

Unit → 6

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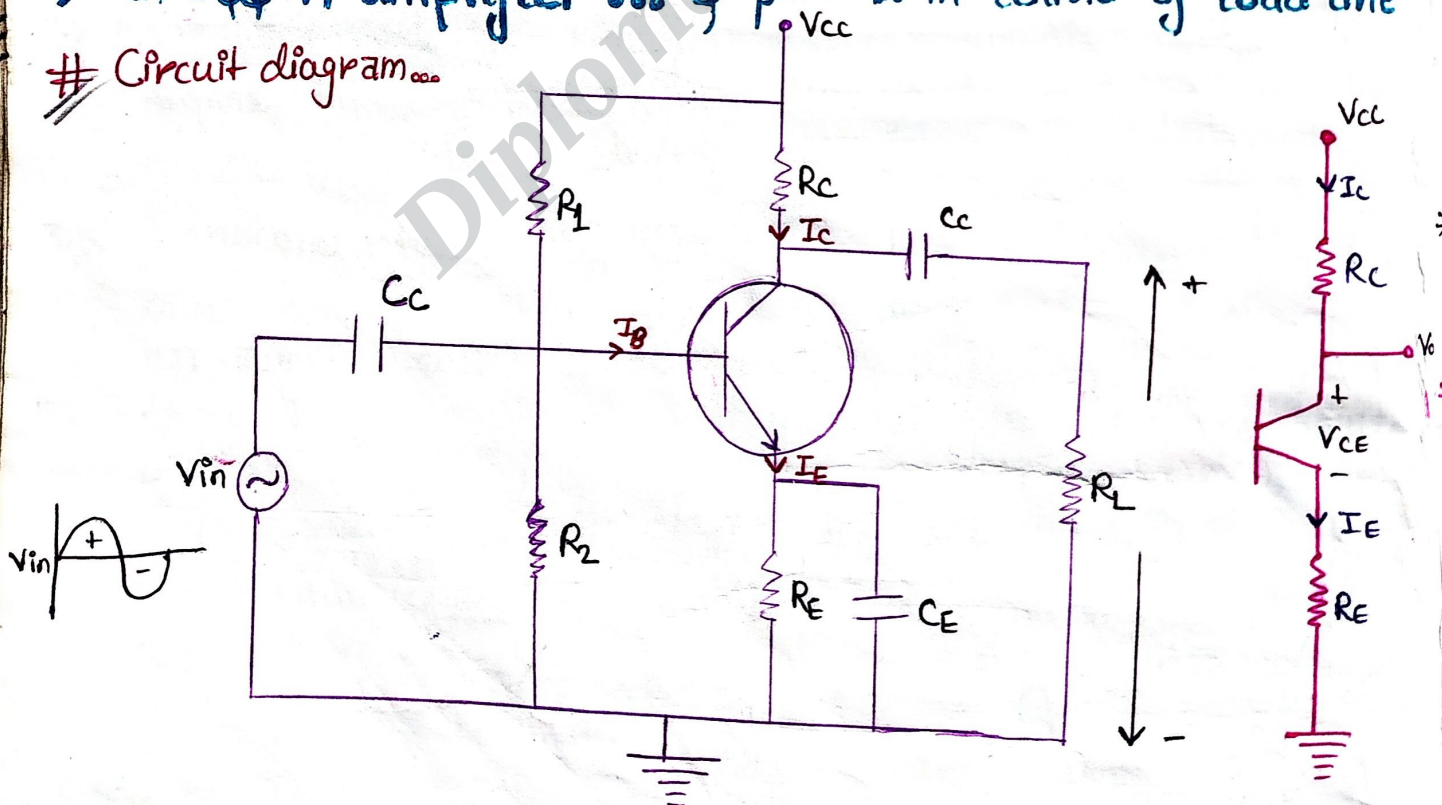
Working of Class A, B, AB, C

Topics

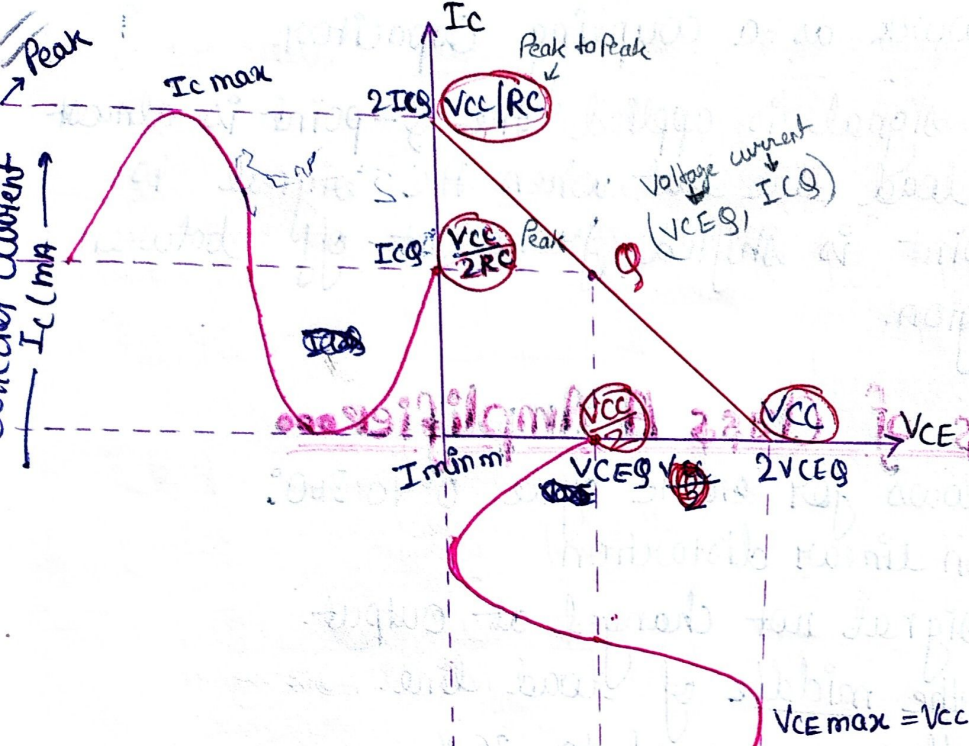
1. Working of class A - Series-fed amplifier and transformer-coupled amplifier. Expression for output power and maximum power efficiency.
2. Class B - Push pull Amplifier and Complementary - Symmetry push-pull amplifier. Expression for output power and maximum power efficiency.
3. Working of Class AB and Class C amplifiers. Stages of practical power amplifier, concept and expression for voltage gain of multistage amplifiers.

1) Class A amplifier ... Q point is in centre of load line

Circuit diagram...



Phase shift b/w i/p and o/p is 180°



$$V_{CC} = I_C R_C + V_{CE} \quad 85$$

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

$$V_{CE \text{ max}} = V_{CC} / I_C = 0$$

$$I_{C \text{ max}} = \frac{V_{CC}}{R_C} / V_{CE} = 0$$

BJT Amplifier in Active Region:- Collector to emitter voltage (V_{CE})

For positive (+) wave form

$I_B = \text{increase}$

$I_C = \beta I_B$

$I_C = \text{increase}$

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

$$\downarrow V_{CE} = V_{CC} - I_C \uparrow R_C$$

For Negative (-) wave form

$I_B = \text{decrease}$

$I_C = \beta I_B$

$I_C = \text{decrease}$

$$\uparrow V_{CE} = V_{CC} - I_C \downarrow R_C$$

* Note :- If $V_{in} = 0$ volt then due to DC biasing collector current I_{CQ} , $V_{CE} = V_{CEQ}$ power dissipation = $I_{CQ} \times V_{CEQ}$.

Working of Class A Amplifier...

The circuit diagram of class A amplifier is shown in fig in which these resistance R_1 , R_2 and R_E work as a biasing resistance and provide stability to the transistor in which R_1 & R_2 work as a voltage divider and R_E work as a feedback resistance.

The capacitor C_1 n/o input capacitor provide input to the transistor. The capacitor C_E work as a bypass capacitor which is used to increase the voltage of the transistor.

The capacitor C_2 work as a coupling Capacitor. 90

When no any signal is applied the Q-point is almost at mid point of load line but when AC signal is applied the Q-point is shifted from cut-off between two structure region.

Characteristics of Class A Amplifier...

1. Output current flows for entire cycle 0° to 360° .
2. Does not have non linear distortion. Q point (Active region)
3. Nature of input signal not changed at output.
4. Q point lies in the middle of load line. Active region
5. Low conversion efficiency equal to 25%.
6. Power dissipation high when input is not applied.
7. Provide undistorted output (because of linear region).
8. Conduction angle 360° .

**# Efficiency of Class A amplifier...

A measure of the ability of an active device to convert the dc power of supply into the AC signal power delivered to the load is called power or conversion or theoretical efficiency.

$$\eta = \frac{\text{AC Power delivered to the load (Pout (ac))}}{\text{Total power from dc supply (Pin (dc))}}$$

$$\text{input power (Dc)} = V_{CEQ} \times I_{CQ}$$

$$P_{in} (dc) = V_{CCQ} \times I_{CQ}$$

Voltage at Q point

$$I_{CQ} = \frac{V_{CC}}{2R_C}$$

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

$P_{in} = \text{Power in/p}$

$$\begin{cases} P_{in} = V_{CCQ} \times I_{CQ} \\ P_{in} = V_{CC} \times \frac{V_{CC}}{2R_C} \end{cases}$$

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

$$I_C (\text{Peak to Peak}) = \frac{V_{CC}}{R_C}$$

$$I_C (\text{Peak}) = \frac{V_{CC}}{2R_C}$$

$$I_{C \text{ rms}} = \frac{V_{CC}}{2R_C \times \sqrt{2}} = \frac{V_{CC}}{2\sqrt{2} R_C} = I_{C \text{ rms}}$$

9. $I_C = 0 \begin{cases} V_{CE} = V_{CC} \\ \text{max.} \end{cases}$
 $V_{CE} = 0 \begin{cases} I_C = \frac{V_{CC}}{R_C} \\ \text{max.} \end{cases}$

$$V_{CC} \text{ (Peak to peak)} = V_{CE}$$

$$V_{CC} \text{ (Peak)} = \frac{V_{CC}}{2}$$

$$V_{CC \text{ rms}} = \frac{V_{CC}}{2\sqrt{2}}$$

Output Power

$$P_{(AC)} = V_{CE \text{ rms}} \times I_{C \text{ rms}}$$

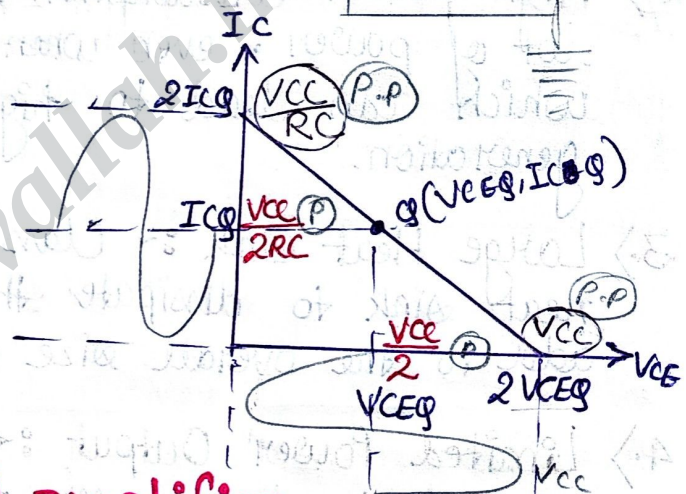
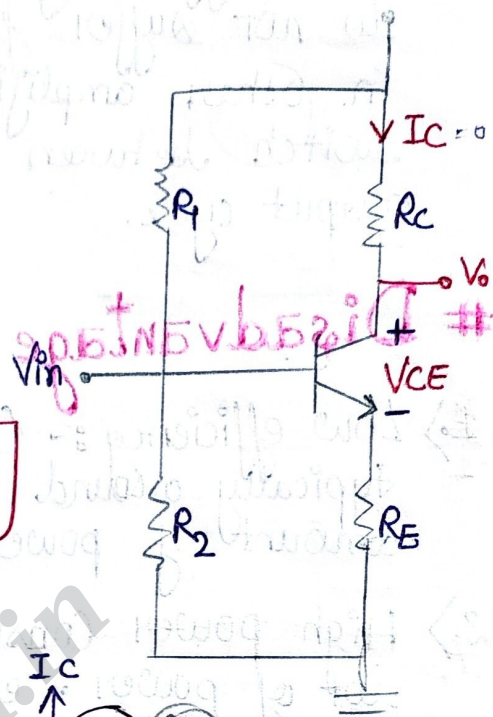
$$= \frac{V_{CC}}{2\sqrt{2}} \times \frac{V_{CC}}{2\sqrt{2} R_C} = \frac{V_{CC}^2}{8R_C} = P_{out}$$

$$\eta = \frac{\text{O/P Power}}{\text{I/P Power}}$$

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

$$\eta = \frac{1}{4} = 0.25$$

$$\eta = 25\% \leftarrow \frac{1}{4} \times 100$$



* Advantages of Class A amplifier...

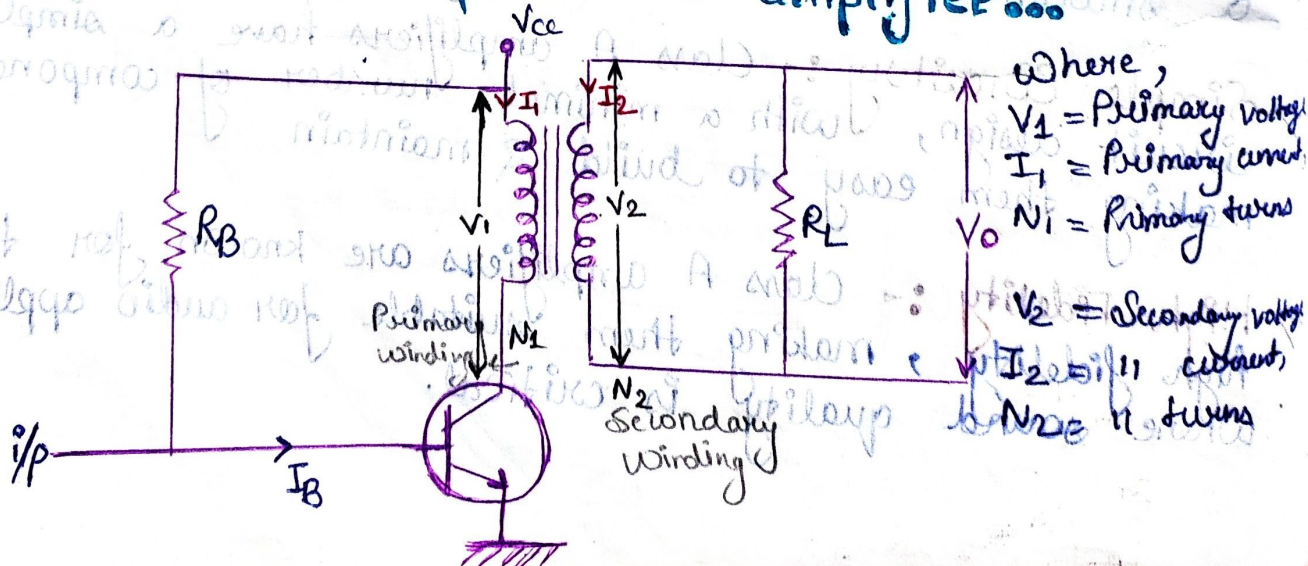
- 1) Low distortion :- Class A amplifiers have low distortion, as the output devices are always conducting, resulting in a smooth and linear output signal.
- 2) Simple Circuitry :- Class A amplifiers have a simple circuit design, with a minimal number of components making them easy to build & maintain.
- 3) High Fidelity :- Class A amplifiers are known for their high fidelity, making them suitable for audio applications where sound quality is critical.

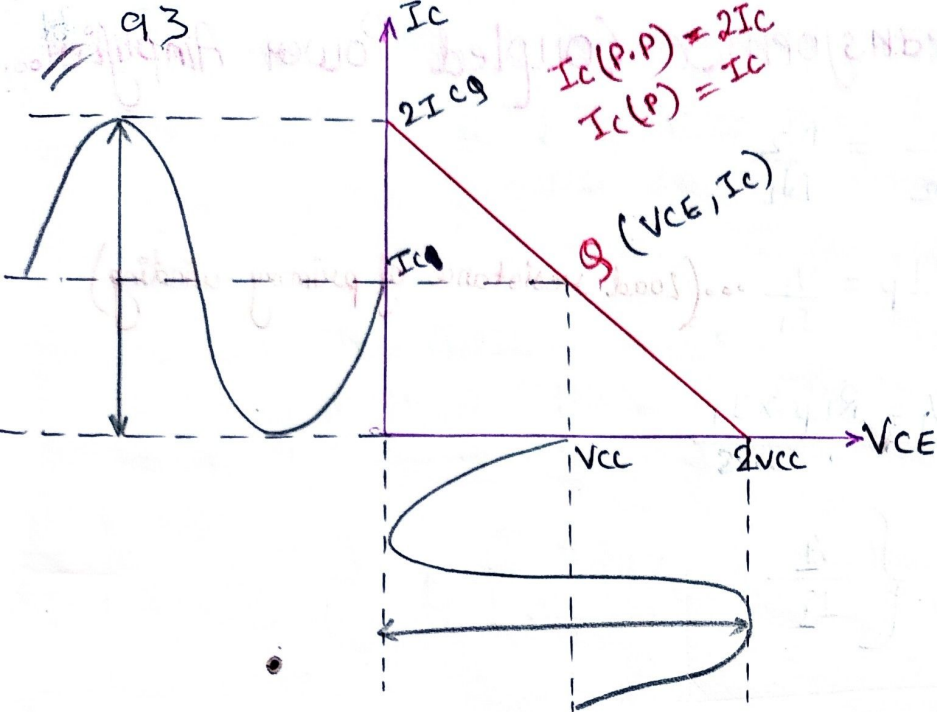
4.) No crossover distortion :- Class A amplifiers have a low efficiency, typically around 25-30%. It has do not suffer from crossover distortion which can occur in other amplifier classes when the output devices switch between positive and negative waves of the output cycle.

Disadvantage of Class A amplifier...

- 1.) Low efficiency :- Class A amplifier have a low efficiency, typically around 25-30% which means that a significant amount of power is wasted as heat.
- 2.) High power Consumption :- Class A amplifier consume a lot of power, even when there is no input signal, which can lead to high electricity bills and heat generation.
- 3.) Large Heat Sink :- Class A amplifier require a large heat sink to dissipate the heat generated, which can add to the overall size and weight of the amplifier.
- 4.) Limited Power Output :- Class A amplifier are typically limited to low power output levels, making them less suitable for high power applications.

**>> Transformer Coupled ^{Class A} Power amplifier...

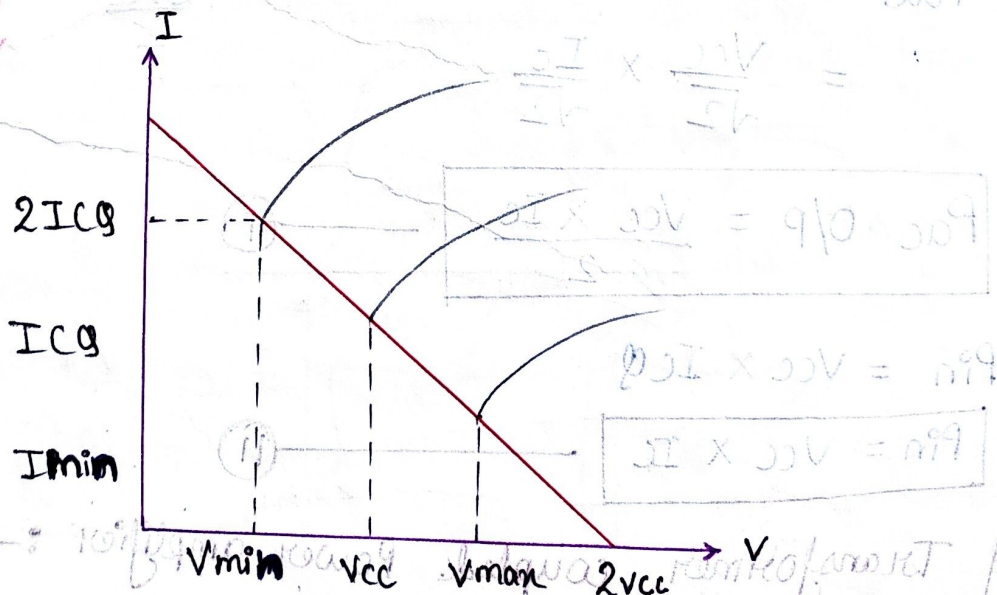




Working of Transformer Coupled Power Amplifier.

The circuit diagram of transformer coupled class A amplifier is shown in the figure in which the resistance R_1 , R_2 and R_E work as a biasing resistance in which R_1 and R_2 work as a feedback resistance.

The Capacitor C_1 and C_2 work as a input capacitor and bypass capacitor. A setup transformer is attached to the transistor whose primary coil is attach to the collector of the transistor and secondary coil is attach with load resistance across which output will be obtained.



Efficiency of Transformer Coupled Power Amplifier

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \quad \text{or} \quad \frac{I_1}{I_2} = \frac{N_2}{N_1}$$

$$\frac{V_2}{I_2} = R_L, \quad R_{LP} = \frac{V_1}{I_1} \dots (\text{load resistance of primary winding})$$

$$V_2 = R_L \times I_2, \quad V_1 = R_{LP} \times I_1$$

$$\frac{V_1}{I_1} \Rightarrow \frac{V_2 \times \frac{N_1}{N_2}}{I_2 \times \frac{N_2}{N_1}} = R_{LP} \dots \left\{ \frac{V_1}{I_1} \right.$$

$$R_{LP} = \frac{V_2}{I_2} \times \left(\frac{N_1}{N_2} \right)^2$$

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

$$\rightarrow I_C (\text{Peak to Peak}) = 2I_{CQ}$$

$$I_C (\text{Peak}) = I_{CQ}$$

$$I_{C(rms)} = \frac{I_{CQ}}{\sqrt{2}}$$

$$V_{C(rms)} = \frac{V_{CC}}{\sqrt{2}}$$

$$P_{out} = V_{C(rms)} \times I_{C(rms)}$$

$$= \frac{V_{CC}}{\sqrt{2}} \times \frac{I_{CQ}}{\sqrt{2}}$$

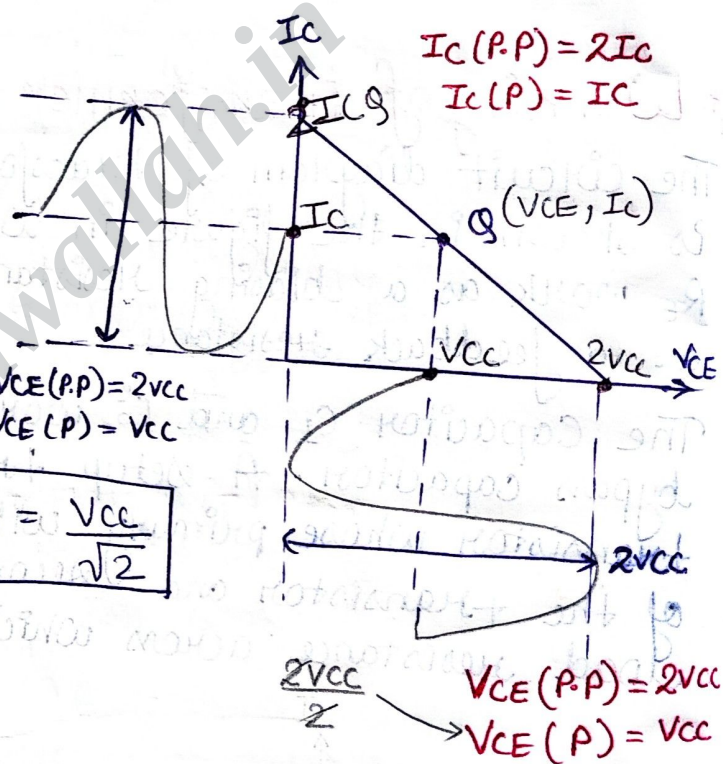
$$P_{ac \text{ O/p}} = \frac{V_{CC} \times I_{CQ}}{2} \quad \text{--- (1)}$$

$$P_{in} = V_{CC} \times I_{CQ}$$

$$P_{in} = V_{CC} \times I_{CQ} \quad \text{--- (2)}$$

→ η of Transformer coupled Power amplifier :-

$$\eta = \frac{P_{out} (AC)}{P_{in} (DC)}$$



$$\eta = \frac{V_{CC} \times I_{C}}{2}$$

$$\eta = \frac{V_{CC} \times I_{C}}{V_{CC} \times I_{C}}$$

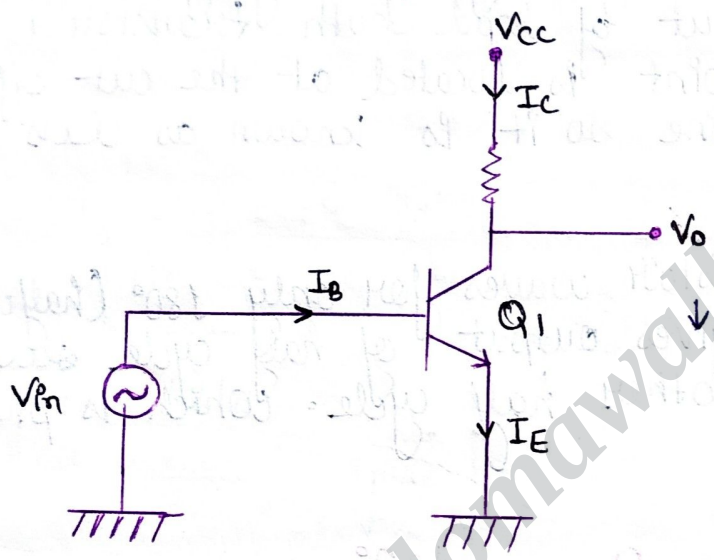
$$\eta = \frac{1}{2}$$

$$\eta = 0.5$$

$$\eta = 50\%$$

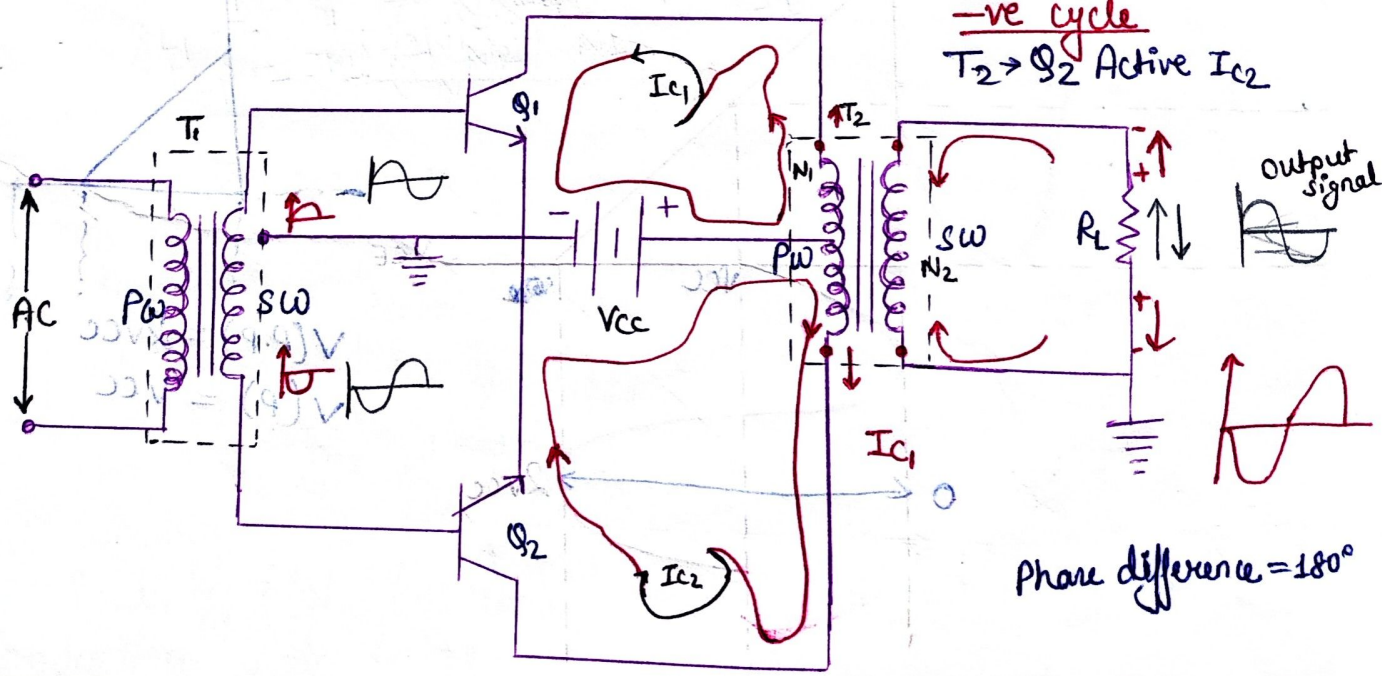
Note: - DC Power dissipation $\downarrow$
 efficiency $\uparrow$
 10 watt $\rightarrow$ 5 watt o/p
 i/p 5w $\rightarrow$ 0 (less)

* 2. > Class B Amplifier...



$V_o = V_{CC} - I_C \uparrow R_C$
 I_i I_{in}
 V_{BE} V_{BE}
 F.B R.B
 I I₂
 R.B R.B

* # Class B Pushpull amplifier...

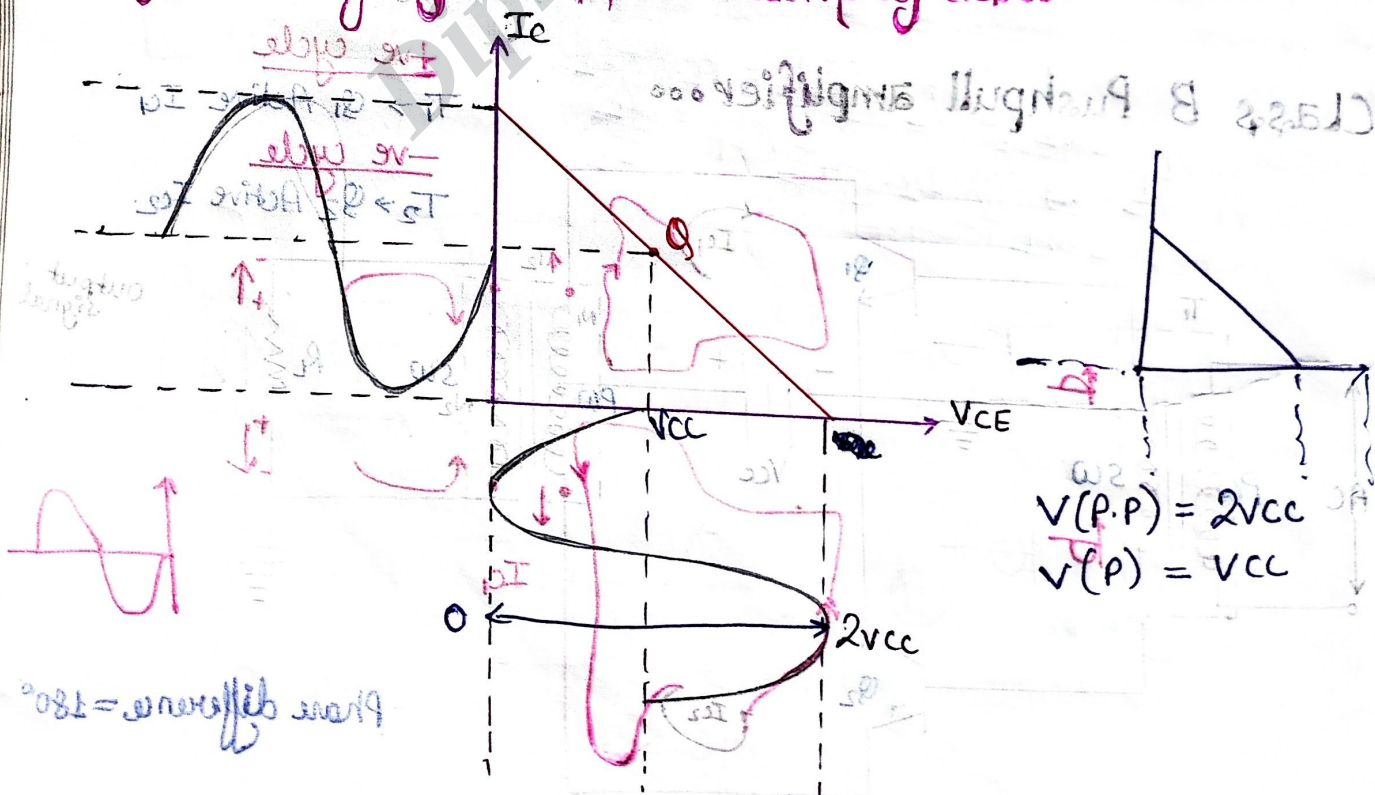


+ve cycle
 T₁ $\rightarrow$ Q₁ Active I_{C1}
-ve cycle
 T₂ $\rightarrow$ Q₂ Active I_{C2}

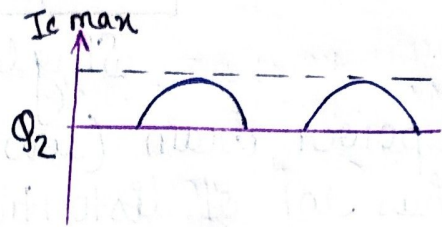
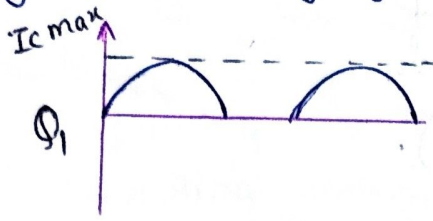
*Working...

- During positive half cycle transistor T_1 will be forward biased and transistor T_2 will be in cut-off state. Only current I_{C1} will flow in output circuit.
- During negative half cycle transistor T_2 will be forward biased and transistor T_1 will remain in cut off state. Only I_{C2} current will flow in output circuit.
- During positive half cycle transistor Q_1 push the current into the load and during negative half cycle transistor Q_2 pull the current out of load both transistor are biased such that Q point is located at the cut off point on the load line so it is known as Class B Push Pull amplifier.
- In class B each transistor waves for only 180° (half cycle). Thus if 1 transistor gives output of half cycle second will give output of another half cycle which is phase shifted the 180° .

* # Efficiency of Class B amplifier...



97 During Positive (+) half cycle Q_1 works
 During negative (-) half cycle Q_2 works



$$I_{DC} \quad Q_1 = \frac{I_{C \max}}{\pi}$$

$$I_{DC} \quad Q_2 = \frac{I_{C \max}}{\pi}$$

$$I_{DC} (Q_1 \& Q_2) = \frac{2 I_{C \max}}{\pi}$$

$$V_{DC} = V_{CC}$$

$$P_{in} (DC) = V_{DC} \times I_{DC}$$

$$P_{in} = V_{CC} \times \frac{2 I_{C \max}}{\pi}$$

$$P_{o/p} = V_{rms} \times I_{rms}$$

$$P_{out} = \frac{V_{CC}}{\sqrt{2}} \times \frac{I_{max}}{\sqrt{2}}$$

$$n = \frac{P_{o/p}}{P_{in}}$$

$$= \frac{\frac{V_{CC}}{\sqrt{2}} \times \frac{I_{C \max}}{\sqrt{2}}}{V_{CC} \times \frac{2 I_{C \max}}{\pi}}$$

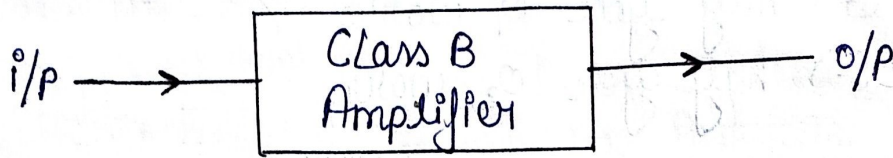
$$n = \frac{\pi}{4} \times 100$$

$$n\% = \pi \times 25$$

$$n = 78.5\%$$

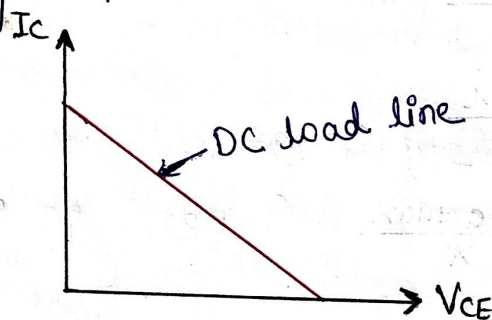
* # Class B Power Amplifier

- Q point is in cut-off region.
- No biasing is used.
- n is very high (78.5%).
- Conduction angle is 180° .

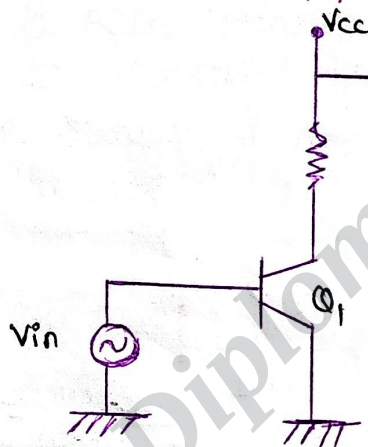


Single Ended

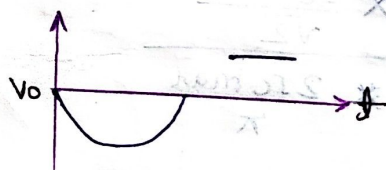
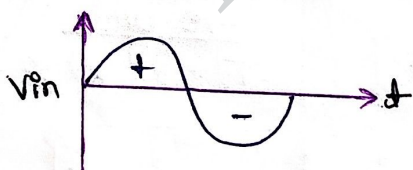
- No power drain (low P_{diss}).
- It has lot of distortion.
- Information of output.



Single Ended Class B amplifier...



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



→ Case : 1

Positive Cycle

$Q_1 \rightarrow J_E J_C$ Active

$F_B R_B$.

Negative cycle

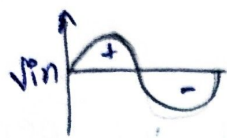
$Q_1 = J_E J_C$

$R_B R_B$ Cut-off

Push - Pull Class B amplifier...

9.9

- 2 transistors NPN used (1NPN & 1PNP).
- Push Pull Mode.

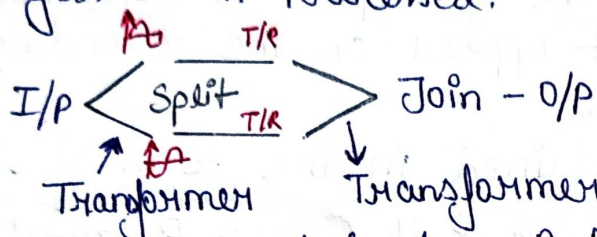


During +ve cycle Q_1 , ON.

During -ve cycle Q_2 , ON.

- Complete information processed.

- Working

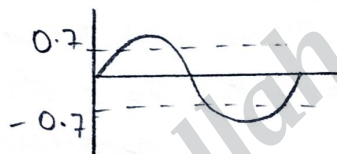


- We use transformer coupled class B Push - Pull amplifier.
- Crossover distortion (COD):

$$V_{BE} = 0.7$$

$$Q_1 =$$

$$Q_2 = \text{off}$$



Working Push - Pull Class B amplifier...

The Push-Pull amplifier is a power amplifier which are used in a electronic circuit when high amplification is required at high frequency.

The circuit diagram of Push-pull amplifier is shown in the figure which contain two transformer. driver transformer and output transformer and two transistors which are seperately work as a class B amplifier.

Working...

- When an AC signal is applied on the primary coil of driver transformer due to mutual inducton it appear on the secondary coil of the transformer.
- For +ve half of the input signal the transistor T_1 become forward biased and transistor T_2 become reverse biased therefore T_1 is in active condition and T_2 is cut-off.

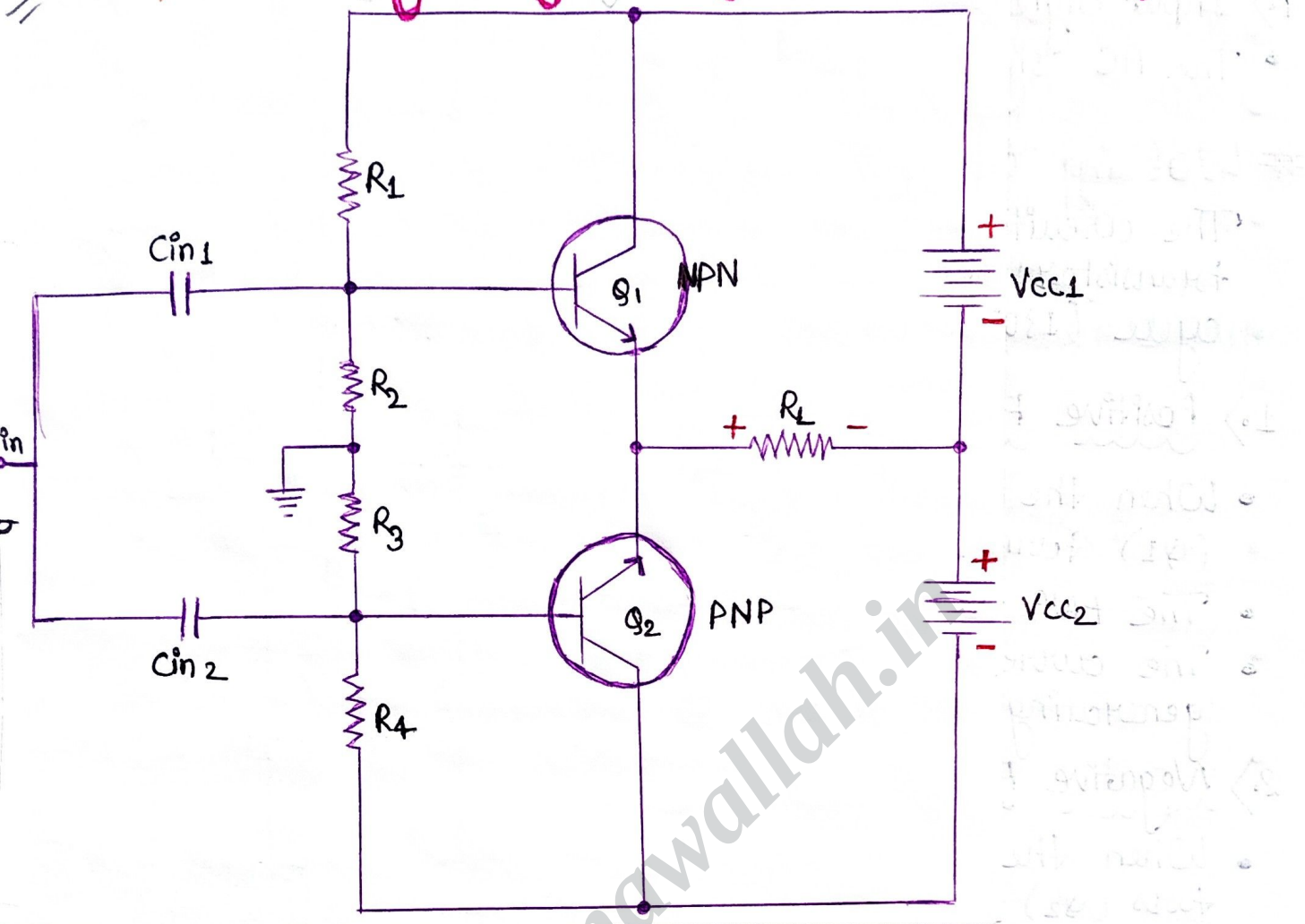
- Hence output is obtained due to T_1 but of negative half cycle transistor T_2 become forward biased and T_1 become reverse biased. therefore T_2 is in active condition and T_1 is cut-off. Hence output is obtained due to T_2 .

- Since, the output terminal of both transistor are connected with the primary coil of output transformer, due to mutual induction it appears on the secondary coil of output transformer. Hence output is obtained in the form of sine wave.

Advantage of Push-Pull Class B amplifier...

Complementary - Symmetry push-pull amplifier...

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Working...

A complementary symmetry push-pull amplifier is a class B amplifier that uses two complementary transistors - one NPN and one PNP - to amplify both halves of an AC signal. It is widely used in audio power amplification due to its high efficiency and reduced power dissipation.

Circuit Diagram Components...

1. Two Complementary transistors :
 - NPN transistor (Q1) conducts during the positive half cycle.
 - PNP transistor (Q2) conducts during the negative half cycle.
2. Power Supply :
 - A dual power supply (+Vcc and -Vcc) is used.
3. Load Resistor : R_L

• Connected at the center between both transistors. 102

4.) Input Signal (V_{in}):

- The AC signal to be amplified.

Working Principle...

The circuit operates in class B mode, meaning each transistor conducts for only half of the input cycle (180° conduction).

1.) Positive Half cycle:

- When the input signal V_{in} is positive, the NPN transistor (Q_1) turns ON.
- The PNP transistor (Q_2) remains OFF.
- The current flows from $+V_{CC}$ through Q_1 and R_L , generating a positive output voltage.

2.) Negative Half cycle:

- When the input signal V_{in} is negative, the PNP transistor (Q_2) turns ON.
- The NPN transistor (Q_1) remains OFF.
- The current flows from $-V_{CC}$ through Q_2 and R_L in the opposite direction, generating a negative output voltage.

Advantages...

1.) High Efficiency :- (78.5%) Since each transistor is active for only half of the cycle, power loss is minimized.

2.) NO DC Component in Output :- The output signal is purely AC, avoiding DC biasing issues.

3.) Lower power Dissipation :- Unlike Class A amplifiers, it does not continuously consume power.

4.) Push-pull Operation Cancels even Harmonics, reducing distortion.

- Connected at the center between both transistors.

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4.) Input Signal (V_{in}):

- The AC signal to be amplified.

Working Principle...

The circuit operates in Class B mode, meaning each transistor or conducts for only half of the input cycle (180° conduction).

1.) Positive Half cycle:

- When the input signal V_{in} is positive, the NPN transistor (Q_1) turns ON.
- The PNP transistor (Q_2) remains OFF.
- The current flows from $+V_{CC}$ through Q_1 and R_L , generating a positive output voltage.

2.) Negative Half cycle:

- When the input signal V_{in} is negative, the PNP transistor (Q_2) turns ON.
- The NPN transistor (Q_1) remains OFF.
- The current flows from $-V_{CC}$ through Q_2 and R_L , in the opposite direction, generating a negative output voltage.

Advantages...

- 1.) High Efficiency :- (78.5%) since each transistor is active for only half of the cycle, power loss is minimized.
- 2.) No DC Component in Output :- The output signal is purely AC, avoiding DC biasing issues.
- 3.) Lower power Dissipation :- Unlike Class A amplifiers, it does not continuously consume power.
- 4.) Push-pull Operation Cancels even Harmonics, reducing distortion.

Disadvantages...

- 1.) Crossover distortion : At very low input voltages, both transistors may be OFF, causing distortion. This can be minimized by using a small bias voltage (class AB operation).
- 2.) Required Dual power Supply : ($+V_{cc}$ and $-V_{cc}$)
- 3.) Complexity : More components compared to class A amplifiers

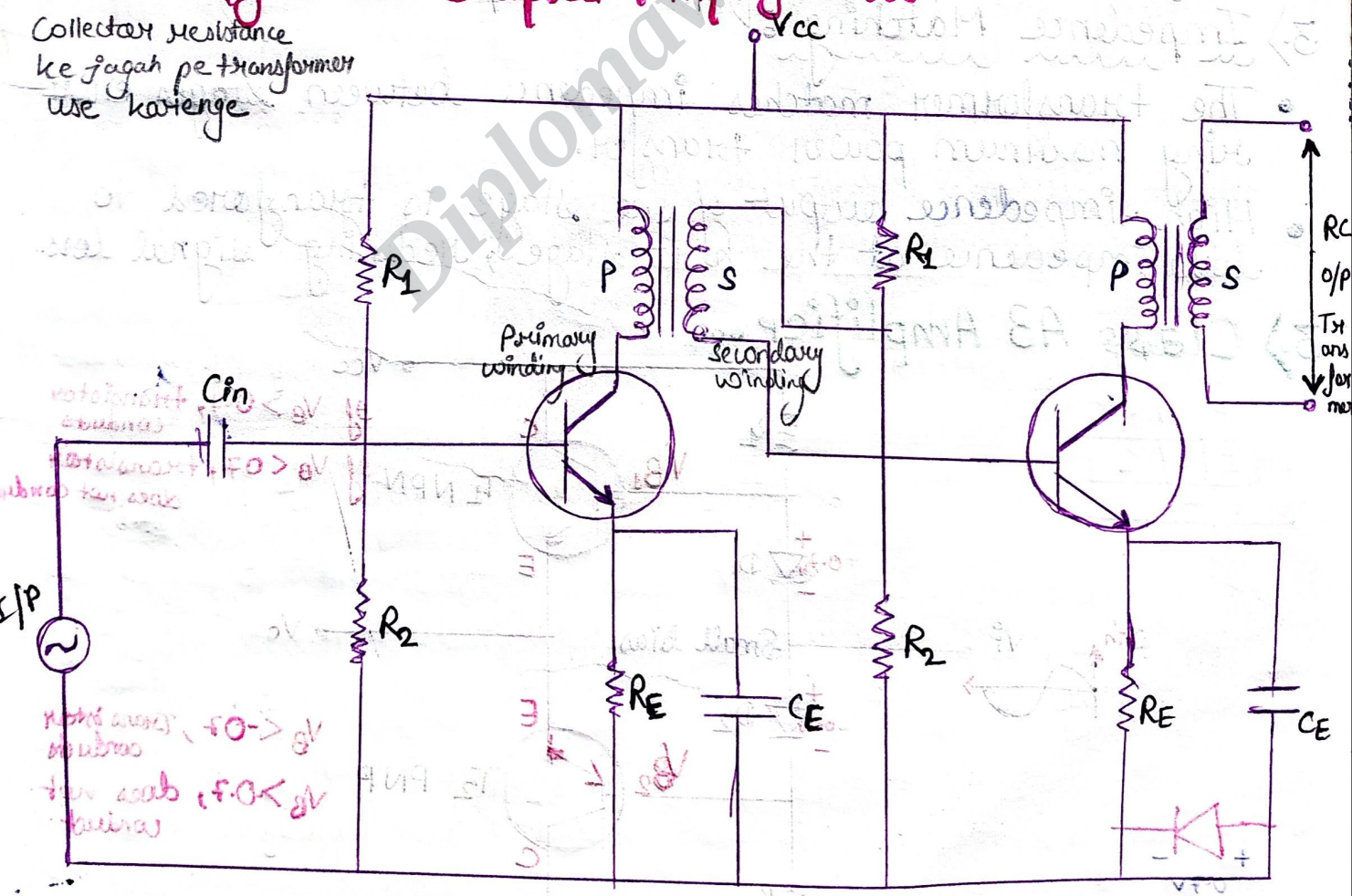
Application...

- 1.) Audio Power Amplifiers (used in speakers and home audio system).
- 2.) Radio Frequency (RF) Transmission
- 3.) Motor Drivers (In applications requiring bi directional control).

class A

Transformer Coupled Amplifier...

Collector resistance ke jagah pe transformer use karenge



Working of Transformer Coupled Amplifier...

1.) Amplification Process:

- The AC input signal is applied to the transistor's base.
- The transistor operates in active region, amplifying the signal.
- The amplified signal appears across the primary winding of transformer (T₁).

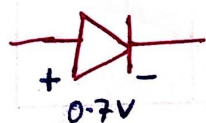
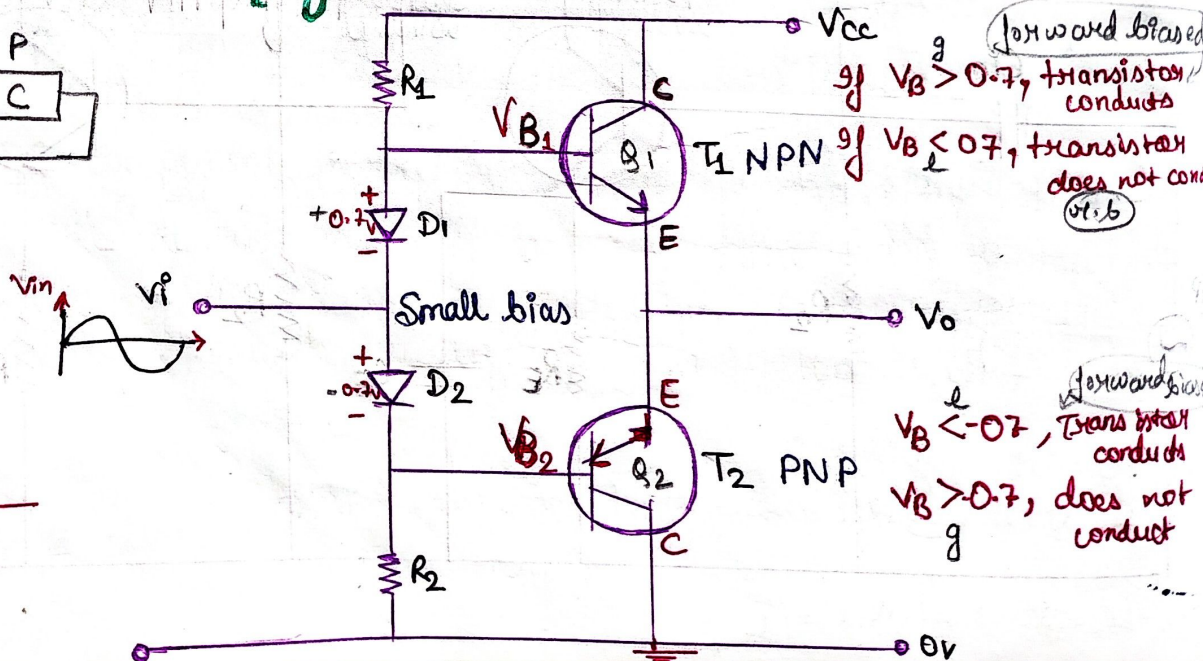
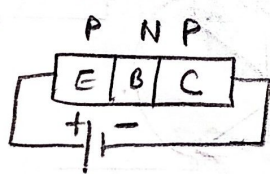
2.) Signal Coupling Via Transformer:

- The primary winding of the transformer acts as a collector load.
- Due to mutual induction, the amplified signal is transferred to the secondary winding.
- The secondary winding supplies the signal to the next stage or output load (R_L).

3.) Impedance Matching:

- The transformer matches impedance between stages ensuring maximum power transfer.
- High-impedance output of one stage is transferred to low impedance at the next stage, reducing signal loss.

3.) Class AB Amplifier...



A class AB amplifier is a type of amplifier that combines the characteristics of both class A and class B amplifiers to achieve a balance between efficiency and linearity.

Working Principle...

1.) Biasing and conduction Angle:

- The amplifier is biased so that transistors (NPN and PNP) conduct slightly even when there is no input signal.
- This eliminates the crossover distortion found in class B amplifiers.
- The conduction angle is slightly more than 180° but less than 360° .

2.) Input Stage:

- The input signal is applied to a push-pull configuration, typically using complementary transistors.
- This ensures that one transistor handles the positive half cycle while other handles the negative half cycle.

3.) Operation in Different signals level:

- For small signals: It behaves like a class A amplifier, with both transistors slightly conducting.
- For large signals: It works like a class B amplifier, where only one transistor is active at a time improving efficiency.

4.) Output Stages:

- The two transistors work together to amplify the signal with reduced distortion and better efficiency than class A.
- The output waveform is nearly identical to the input but amplified in voltage and current.

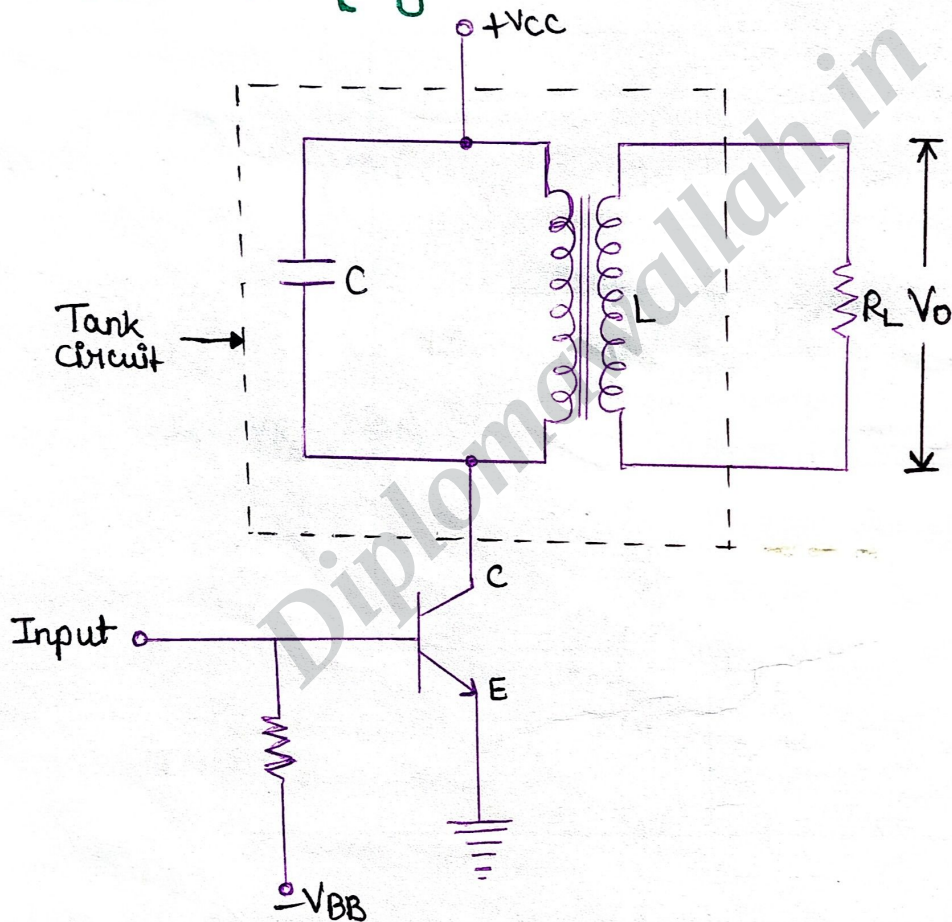
Advantage...

- Reduced crossover distortion (compared to Class B)
- Higher efficiency than Class A (typically 50-70%).
- Suitable for audio amplification application.

Disadvantage...

- More complex biasing.
- Slightly lower efficiency than Class B.

Class C Amplifier...



A Class C amplifier is a type of power amplifier known for its high efficiency but with significant distortion, making it suitable mainly for RF (radio frequency) and high-frequency applications like transmitters.

Working Principle...

- 1.) Biasing :- The transistor is biased well below the cut-off region, meaning it stays off until the input signal reaches a certain threshold.
- 2.) Operation :- The transistor turns on for only a small portion of the input cycle, creating a train of pulses instead of a continuous waveform.
- 3.) Tuned Circuit :- Since the output waveform is highly distorted, a resonant LC circuit. (Inductor-Capacitor circuit) is used at the output to filter and reconstruct a sinusoidal waveform.

Advantage...

- Less physical size
- Used in RF applications.
- High efficiency ($> 95\%$)
- Low power loss in power transistors oil-on-10.

Disadvantage...

- RF interference occurs.
- Ideal inductor should be selected.
- Not suitable for audio application.

Application...

- Tuned amplifiers
- RF amplifiers
- Oscillators
- Booster amplifiers
- High frequency repeaters.

Expression for voltage gain of multistage amplifier...

The voltage gain of a multistage amplifier is the product of the voltage gains of each individual stage.

★ Expression :-

The voltage gain of multistage amplifier can be expressed,

$$A_V = A_{V1} \times A_{V2} \times A_{V3} \times \dots \times A_{Vn}$$

Where

- A_V is the overall voltage gain of the multistage amplifier.
- $A_{V1}, A_{V2}, A_{V3}, \dots, A_{Vn}$ are the voltage gains of each individual stage.

★ Concept :

The concept behind this expression is that each stage of the amplifier amplifies the input signal by a certain amount, and the overall gain of the amplifier is the product of these individual gains.

For example, if we have a two-stage amplifier with a voltage gain of 10 in the first stage and a voltage gain of 5 in the second stage, the overall voltage gain of the amplifier would be

$$\begin{aligned} A_V &= A_{V1} \times A_{V2} \\ &= 10 \times 5 \\ &= 50 \end{aligned}$$

This means that the output voltage of the amplifier would be 50 times the input voltage.