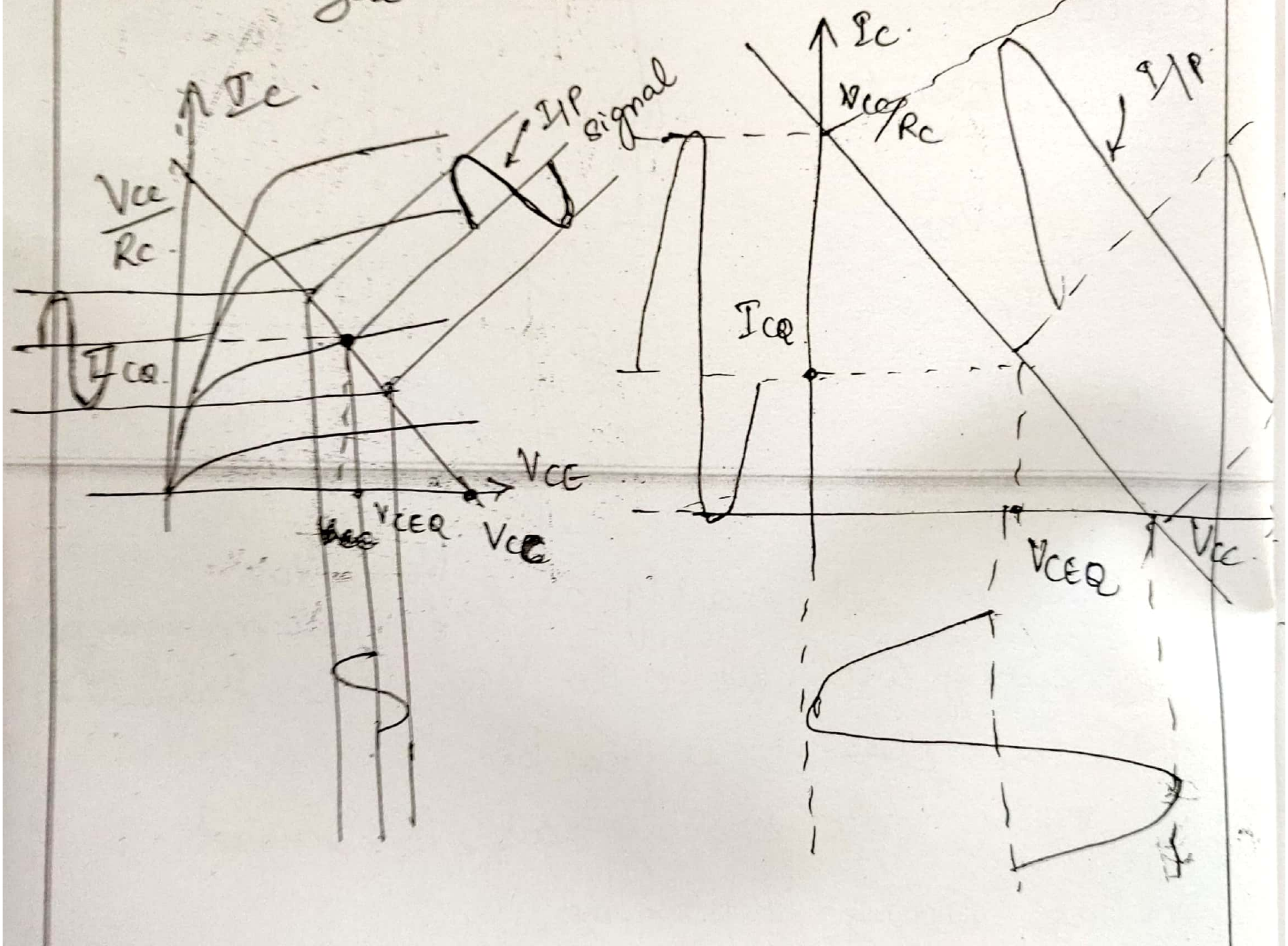


* If I_{CQ} is set exactly as half, the maximum o/p swing will be 0 to V_{CE}/R_C, the largest collector current is possible.
* If V_{CE} is also exactly half, the largest voltage swing is possible.
* Q point is set based on this consideration.

AC operation

* A small i/p signal will cause the base current to vary above and below the dc bias point, which will cause I_C & V_{CE} to vary around its dc bias value.

* As the i/p is made larger, the o/p will vary such that for Ic the min value is zero & max value is V_{CC}/R_C & for V_{CE} the minimum value is zero & max. value is Vcc.



Power Considerations

DC I/P power.

With no i/p signal, the dc current drawn is the collector current ICQ.

$$P_i(dc) = V_{cc} \times I_{CQ}.$$

AC Operation

* The o/p voltage & current varying around the bias point provide ac power to load.
* The ac signal V_i causes I_B to vary around the dc bias current & collector current around I_{CQ}.
* The ac i/p signal results in ac current & ac voltage signals. The larger the i/p, the larger the o/p.

AC o/p power

$$P_{oac} = V_m(rms)\, I_m(rms) \qquad V_m = V_{CE} \quad I_m = I_c.$$

$$P_{oac} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} = \frac{V_m I_m}{2} = \frac{V_m^2}{2R_c} \text{ or } \frac{I_m}{2} . R_c$$

$$= \frac{\left(\frac{V_{max} - V_{min}}{2}\right)\left(\frac{I_{max} - I_{min}}{2}\right)}{2}.$$

$$P_{oac.} = \frac{V_{pp} I_{pp}}{8}$$

$$P_{oac} = \frac{V_{pp}}{8}\left(\frac{V_{pp}}{R_c}\right) = \frac{V_{pp}^2}{8R_c} \text{ or } \frac{I_{pp}^2 R_c}{8}.$$

$$\boxed{P_{oac} = \frac{V_m^2}{2R_c} = \frac{V_{pp}^2}{8R_c}}$$

Efficiency

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

Maximum Efficiency

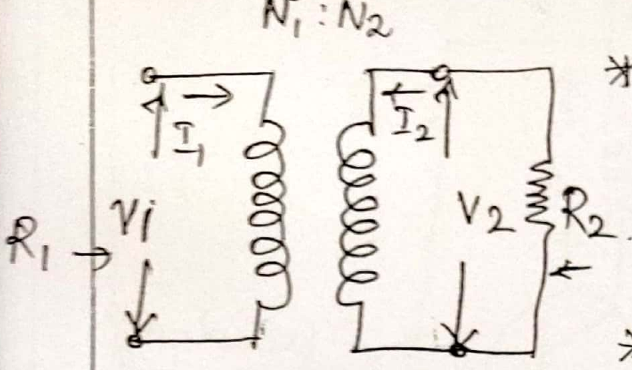
$$P_{o(ac)}\ max = \frac{V_{cc}^2}{8R_c}$$

$$P_{i(dc)}\ max = V_{cc} \times I_{CQ} = V_{cc} \times \frac{V_{cc}}{2R_c}$$

$$\therefore \% \eta_{max} = \frac{\frac{\cancel{V_{cc}^2}}{8\cancel{R_c}}}{\frac{\cancel{V_{cc}^2}}{2\cancel{R_c}}} \times 100\% = \frac{\cancel{2}}{\cancel{8}4} \times 100\% = 25\%$$

Transformer Coupled class A Amplifier

Transformer action



* A transformer can increase or decrease voltage or current levels according to the turns ratio.

* The impedance connected to one side of transformer can be made to appear larger or smaller at the other side of the transformer, depending on the square of the transformer winding turns ratio.

Voltage Transformation

The transformer can step up or down a voltage applied to one side directly as the ratio of the turns on each side. The voltage transformation is given by:

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

$$V_2 = V_1 \times \left(\frac{N_2}{N_1}\right)$$

If $N_2 > N_1$, then $V_2 > V_1$.

Current Transformation

The current transformation ratio:

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

$$I_2 = I_1 \left(\frac{N_1}{N_2}\right).$$

The current in the secondary ~~side~~ winding, is ~~larger than~~ inversely proportional to the number of turns in the windings.

Impedance Transformation

$$\frac{R_2}{R_1} = \frac{V_2 / I_2}{V_1 / I_1} = \frac{V_2}{V_1} \times \frac{I_1}{I_2} = \frac{N_2}{N_1} \times \frac{N_2}{N_1}$$

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

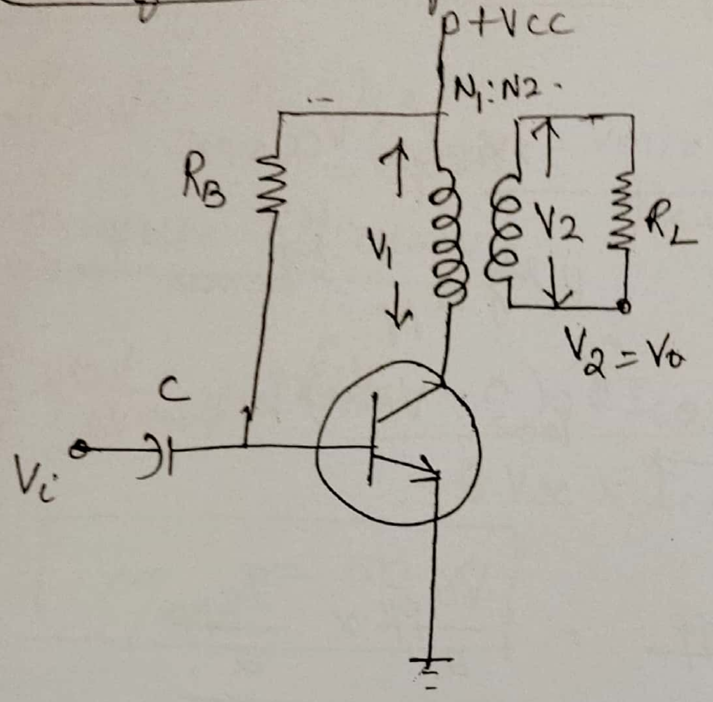
$$\boxed{R_1 = a^2 R_2}$$

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

The reflected impedance is related directly the square of turns ratio.

If $N_2 > N_1$ then $R_2 > R_1$

Transformer Coupled Class A Amplifier



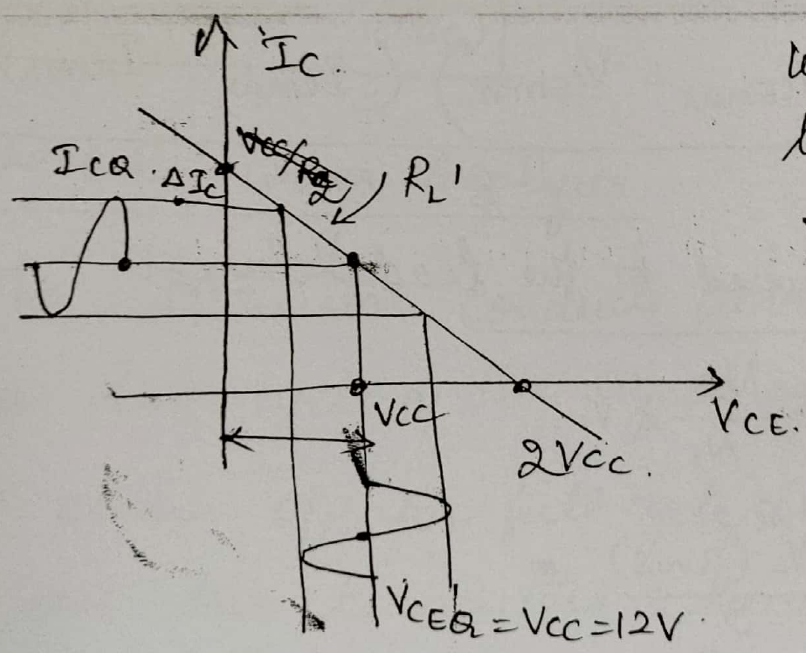
dc load line

Transformer dc winding determines the dc load line.

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

Q-point

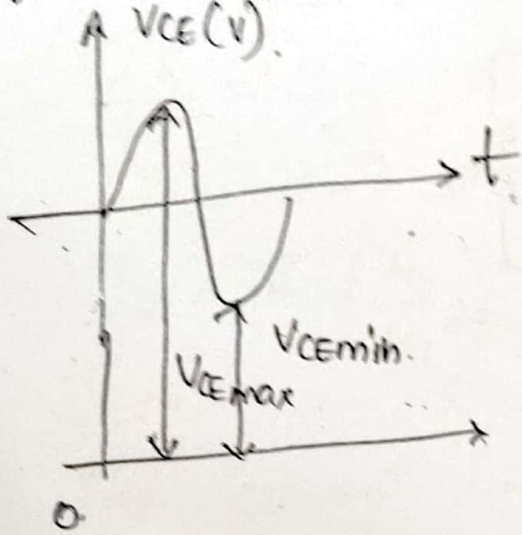
Intersection of dc load line with I_B.



Ac load line

Draw the ac load line on O/P characteristics. The slope is $-1/R_2$. The O/P swing can exceed Vcc.

Signal swing & O/P AC power



$V_{CEpp} = V_{CE\,max} - V_{CE\,min}$

III^{rly} $I_{Cpp} = I_{C\,max} - I_{C\,min}$

$P_{ac} = V_{rms} \times I_{rms} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} =$

$$P_{oac} = \frac{\frac{V_{CEpp}}{2} \frac{I_{cpp}}{2}}{2} = \frac{\frac{V_{CEpp}}{2} \times \frac{I_{Cpp}}{2}}{2}$$

$$= \frac{(V_{CEmax} - V_{CEmin})(I_{Cmax} - I_{Cmin})}{8}$$

Voltage delivered to the load & Current

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

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

$$I_L = \frac{\cancel{V_L^2(rms)}}{\cancel{R_L}} \left(\frac{N_1}{N_2}\right) I_1 .$$

$$\therefore P_L = I_L^2(rms) \times R_L .$$

Efficiency

$P_{idc} = V_{cc} \times I_{CQ}$

$\therefore \% \eta = \dfrac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 V_{cc} I_{CQ}}$

Maximum Efficiency

$\% \eta_{max} = \dfrac{(2V_{cc} - 0)(2I_{CQ} - 0)}{8 V_{cc} \times I_{CQ}} = \dfrac{(2 \times 15)(2 \times}{8 \times 15 \times}$

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

$\boxed{P_Q = P_{i(dc)} - P_{o(ac)}}$

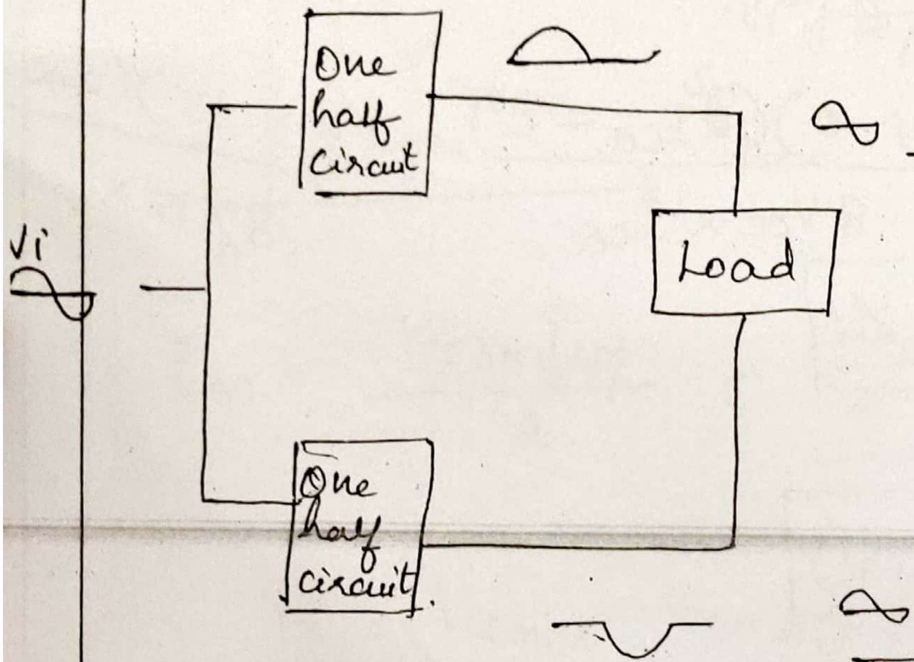
Class B Power Amplifier

* The transistor conducts current only for one half cycle of the signal cycle.
* To obtain O/P for full cycle, it is necessary to use two transistors & have each conduct on opposite half cycles, the combined operation providing a full cycle of O/P signal.

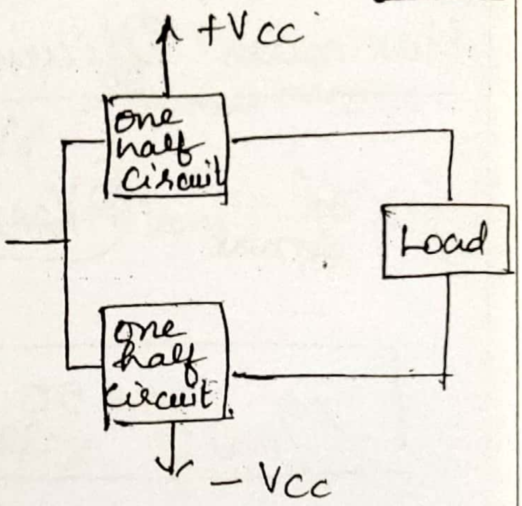
Push-pull circuit : one part of circuit pushes high & other ~~push~~ pulls low.

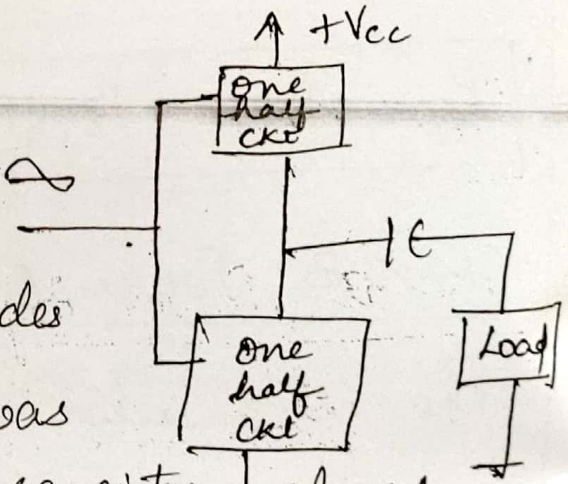
Block Representation of push pull circuit

operation



Connection of push pull to load





* Class B Operation provides greater efficiency than was possible using a single transistor class A operat[ion]

Input (DC) power

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

I_{dc} → average/dc current drawn from the power supplies.

* Current drawn from 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.

$$I_{dc} = \frac{I_m}{\pi} + \frac{I_m}{\pi} = \frac{2I_m}{\pi}.$$

$I_m \rightarrow$ peak value of O/P current.

$$P_{i\,dc} = V_{cc}\left(\frac{2\,I_m}{\pi}\right).$$

O/P AC Power

The power delivered to the load can be calculated by using an rms meter to measure the voltage across the load

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

$$V_L(rms) = \frac{V_L}{\sqrt{2}} \qquad V_L = \frac{V_{pp}}{2}$$

$$V_{L\,rms} = \frac{V_{pp}}{2\sqrt{2}}$$

$$\therefore P_o(ac) = \frac{V_L^2}{2R_L} \qquad V_{L\,rms}^2 = \frac{V_{pp}^2}{8}$$

Efficiency.

$$\%\eta = \frac{P_{o\,ac}}{P_{i\,dc}} \times 100 = \frac{V_L^2/2R_L}{V_{cc}\left(\frac{2 \times I_m}{\pi}\right)} = \frac{V_L^{\cancel{2}}/2\cancel{R_L}}{V_{cc}\left(\frac{2}{\pi} \times \frac{\cancel{V_L}}{\cancel{R_L}}\right)}$$

$I_m = V_L/_{\frown}$

$$\% \eta = \frac{\pi}{4} \times \frac{V_L}{V_{cc}} \times 100\%$$

Maximum Efficiency $V_L = V_{cc}$

$$\text{Maximum Efficiency} = \frac{\pi}{2} \times \frac{\cancel{V_{cc}}}{\cancel{V_{cc}}} \times 100\%$$

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

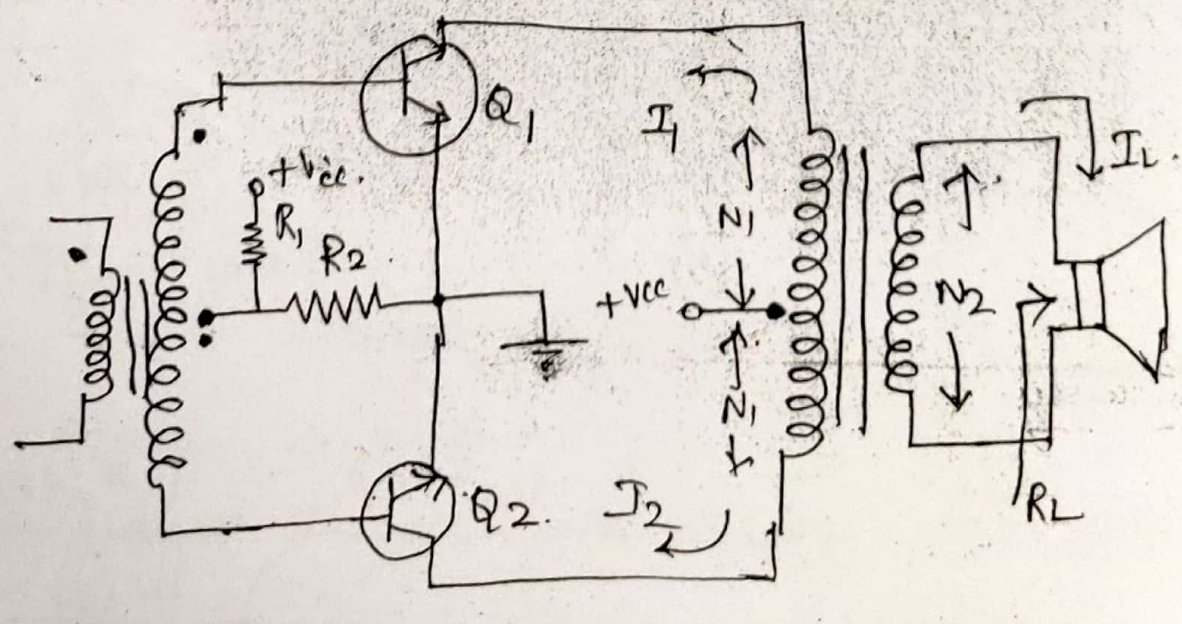
Power dissipated by o/p Transistors

$$P_{2Q} = P_{i(dc)} - P_{o(ac)}$$

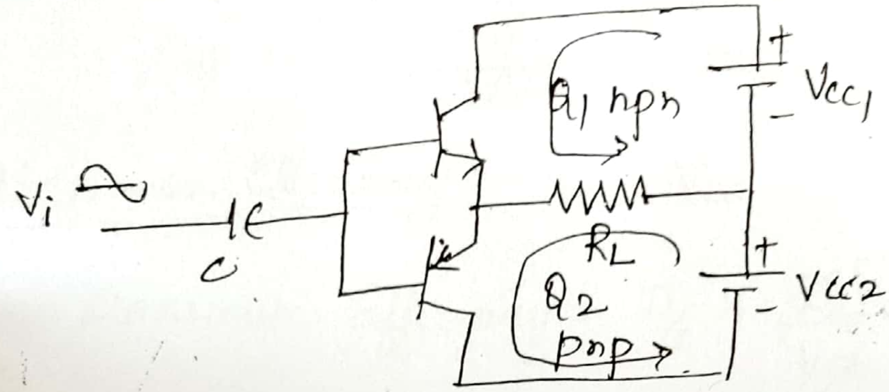
$$P_Q = \frac{P_{2Q}}{2}.$$

Class B Amplifier Circuits

Transformer Coupled Push Pull Circuit



Circuit Diagram:

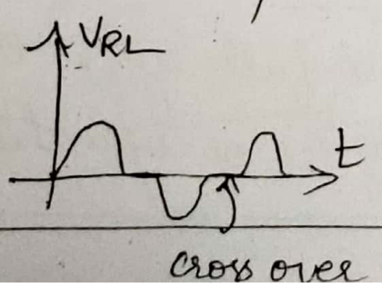


* The npn (Q_1) will be biased into conduction during the positive half cycle of the i/p resulting in a half cycle of signal across the load.
* During negative half cycle of signal, the pnp transistor is biased into conduction.
* During a complete i/p cycle, a complete o/p cycle appears across the load.

Disadvantage

1) need for two power supply.
2) Crossover distortion :-

During the signal cross over from positive to negative there is some nonlinearity in the o/p signal. This is because the circuit does not provide exact switching.



cross over

Class AB will eliminate this distortion.

SRM

Amplifier Distortion

* A pure sinusoidal signal has a single frequency at which the voltage varies positive & negative by equal amounts. Any signal varying over less than 360° cycle is considered to have distortion.

Reasons for distortion

* device characteristics not linear → amplitude distortion
* circuit elements & devices respond to the i/p signal differently at various frequency → frequency distortion

Fourier Analysis

* technique for describing distortion.
* Any periodic waveform is described in terms of fundamental frequencies & higher frequency components at integer multiples.
* 1KHz signal → O/P 1KHz → fundamental frequency
  2KHz → 2^{nd} harmonics
  3KHz → 3^{rd} harmonic.

Harmonic Distortion

A signal is considered to have harmonic distortion if there are harmonic frequency components.

% nth harmonic distortion $= \% D_n = \frac{|A_n|}{|A_1|} \times 100\%$

$A_1 \rightarrow$ amplitude of fundamental frequency

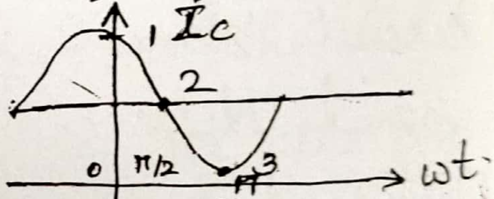
$A_n \rightarrow$ amplitude of n^{th} frequency component.

$A_1 > A_n$.

Second Harmonic Distortion

Consider a distorted signal waveform

$i_c \simeq I_{CQ} + I_0 + I_1 \cos\omega t + I_2 \cos\omega t$.



At 1 :- $\omega t = 0$.

$i_c = I_{cmax} = I_{CQ} + I_0 + I_1 + I_2 \rightarrow (1)$

At 2 $\omega t = \pi/2$.

$i_c = I_{CQ} = I_{CQ} + I_0 + I_1 \cos \pi/2 + I_2 \cos 2\pi/2$

$I_{CQ} = I_{CQ} + I_0 - I_2 \rightarrow (2)$

At 3 $\omega t = \pi$.

$i_c = I_{cmin} = I_{CQ} + I_0 - I_1 + I_2 \rightarrow (3)$

Solving (1), (2) & (3).

$I_0 = I_2 = \dfrac{I_{cmax} + I_{cmin} - 2I_{CQ}}{4}$

$I_1 = \dfrac{I_{cmax} - I_{cmin}}{2}$

2nd Harmonic Distortion :-

$$D_2 = \left| \frac{I_2}{I_1} \right| \times 100\%$$

$$= \left| \frac{\frac{1}{2}(I_{cmax} + I_{cmin}) - I_{CQ}}{I_{cmax} - I_{cmin}} \right| \times 100\%$$

Ill.ly D_2 in terms of voltage

$$D_2 = \left| \frac{\frac{1}{2}(V_{CEmax} + V_{CEmin}) - \cancel{I_{CQ}}\, V_{CEQ}}{V_{CEmax} - V_{CEmin}} \right| \times 100\%$$

Power of a signal having distortion

$$P_1 = \frac{I_1^2 R_C}{2}$$

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

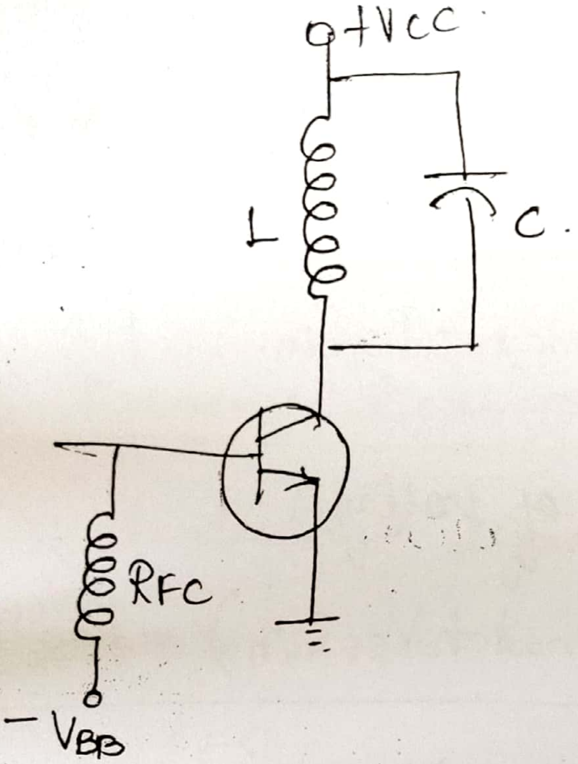
$$P = \cancel{\ell}.\left(I_1^2 + I_2^2 + I_3^2 + \cdots\right)\frac{R_C}{2}$$

$$P = (1 + D_2^2 + D_3^2 + \cdots) I_1^2 \frac{R_C}{2} = (1 + THD^2) P_1 .$$

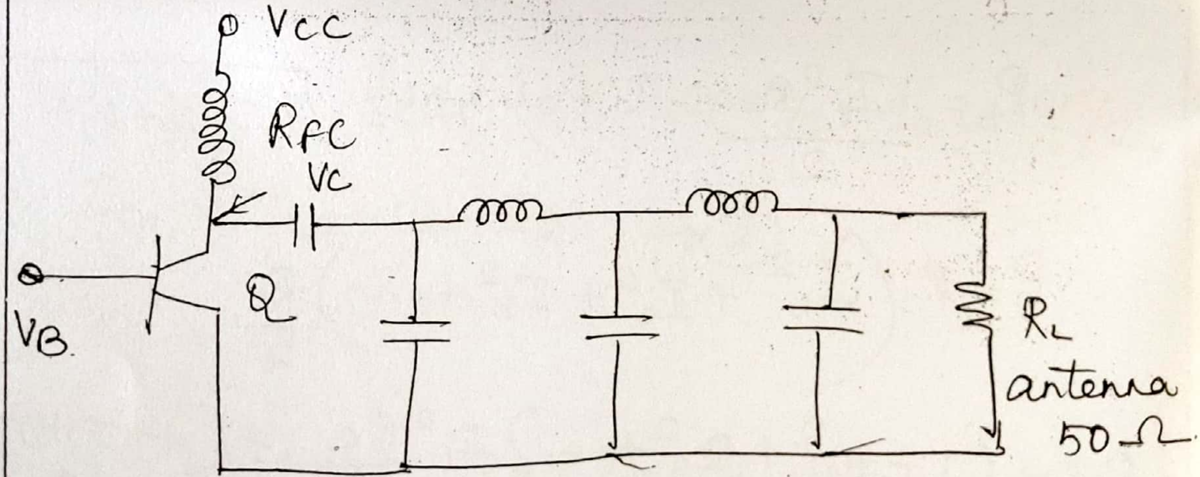
total harmonic distortion.

Class-C Amplifier

* biased to operate for less than 180° but LC provides full O/P.



~~Class D Amplifier~~ Schematic diagram of Class-C Amplifier



Operation : When the i/p voltage is positiv and above the cut in voltage of the tran the transistor operates in the saturation reg. In this region, the o/p is proportio to the saturation voltage of Q. ~~and~~ The o/p remai

When $Q_2 \rightarrow$ off $V_C(t) = V_{cc}$.

$\therefore$ From ① $\Rightarrow$ $V_{cc} = V_{CEsat} + V_{dc}$ of $V_m \cos \omega_0 t$.

$$V_{cc} = V_{CEsat} + \frac{V_m}{\pi}$$

$$\therefore V_m = \pi (V_{cc} - V_{CEsat}).$$

Dc Power

$P_{dc} = V_{cc} \times I_{dc}$.

$I_{dc} \rightarrow$ average value of supply current.

The same average current flows through the transistor when it is in saturation region.

$$P_d = V_{CEsat} I_{dc}.$$

P_d ↑ power dissipated

The remaining power must appear as useful ac power across Load

$\therefore P_{ac} = P_{dc} - P_d = V_{cc} I_{dc} - V_{CEsat} I_{dc} = I_{dc} (V_{cc} - V_{CEsat})$

$$\% \eta = \frac{P_{ac}}{P_{dc}} \times 100 = \frac{I_{dc} (V_{cc} - V_{CEsat})}{V_{cc} I_{dc}} \times 100$$

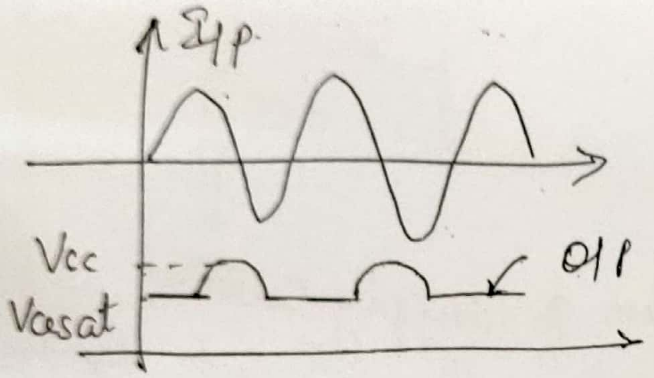
$$\% \eta = \left(1 - \frac{V_{CEsat}}{V_{cc}}\right) \times 100$$

Note $V_{CEsat} << V_{cc}$

$\% \eta > 90\%$.

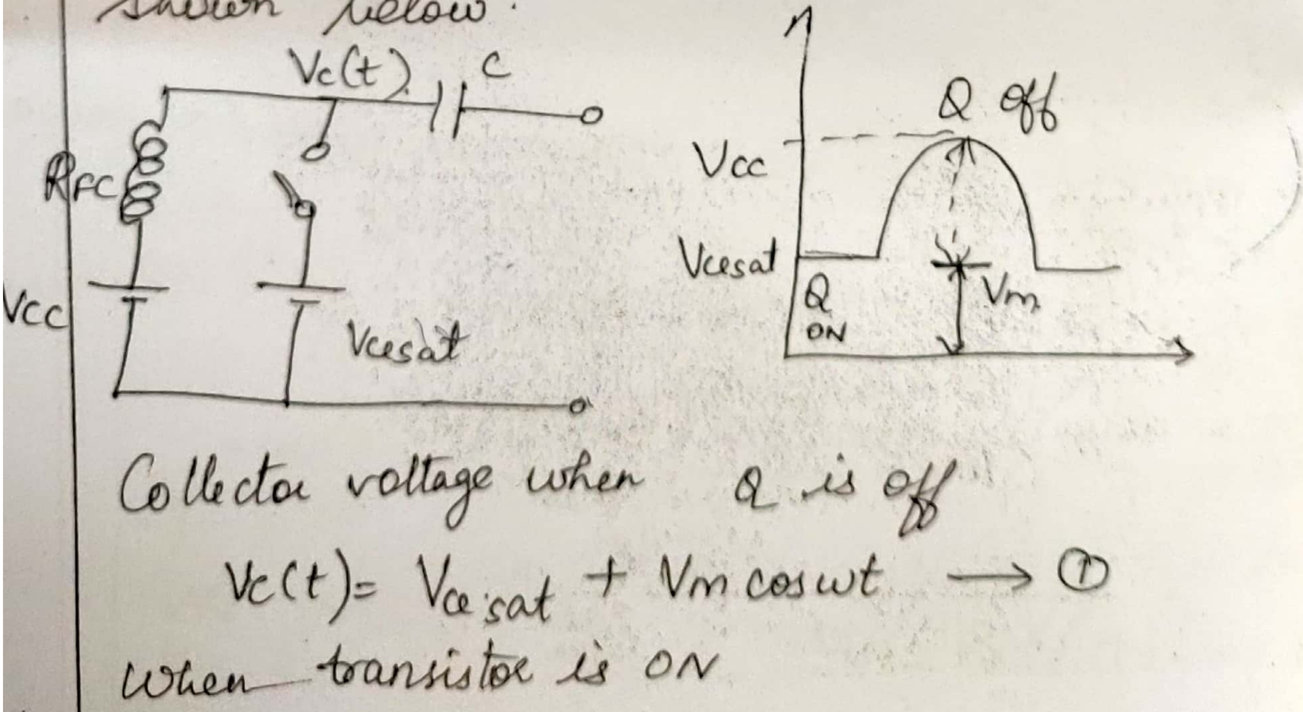
SRM

constant. As long as the i/p voltage is ~~more~~ lesser than the cut in voltage, the transistor remains off, while the induced emf in the inductor provides the collector current as shown below



Efficiency of class-C Amplifier

The class-C amplifier can be modeled as shown below.



Collector voltage when Q is off

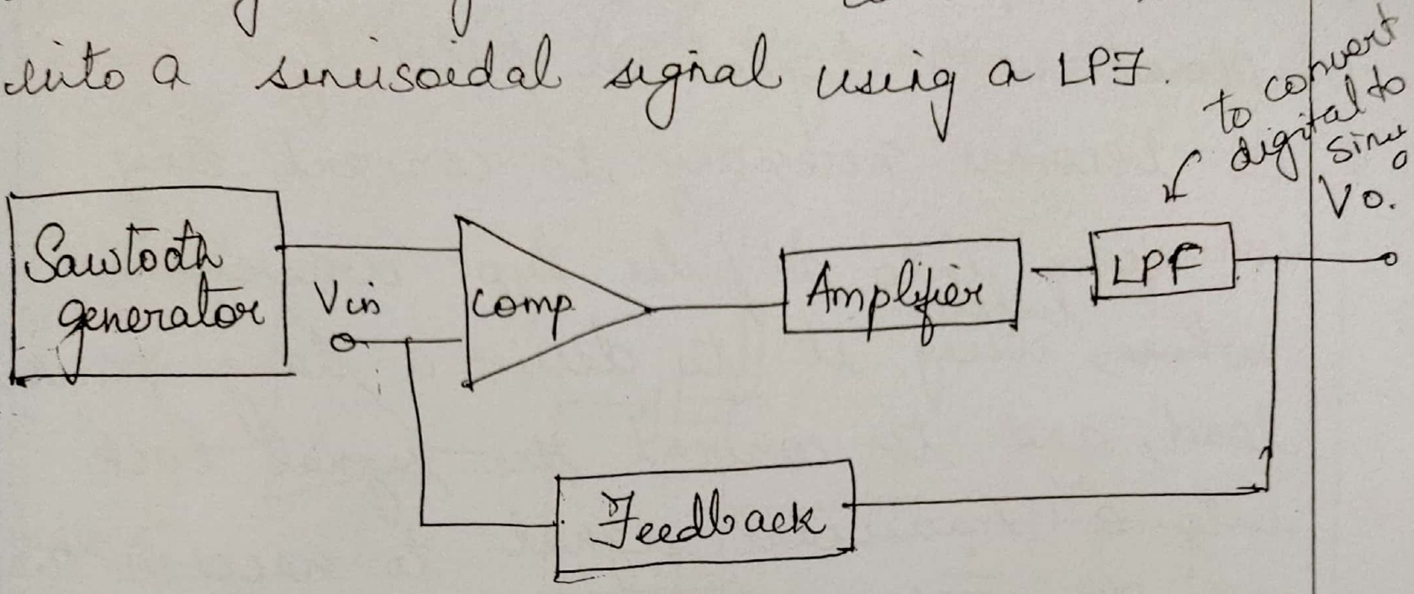
$$V_C(t) = V_{ce\,sat} + V_m \cos\omega t \longrightarrow (1)$$

When transistor is ON

$$V_C(t) = V_{cesat}$$

The dc resistance of the coil is zero & the time average value of $V_C(t)$ is zero.

amplifier (ie) the unit required to amplify the digital signal & then convert it back into a sinusoidal signal using a LPF.



operation of class-D Amplifier

There are 3 stages of operation:

① Generation of pulses
② Modulation
③ Filtering

Generation of pulses:

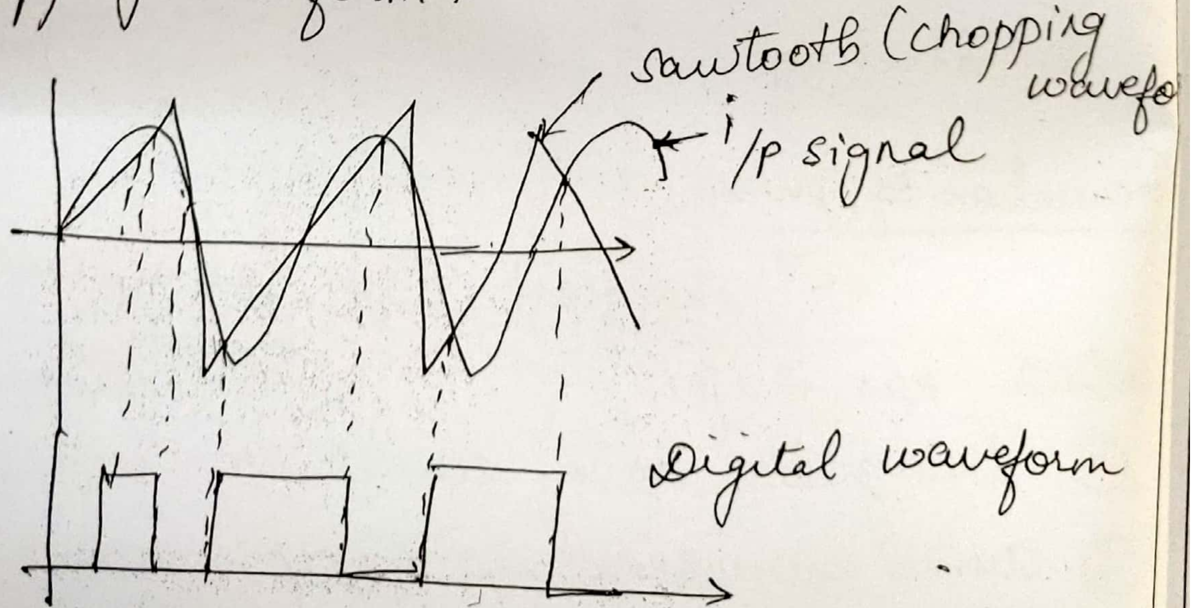
The first stage has a comparator which has 2 i/ps.

ⓐ triangular wave signal
ⓑ audio sinusoidal i/p signal

The O/P of comparator is rectangular pulses with duty cycle according to the input sinusoidal signal.

Class D Power Amplifier

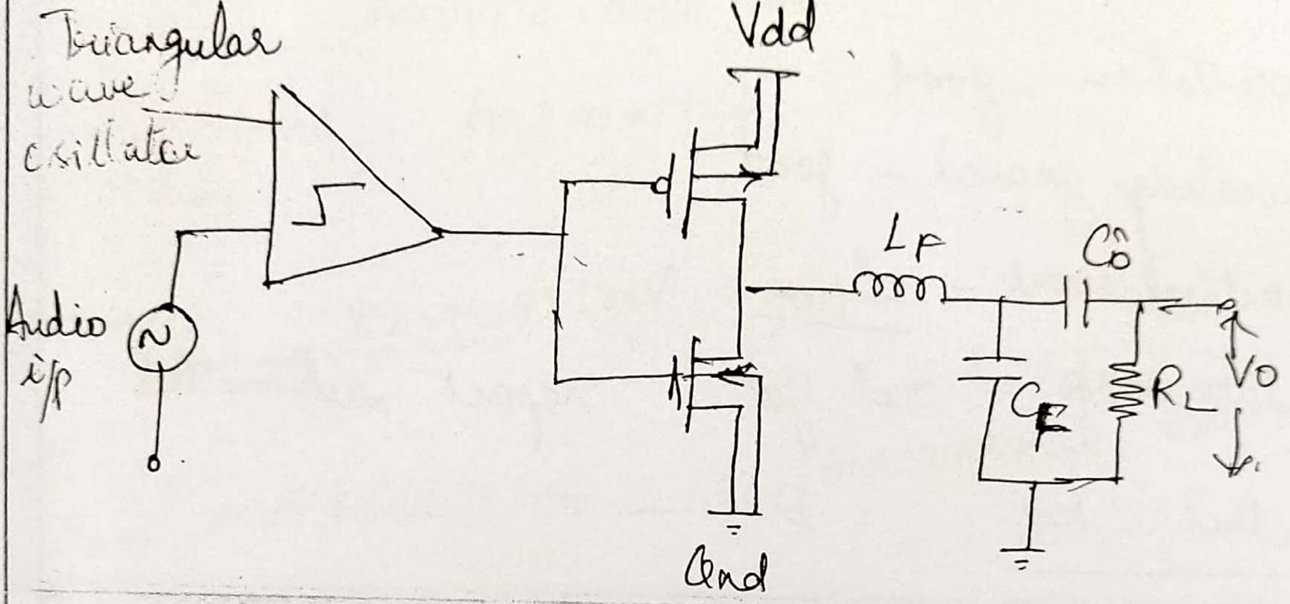
* Class D power amplifier is designed to operate with digital or pulse type signal.
* It becomes necessary to convert any waveform into a pulse type waveform, ~~where~~ before using it to derive a large power load, and to convert the signal back into a sinusoidal signal to recover the original signal.
* Following figure shows a sinusoidal signal that is to be converted into a pulse type signal using some form of sawtooth or chopping waveform.



Block diagram of class D Amplifier

Following shows the block diagram of class D

The comparator should be fast so that it can respond to high frequency triangular waves.



2) Modulation :-

Second stage consists of a complementary pair of a p-channel & an n-channel device in push pull configuration.

3) Filtering

Since the harmonics have a frequency higher than the fundamental frequency, it is easy to remove these by passing this o/p to a low pass filter.

Industrial training BSNL

(1) 206 - Syed Imran Hazari

presentation - good
knowledge gained - good
practical work - h/w
future work - not yet report submitted

(2) Prudhvi - 198 BSNL

presentation - slide preparation - poor
↳ okay → reading from slide
knowledge gained - ~~nothing~~ okay.
future work → nothing
report - submitted.

(3) 186 - P.C. Pavan - BHEL - Electronic

presentation - good.
Knowledge gained - good
practical work - okay
future work - nothing.
report - submitted

Note:

1. Fundamental frequency is not considered a harmonic

2. Fourier Analysis does not allow for fractional harmonics.

HARMONIC DISTORTION

Let

$A_1 \rightarrow$ Amplitude of f_0 (fundamental frequency)

$A_n \rightarrow$ ~~nth~~ Amp. of n^{th} harmonic

then a harmonic distortion can be defined

$$\% \ n^{th} \text{ harmonic distortion} = \% D_n = \frac{|A_n|}{|A_1|} \times 100\%$$

PROBLEMS

Calculate the harmonic distortion components for an output signal having fundamental amplitude of 2.5V, second harmonic amp. of 0.25V, third har. amp. of 0.1V and fourth harmonic amp. of 0.05V.

AMPLIFIER DISTORTION

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

* Distortion can occur because the device characteristic is not linear

* one technique for describing distortion but period waveforms uses Fourier Analysis

FOURIER ANALYSIS:

* A method that describes any periodic waveform interms of its fundamental freq component and harmonics (freq. components are integer multiples)

* For example,

Let, $f_0 = 1KHZ$

then $2KHZ$ = second harmonic

$3KHZ$ = third harmonic

.... and so on.

Solution

given $A_1 = 2.5V$ $A_2 = 0.25V$ $A_3 = 0.1V$ $A_4 = 0.05$

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

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

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

Total Harmonic Distortion (THD)

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

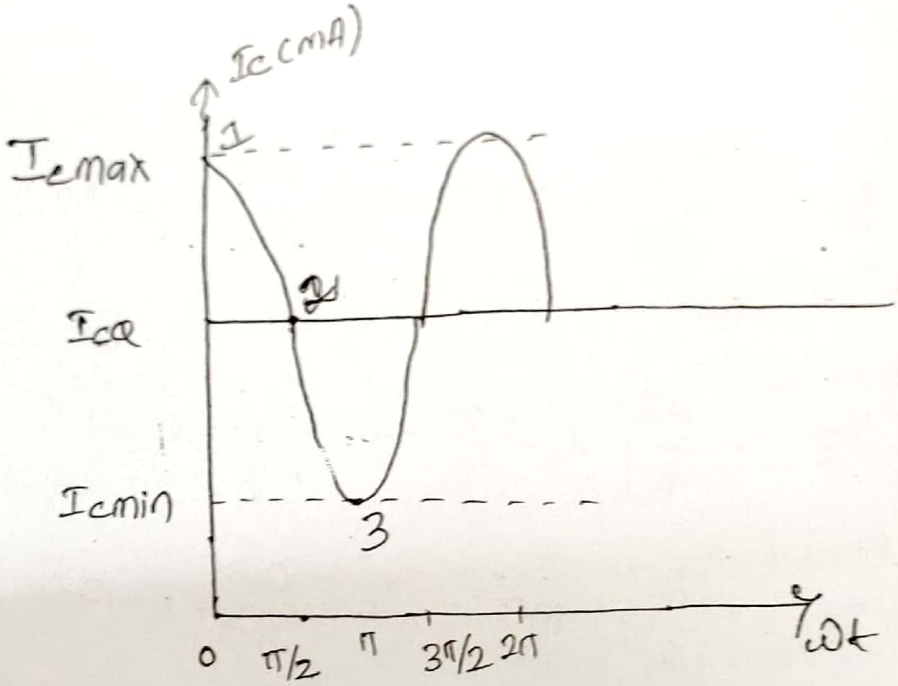
2) calculate THD for the above problem

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

$$= \sqrt{(0.1)^2 + (0.04)^2 + (0.02)^2} \times 100\%$$

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

Second Harmonic Distortion



* Above figure is used to obtain second harmonic distortion. A collector current waveform is shown with the quiescent, minimum and maximum signal levels.

An equation that approximately describes the distorted signal waveform is

$$i_c \simeq I_{CQ} + I_0 + I_1 \cos \omega t + I_2 \cos 2\omega t \ldots$$

where

I_{CQ} - original quiescent current

I_0 - additional dc current

I_1 - fundamental component of the distorted ac signal

I_2 - second harmonic component at twice the fundamental freq

At Point 1; $\omega t = 0$, $i_c = I_{cmax}$

$\therefore$ ① $\Rightarrow$ $I_{cmax} = I_{CQ} + I_0 + I_1 \cos 0 + I_2 \cos 0$

$I_{cmax} = I_{CQ} + I_0 + I_1 + I_2$ .... ②

At point 2: $\omega t = \pi/2$, $i_c = I_{CQ}$

① $\Rightarrow$ $I_{CQ} = I_{CQ} + I_0 + I_1 \cos \pi/2 + I_2 \cos \pi$

$I_{CQ} = I_{CQ} + I_0 - I_2$ .... ③

At Point 3: $\omega t = \pi$, $i_c = I_{cmin}$

① $\Rightarrow$ $I_{cmin} = I_{CQ} + I_0 + I_1 \cos \pi + I_2 \cos 2\pi$

$I_{cmin} = I_{CQ} + I_0 - I_1 + I_2$ .... ④

To Find I_1 and I_2

③ $\Rightarrow$ $\cancel{I_{CQ}} = \cancel{I_{CQ}} + I_0 - I_2$

$\therefore$ $I_0 = I_2$ ..... ⑤

Sub ⑤ in ② $\Rightarrow$ $I_{cmax} = I_{CQ} + \cancel{I_1} + 2I_2$ ... ⑥

Sub ⑤ in ④ $\Rightarrow$ $I_{cmin} = I_{CQ} - \cancel{I_1} + 2I_2$ ... ⑦

⑥ + ⑦ $\Rightarrow$ $I_{cmax} + I_{cmin} = 2I_{CQ} + 4I_2$

$$\therefore \quad I_0 = I_2 = \frac{I_{cmax} + I_{cmin} - 2I_{CQ}}{4} \quad \ldots (8)$$

$$⑥ - ⑦ \Rightarrow \quad I_1 = \frac{I_{cmax} + I_{cmin}}{2} \quad \ldots (9)$$

$$\text{W.K.T} \Rightarrow \quad D_2 = \frac{|I_2|}{|I_1|} \times 100\%$$

$$D_2 = \left| \frac{\dfrac{I_{cmax} + I_{cmin} - 2I_{CQ}}{4}}{\dfrac{I_{cmax} + I_{cmin}}{2}} \right| \times 100\%$$

In a similar manner the second harmonic distortion can be expressed in terms of collector-emitter voltages:

$$D_2 = \left| \frac{\dfrac{V_{CEmax} + V_{CEmin} - 2V_{CEQ}}{4}}{\dfrac{V_{CEmax} + V_{CEmin}}{2}} \right| \times 100\%$$

PROBLEMS

An output waveform displayed on CRO provides the following measurements:

ⓐ $V_{CE\,min} = 1V$ $\quad V_{CE\,max} = 22V$, $\quad V_{CEQ} = 12V$

ⓑ $V_{CE\,min} = 4V$ $\quad V_{CE\,max} = 20V$ $\quad V_{CEQ} = 12V$

Solution

ⓐ

$$D_2 = \left| \frac{\frac{(1+22)-24}{4}}{\frac{1+22}{2}} \right| \times 100\%$$

$$= \left| \frac{-1/4}{23/2} \right| \times 100\%$$

$$\boxed{D_2 = 2.17\%}$$

ⓑ

$$D_2 = \left| \frac{\frac{(4+20)-24}{4}}{\frac{4+20}{2}} \right| \times 100\%$$

$$= \left| \frac{0}{12} \right| \times 100\%$$

$$\boxed{D_2 = 0\%}$$ (No Distortion)

Power of Signal Having Distortion

When distortion is Present, the out Power delivered to the load resistor R_C due to the fundamental component of the distorted signal is

$$P_1 = \frac{I_1^2 R_C}{2}$$

(fun. current $= I_1$ ∴ RMS $= (I_1/$

The total Power due to all the harmonic components of the distorted Sign is,

$$P = \left(I_1^2 + I_2^2 + I_3^2 + \cdots \right) \frac{R_C}{2}$$

$$P = I_1^2 \left(1 + \frac{I_2^2}{I_1^2} + \frac{I_3^2}{I_1^2} + \cdots \right) \frac{R_C}{2}$$

$$P = I_1^2 \left(1 + D_2^2 + D_3^2 + \cdots \right) \frac{R_C}{2}$$

$$= (1 + THD^2) \frac{I_1^2 R_C}{2}$$

$\left(\because THD = \sqrt{D_2^2 + D_3^2 \cdots} \right.$

$$\left\{ P = (1 + THD^2) P_1 \right\}$$

$\left(\because \frac{I_1^2 R_C}{2} = P_1 \right)$

PROBLEMS

① For harmonic distortion reading of $D_2 = 0.1$ $D_3 = 0.02$ $D_4 = 0.01$ with $I_1 = 4A$ and $R_C = 8\Omega$. calculate the total harmonic distortion, fundamental power component and total power.

Solution

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

$$= \sqrt{0.1^2 + 0.02^2 + 0.01^2} \times 100\%$$

$$\boxed{\%THD = 10.2\%}$$

To Find P_1

$$\text{Fundamental Power component} = \frac{I_1^2 R_C}{2}$$

$$= \frac{4^2 \times 8^4}{\cancel{2}}$$

$$\boxed{P_1 = 64W}$$

To Find Total Power

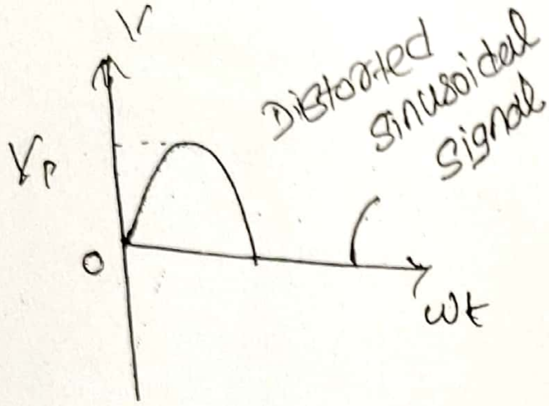
$$P = (1 + THD^2) P_1$$

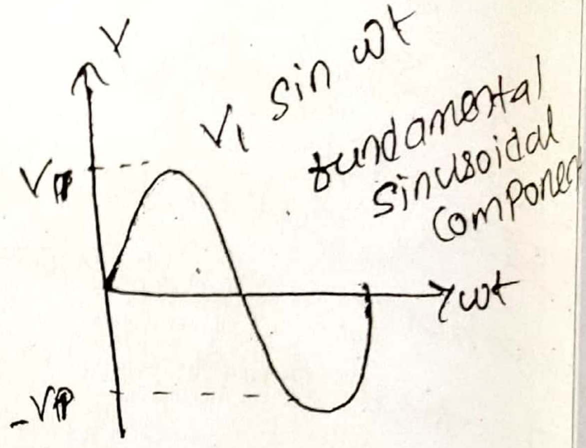
$$= (1 + 0.1^2) 64W$$

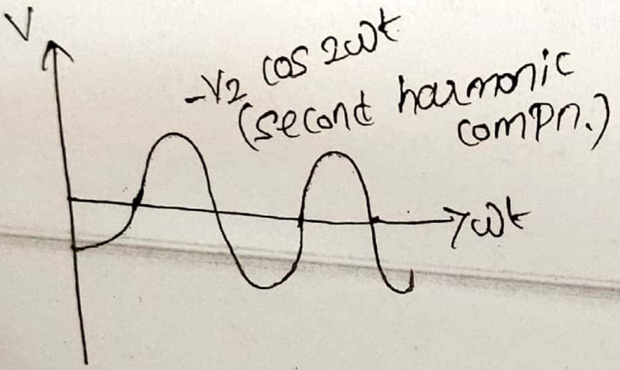
$$\boxed{P = 64.64W}$$

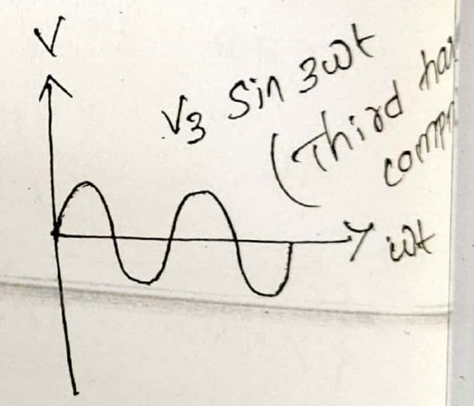
SRM

aphical Description of Harmonic Components of Distorted signal

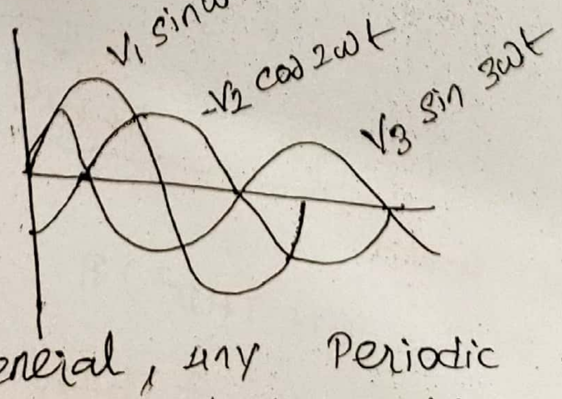








Using Fourier technique, the distorted waveform can be made by adding the fundamental and harmonic components as shown be



Note: In general, any Periodic distorted wavefo can be represented by adding a fundamental and all harmonic components, each component of varying Amplitude and at various phase an