

# GUJARAT TECHNOLOGICAL UNIVERSITY

BE-4 SEMESTER – OLD PAPER – S22 TO W25 – QUESTION BANK ANSWER

**Subject Name & Code:**

**ANALOG CIRCUIT DESIGN (3141002)**

**(Disclaimer:** The purpose of these AI-generated responses is just education and reference. Utilise them to grasp topics and structure, but always rewrite in your own words and double-check)

## Unit 6: Power Amplifiers

**Q.1 – Explain class B power amplifier.**

**(7 marks)**

**Ans:**

**Definition:** A class B power amplifier conducts for exactly  $180^\circ$  (half cycle) of the input signal. It uses two complementary transistors (nnp and pnp) in push-pull configuration to amplify both halves of the waveform.

**Circuit description (push-pull class B):**

- Two transistors: Q1 (nnp) for positive half cycle, Q2 (pnp) for negative half cycle.
- Input applied to both bases through a center-tapped transformer or directly via complementary pair.
- Outputs connected to load (speaker) through center-tapped transformer or direct coupling.

**Diagram prompt:**

[DG PROMPT]

Title: Class B push-pull power amplifier

Description: Draw input signal source connected to center-tapped transformer primary. Transformer secondary has two windings: one to base of nnp transistor (Q1) and other to base of pnp transistor (Q2) with opposite polarity. Emitters of both transistors connected together and to ground through load resistor (or speaker). Collectors connected to  $+V_{cc}$  (nnp) and  $-V_{cc}$  (pnp) respectively. Alternatively, draw complementary symmetry circuit: nnp base to input, pnp base to input, emitters together to load to ground, collectors to  $+V_{cc}$  and  $-V_{cc}$ .

**Working principle:**

- **Positive half cycle:** Base of nnp positive, Q1 turns on (conducts), Q2 off. Output current flows from  $+V_{cc}$  through Q1 to load.
- **Negative half cycle:** Base of pnp negative, Q2 turns on, Q1 off. Output current flows from load through Q2 to  $-V_{cc}$ .
- Each transistor conducts for  $180^\circ$ , output waveform is a full sine wave.

**Characteristics:**

- Conduction angle =  $180^\circ$
- Maximum theoretical efficiency = 78.5%
- Cross-over distortion occurs near zero crossing (due to 0.7V base-emitter threshold).
- Power dissipation is lower than class A.

**Advantages:**

- Higher efficiency (60-70% practical)
- Less heat generation
- Suitable for battery-operated devices

**Limitations:**

- Cross-over distortion (solved by class AB)
- Requires complementary transistors or center-tapped transformer

**Applications:**

- Audio power amplifiers (car stereos, home theaters)
- RF power amplifiers
- Servo motor drives

**Numerical example:** For a class B amplifier with  $V_{CC} = 12V$ , load  $R_L = 8\Omega$ , max output power  $P_o = \frac{V_{CC}^2}{2R_L} = \frac{144}{16} = 9W$ . Efficiency = 78.5%  $\rightarrow$  input power  $\approx 11.46W$ , dissipation  $\approx 2.46W$ .

**Q.2 – Explain class A power amplifier.****(7 marks)****Ans:**

**Definition:** A class A power amplifier conducts for the entire  $360^\circ$  of the input cycle. The transistor is biased in the active region such that output current flows continuously.

**Circuit (common-emitter with resistive or transformer load):**

- Single transistor (nnp) with biasing resistors  $R_1, R_2$  and emitter resistor  $R_E$  (bypassed for AC).
- Output load  $R_L$  connected in collector circuit (direct or via transformer).

**Diagram prompt:**

[DG PROMPT]

Title: Class A power amplifier (transformer-coupled)

Description: Draw npn transistor. Base biased by voltage divider  $R_1$  (to  $V_{CC}$ ) and  $R_2$  (to ground). Emitter to ground through resistor  $R_E$  (bypassed by capacitor). Collector to primary of output transformer. Secondary of transformer connected to load resistor  $R_L$ . Input signal through coupling capacitor to base. Show DC load line and AC load line.

**Working:**

- Transistor biased at center of load line (Q-point at  $V_{CE} = V_{CC}/2$ ).
- Input signal varies base current; collector current flows for full cycle.
- Output voltage across load is a replica of input (but amplified).

**Characteristics:**

- Conduction angle =  $360^\circ$
- Maximum theoretical efficiency = 25% (resistive load), 50% (transformer-coupled)
- Low distortion (no crossover distortion)
- High power dissipation (transistor always conducting)

**Advantages:**

- Simple design (single transistor)
- Low distortion
- Good linearity

**Limitations:**

- Very low efficiency (max 25-50%)
- Large heat sink required
- Not suitable for high power applications

**Applications:**

- Low-power audio preamplifiers
- Radio frequency (RF) amplifiers (small signal stages)
- Headphone amplifiers

**Numerical example:** Transformer-coupled class A:  $V_{CC} = 12V$ ,  $R'_L = 16\Omega$  (reflected),

$$\max P_o = \frac{V_{CC}^2}{2R_L} = \frac{144}{32} = 4.5W, \text{ efficiency } 50\% \rightarrow \text{input power } 9W, \text{ dissipation } 4.5W.$$

### Q.3 – Explain the working of class AB amplifier in brief.

(4 marks)

**Ans:**

**Definition:** Class AB amplifier is a compromise between class A and class B. It conducts for more than  $180^\circ$  but less than  $360^\circ$  (typically  $200^\circ$ - $240^\circ$ ). It eliminates crossover distortion of class B while achieving better efficiency than class A.

**Working:**

- Two complementary transistors (nnp and pnp) biased just above cutoff (small quiescent current).
- Biasing network (diodes or voltage divider) applies approximately 0.7V between bases, keeping both transistors slightly ON even at zero input.
- For small signals, both conduct (class A region). For large signals, one transistor conducts fully while the other cuts off (class B region).

**Key feature:** The small standing current eliminates the dead zone near zero crossing, removing crossover distortion.

**Advantages:**

- No crossover distortion
- Efficiency higher than class A (approx 50-70%)
- Good linearity

**Applications:**

- High-fidelity audio amplifiers
- Operational amplifier output stages
- Consumer electronics (TVs, radios)

**Diagram prompt:**

[DG PROMPT]

Title: Class AB amplifier with diode biasing

Description: Draw complementary npn and pnp transistors with emitters connected together to load to ground. Bases connected together via two series diodes (anode of D1 to npn base, cathode to pnp base). Resistor from Vcc to diode junction and from diode junction to -Vee sets bias current. Input applied to diode junction through capacitor.

### Q.4 – Write short note on class-B push-pull power amplifier.

(4 marks)

**Ans:**

**Class-B push-pull power amplifier** uses two matched transistors (nnp and pnp) that operate alternately to amplify the full input signal.

**Configuration:**

- **Transformer-coupled:** Input transformer provides phase-split signals; output transformer combines currents.
- **Complementary symmetry (OTL/OCL):** Direct coupling, no transformers.

**Operation recap:**

- Positive half-cycle: npn conducts, pnp off.
- Negative half-cycle: pnp conducts, npn off.
- Load receives full sine wave.

**Key parameters:**

- Efficiency: up to 78.5%

- Power output:  $P_o = \frac{V_{CC}^2}{2R_L}$  for complementary symmetry.
- Cross-over distortion: present but can be minimized by slight bias (class AB).

**Advantages:**

- High efficiency, low power loss
- No DC in output transformer (if capacitor coupled)
- Suitable for high-power applications

**Applications:**

- Audio power amplifiers (50W–500W)
- DC motor controllers
- Servo amplifiers

**Disadvantage:** Requires matched complementary transistors.

**Diagram prompt (complementary symmetry):**

See Q.1 diagram prompt.

**Q.5 – Write short note on transformer coupled audio power amplifier.**

(4 marks)

**Ans:**

**Transformer coupled audio power amplifier** uses a transformer to couple the output of the transistor to the load (e.g., speaker).

**Features:**

- The primary winding of the transformer acts as the collector load.
- Secondary winding matches the low impedance of the speaker ( $4\Omega$ ,  $8\Omega$ ) to the higher impedance of the transistor (hundreds of ohms).
- Impedance matching maximizes power transfer:  $\frac{N_p}{N_s} = \sqrt{\frac{R_{load}}{R_L}}$ .

**Advantages:**

- Allows impedance matching for maximum power transfer.
- DC current flows through primary but not through load (protects speaker).
- Can provide voltage step-up/step-down.

**Disadvantages:**

- Heavy, bulky, expensive.
- Limited frequency response (bandwidth restricted by transformer inductance).
- Introduces phase shift and distortion at low frequencies.

**Typical use:** Vacuum tube amplifiers, early transistor radios, some vintage hi-fi equipment.

**Real-world application:** Now largely replaced by OTL (output transformerless) and OCL (output capacitorless) designs using direct coupling and split power supplies.

**Diagram prompt:**

See Q.2 diagram prompt (transformer-coupled).

**Q.6 – State at least one use of class A, class B, class C amplifiers.**

(3 marks)

**Ans:**

Amplifier Class	At least one use
<b>Class A</b>	Low-power audio preamplifiers / RF oscillators / Headphone amplifiers
<b>Class B</b>	Audio power amplifiers (push-pull) / Battery-operated PA systems

Amplifier Class      At least one use

**Class C**              Radio frequency (RF) power amplifiers (e.g., in transmitters), tuned amplifiers

**Additional note:** Class C amplifiers conduct for  $<180^\circ$  and are used only for tuned RF applications due to high distortion.

**Q.7 – Compare class A and class B amplifiers.**

**(4 marks)**

**Ans:**

Parameter	Class A	Class B
Conduction angle	$360^\circ$	$180^\circ$
Quiescent current	High	Very low (near zero)
Maximum efficiency	25% (resistive load), 50% (transformer)	78.5%
Distortion	Low (no crossover distortion)	Crossover distortion present
Number of transistors	Single (or one output device)	Two complementary or push-pull
Power dissipation	High (always ON)	Low (only half cycle)
Heat sink requirement	Large	Moderate
Linearity	Excellent	Good (with proper biasing)
Typical application	Small signal stages, preamps	High-power audio amplifiers

**Conclusion:** Class A is simpler but inefficient; class B is efficient but requires push-pull configuration and suffers crossover distortion.

**Q.8 – State main factors governing design of large signal (power) amplifiers.**

**(4 marks)**

**Ans:**

The design of large signal (power) amplifiers is governed by the following factors:

1. **Power output capability** – Required output power (watts) determines transistor ratings and power supply.
2. **Efficiency** – Higher efficiency reduces heat dissipation and power supply cost (class B or AB preferred over A).
3. **Thermal management** – Heat sink selection, thermal resistance, and forced-air cooling to keep junction temperature below limit.
4. **Distortion** – Acceptable total harmonic distortion (THD) – class A gives lowest, class B gives crossover distortion, class AB is compromise.
5. **Impedance matching** – Transformer or direct coupling to match load impedance

(e.g.,  $4\Omega$  speaker) for maximum power transfer.

6. **Power supply** – Voltage and current ratings, regulation, ripple rejection.
7. **Transistor ratings** –  $V_{CEO}$ ,  $I_C$ ,  $P_D$ ,  $f_T$ , safe operating area (SOA).
8. **Protection circuits** – Overcurrent, short-circuit, thermal shutdown, SOA protection.
9. **Bandwidth** – Frequency response required for the application (audio: 20Hz–20kHz, RF: narrowband).
10. **Bias stability** – Thermal runaway prevention using emitter resistors or temperature-compensated biasing.

**Real-world application:** Designing a 100W audio amplifier requires careful selection of class AB operation, large heatsink,  $\pm 45V$  supply, and output transistors with SOA for  $4\Omega$  load.

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