TI Designs

Hi-Fi Headphone Amplifier Power Supply Reference Design

Description

Headphone amplifiers usually require positive and negative voltages. In this reference design, both voltages are generated from a single input voltage with an integrated split-rail charge-pump converter. It provides a small solution size with five capacitors and four resistors.

Resources

TIDA-01341	Design Folder
LM27762	Product Folder
OPA1622	Product Folder

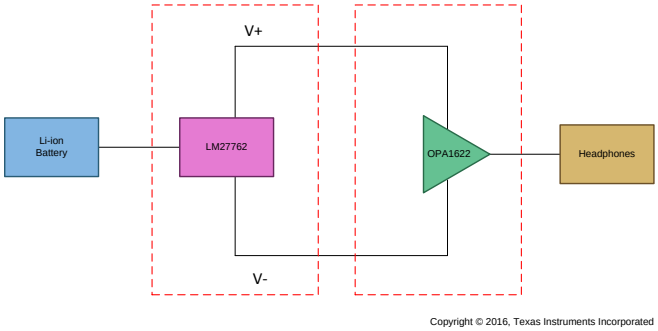
ASK Our E2E Experts

Features

- Small Solution Size
- Low Distortion
- Small BOM - Only Nine External Components
- Adjustable Output Voltages
- Tested Circuit Design - Test Report and Design Files Included

Applications

Smartphone Hi-Fi Audio



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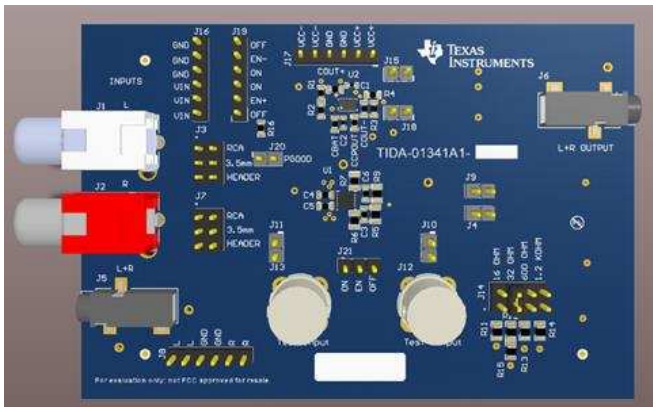

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1 System Overview

1.1 System Description

The system consists of two main parts, a power supply and an audio amplifier. It is designed to operate directly from a Li-ion battery.

The power supply is based on the LM27762 device. It provides adjustable regulated positive and negative operating voltages for audio amplifier. Negative output voltage is generated by an inverting charge pump. In audio applications it is important that power supply introduces as little noise as possible to the amplifier power rail. As the both outputs in the LM27762 device have internal LDOs, the achieved output ripple is extremely low.

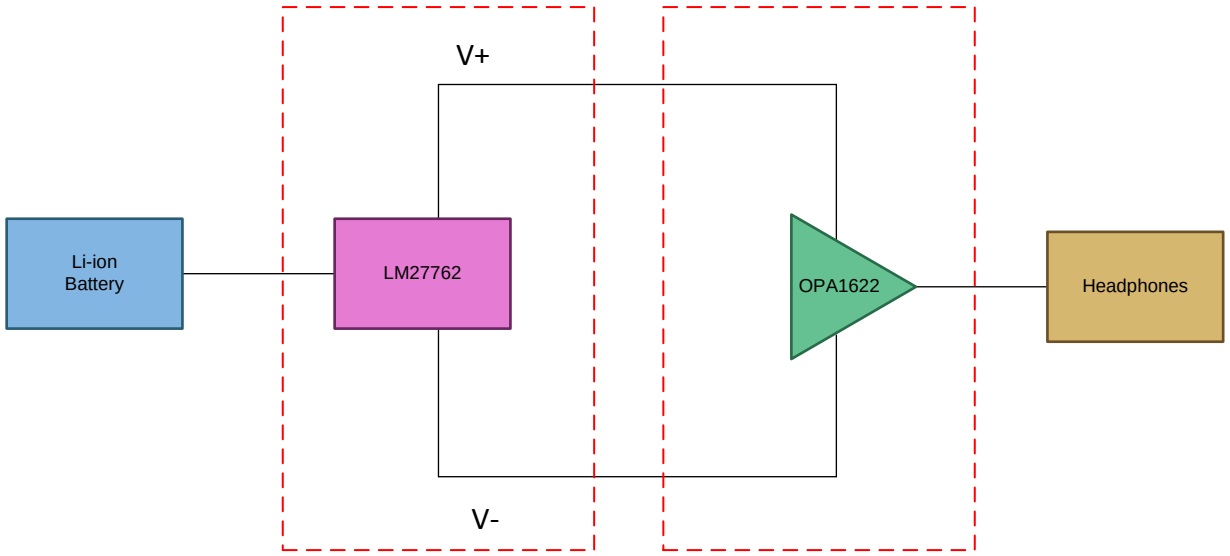
The audio amplifier used for this design is the OPA1622 operational amplifier. In this design it is used in a single-ended configuration. The OPA1622 device delivers excellent audio performance with very low noise density and ultra-low total harmonic distortion + noise (THD+N). It has high capacitive-load-drive capability — and important feature in driving mobile device headphones.

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
Input voltage	2.7 V to 5.5 V
Output voltage	From ±1.5 V to ± 5 V
Output current	250 mA per output
THD+N	Better than –107 dB at 1 kHz
Noise density	2.8 nV/sqrt (Hz)

1.3 Block Diagram



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1.4 Highlighted Products

1.4.1 LM27762 Low-Noise Positive- and Negative-Output Charge Pump

- Generates low-noise adjustable positive supply (from 1.5 V to 5 V) and negative supply (from –1.5 V to –5 V)
- ±250-mA output current
- Inverting charge pump followed by negative LDO
- Current limit and thermal protection
- Power Good pin

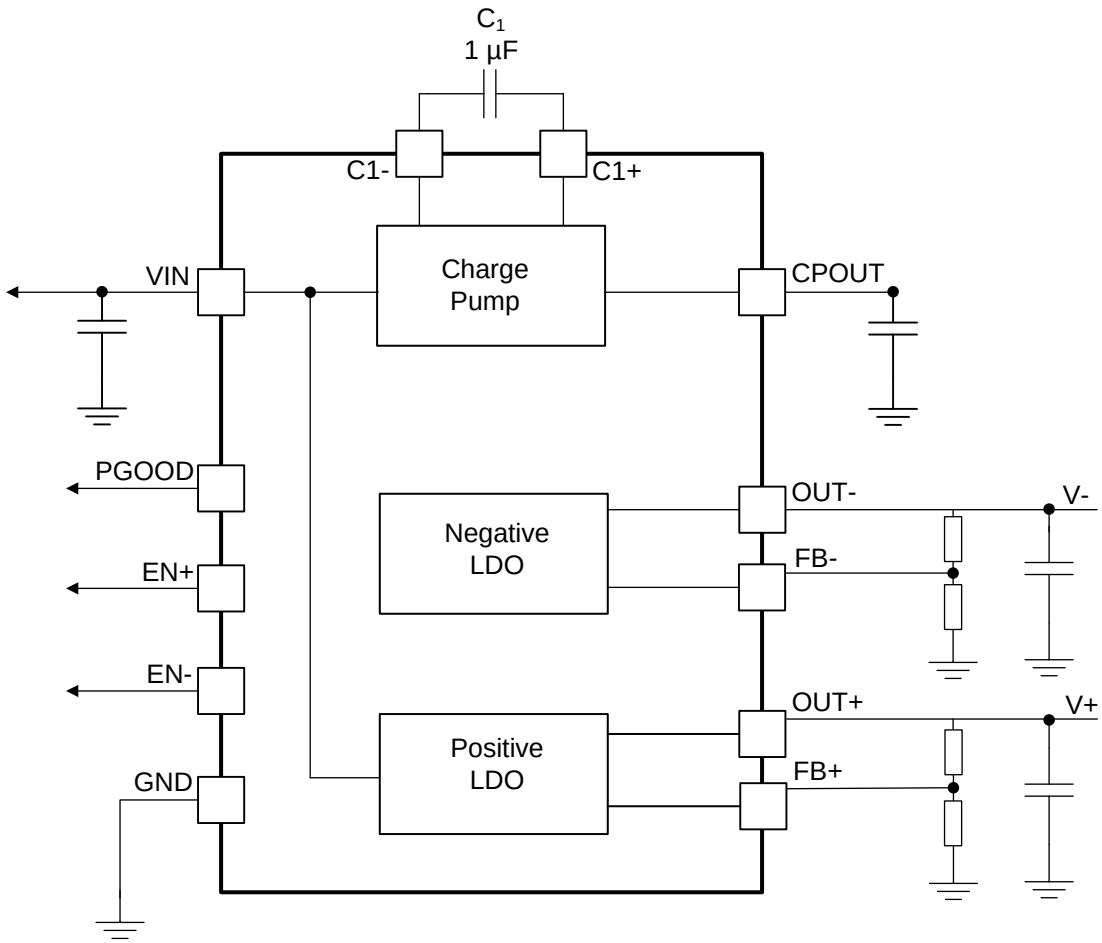

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Figure 1. Block Diagram of LM27762 Device

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1.4.2 OPA1622 SoundPlus™ Audio Operational Amplifier

- High-fidelity (Hi-Fi) sound quality
- Ultra-low-noise 2.8 nV/sqrt (Hz) at 1 kHz
- Ultra-low total harmonic distortion + noise: –119 dB THD+N (142 mW/channel into 32 Ω/channel)
- Wide gain bandwidth product: 32 MHz (G = 1000)
- Power Good pin

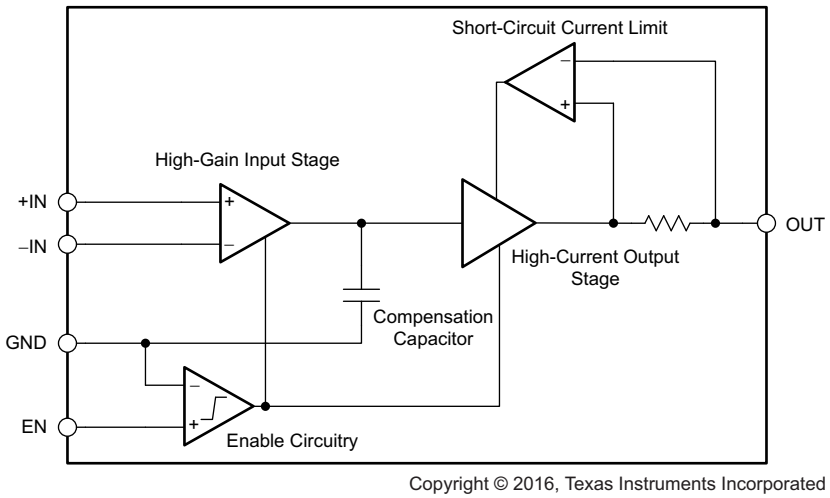

Figure 2. Block Diagram of OPA1622 Device

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2 Getting Started Hardware

The board has several options for power supply, input, and output connections and selectable load resistors which can be used in performance measurements. The output voltage of the LM27762 device is set to ±5 V as default. If lower output voltage is preferred for the headphones being used, it is possible to adjust it with resistors.

2.1 Hardware

The power supply must be connected to connector J16. Input voltage range is from 3.3 V to 5.5 V. Place jumpers to headers J19, J21, J15, and J18 as shown in Figure 3.

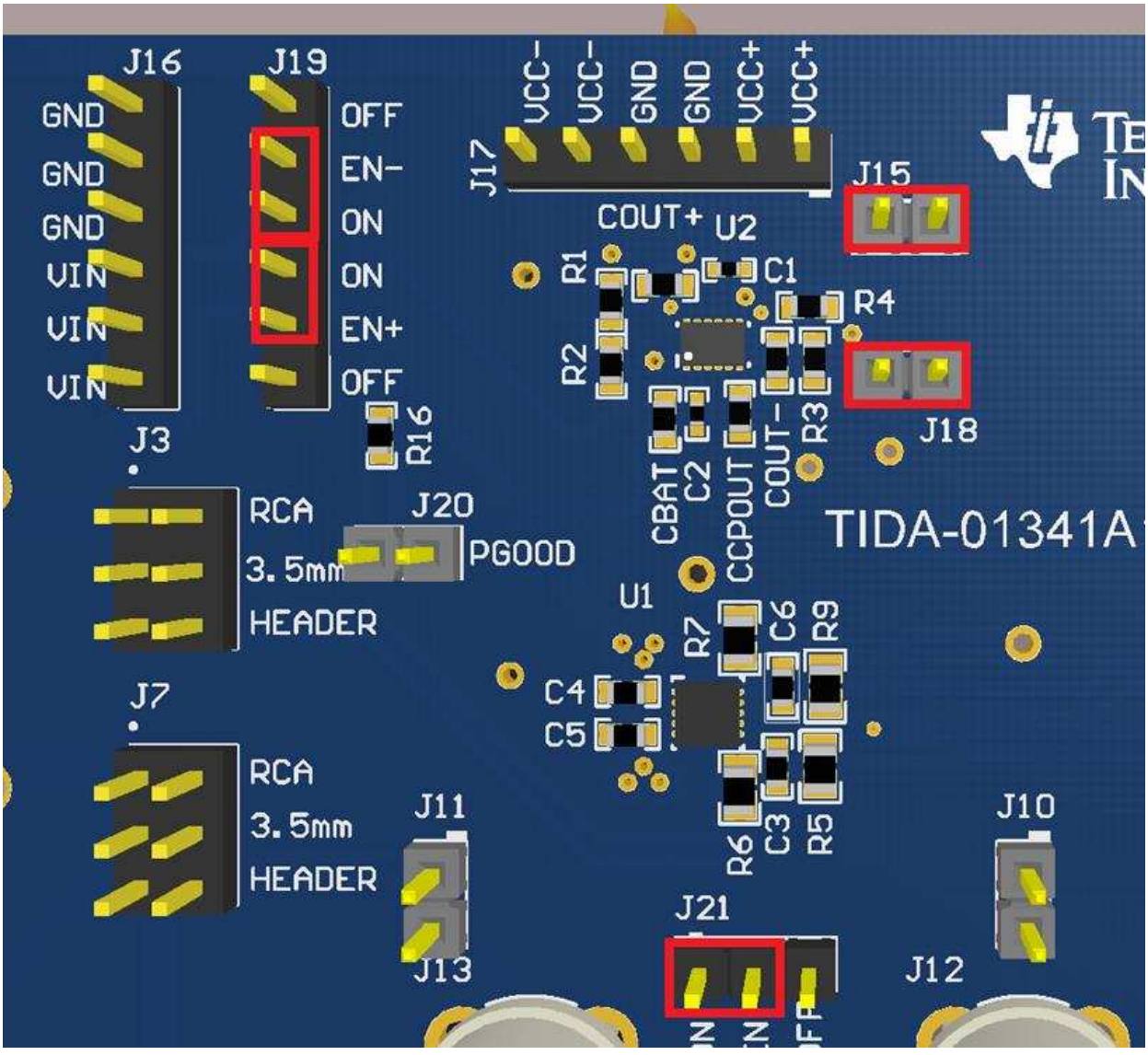

Figure 3. Jumper Placement and Power Connector

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2.2 Input and Output Connectors

An input signal can be connected to the board through:

- RCA connectors (J1 and J2)
- 3.5-mm stereo connector (J5)
- Pin header (J8)

For audio output signal there is a 3.5-mm stereo connector (J6).

Place jumpers to headers J3 and J7 to select appropriate input connector. Place jumpers to headers J4 and J9 to connect output signal to output connector as shown in Figure 4.

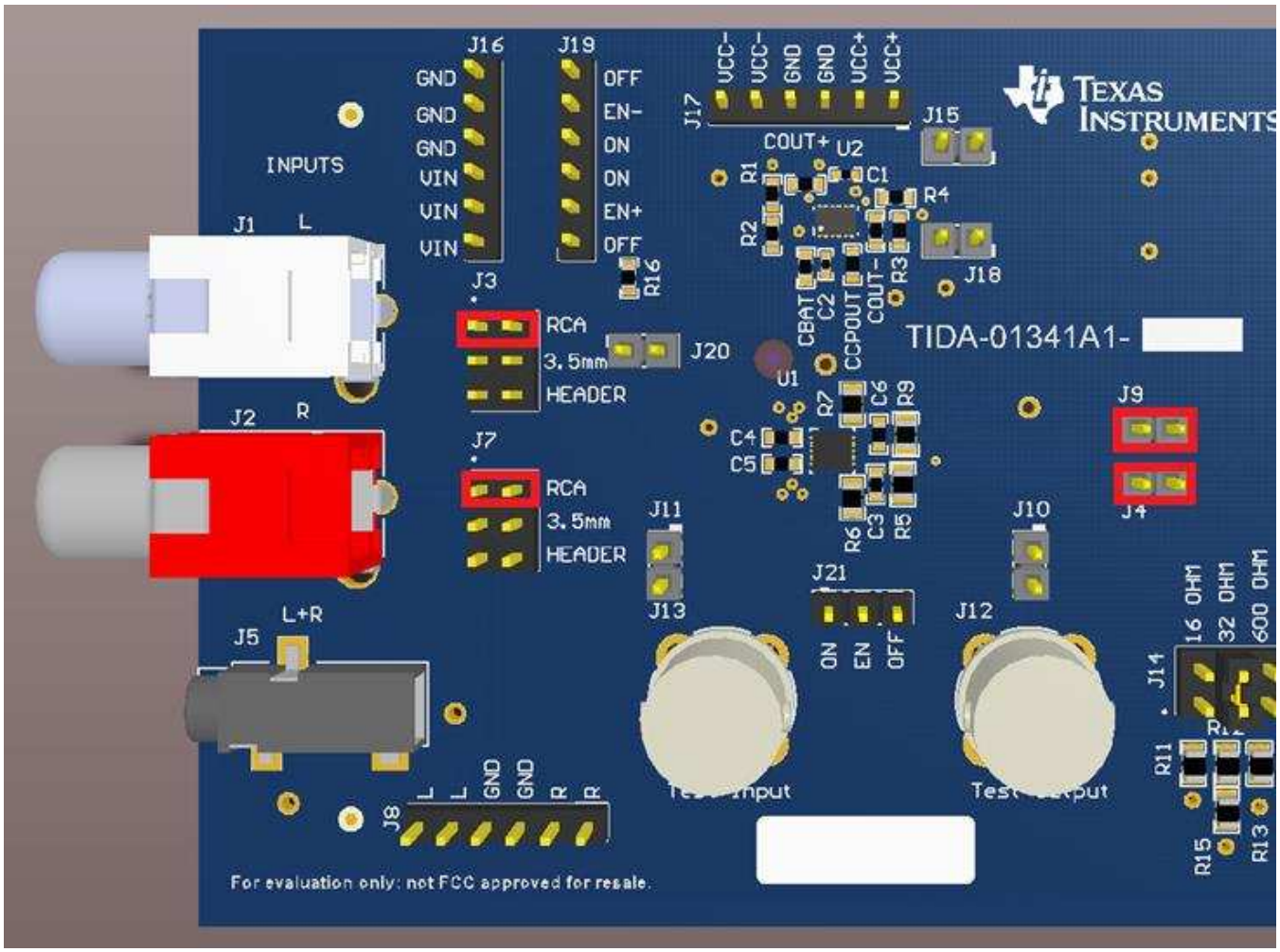

Figure 4. Jumper Placement and Power Connector

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2.3 Load Resistors

The design features the following onboard load resistors: 16 Ω, 32 Ω, 600 Ω and 1.2 kΩ. These can be used as load for the amplifier when doing measurements. For example, to select the 32-Ω load, place jumper to header J14 as shown in Figure 5 to select a load.

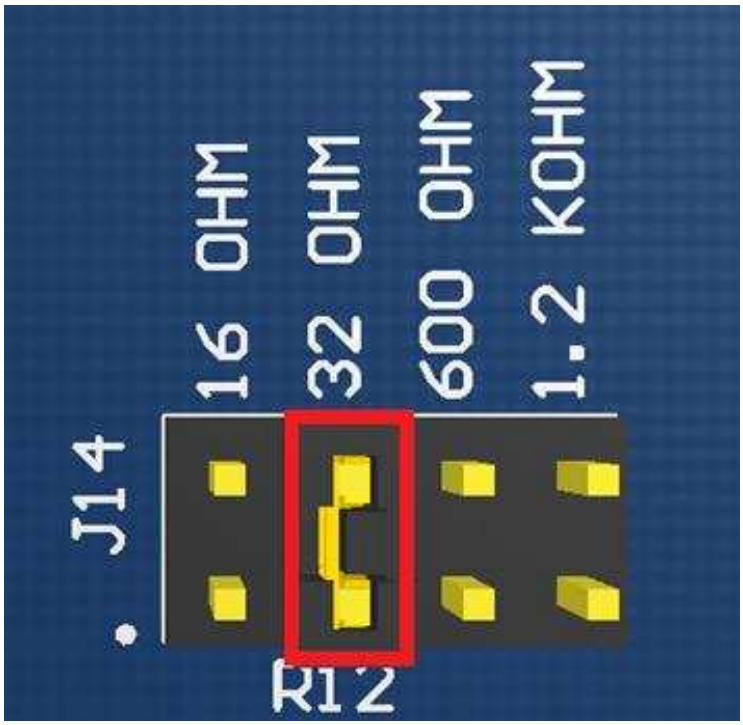

Figure 5. Selecting Load Resistor

2.4 Setting Output Voltage

The output voltage of the LM27762 device can be adjusted by replacing resistors R1...R4. Positive output voltage for given resistor values is:

$$V_{OUT} = 1.2\ V \times (R1 + R2) / R2 \quad (1)$$

And the negative output voltage:

$$V_{OUT} = -1.2\ V \times (R3 + R4) / R4 \quad (2)$$

Note that the value of R2 and R4 must be no less than 50 kΩ.

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3 Testing and Results

Performance of the power supply was verified by measuringTHD+N with different input voltages and output loads. Measurements were performed using Audio Precision SYS-2722 audio analyzer.

3.1 Test Setup

A top-level diagram of test setup is shown in Figure 6. The power supply used provides input voltage for the LM27762 device. For reference measurements amplifier can be powered directly from a laboratory power supply or battery.

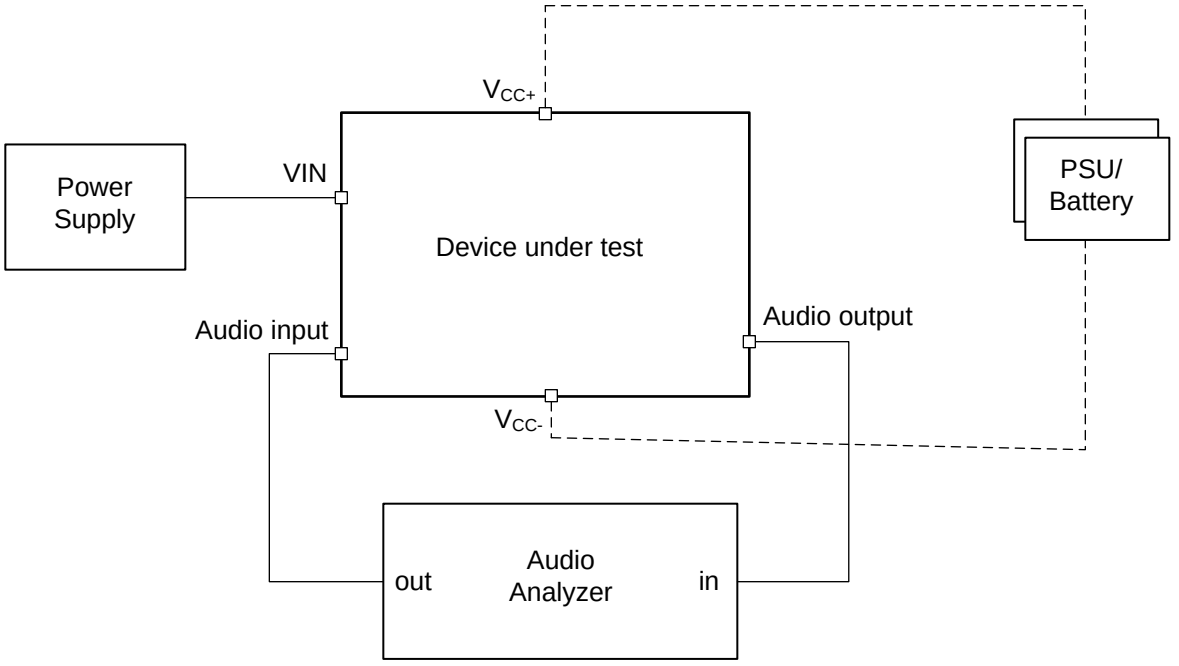

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Figure 6. Test Setup

Measurements were done in three steps:

1. Measurement of the amplifier using ±3-V battery as a power supply.
2. Measurement of the amplifier using the laboratory power supply.
3. Measurement of the complete system using the laboratory power supply.

In each step, three types of measurements were done:

- Fast-fourier transfer (FFT) of output signal using 1-V_{RMS}, 1-kHz sine wave as input signal
- THD+N vs frequency
- THD+N vs output power or amplitude

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3.2 Test Results

For all THD+N vs frequency measurements, the input signal was swept from < 10 Hz to 20 kHz and had an amplitude of 1 V_{RMS} on the output of the OPA1622 device. Measurement bandwidth of the audio analyzer was set to 80 kHz.

Figure 7 shows that using the LM27762 device as a power supply, the THD+N degrades only by an average of < 2 dB compared to battery-powered systems.

For all THD+N vs amplitude / power measurements, the output amplitude was swept from 10 mV_{RMS} to 3 V_{RMS} at frequency of 1 kHz. The measurement bandwidth of the audio analyzer was set to 22 kHz.

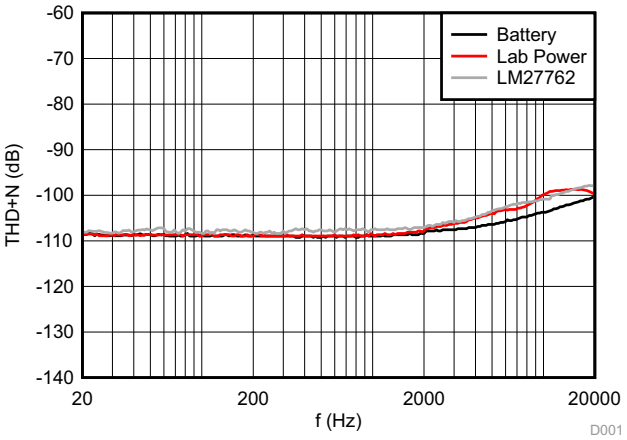

Figure 7. THD+N vs Frequency

Figure 8 shows that maximum output power is limited by operating voltage of the OPA1622 device. For example, with a 32-Ω load, the operating voltage of the amplifier is ±3 V. The OPA1622 device requires a 900-mV headroom for V_{CC}, so the maximum amplitude of the output signal is 2.1 VP (1.48 V_{RMS}).

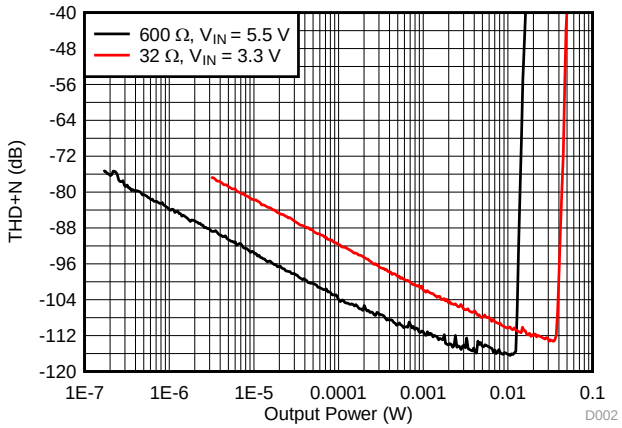

Figure 8. THD+N vs Output Power

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For all FFT measurements, a frequency of 1 kHz and amplitude of 1 V_{RMS} on the output was used. The 1-V_{RMS} fundamental corresponds to 0 dBV (see Figure 9).

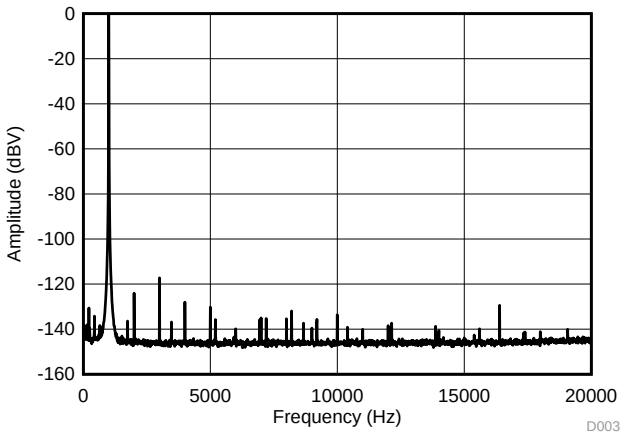

Figure 9. FFT of Left Channel With 32-Ω Load

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4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-01341.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01341.

4.3 PCB Layout Recommendations

The high switching frequency and large switching currents of the LM27762 make the choice of layout important. Use the following steps as a reference to ensure the device is stable and maintains proper light-emitting diode (LED) current regulation across its intended operating voltage and current range.

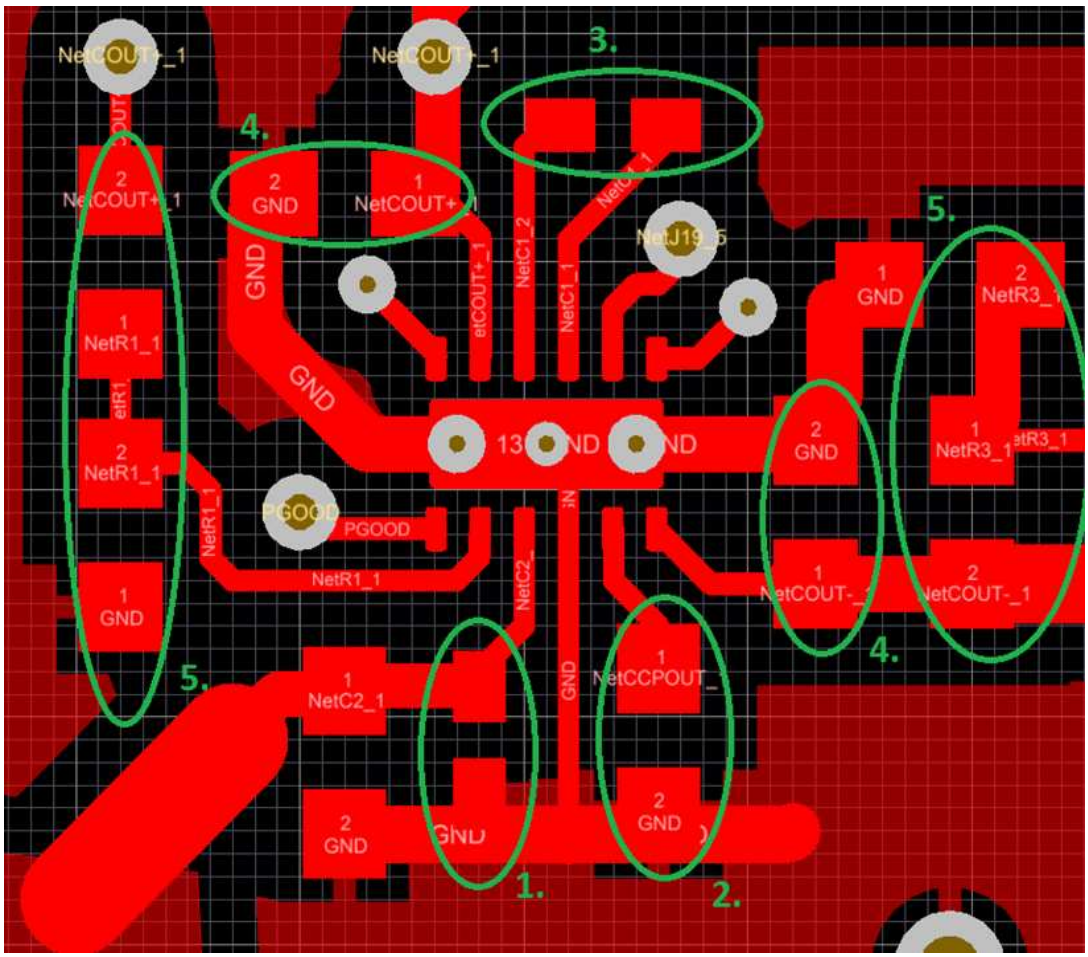

Figure 10. Recommended PCB Layout

1. Place C_{IN} on the top layer and as close as possible to the device.
2. Place C_{CPOUT} on the top layer and as close as possible to the CP and GND pins. The returns for both C_{IN} and C_{CPOUT} must come together at one point, as close as possible to the GND pin.
3. Place C1 on the top layer and as close as possible to the device.
4. Place C_{OUT+} and C_{OUT-} on the top layer and as close as possible to the respective OUT pin.
5. Place R1 to R4 on the top layer and as close as possible to the respective FB pin. For the best performance the ground connection of R2 and R4 must connect back to the GND connection at the thermal pad of the device.

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4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01341.

4.4 Altium Project

To download the Altium project files, see the design files at TIDA-01341.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01341.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01341.

5 Software Files

To download the software files, see the design files at TIDA-01341.

6 Related Documentation

1. Texas Instruments, *Handbook of Operational Amplifier Applications*, Application Report (SBOA092)
2. Texas Instruments, *Chapter 10, Op Amp Noise Theory and Applications* (SLOA082)

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7 Terminology

THD+N - Total Harmonic Distortion + Noise

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