Application Report
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Passive Component Selection Guide for Class-D Audio Amplifier

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ABSTRACT

As the performance of class-D audio amplifiers gets better and system complexity increases, special care must be taken in the printed circuit board (PCB) design phase to choose passive components for the device to ensure a robust solution. As in most of the engineering practices, there is no unique solution to a given problem nor a unique components selection, but this application note can help guide you to reach an optimal solution.

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1 Introduction

1.1 Scope

This application note can help system designers implement best practices and understand component selection options while designing the audio segment of the system. It serves as a guide to select passives required for the amplifier. This helps in extracting best possible audio quality from the class-D audio amplifier. This is intended for the audiences who are involved in designing audio systems.

1.2 Critical Components

One of the main concerns while designing an audio system is choosing the right passive component that maintains the quality of the audio along with small system size and lower cost. Another big concern that arises due to (System-on-Chip) SoC IC is routing analog, digital, and power signals with integrity, avoiding interference with each other, and maintaining audio quality. The third concern while routing signals is that other system devices should not negatively interfere with the audio chip and vice versa due to EMI and other voltage and current switching. For layout guidelines, refer to the *PCB Layout Guidelines for TAS2xxx Series Class-D Boosted Audio Amplifier Application Report* and *PCB Layout Guidelines for TAS2xxx Series Class-D Non-boosted Audio Amplifier Application Report*, respectively.

Table 1 outlines the components requiring the most attention while designing a PCB that incorporates a Texas Instruments audio amplifier SoC.

Table 1. Critical Components

COMPONENT	DESCRIPTION
Decoupling capacitor	Connect on all supply pins, boost pin, and internal LDO pin with respect to GND.
Bootstrap capacitor	The bootstrap capacitor needs to be connected between the bootstrap pin and respective Class-D output pin. Applicable for non-boosted audio amplifiers.
Charge pump capacitor	Connect on high-side gate CP regulator output with respect to power stage supply. Applicable for boosted audio amplifiers.
Boost inductor	Connect between the battery supply and boost switching input node. Applicable for boosted audio amplifiers.
Ferrite bead	Place close to Class-D output if used for EMI and should be used if EMI capacitors are used.
Ferrite bead filter capacitor	Place to configure EMI filter cutoff if EMI filter is used.

2 A Quick Reference Guide to Select Passive Devices

2.1 Power Supply Bypass Capacitors

Bypass capacitors serve two main purposes. It fulfills the sudden switching current requirement for the device and helps in decoupling voltage noise fluctuations on power pins, ensuring a reliable constant solid power supply seen by the device pin, and thus better performance.

The key specifications while choosing a capacitor are the following:

- Capacitance value
- Voltage rating
- Resonant frequency ESR, ESL

Capacitors can be modeled as Figure 1, where R is ESR (equivalent series resistance), L is ESL (equivalent series inductance), and C is capacitance itself. Due to these components, a capacitor behaves as a capacitor up to a certain frequency, but beyond that frequency, it starts acting as an inductor. This frequency is termed as self-resonant frequency and is one of the very critical parameters while choosing a capacitor because beyond this frequency, it loses its capacitive properties and does not offer any decoupling.

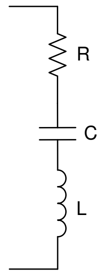

Figure 1. Equivalent Capacitor Model

Self-resonant frequency (f_{SR}) happens when the impedance of the capacitor becomes equal to impedance of the ESL.

$$f_{SR} = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

As evident from Equation 1, lower capacitance and inductance leads to higher resonating frequency. ESL and ESR are package-governed and generally smaller in size than the ESL and ESR. TI recommends small size ceramic capacitors which satisfy required capacitance values and voltage rating because, in general, ceramic capacitors offer less ESR as compared to their tantalum parts. They are also cheaper. If the bulk capacitor (for example, 1 µF, 4.7 µF, and 10 µF) with the required capacitance and voltage rating for the device pin is available in the 0402 or lower package, then a supplementary smaller capacitance (0.1 µF) capacitor is not required in parallel to the bulk capacitor. In case you are using the 0603 or a bigger sized capacitor, smaller packages with less capacitance are recommended in parallel for smooth device operation.

Table 2 shows typical ESL and ESR values for different surface mount capacitor packages.

Table 2. SMD Packages and Their Typical ESL

PACKAGE	ESL (pH)
201	400
402	500
603	750
805	800
1206	1250

Choosing a low inductance, but higher value capacitor enables a low impedance path from the power supply to ground to shunt unwanted energy.

For the boost capacitor, a tantalum capacitor is preferred for the bulk capacitor and ceramic for the smaller capacitor. MLCC capacitors can produce noise in the audio domain due to the piezoelectric effect and thus can cause interference in hearing. This phenomenon is termed as singing capacitors. See the *Singing Capacitors (Piezoelectric Effect)* for more insight into the singing capacitor phenomenon. The boost capacitor must also meet the L/C less than 1/3 criteria for the boost stability where L is the boost inductor and C is the derated value of the boost capacitor at the operating boost voltage level.

2.2 Bootstrap Capacitors/Charge Pump Capacitor

The fundamentals for selecting the right capacitor remain the same as discussed in Section 2.1.

2.3 EMI Filter

In case the system designer chooses to use a filter due to EMI reasons, TI recommends a ferrite bead plus a capacitor-based filter. Resonant frequency of the filter must be kept around 10 Mhz and a linear ferrite bead must be chosen for best THD and noise performance. Refer to the *Post Filter Feedback Class-D Amplifier Benefits and Design Considerations Application Report* to choose the correct part. For example, ferrite bead part number NFZ2MSM181SN10L can be used for higher performance than MPZ1608S221A.

2.4 Boost Inductor

Multiple factors need to be taken into consideration while choosing an inductor. The following are critical parameters that need to be addressed:

- Inductance value
- Current carrying capability
- Saturation current
- DC resistance (DCR)
- Self-resonant frequency
- Max Volt-time product (V × µs)

The inductance value is a parameter that is governed by the boost design. The TAS2562, TAS2563, TAS2564, TAS2110, and so forth are boosted TI class-D smart audio amplifiers that support an inductor value between 0.47 µH to 2.5 µH to satisfy sufficient energy transfer. TI recommends using 1 µH for the best device performance. This should be the inductance offered by the part in the boost switching frequency range.

The current carrying capability is usually specified as two different values: Irms and Isat. Irms is clearly the RMS current that the part can withstand. Isat varies from manufacturer to manufacturer. It is usually specified as the DC current value that causes the inductance to drop 10%. Recall a totally saturated inductor has a permeability of 1.0 µ0, the same as free space, while the permeability of the core in an unsaturated state is much higher. Since µ is proportional to inductance, you can conclude that a saturated inductor has minimal inductance. This minimal inductance can cause excessive ripple currents in the bridge switches. In particular, boost inductors must not be allowed to enter the saturation region, therefore, you need to choose a part whose Isat > ILIM to deliver Class-D peak power. TI recommends choosing an inductor with 20% margin over this so that it never goes into the saturation region across inductor parts.

The DCR is the resistance offered by the inductor to a DC voltage applied across it. In order to have the best possible device efficiency, DCR should be as low as possible. Typically, it is around 15 mΩ, but the lower the better.

The self-resonating frequency (SRF) is the parallel resonant frequency of the inductor which exists during parasitic capacitance offered by the part and the routing. The SRF must be much higher than the boost switching frequency of operation. TI recommends choosing a part with SRF > 10 x (max boost switching frequency).

3 References

- Texas Instruments, *Layout Guidelines For TPA300x Series Parts Application Report* (SLOA103)
- Texas Instruments, *Post Filter Feedback Class-D Amplifier Benefits and Design Considerations Application Report* (SLOA260)
- *Singing Capacitors (Piezoelectric Effect)*
- *Saturn PCB Tool*