

Small, High Efficiency Split-Rail Supply Reference Design for Portable Audio Applications

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ABSTRACT

Headphone amplifiers usually require positive and negative voltages. In this reference design, both voltages are generated from a single input voltage with an all integrated split-rail converter. The split-rail converter only requires one inductor and a minimal amount of external components to achieve a high efficiency power supply that keeps the distortion of the system very low. End users benefit from high fidelity audio performances with longer playback time in mobile applications.

Contents

1	Introduction	2
2	Design Description.....	3
	2.1 Functional Design.....	3
	2.2 Audio Amplifier	3
	2.3 Power Supply.....	4
	2.4 Component Selection	5
3	Experimental Results.....	6
	3.1 Test Setup	6
	3.2 Schematic.....	7
	3.3 Test Results	9
4	Summary	10

List of Figures

1	Overall System Functionality	2
2	Solution Size	2
3	Design Functional Block Diagram	3
4	Amplifier Simplified Application Schematic.....	3
5	TPS65132 Block Diagram	4
6	Efficiency.....	5
7	Test Setup	6
8	Schematic.....	8
9	THD + N Battery Versus TPS65132	9
10	Power Supply Comparison at 10 mW, $R_L = 32 \Omega$	9
11	THD + N Versus Output Power	9

List of Tables

1	Jumpers	7
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1 Introduction

Listening to digital music using smartphones or tablet PCs has become an increasingly popular method to enjoying music. The rising popularity of these usage of such devices, has created the need to expand their basic functionalities, Nowadays a increasing number of smartphones and tablets contain dedicated hardware to play different audio sources . Besides the performance of the amplifier, it is necessary to fulfill a long battery life and use as little space as possible on the printed circuit board. For such requirements, the following design offers a suitable solution.

The most common way to access the audio quality of an amplifier system is by measuring the total harmonic distortion plus noise (THD + N). Using this measuring technique, all switching noise and frequency components that are not related to the injected test signal, degrade the result of the THD + N measurement. This method allows evaluating the audio quality in a single figure and makes comparing different solutions possible.

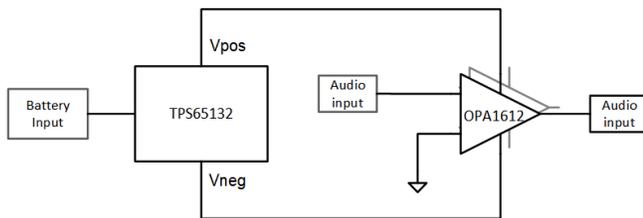


Figure 1. Overall System Functionality

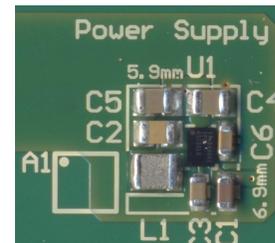


Figure 2. Solution Size

2 Design Description

2.1 Functional Design

As Figure 3 shows, the reference design circuit can be split into two sections.

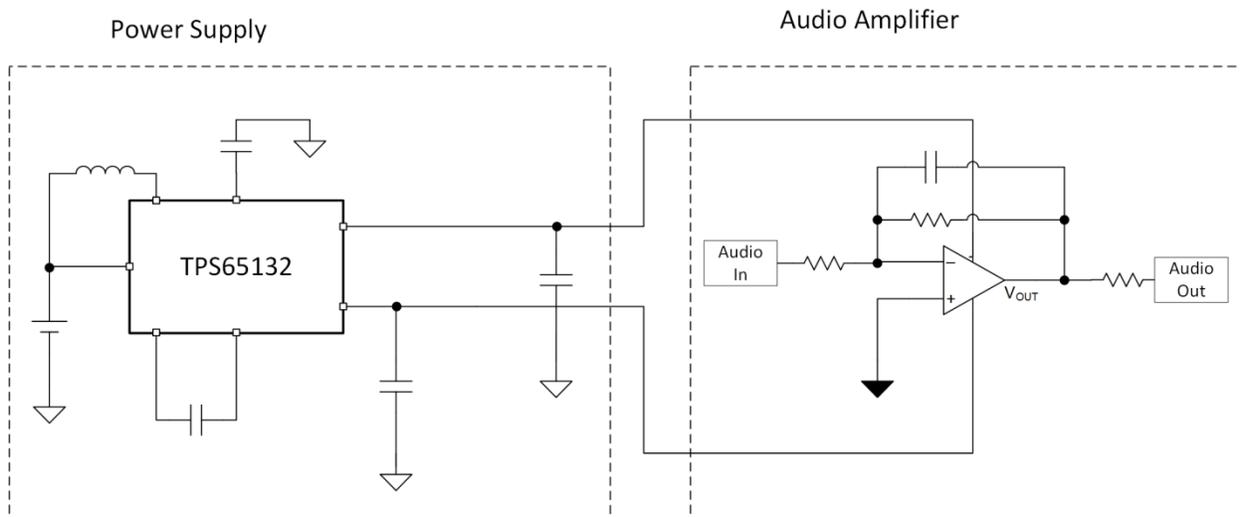


Figure 3. Design Functional Block Diagram

2.2 Audio Amplifier

The amplifier used for the design is the OPA1612 in a single-ended input application. This device delivers excellent audio performance. Figure 4 shows the simplified application circuit for a single channel amplifier. For further information on the OPA1612 amplifier, visit the OPA1612 datasheet ([SBOS450](#)).

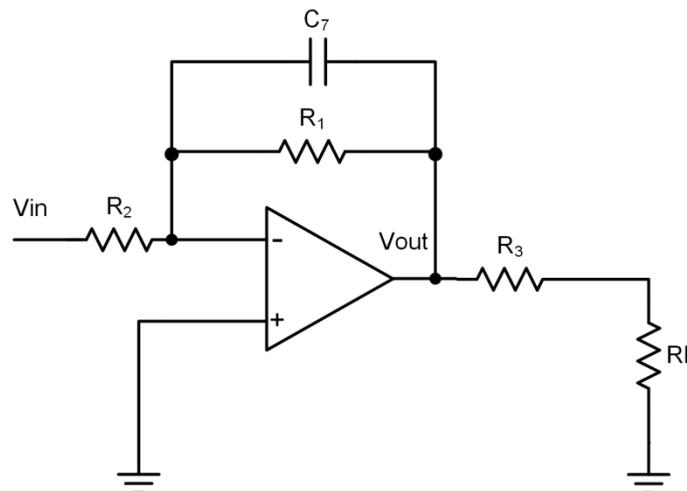


Figure 4. Amplifier Simplified Application Schematic

The gain of the amplifier stage is set by the input R_1 and feedback resistor R_2 . Use Equation 1 to determine the resistors for negative gain:

$$G = \frac{V_{OUT}}{V_{IN}} = -\frac{R_1}{R_2} \quad (1)$$

Choosing the resistor R_1 in the range of 1 k Ω to 10 k Ω is suitable to avoid the introduction of additional noise to the feedback loop.

The capacitor C_7 adjusts the crossover frequency for the operational amplifier (Equation 2).

$$f_c = \frac{1}{2\pi C_7 R_2} \quad (2)$$

To avoid a non-linear phase shift within the audible frequencies, the crossover frequency is shifted to ten times the highest frequency that should be amplified. With these two components, calculating the input resistor R_1 for the required gain is possible.

TI recommends using the output resistor R_3 to avoid oscillations when a non-resistive load is used instead of R_L , which is the case when using headphones. Find a suitable resistance on the output of the amplifier in the designs schematic. Refer to the datasheet and design guides of the amplifier for further details.

The OPA1612 amplifier is also available in a WQFN package for a small form factor. In this circuit, a standard SOIC package is chosen to make adjusting the gain values and verifying the design requirements easy. For the same simplifying reason, the main components are utilized in a 0805 size.

2.3 Power Supply

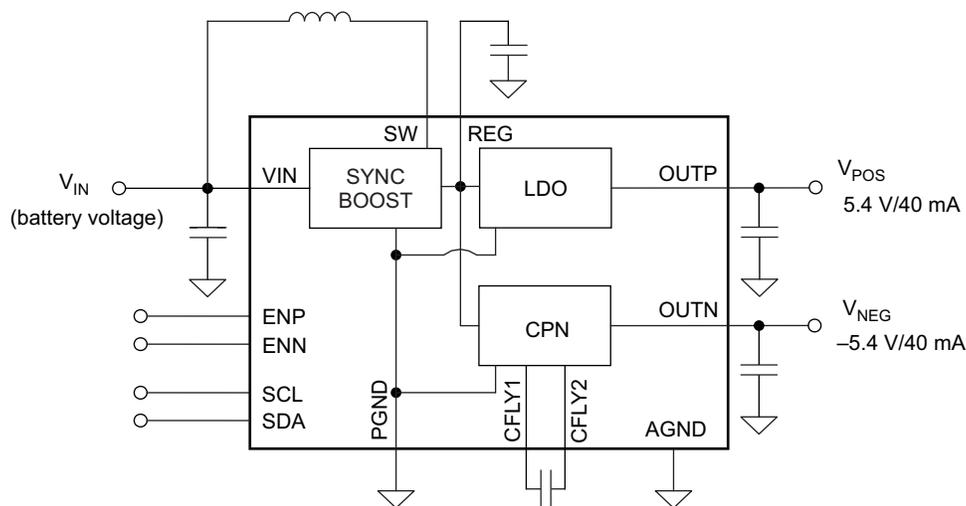


Figure 5. TPS65132 Block Diagram

The TPS65132 is a dual-output, integrated switching converter. The two outputs are generated from the input voltage V_{IN} by utilizing a boost converter, which generates the pre-regulating voltage V_{REG} . The positive output V_{POS} is regulated by an internal low dropout regulator (LDO). An inverting charge pump generates the negative voltage V_{NEG} out of V_{REG} . For further information on the TPS65132 converter, visit the TPS65132 datasheet ([SLVSBM1](#)).

For proper operation, the device only requires a minimum of seven external components: one inductor for the boost, four capacitors on the different output voltage rails, one flying capacitor for the charge pump, and one on the input voltage. With the used topology, the converter achieves the highest efficiency for the power conversion of the two outputs. Figure 6 shows the efficiency over output current with typical input voltages for a single cell battery.

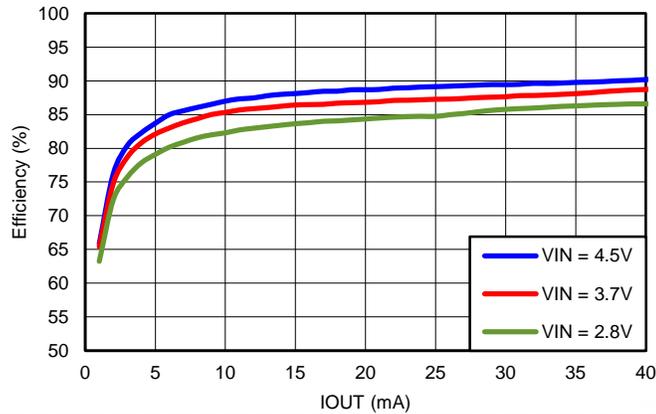


Figure 6. Efficiency

The challenge for powering an audio device is to introduce as little noise as possible from the circuit supply. Due to the internal LDO, the positive output already achieves a significant reduction of the output voltage ripple and significant load regulation. The negative voltage is designed without an output regulator. The output voltage ripple of the charge pump is easy to improve by adding an additional capacitance to the V_{NEG} output. This addition also decreases the output impedance of the negative voltage supply. Neither of the two outputs V_{POS} and V_{NEG} , switch within the audible frequency range.

2.4 Component Selection

The component selection for the power supply is simple. Select the components according to the values in Section 3.2 or the Bill of Materials (BOM) Section from the PMP9781 datasheet ([PMP9781](#)). View the TPS65132 datasheet for further details about the components ([SLVSBM1](#)).

3 Experimental Results

3.1 Test Setup

Because the THD + N test is basically a wide-band measurement, the selected bandwidth influences the results of a tested amplifier. Every noise above and below the bandwidth borders is added to the analyzed THD + N figures. Therefore, the test result with high upper- cut-off frequencies of 22 kHz typically ends up with a lower THD + N, as with 30 kHz or 80 kHz.

The following test uses the Audio Precision SYS-2722 audio analyzer with the bandwidth limit set to < 10 Hz to 80 kHz.

The block diagram in [Figure 7](#) shows the complete test setup. The board is connected through the BNC input to the audio analyzer generator output. The output voltage over the selected on-board load resistor is connected through the BNC output to the analyzer input. Two standard AA batteries supply the board for a typical V_{IN} of 3-V DC during the test. If using an external bench power supply, some noise can be injected on either the positive input or the ground. The ground is connected to the negative input pin of the amplifier. This type test Setup can impact the total results. This is also valid for the programming connector and any voltage- or ampere-meter connected to the headers during THD + N measurements.

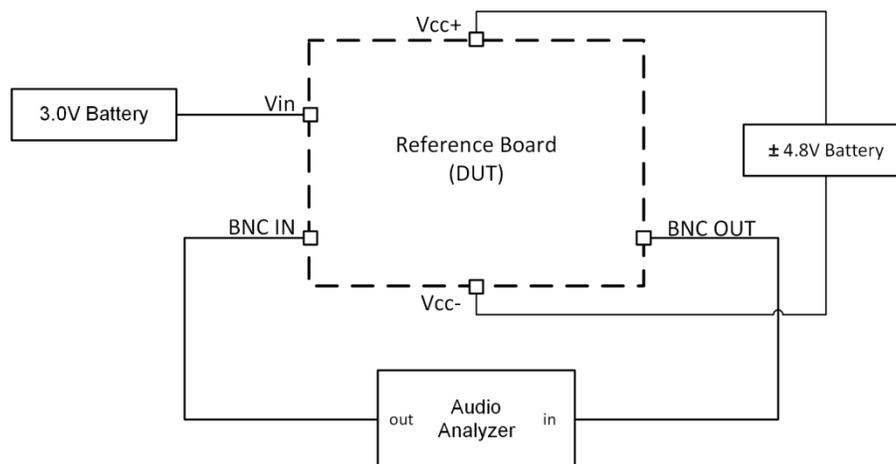


Figure 7. Test Setup

3.2 Schematic

The reference design offers two usable modes:

- **Playback Mode:** The jumpers must be set according to the “Playback Mode” column in Table 1. The board can be used to play an input source in stereo. Both channel (right and left) are connected through the amplifier to the output., Connect the TI PCM5102EVM-U directly to the RCA input to listen to a whole audio chain system (digital source to headphones).
- **Test Mode:** Evaluating the application performance is possible by setting the jumpers to “Test Mode”. In Test Mode the BNC connectors are connected to a single channel (right) of the amplifier. Jumper J19 is used to select the desired load for testing.

Ensure that all jumpers are placed to support one application only, either in the Playback Mode or the Test Mode. For a detailed description of all connection headers and jumpers on the board, refer to [Table 1](#).

Table 1. Jumpers

JUMPER	DESCRIPTION	PLAYBACK MODE	TEST MODE
J1	Supply to Vcc+ connector ⁽¹⁾	1-2	
J2	Input voltage header		
J3	Supply to Vcc- connector ⁽¹⁾	1-2	
J4	Vcc+ and Vcc- header		
J5	Supply enable or disable	2-3, 4-5	
J6	I ² C header		
J7	Left input selector	1-2 RCA 3-4 TRS 5-6 Pin header	None
J8	Left RCA input		
J9	Left amplifier to output TRS connector	1-2	
J10	3.5-mm TRS output		
J11	Right input selector	1-2 RCA 3-4 TRS 5-6 Pin header	None
J12	Right RCA input		
J13	Right amplifier to output TRS connector	1-2	
J14	3.5-mm TRS input		
J15	Right amplifier to output BNC connector	None	1-2
J16	Right amplifier to input BNC connector	None	1-2
J17	Output BNC connector		
J18	Input BNC connector		
J19	Right amplifier load selector	None	1-2: 16 Ω 3-4: 32 Ω 5-6: 604 Ω 7-8: 1.2 kΩ

⁽¹⁾ With Jumper J1 and J3 the supply can be disconnected from the amplifier to measure current or supply an external amplifier.

The schematic in Figure 8 shows the power supply and the audio section of the design.

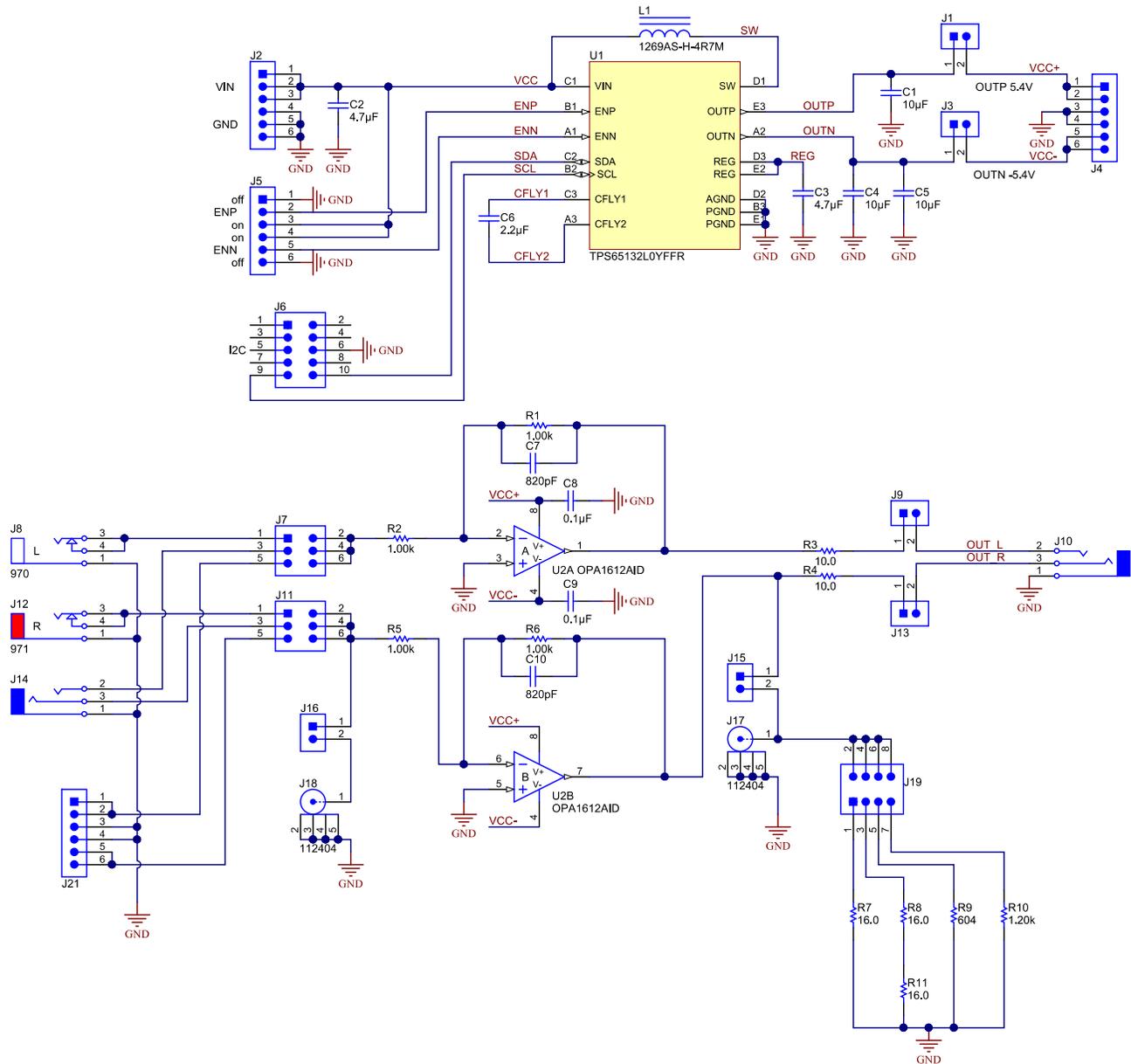


Figure 8. Schematic

3.3 Test Results

Figure 9 shows the absolute test result for the distortion and noise of the headphone amplifier when supplied with ± 4.8 V on the respective pins V_{CC+} and V_{CC-} . In one measurement, the OPA1612 amplifier is supplied by another pair of batteries, which is considered to be a low-noise voltage source. In the other measurement, the amplifier is supplied by the TPS65132 device. The input voltage for the TPS65132 switching converter is maintained by 3-V batteries.

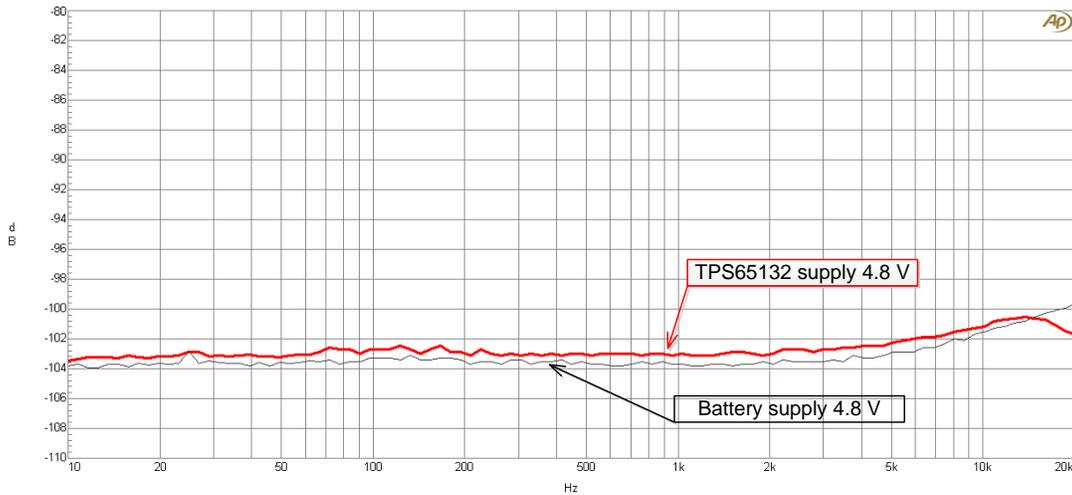


Figure 9. THD + N Battery Versus TPS65132

This design approach degrades the THD + N of the system only by an average of < 1 dB compared to the external battery and provides an excellent result by combining a small number of components and a small solution size.

There are further approaches to achieve or even improve the total distortion. One such approach is to filter the negative rail of the TPS65132 switching converter by connecting an external LDO on its output.

Figure 10 shows the relative comparison of the battery supply with different approaches. To test the LDO performance, the TPS72301 LDO was chosen. This LDO comes in a small SOT23 package and is capable of currents up to 200 mA with low noise and a high power supply rejection ratio (PSRR). If there is a need to decrease the THD + N even further, that option is suitable.

Figure 11 shows the THD + N versus the output power with different load resistors, which represent the typical impedance of different headphones. For all amplitudes, the perturbation frequency is 1 kHz. The output voltage is set to ± 5.0 V for these measurements.

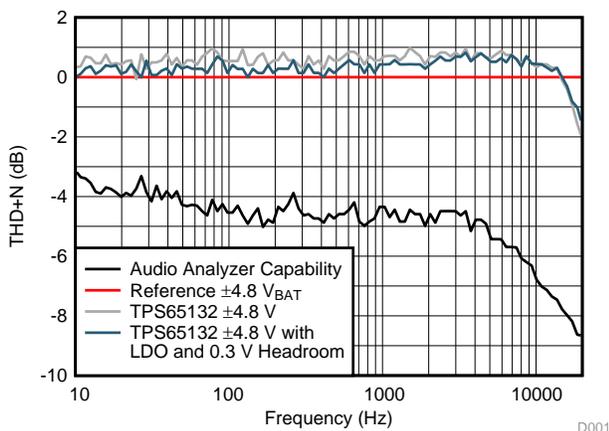


Figure 10. Power Supply Comparison at 10 mW, $R_L = 32 \Omega$

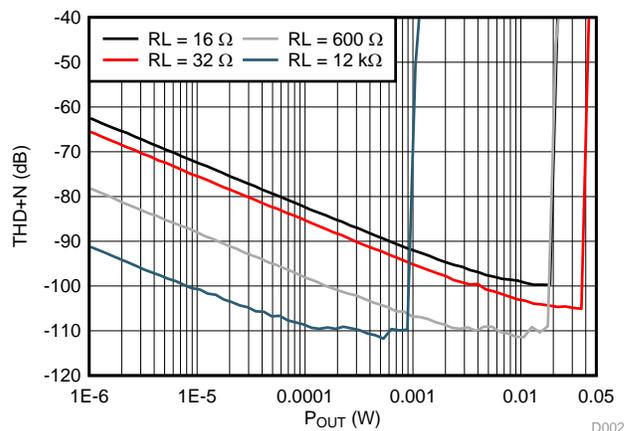


Figure 11. THD + N Versus Output Power

4 Summary

The TPS65132 switching converter is a very good solution for a handheld music playback system. The device can supply currents up to 150 mA, has only a few external components, and ensures a high-fidelity audio performance for a mobile device. With a high peak efficiency of over 90% and flexible programming, the device is suitable for multiple state-of-the-art audio amplifiers such as the OPA1612.

The ability to program the TPS65132 enables the user to set the output current and voltage for the desired application. If the amplifier is able to drive higher output power, the output current of the TPS65132 can be set to 80 mA or 150 mA. Refer to the TPS65132 ([SLVSBM1](#)) datasheet if currents higher than 80 mA are required.

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