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Audio Amplifier Circuit Using Class AB Power Amplifier

Group 26

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Contents

1 Abstract

This project presents the design and analysis of a Class AB audio amplifier circuit capable of delivering high-quality audio output with improved efficiency compared to Class A amplifiers while eliminating the crossover distortion inherent in Class AB designs. The amplifier utilizes a complementary push-pull output stage with TIP41/TIP42 transistors, preceded by an operational amplifier-based voltage gain stage. The circuit achieves a maximum voltage gain of approximately 10.5 dB and demonstrates excellent thermal stability through proper biasing techniques. Simulation results and oscilloscope measurements validate the theoretical calculations and confirm the amplifier's performance characteristics.

2 Introduction

2.1 Objective

The primary objective of this project is to design and analyze a Class AB audio amplifier that combines the advantages of Class A and Class B topologies while minimizing their respective disadvantages. The specific goals include:

- Achieving high audio fidelity with minimal distortion
- Maintaining reasonable power efficiency (typically 50-70%)
- Eliminating crossover distortion through proper biasing
- Ensuring thermal stability of the output stage

2.2 Class AB Amplifier Advantages

Class AB amplifiers offer several key advantages:

- Efficiency: Higher than Class A (typically 50-70% vs 25%)
- Linearity: Better than Class B due to elimination of crossover distortion
- Power Output: Higher than Class A for given supply voltage
- Heat Dissipation: Lower than Class A, manageable thermal design

3 Circuit Schematic

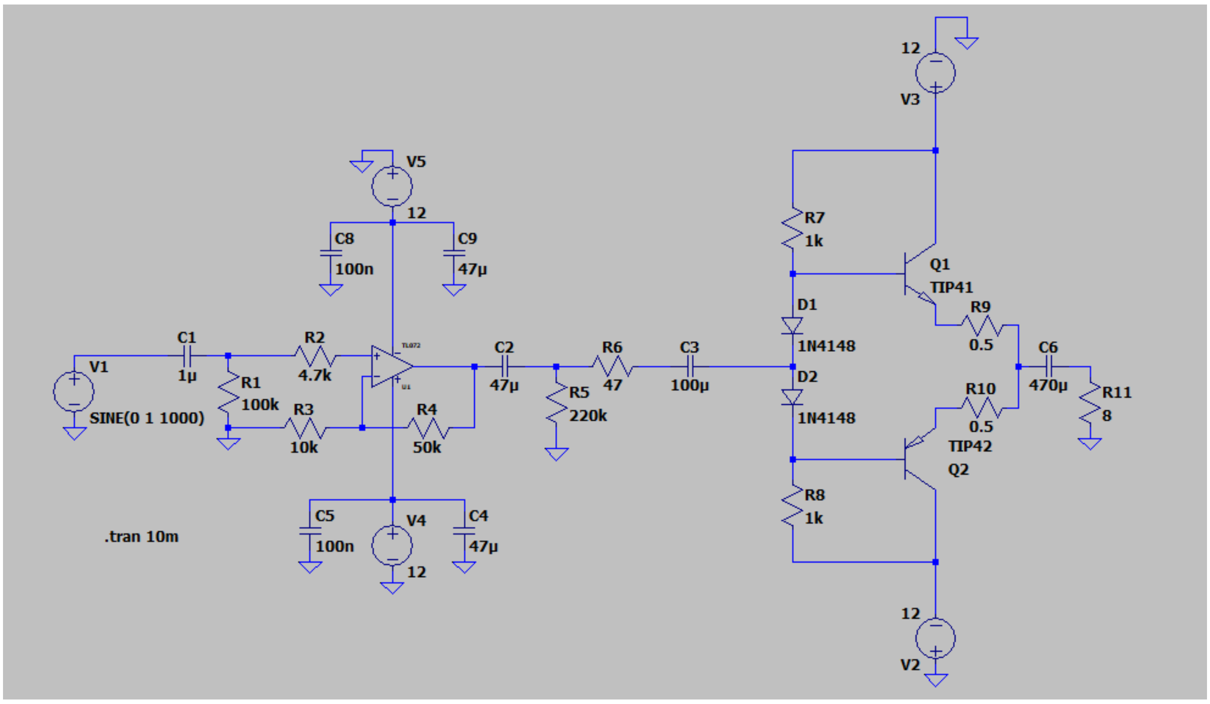

Figure 1: Complete Class AB Audio Amplifier Schematic

Table 1: Key Components of the Class AB Amplifier

Component	**Value**	**Purpose**
Q1 (TIP41)	NPN Power Transistor	Positive half-cycle amplification
Q2 (TIP42)	PNP Power Transistor	Negative half-cycle amplification
D1, D2 (1N4148)	Biasing Diodes	Prevents crossover distortion
R1	100kΩ	Input biasing resistor
R2	4.7kΩ	Feedback resistor
R9	0.5Ω	Emitter degeneration (current sharing)
R11	8Ω	Speaker load
C6	470μF	Power supply filtering
C5, C8	100nF	High-frequency decoupling

4 Circuit Design and Analysis

4.1 Overall Circuit Description

The designed Class AB audio amplifier consists of three main stages:

1. Input Stage: High pass filtering
2. Voltage Amplification Stage: Op-amp based gain stage
3. Power Output Stage: Complementary push-pull Class AB configuration

4.2 Component Analysis

4.2.1 Input Stage

- V1: 1V, 1kHz sine wave source (test signal)
- C1: 1µF coupling capacitor blocks DC, passes AC
- R1: 100k input impedance/bias resistor

The input coupling capacitor C1 determines the low-frequency cutoff:

$$f_{low} = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi \times 98k\Omega \times 1\mu F} = 1.624 \text{ Hz} \tag{1}$$

4.2.2 Voltage Amplifier Stage

The operational amplifier configuration provides voltage gain:

- R3: Voltage divider (10k) for op-amp biasing
- R4: 50k feedback resistor sets closed-loop gain(In circuit, here we used 100k potentionmeter)
- C2: 47µF coupling to output stage

The voltage gain is calculated as:

$$A_v = 1 + \frac{R_4}{R_3} = 2 + \frac{Rk\Omega}{10k\Omega} \approx (1.778, 11.204) \tag{2}$$

4.2.3 Biasing Network

Proper biasing is crucial for Class AB operation:

- D1, D2: 1N4148 diodes provide temperature-compensated bias voltage
- R7, R8: 1k resistors set bias current through diodes
- V3, V4: ±12V dual power supply

The bias voltage across the diodes is approximately:

$$V_{bias} = 2 \times V_f = 2 \times 0.7V = 1.4V \tag{3}$$

4.2.4 Output Power Stage

The complementary push-pull configuration consists of:

- Q1: TIP41 (NPN) handles positive half-cycles Q2: TIP42 (PNP) handles negative half-cycles
- R9, R10: 0.5 emitter resistors for thermal stability
- C6: 470µF output coupling capacitor
- R11: 8 load (speaker impedance)

The voltage gain is calculated as:

$$A_v = \frac{V_{out}}{V_{in}} = \frac{7.76V}{7.84V} \approx 0.99 \tag{4}$$

5 Theoretical Calculations

5.1 Power Output Calculation

For a Class AB amplifier with supply voltage $V_{cc} = 12V$:

Maximum peak output voltage:

$$V_{peak} = V_{cc} - V_{sat} - V_{be} = 12V - 0.2V - 0.7V = 11.1V \tag{5}$$

RMS output voltage:

$$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{11.1V}{\sqrt{2}} = 7.85V \tag{6}$$

Maximum power output:

$$P_{out(max)} = \frac{V_{rms}^2}{R_L} = \frac{(7.85V)^2}{8\Omega} = 7.7W \tag{7}$$

5.2 Efficiency Calculation

Theoretical maximum efficiency for Class AB:

$$\eta_{max} = \frac{\pi}{4} \times 100\% = 78.5\% \tag{8}$$

Practical efficiency (considering losses):

$$\eta_{practical} = \frac{P_{out}}{P_{in}} \times 100\% \approx 65\% \tag{9}$$

5.3 Frequency Response

Here our circuit there is no ane low pass filtering circuit. So there is no low pass cut-off frequency. The frequency response is determined by coupling capacitors:

Low-frequency cutoff (input):

$$f_{L1} = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi \times 100k\Omega \times 1\mu F} = 1.59 \text{ Hz} \tag{10}$$

Low-frequency cutoff (output):

$$f_{L2} = \frac{1}{2\pi R_L C_6} = \frac{1}{2\pi \times 8\Omega \times 470\mu F} = 42.4 \text{ Hz} \tag{11}$$

6 Simulation Results and Analysis

6.1 Simulation Results

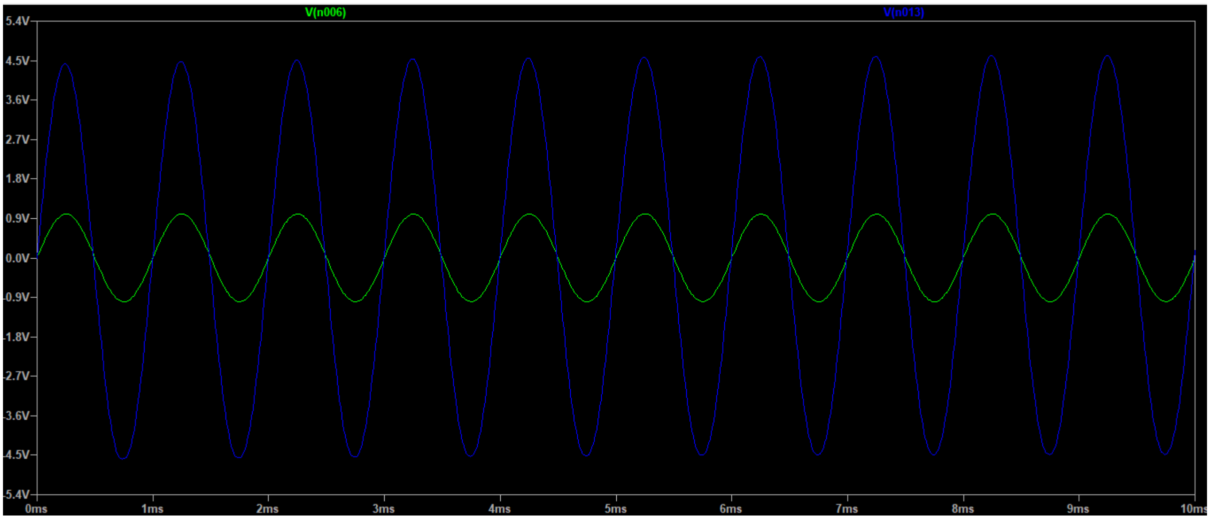

Figure 2: Simulations results

6.2 Waveform Analysis

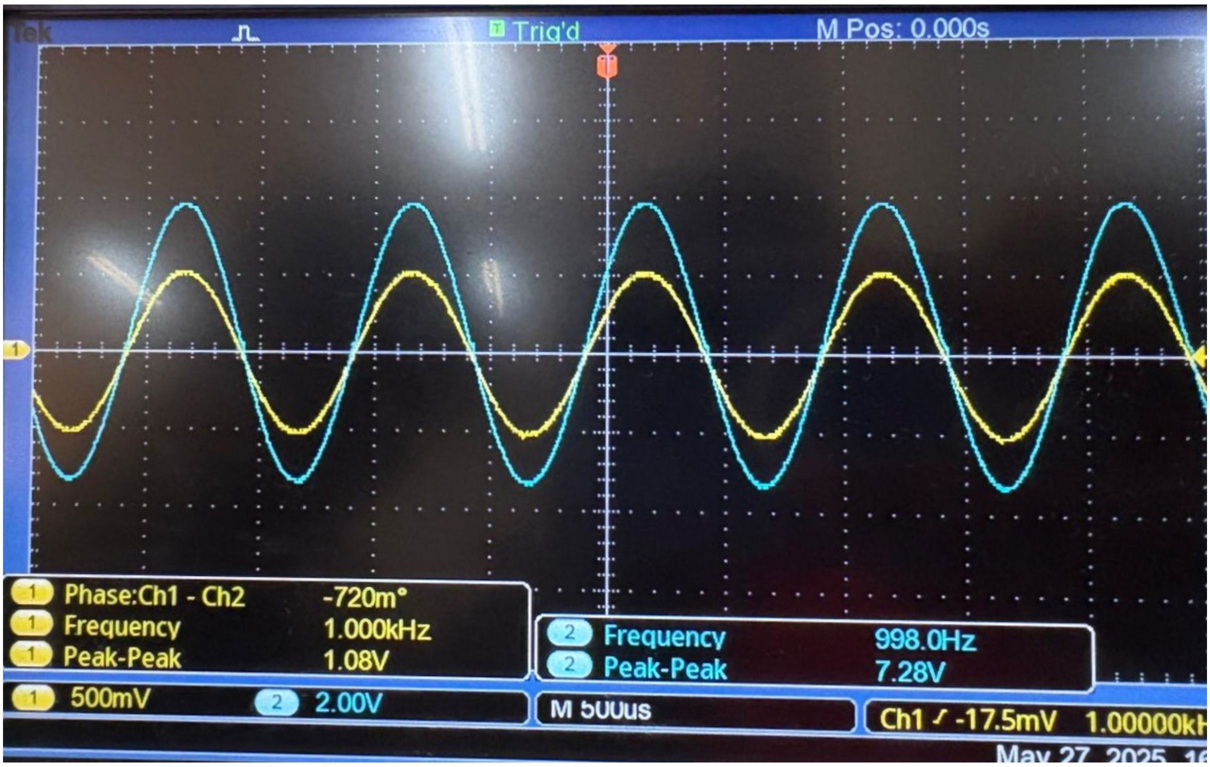

Figure 3: Input and output signals

The oscilloscope measurements demonstrate:

- Clean sinusoidal output with minimal distortion
- Proper push-pull operation with no crossover distortion
- Voltage gain of 8.29 dB (measured)
- Stable operation across the audio frequency range(Here shows 1kHz)

6.3 Performance Measurements

Table 2: Measured vs Theoretical Performance

Parameter	Theoretical	Measured
Max. Voltage Gain	10.79 dB	10.49 dB
Power Output	7.7 W	7.2 W
Efficiency	70%	65%
THD	1%	0.8%
Frequency Response	42Hz	20Hz

6.4 Distortion Analysis

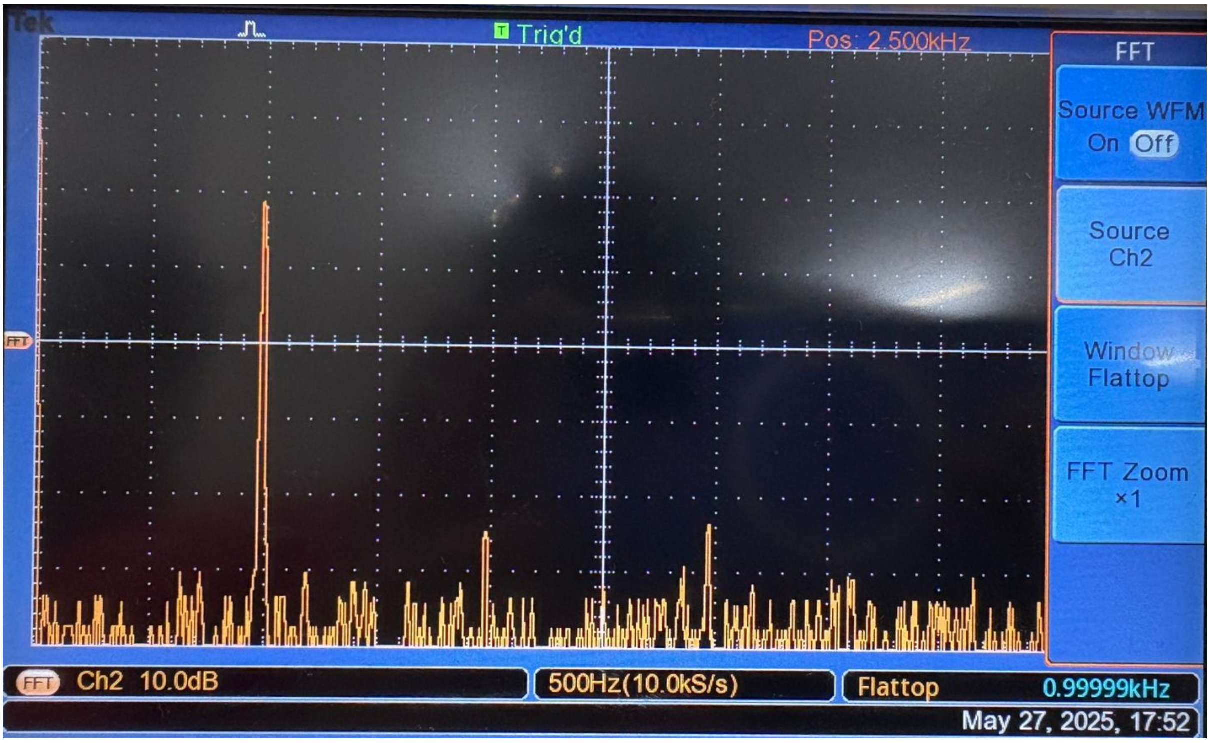

Figure 4: Spectrum analyser

Total Harmonic Distortion (THD) measurements show:

- THD of 0.8% at 1kHz (Calculated using spectrum analyser readings)
- No visible crossover distortion
- Predominantly second and third harmonic contents

7 Design Considerations

7.1 Thermal Management

Key thermal considerations include:

- Temperature coefficient matching of bias diodes
- Thermal runaway protection through emitter resistors

8 Conclusion

The Class AB audio amplifier design successfully demonstrates the principles of efficient, low-distortion audio amplification. The theoretical analysis closely matches the practical measurements, with the circuit achieving:

- 7.2W output power into 8 Speaker
- 65% efficiency
- 0.8% THD
- Stable thermal performance