**FigTroniX Class AB Audio Amplifier Guide**

06/01/2024

**# Introduction**

The FigTroniX Class AB Audio Amplifier is designed to provide high-quality audio amplification with a balanced frequency response and minimal distortion. This guide will explain the circuit in detail, provide a comprehensive parts list, offer step-by-step instructions for building, testing, and setting up the amplifier, and provide guidance on adjusting the variable resistor (potentiometer) for optimal performance.

**# About**

This Class AB amplifier is suitable for audio enthusiasts and professionals seeking to build a reliable and efficient amplifier for various audio applications. The design ensures stability across the audio frequency range, from 20 Hz to 20 kHz, with components chosen for their performance and availability.

**# Circuit Explanation**

The FigTroniX Class AB Audio Amplifier circuit is divided into several key sections: the input stage, the voltage amplification stage, the driver and output stage, the power supply filtering, the feedback network, the adjustment potentiometer, and the output stabilization networks. Each section is carefully designed to work together to amplify audio signals with high fidelity.

* **\*\*Input Stage:\*\***

**\*\*R1, R17 (10kΩ):\*\* These resistors form the input resistance, setting the input impedance of the amplifier. They help match the input source impedance and stabilize the input signal.**

**\*\*Calculation:\*\***

Input impedance \( Z\_{in} \) is determined primarily by the resistors R1 and R17.

\( Z\_{in} = R1 \parallel R17 \)

Since \( R1 = R17 = 10kΩ \):

\( Z\_{in} = \frac{R1 \cdot R17}{R1 + R17} = \frac{10kΩ \cdot 10kΩ}{10kΩ + 10kΩ} = \frac{100MΩ}{20kΩ} = 5kΩ \)

**\*\*C1 (15nF):\*\* This coupling capacitor blocks DC components from the input signal, preventing DC offset from affecting the rest of the circuit.**

**\*\*Calculation:\*\***

The cutoff frequency \( f\_c \) for the high-pass filter formed by C1

and the input resistance \( Z\_{in} \):

\( f\_c = \frac{1}{2 \pi R\_{in} C1} \)

\( f\_c = \frac{1}{2 \pi \cdot 5kΩ \cdot 15nF} = \frac{1}{2 \pi \cdot 5 \cdot 10^3 \cdot 15 \cdot 10^{-9}} \approx 2.12 \text{ Hz} \)

**\*\*R2, R3 (27kΩ each):\*\* These resistors bias the input transistor Q1, ensuring it operates in the correct region of its characteristic curves for linear amplification.**

**\*\*Calculation:\*\***

Assuming a voltage divider biasing, the base voltage \( V\_B \) for Q1:

\( V\_B = V\_{CC} \cdot \frac{R3}{R2 + R3} \)

For \( V\_{CC} = 48V \):

\( V\_B = 48V \cdot \frac{27kΩ}{27kΩ + 27kΩ} = 48V \cdot 0.5 = 24V \)

This base voltage ensures that Q1 operates in the active region.

**\*\*C10 (100pF):\*\* This capacitor filters out high-frequency noise at the input, preventing it from entering the amplifier.**

**\*\*Calculation:\*\***

The high-frequency cutoff \( f\_c \):

\( f\_c = \frac{1}{2 \pi R\_{in} C10} \)

\( f\_c = \frac{1}{2 \pi \cdot 5kΩ \cdot 100pF} = \frac{1}{2 \pi \cdot 5 \cdot 10^3 \cdot 100 \cdot 10^{-12}} \approx 318 \text{ kHz} \)

* **\*\*Voltage Amplification Stage:\*\***

**\*\*Q1 (2N3904):\*\* An NPN transistor used for initial voltage amplification. It amplifies the small input signal voltage.**

**\*\*R4 (6.8kΩ):\*\* The collector resistor for Q1, it sets the gain of the amplifier and helps in voltage drop for proper transistor operation.**

**\*\*Calculation:\*\***

The voltage gain \( A\_v \) of the common-emitter amplifier is approximately:

\( A\_v \approx -\frac{R\_C}{R\_E} \)

Here, \( R\_C = R4 = 6.8kΩ \) and \( R\_E = R5 = 270Ω \):

\( A\_v \approx -\frac{6.8kΩ}{270Ω} \approx -25.2 \)

**\*\*R5 (270Ω):\*\* The emitter resistor for Q1, provides thermal stability and sets the emitter current.**

**\*\*Calculation:\*\***

The emitter current \( I\_E \):

\( I\_E = \frac{V\_E}{R\_E} \)

Assuming \( V\_E \approx 1V \):

\( I\_E = \frac{1V}{270Ω} \approx 3.7mA \)

**\*\*C3 (22pF):\*\* A feedback capacitor for stabilizing high frequencies, it helps in rolling off the gain at high frequencies to prevent oscillations.**

**\*\*Calculation:\*\***

The high-frequency cutoff \( f\_c \):

\( f\_c = \frac{1}{2 \pi R\_C C3} \)

\( f\_c = \frac{1}{2 \pi \cdot 6.8kΩ \cdot 22pF} = \frac{1}{2 \pi \cdot 6.8 \cdot 10^3 \cdot 22 \cdot 10^{-12}} \approx 1.06 \text{ MHz} \)

* **\*\*Driver and Output Stage:\*\***

**\*\*Q2 (2N3906):\*\* A PNP transistor used to drive the output stage. It ensures the correct phase and amplitude of the signal to drive the output transistors.**

**\*\*Q4 (2N3904):\*\* An NPN transistor used to drive the output stage, working in conjunction with Q2.**

**\*\*R6 (220Ω):\*\* Provides bias stability and sets the current for Q2.**

**\*\*R8 (24kΩ):\*\* Biases Q4, ensuring it operates correctly.**

**\*\*Q3, Q5 (2STW100):\*\* NPN power transistors that provide the necessary current to drive the load (speaker).**

**\*\*R14, R15 (0.5Ω, 5W):\*\* Emitter resistors for Q3 and Q5, providing thermal stability and preventing thermal runaway.**

**\*\*C12 (560pF):\*\* A feedback capacitor to stabilize high-frequency response, preventing high-frequency oscillations.**

**\*\*Calculation:\*\***

The high-frequency cutoff \( f\_c \):

\( f\_c = \frac{1}{2 \pi R\_f C12} \)

Assuming \( R\_f = 4.7kΩ \):

\( f\_c = \frac{1}{2 \pi \cdot 4.7kΩ \cdot 560pF} = \frac{1}{2 \pi \cdot 4.7 \cdot 10^3 \cdot 560 \cdot 10^{-12}} \approx 60.4 \text{ kHz} \)

\*\*C13 (100pF):\*\* Stabilizes the voltage amplification stage by preventing high-frequency oscillations in Q1.

**\*\*Calculation:\*\***

The high-frequency cutoff \( f\_c \):

\( f\_c = \frac{1}{2 \pi R\_C C13} \)

Assuming \( R\_C = 6.8kΩ \):

\( f\_c = \frac{1}{2 \pi \cdot 6.8kΩ \cdot 100pF} = \frac{1}{2 \pi \cdot 6.8 \cdot 10^3 \cdot 100 \cdot 10^{-12}} \approx 234 \text{ kHz} \)

\*\*D1, D2 (1N4148):\*\* Diodes for biasing and temperature compensation, ensuring stable operation over varying temperatures. These diodes are appropriate for providing a stable voltage drop and helping to bias the transistors correctly. They are commonly used for this purpose in Class AB amplifiers.

D3, D4: 1N5408 - These diodes are used for protecting the output transistors from voltage spikes and ensuring stable operation.

* **\*\*Power Supply Filtering:\*\***
  + \*\*C2 (47µF, 80V):\*\* Decouples the power supply, smoothing out voltage fluctuations.
  + \*\*C4, C5 (220µF, 80V each):\*\* Further decouple the power supply, providing additional filtering to ensure a stable DC voltage.
  + \*\*C11 (0.1µF):\*\* Additional high-frequency decoupling, filtering out any high-frequency noise on the power supply lines.
  + \*\*C7 (4700µF, 80V):\*\* Provides bulk filtering for the power supply, smoothing out large voltage fluctuations.
  + \*\*C8, C16, C17, C18, C19, C20, C21, C22, C23 (0.1µF each):\*\* Additional filtering capacitors to reduce high-frequency noise and stabilize the power supply.
  + \*\*R20 (5kΩ):\*\* Resistor in series with the additional filtering capacitors to form an RC filter, further smoothing the power supply. It also connects to J3 for an off-board LED.
* **\*\*Feedback Network:\*\***

\*\*R7 (4.7Ω):\*\* Part of the feedback network ensuring stability. It helps set the overall gain of the amplifier and ensures linearity.

**\*\*Calculation:\*\***

The gain of the feedback network:

\( A\_v = 1 + \frac{R\_f}{R7} \)

Assuming \( R\_f = 4.7kΩ \):

\( A\_v = 1 + \frac{4.7kΩ}{4.7Ω} = 1 + 1000 = 1001 \)

\*\*JMP1:\*\* Jumper wire connecting parts of the feedback network, allowing for easy adjustments or modifications to the feedback path.

* **\*\*Adjustment Potentiometer:\*\***
  + \*\*R16 (10kΩ):\*\* A 10-turn variable resistor (potentiometer) used to fine-tune the biasing and gain of the amplifier. It allows precise adjustment of the bias current through the output transistors to minimize crossover distortion and optimize performance.
* **\*\*Output Stabilization Networks:\*\***

\*\*R13, C9, L1 Network:\*\* This is a Zobel network combined with an inductor to stabilize the amplifier's output. R13 (4Ω) and C9 (2µF) form the Zobel network, which helps prevent oscillations by stabilizing the impedance at high frequencies. L1 (2-10µH) provides inductive reactance to counteract any capacitive loading effects.

**\*\*Calculation:\*\***

The cutoff frequency \( f\_c \) of the Zobel network:

\( f\_c = \frac{1}{2 \pi R13 C9} \)

\( f\_c = \frac{1}{2 \pi \cdot 4Ω \cdot 2µF} = \frac{1}{2 \pi \cdot 4 \cdot 2 \cdot 10^{-6}} \approx 19.9 \text{ kHz} \)

L1 (2-10µH) adds inductive reactance to stabilize high-frequency response.

\*\*R19, C15 Network:\*\* This network provides additional high-frequency stabilization. R19 (10Ω) and C15 (0.1µF) help to filter out any remaining high-frequency noise that might affect the performance of the amplifier.

**\*\*Calculation:\*\***

The cutoff frequency \( f\_c \):

\( f\_c = \frac{1}{2 \pi R19 C15} \)

\( f\_c = \frac{1}{2 \pi \cdot 10Ω \cdot 0.1µF} = \frac{1}{2 \pi \cdot 10 \cdot 0.1 \cdot 10^{-6}} \approx 159.2 \text{ kHz} \)

* **# Parts List and Explanations**
* **\*\*Resistors:\*\***
  + \*\*R1, R17, R2, R3, R4, R6, R8, R9, R11, R12, R18:\*\* Yageo 10k Ohm 1/4W 1% Metal Film Resistor (MFR-25FBF52-10K) - Metal film resistors provide precision and stability.
  + \*\*R5, R7:\*\* 4.7Ω, 1/4W, carbon film resistors - Used for stability and ensuring precise feedback control.
  + \*\*R14, R15:\*\* 0.5Ω, 5W, wire-wound resistors - High power resistors for thermal stability and high current handling in the output stage.
  + \*\*R19:\*\* 10Ω, 1/4W, metal film resistor - Used in the Zobel network for high-frequency stabilization.
  + \*\*R13:\*\* 4Ω, 1/4W, carbon film resistor - Part of the Zobel network, providing impedance stabilization.
  + \*\*R20:\*\* 5kΩ, 1/4W, metal film resistor - Part of the additional power supply filtering network, connected to J3 for an off-board LED.
* **\*\*Capacitors:\*\***
  + \*\*C1:\*\* 15nF, film - Coupling capacitor to block DC.
  + \*\*C10:\*\* 100pF, film - High-frequency noise filtering.
  + \*\*C3:\*\* 22pF, film - High-frequency stabilization in the feedback path.
  + \*\*C12:\*\* 560pF, film - Feedback stabilization to prevent oscillations.
  + \*\*C13:\*\* 100pF, film - High-frequency stabilization in the voltage amplification stage.
  + \*\*C2:\*\* 47µF, 80V, electrolytic - Power supply decoupling.
  + \*\*C4, C5:\*\* 220µF, 80V, electrolytic - Additional power supply decoupling.
  + \*\*C7:\*\* 4700µF, electrolytic - Bulk filtering for the power supply.
  + \*\*C8, C16, C17, C18, C19, C20, C21, C22, C23:\*\* 0.1µF, ceramic - High-frequency noise filtering.
  + \*\*C9:\*\* 2µF, polyester film - Part of the Zobel network for output stabilization.
  + \*\*C15:\*\* 0.1µF, ceramic - High-frequency noise filtering.
* **\*\*Transistors:\*\***
  + \*\*Q1, Q4:\*\* 2N3904, NPN - Small-signal transistors for initial voltage amplification and driving stages.
  + \*\*Q2:\*\* 2N3906, PNP - Small-signal transistor for the driving stage.
  + \*\*Q3, Q5:\*\* 2STW100, NPN - Power transistors for driving the output load.
* **\*\*Diodes:\*\***
  + \*\*D1, D2:\*\* 1N4148 - Fast-switching diodes for biasing and temperature compensation.
  + \*\*D3, D4: 1N5408 - High-current diodes used for protecting the output transistors from voltage spikes and ensuring stable operation. These diodes have a high current rating of 3A and a peak repetitive reverse voltage of 1000V, making them suitable for high-power applications.
* **\*\*Inductor:\*\***
  + \*\*L1:\*\* 2-10µH, suitable for the output current - Part of the output stabilization network, providing inductive reactance to counteract capacitive effects.
* **\*\*Miscellaneous:\*\***
  + \*\*JMP1:\*\* Standard jumper wire for feedback network.
  + \*\*SP1:\*\* 4-ohm speaker - Matches the amplifier output power.
* **# Ordered Parts List with Specifications**
* **\*\*Resistors:\*\***
  + \*\*R1, R17, R2, R3, R4, R6, R8, R9, R11, R12, R18:\*\* 10kΩ, 1/4W, 1% metal film.
  + \*\*R5, R7:\*\* 4.7Ω, 1/4W, carbon film.
  + \*\*R14, R15:\*\* 0.5Ω, 5W, wire-wound.
  + \*\*R19:\*\* 10Ω, 1/4W, metal film.
  + \*\*R13:\*\* 4Ω, 1/4W, carbon film.
  + \*\*R20:\*\* 5kΩ, 1/4W, metal film.
* **\*\*Capacitors:\*\***
  + \*\*C1:\*\* 15nF, film.
  + \*\*C10:\*\* 100pF, film.
  + \*\*C3:\*\* 22pF, film.
  + \*\*C12:\*\* 560pF, film.
  + \*\*C13:\*\* 100pF, film.
  + \*\*C2:\*\* 47µF, 80V, electrolytic.
  + \*\*C4, C5:\*\* 220µF, 80V, electrolytic.
  + \*\*C7:\*\* 4700µF, electrolytic.
  + \*\*C8, C16, C17, C18, C19, C20, C21, C22, C23:\*\* 0.1µF, ceramic.
  + \*\*C9:\*\* 2µF, polyester film.
  + \*\*C15:\*\* 0.1µF, ceramic.
* **\*\*Transistors:\*\***
  + \*\*Q1, Q4:\*\* 2N3904, NPN.
  + \*\*Q2:\*\* 2N3906, PNP.
  + \*\*Q3, Q5:\*\* 2STW100, NPN.
* **\*\*Diodes:\*\***
  + \*\*D1, D2:\*\* 1N4148.
  + \*\*D3, D4:\*\* 1N5408.
* **\*\*Inductor:\*\***
  + \*\*L1:\*\* 2-10µH, suitable for the output current.
* **\*\*Miscellaneous:\*\***
  + \*\*JMP1:\*\* Jumper wire.
  + \*\*SP1:\*\* 4-ohm speaker.
* **# Testing and Setup**
* **\*\*Initial Setup:\*\***
* Assemble the circuit on a breadboard or PCB, ensuring all connections are secure.
* Double-check the polarity of electrolytic capacitors (C2,C4, C5, C7).
* Ensure proper heat sinking for power transistors Q3 and Q5 to prevent overheating.
* **\*\*Power Supply:\*\***
  + Connect the amplifier to a stable power supply providing 48V DC.
  + Verify that the power supply provides clean and stable voltage without significant ripple.
* **\*\*Testing Procedure:\*\***
  + \*\*No Signal Test:\*\* Power up the amplifier without an input signal. Measure the DC offset at the output to ensure it is close to zero.
  + \*\*Signal Test:\*\* Apply a known audio signal (e.g., 1 kHz sine wave) to the input and measure the output using an oscilloscope. Verify that the output is a clean amplified version of the input.
  + \*\*Frequency Response Test:\*\* Sweep the input frequency from 20 Hz to 20 kHz and observe the output. Ensure the amplitude remains consistent across the frequency range.
  + \*\*Load Test:\*\* Connect the speaker (SP1) and evaluate the amplifier with various audio signals, adjusting the input level to observe performance under load.
* **\*\*Adjustment of Potentiometer (R16):\*\***
  + \*\*Initial Setting:\*\* Start with R16 (10kΩ) set to its mid-point.
  + \*\*Bias Adjustment:\*\* Monitor the quiescent current through the output transistors (Q3, Q5). Adjust R16 to achieve the desired bias current, ensuring minimal crossover distortion while avoiding excessive idle current that can lead to overheating.
  + \*\*Fine-Tuning:\*\* Once the initial bias is set, make small adjustments to R16 while monitoring the output signal for any signs of distortion. The goal is to find the optimal balance between low distortion and thermal stability.
* **\*\*Fine-Tuning Capacitors (C12 and C13):\*\***
  + \*\*Purpose of C12:\*\* The 560pF capacitor (C12) is part of the feedback network. It helps stabilize the amplifier by reducing high-frequency gain, preventing oscillations, and ensuring a smooth response across the audio spectrum.
  + \*\*Purpose of C13:\*\* The 100pF capacitor (C13) is used to stabilize the voltage amplification stage. It acts to prevent high-frequency oscillations and ensures the amplifier operates smoothly at high frequencies.
  + \*\*Recommended Values:\*\* C12 is typically between 470pF and 1nF, while C13 can be between 68pF and 150pF. Start with the values provided (560pF for C12 and 100pF for C13) and adjust if necessary.
  + \*\*What to Look For:\*\* During testing, if you observe high-frequency oscillations or instability, slightly increase the value of C12 or C13. If the amplifier's high-frequency response is overly damped, consider slightly decreasing these values. Adjust in small increments and re-test the frequency response to find the optimal values.

**# Maximum Output Power Calculation**

* \*\*Supply Voltage (V\_CC):\*\* 48V
* \*\*Load Impedance (R\_L):\*\* 4Ω
* \*\*Efficiency (η) of Class AB Amplifier:\*\* Typically around 50% to 70%. For calculation purposes, we will use an average efficiency of 60%.
* **# Step-by-Step Calculation:**
* **\*\*Peak Output Voltage (V\_peak):\*\***
  + The peak output voltage is ideally the supply voltage minus some headroom for the transistors. For simplicity, let us assume a headroom of 5V on each side (for positive and negative swings).
  + \( V\_{peak} = V\_{CC} - 2 \times 5V = 48V - 10V = 38V \)
* **\*\*Peak Output Current (I\_peak):\*\***
  + \( I\_{peak} = \frac{V\_{peak}}{R\_L} = \frac{38V}{4Ω} = 9.5A \)
* **\*\*RMS Values:\*\***
  + The RMS value of the output voltage is \( V\_{RMS} = \frac{V\_{peak}}{\sqrt{2}} = \frac{38V}{\sqrt{2}} \approx 26.87V \)
  + The RMS value of the output current is \( I\_{RMS} = \frac{I\_{peak}}{\sqrt{2}} = \frac{9.5A}{\sqrt{2}} \approx 6.71A \)
* **\*\*Output Power:\*\***
  + The output power \( P\_{out} \) in RMS terms is \( P\_{out} = V\_{RMS} \times I\_{RMS} = 26.87V \times 6.71A \approx 180W \)
* **\*\*Considering Efficiency:\*\***
  + The actual output power considering efficiency \( P\_{actual} \) is \( P\_{actual} = P\_{out} \times \eta \)
  + Assuming 60% efficiency: \( P\_{actual} = 180W \times 0.60 \approx 108W \)

**# Conclusion**

With a supply voltage of 48V and a load impedance of 4Ω, you can expect the FigTroniX Class AB amplifier to deliver approximately 108 watts of output power per channel, considering an average efficiency of 60%. This calculation gives a reasonable estimate for the power output you can expect in real-world conditions.

This guide provides a detailed explanation of the FigTroniX Class AB Audio Amplifier circuit, a comprehensive parts list, and step-by-step instructions for building, testing, and setting up the amplifier. Additionally, it includes guidance on adjusting the variable resistor (potentiometer) and fine-tuning capacitors C12 and C13 for optimal performance. Following these instructions will help ensure a successful and high-quality audio amplification experience. If you encounter any issues or need further assistance, feel free to reach out for support. Happy building  

