参考資料

TI Designs: TIDA-050024
中電力オーディオ・パワー・アンプ・アプリケーション用のエンベロープ・トラッキング電源のリファレンス・デザイン

TEXAS INSTRUMENTS

概要

このリファレンス・デザインは、TI 製の TPS43061 昇圧コントローラによる、中電力オーディオ・パワー・アンプ (PA) アプリケーション用のエンベロープ・トラッキング電源の回路です。FB ピンにオーディオ・エンベロープ信号を追加することにより、オーディオ信号のエンベロープに応じて昇圧コンバータの出力電圧を変化させられます。昇圧コンバータは動的に変化する電源電圧を PA に供給するため、PA は出力電力範囲の全体にわたって高い効率で動作します。

リソース

TIDA-050024	デザイン・フォルダ
TPS43061	プロダクト・フォルダ
TPS61322	プロダクト・フォルダ
TPA3128D2	プロダクト・フォルダ
TPA3126D2	プロダクト・フォルダ
TLV9064	プロダクト・フォルダ
CSD87355Q5D	

TI E2E™ Community

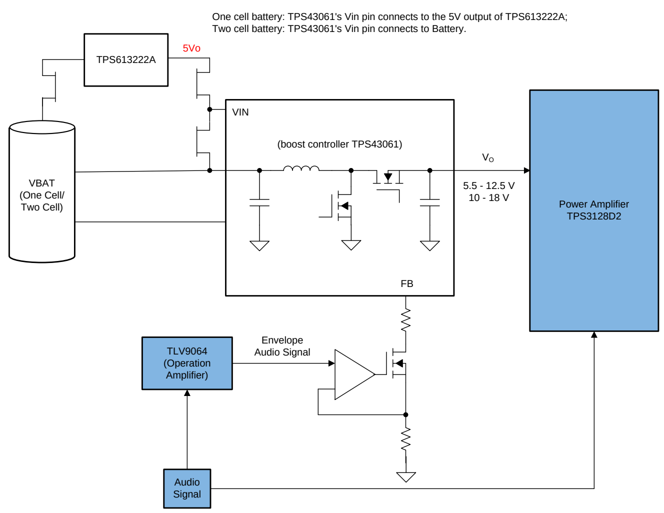
E2E™エキスパートに質問

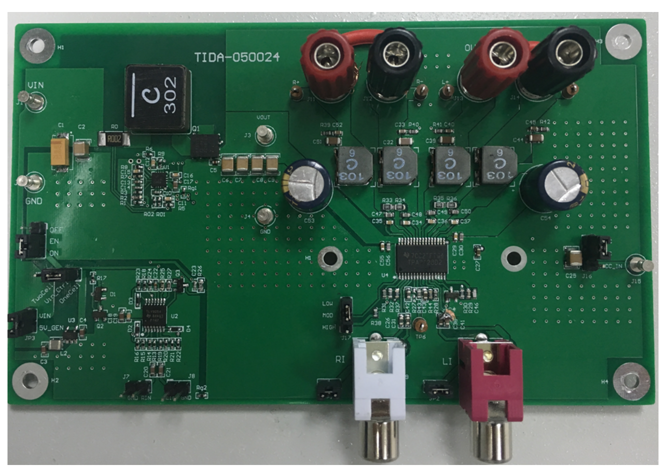
特長

- 広い入力電圧範囲: 2.5～8.4V
- 1 セルのリチウム・バッテリで 2Ω 負荷へ 36W
- 2 セルのリチウム・バッテリで 2Ω 負荷へ 64W
- 高効率
- 長いバッテリ寿命
- 高速応答

アプリケーション

- ワイヤレス・スピーカー
- スマート・スピーカー
- サウンドバー





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1 System Description

In a portable Bluetooth® speaker, battery lifetime is of upmost importance. In most applications, Bluetooth speakers typically work at a low-sensitivity (efficiency) music volume. Therefore, if the supply voltage of the PA set low when the music volume is low, and set high when the music volume is high, the conversion efficiency of the Bluetooth speaker can be greatly improved, therefore extending the battery lifetime to be much longer.

This reference design delivers an envelope-tracking power supply circuit for the PA TPA3128D2 and TPS3126D2 with boost controller TPS43061. The objective of envelope tracking is to improve the efficiency of a PA across the whole output-power range. By adding an audio envelope signal to the FB pin, the output voltage of the boost converter changes in accordance with the envelope of the audio signal, and therefore, the PA operates at high efficiency even when the music volume is low.

1.1 Key System Specifications

表 1 lists the TPS43061 output voltage corresponding to the different amplitude audio signals in a one-cell Lithium-battery-input application. When the audio signal is 0 mV, the output voltage of TPS43061 is 5.5 V. When the audio signal is 300 mV, the output voltage of TPS43061 is 12.5 V.

表 1. System Specifications (One-Cell)

AUDIO SIGNAL_PEAK (mV)	OUTPUT VOLTAGE OF THE BOOST CONVERTER (V)	LOAD RESISTANCE	GAIN OF PA
0	5.50	2 Ω (PBTL mode)	32 DB
50	6.67		
100	7.83		
150	9.00		
200	10.16		
250	11.32		
300	12.50		

表 2 gives the TPS43061 output voltage corresponding to the different amplitude audio signal in a two-cell Lithium battery input application. When the audio signal is 0 mV, the output voltage of TPS43061 is 10 V. When the audio signal is 400 mV, the output voltage of TPS43061 is 18 V.

表 2. System Specifications (Two-Cell)

AUDIO SIGNAL_PEAK (mV)	OUTPUT VOLTAGE OF THE BOOST CONVERTER (V)	LOAD RESISTANCE	GAIN OF PA
0	10	2 Ω/3 Ω (PBTL mode)	32 DB
50	11		
100	12		
150	13		
200	14		
250	15		
300	16		
350	17		
400	18		

2 System Overview

2.1 Block Diagram

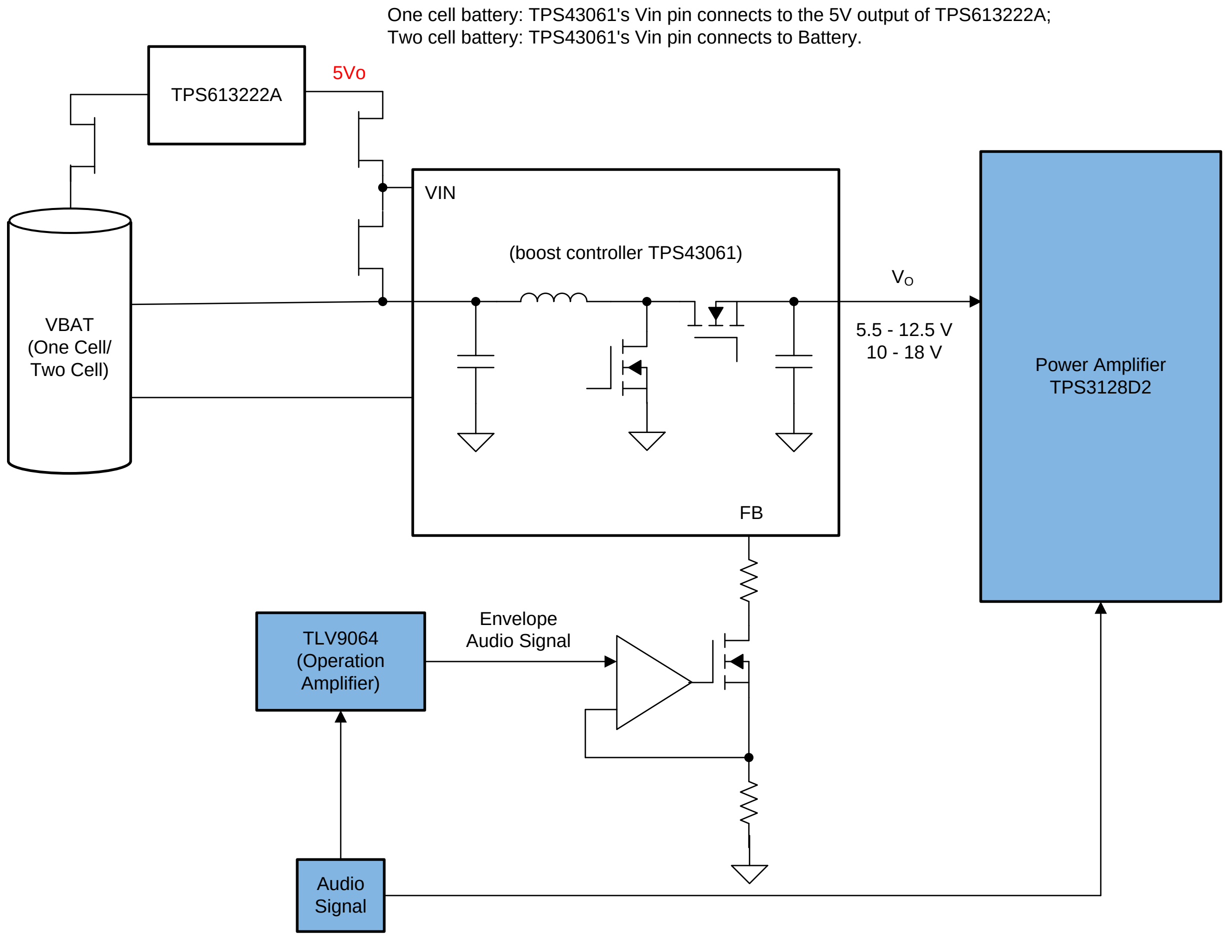

図 1. Block Diagram

図 1 shows the block diagram of TIDA-050024. The minimum start-up voltage of TPS43061 is 4.5 V. In a one-cell Lithium battery input application, a tiny boost converter TPS61322 is added to boost the battery voltage to 5 V to supply the VIN pin of the TPS43061. The TLV9064 operational amplifier (op amp) samples both the left- and right-channel audio inputs and creates an envelope signal. This envelope signal biases a transistor that adjusts the output voltage of the boost converter in accordance with the amplitude of the audio signal. Thus, the supply voltage of the PA goes low when the music volume is low, and the supply voltage of the PA goes high when the music volume is high. These adjustments greatly improve the conversion efficiency of the Bluetooth speaker.

2.2 Design Considerations

By adding a tiny boost converter TPS61322 into the circuit, this reference design can be implemented in both one-cell Lithium battery and two-cell Lithium battery input applications. In a one-cell Lithium battery input application, the supply voltage of the PA can change from 5.5 V to 12.5 V. In a two-cell Lithium battery input application, the supply voltage of the PA can change from 10 V to 18 V.

2.3 Highlighted Products

This TI design incorporates the following devices:

- TPS43061 is a low-IQ current mode synchronous boost controllers
- TPS61322 is a 0.87-V to 5.5-V input, 5-V output synchronous boost converter
- TLV9064 is a low-voltage, low-cost operational amplifier
- TPS3128D2 is a power amplifier for driving speakers up to 60 W in PBTL mode
- TPS3126D2 is a power amplifier for driving speakers up to 100 W in PBTL mode

2.3.1 TPS43061

TPS43061 is a low-IQ, current-mode, synchronous-boost controller with a wide-input voltage range from 4.5 to 38 V and boosted output range up to 58 V. Synchronous rectification enables high efficiency for high-current applications. The resulting low-power losses, combined with a 16-pin 3-mm × 3-mm WQFN package, support high power density and high-reliability boost converter solutions over an extended (–40°C to +150°C) temperature range. The TPS43061 has a 5.5-V gate-drive supply and driver strength optimized for low Qg NexFET power MOSFETs. Also, TPS43061 provides an integrated bootstrap diode for the high-side gate driver to reduce the external parts count.

2.3.2 TPS613222A

TPS61322A is an orderable part number option for TPS61322, a synchronous boost converter with only 6.5-μA quiescent current. TPS613222A provides a power-supply solution for products powered by alkaline batteries, NiMH rechargeable batteries, or one-cell Li-ion batteries. The minimum current limit is 1.2 A. The device is based on a hysteretic control topology using synchronous rectification to obtain maximum efficiency at minimal quiescent currents.

2.3.3 TLV9064

The TLV9064 is a quad, low-voltage (1.8 V to 5.5 V) op amp with rail-to-rail input- and output-swing capabilities. This device is a highly cost-effective solution for applications where low-voltage operation, a small footprint, and high capacitive-load drive are required. Although the capacitive-load drive of the TLV9064 is 100 pF, the resistive open-loop output impedance makes stabilizing with higher capacitive loads simpler. This op amp is designed specifically for low-voltage operation (1.8 V to 5.5 V) with performance specifications similar to the OPAx316 and TLVx316 devices.

2.3.4 TPA3128D2

The TPA3128D2 is a digital amplifier for driving speakers up to 60 W/ 2 Ω in parallel bridge tied load (PBTL) mode. The TPA3128D2 has low idle-power loss and helps to extend the battery life of Bluetooth/wireless speakers and other battery-powered audio systems. The high efficiency of the TPA3128D2 device allows it to do 2 × 30 W without external heat sink on a dual-layer PCB. This device proposed an efficiency-boost mode, which can dynamically reduce the current ripple of the external LC filter and the idle current. The TPA3128D2 device is fully protected against faults with short-circuit protection and thermal protection as well as overvoltage, undervoltage, and DC protection. Faults are reported back to the processor to prevent devices from being damaged during overload conditions.

2.3.5 TPA3126D2

The TPA3126D2 is a 50-W, stereo, low-idle-current Class-D amplifier in a thermally enhanced package. The TPA3126D2 includes TI's proprietary hybrid modulation scheme, which dynamically reduces idle current at low power levels to extend the battery life of portable audio systems, such as Bluetooth speakers.

2.4 System Design Theory

図 2 shows the boost converter schematic of TIDA-050024. A tiny boost converter TPS61322 is added to convert the one-cell battery voltage to 5 V. Thus, the boost controller TPS43061 can start up successfully at the one-cell battery input condition. TPS61322 is not required in two-cell battery-input applications. 図 3 shows the power amplifier schematic of TIDA-050024.

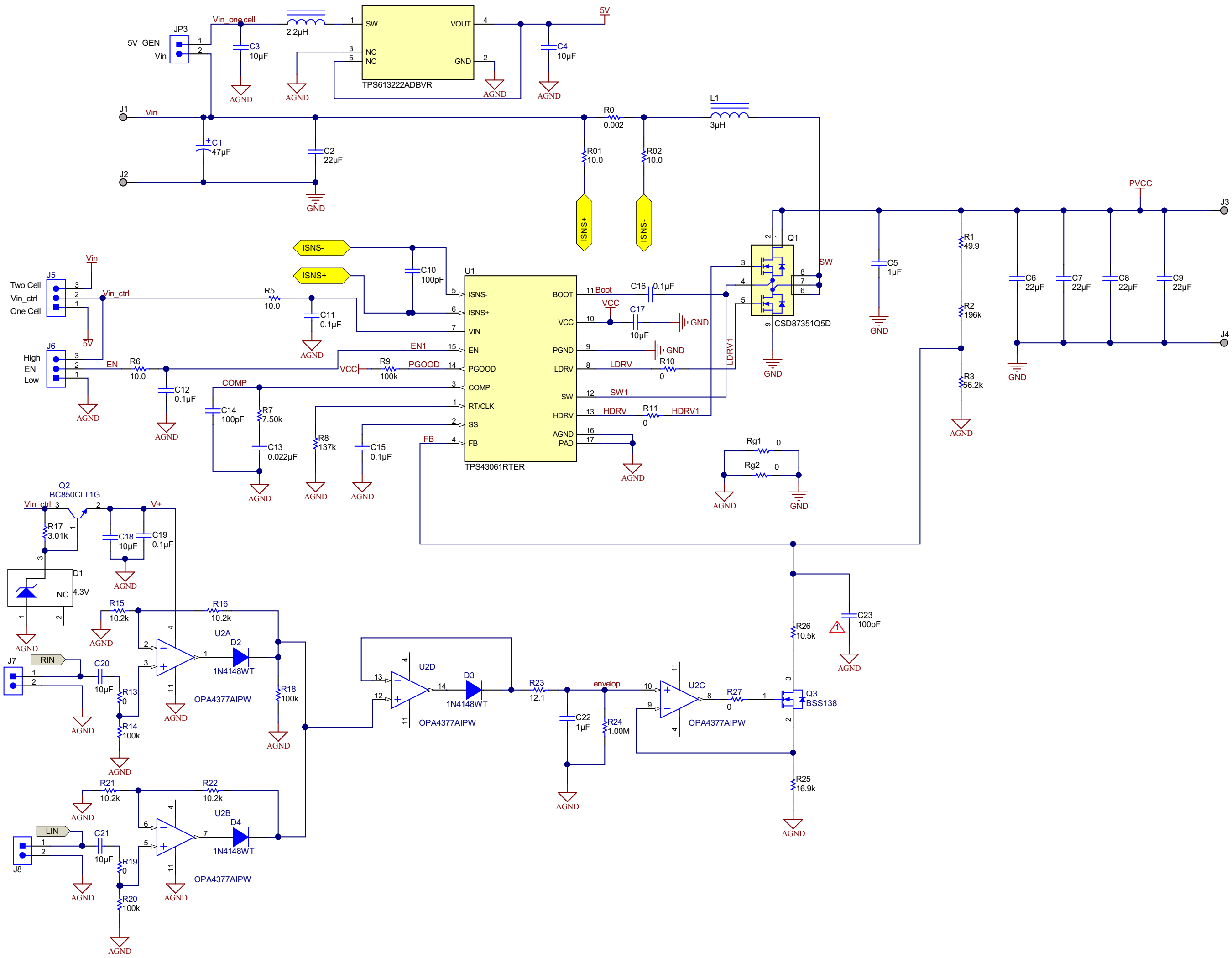

図 2. Schematic of TIDA-050024 (Boost Converter)

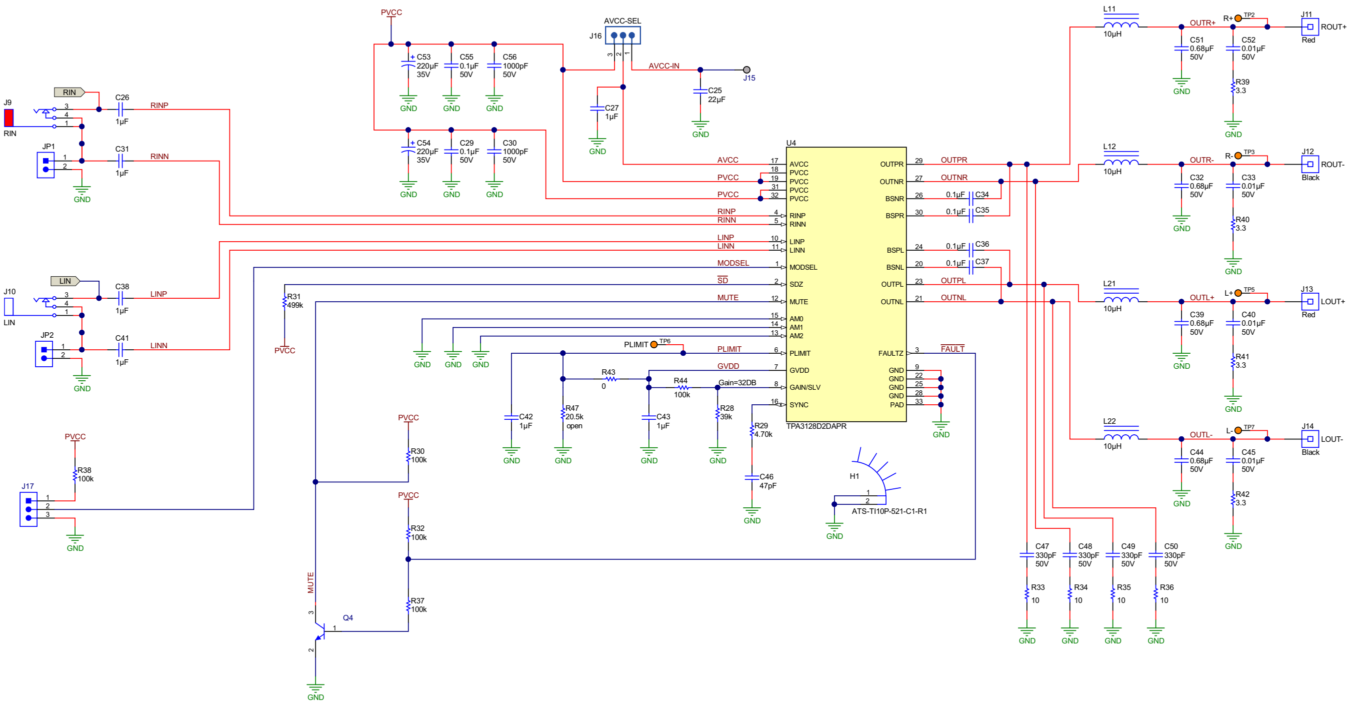

図 3. Schematic of TIDA-050024 (Power Amplifier)

The U2A op amp detects the audio signal from the right channel. U2B detects the audio signal from the left channel. The output of U2A and U2B is connected together by D2 and D4 so only the audio signal with higher volume can pass through. The op amp U2D, diode D3, resistor R23, R24, and capacitor C22 form the envelope-tracking circuit. It samples out the peak envelope waveforms of the input audio signal. Op amp U2C, MOSFET Q3, and resistor R16 convert the envelope voltage signal to an envelope-current signal. This envelope-current signal changes the output voltage of the TPS43061 in accordance with the amplitude of the input audio signal.

When the input audio signal is 0 V, the output of the envelope-tracking circuit is 0 V, and the current flowing through Q3 is 0 A. The output voltage is determined by the dividing resistor R2 and R3. A standard low-side 56.2-kΩ resistor, R3, is used in this example. The high-side resistor R2 can be calculated by 式 1:

$$\frac{V_{O(min)} - V_{FB}}{R2} = \frac{V_{FB}}{R3}$$

where

- V_{FB} is TPS43061 feedback regulation voltage (V_{FB} = 1.22 V)
- $V_{O(min)}$ is the minimum output voltage the boost converter, defined as 5.6 V in the one-cell battery input application and 10 V in the two-cell battery input application. (1)

Thus, when $V_{O(min)}$ = 5.5 V, R2 = 196 kΩ; when $V_{O(min)}$ = 10 V, R2 = 402 kΩ.

When the input audio signal reaches its maximum amplitude, the current flowing through Q3 also reaches its maximum value.

$$I_{Q3(max)} = \frac{\left(V_{O(max)} - V_{FB}\right)}{R2} - \frac{V_{FB}}{R3} \quad (2)$$

Value for resistor R25 can be calculated by 式 3:

$$R25 = \frac{V_{envelop(max)}}{I_{Q3(max)}} \quad (3)$$

where

- $V_{envelop(max)}$ is two times the maximum amplitude of the input audio signal. It is defined as 2 × 300 mV in the one-cell battery input application and 2 × 400 mV in the two-cell battery input application.

In the one-cell battery input application, R25 = 18.7 kΩ; in the two-cell battery input application, R25 = 40.2 kΩ.

The resistance of R26 must be small enough to make sure the total voltage drop across the R25 and R26 is lower than the feedback regulation voltage V_{FB} of the TPS43061.

3 Hardware, Testing Requirements, and Test Results

3.1 Required Hardware

3.1.1 Hardware

This reference design uses following hardware to do the measurement:

- 20-A output capability DC power supply
- One 2-Ω/100-W and one 3-Ω/100-W resistive load
- Digital oscilloscope
- Signal generator

3.2 Testing and Results

3.2.1 Test Setup

This section describes how to properly connect and set up the TIDA-050024.

- Connect the positive terminal of DC power supply to J1 (V_{IN}), and its GND terminal to J2 (GND).
- Connect the TPA3128 / TPA3126 in PBTL mode, short ROUT+ and ROUT–, short LOUT+ and LOUT–.
- Connect the 2-Ω /100-W resistive load between ROUT and LOUT.
- Keep the DC power supply off. Set the DC power supply to 3.75 V/7.2 V.
- Short JP3 in the one-cell battery input application, leave JP3 open in the two-cell battery input application.
- Short pin1 and pin2 of J5 in the one-cell battery input application, short pin2 and pin3 of J5 in the two-cell battery input application.
- Short pin2 and pin3 of J6.
- Turn on the DC power supply.

3.2.2 Test Results

図 4 shows the output voltage versus the amplitude of the input audio signal at the one-cell Lithium battery-input application. 図 5 shows the output voltage versus the amplitude of the input audio signal at the two-cell Lithium battery input application.

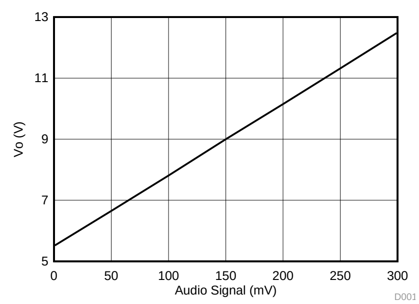

図 4. V_{OUT} vs Audio Signal (One-cell)

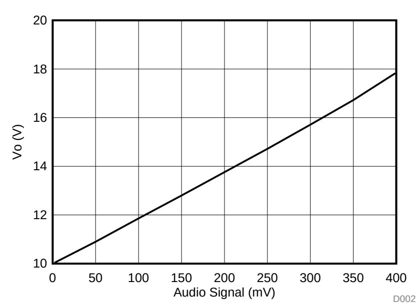

図 5. V_{OUT} vs Audio Signal (Two-cell)

図 6 through 図 9 show the output voltage transition of the boost converter from $V_{O(min)}$ to $V_{O(max)}$ when the input audio signal steps up from 0 mV to 300 mV (V_{IN} = 3.6 V, R_{LOAD} = 2 Ω). The output voltage of TPS43061 rises up from the lowest value to the highest value within approximately 0.5 ms at this big audio signal step. TIDA-050024 uses two 220-µF electrolytic capacitors at the output side of the TPS43061, which act as the decoupling capacitors of TPA3128D2. Changing from two 220-uF electrolytic capacitors to two 470-uF electrolytic capacitors, the output voltage of TPS43061 can rise from $V_{O(min)}$ to $V_{O(max)}$ within around 1 ms in the worst-case conditions.

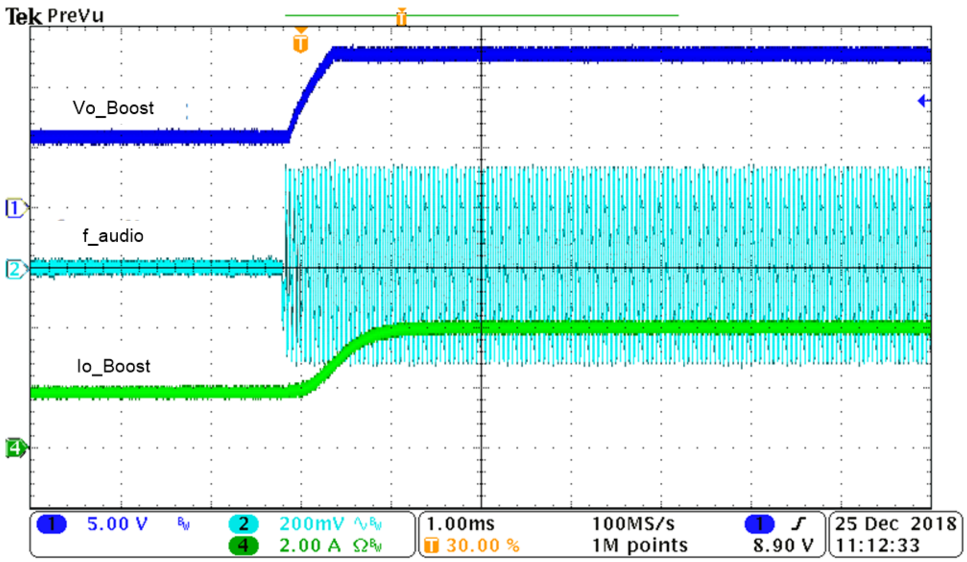

図 6. Output Voltage Transition at f_audio = 20 kHz

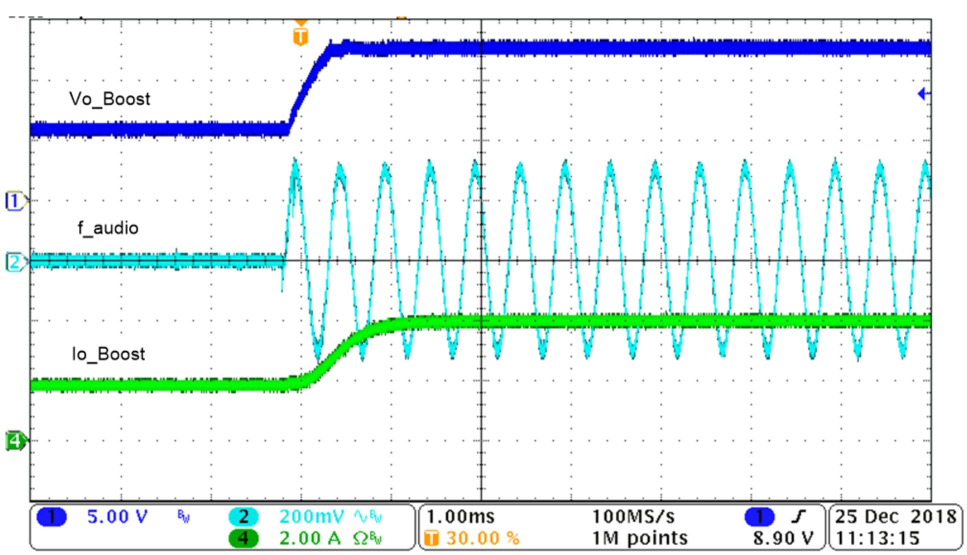

図 7. Output Voltage Transition at f_audio = 2 kHz

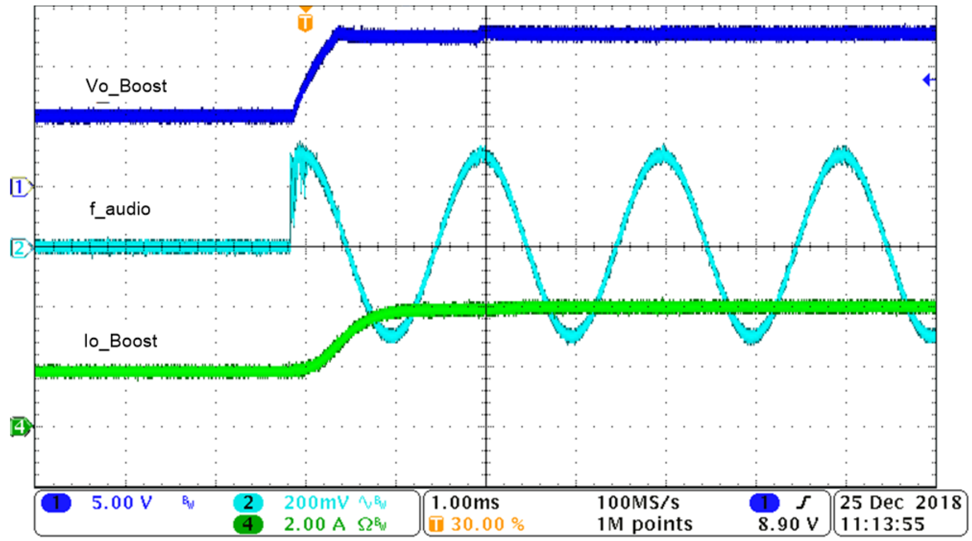

図 8. Output Voltage Transition at f_audio = 500 Hz

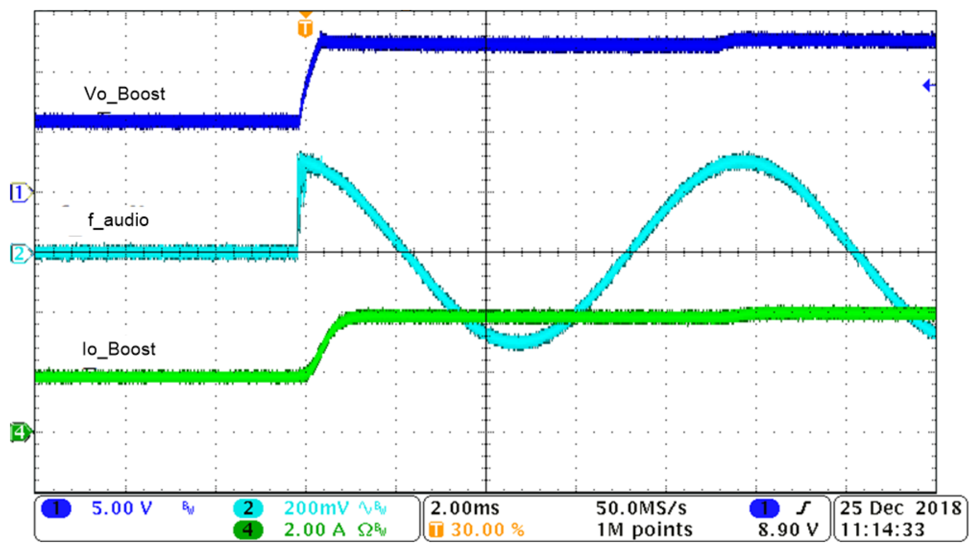

図 9. Output Voltage Transition at f_audio = 100 Hz

図 10 shows the waveforms of the input audio signal and the output voltage of TPS43061 while playing music. The output voltage of TPS43061 changes in accordance with the input audio signal.

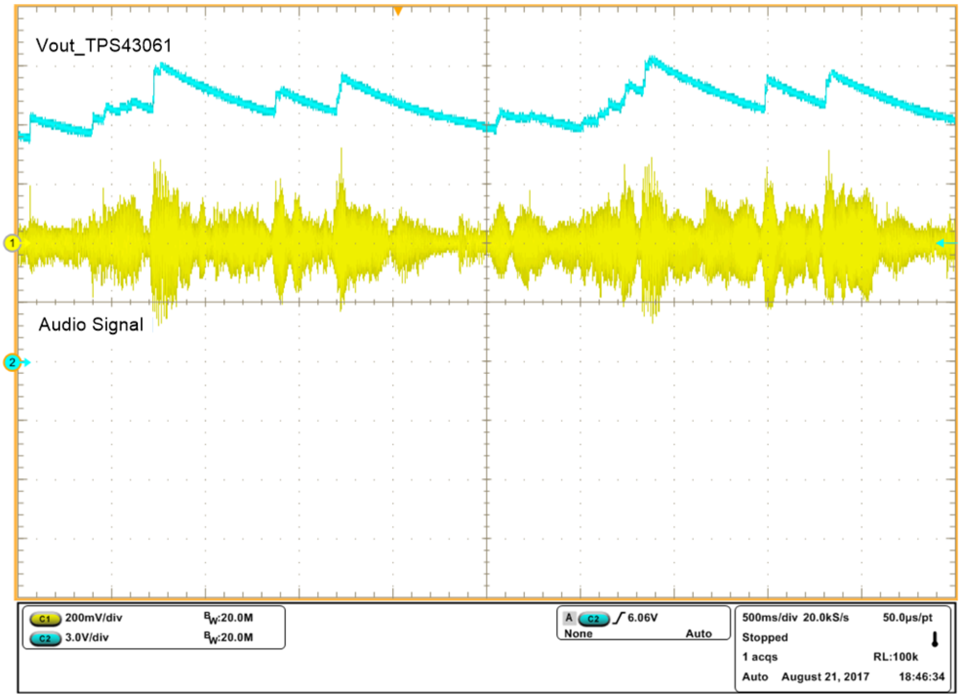

図 10. Output Voltages of the TPS43061 While Playing Music

図 11, 図 12, 図 13, and 図 14 show the results of comparing the efficiency of the TIDA-050024 envelope-tracking solution with the traditional fixed-supply-voltage solution. With an envelope-tracking solution, the system efficiency is more than 15% higher than that of the fixed-supply-voltage solution when the music volume is low. In most real application conditions, the music volume is low or medium, so with TIDA-050024 the battery lifetime can be greatly prolonged. With TPA3126D2, the total conversion efficiency is about 4% higher than that when using the TPA3128D2 device.

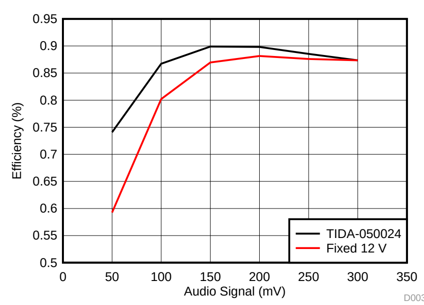

図 11. Efficiency Comparison Result With TPA3128D2 (V_{IN} = 3.75 V, R_{OUT} = 2 Ω)

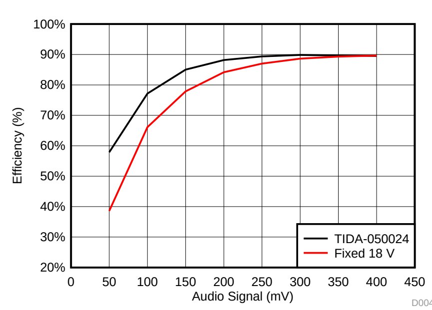

図 12. Efficiency Comparison Result With TPA3128D2 (V_{IN} = 7.2 V, R_{OUT} = 3 Ω)

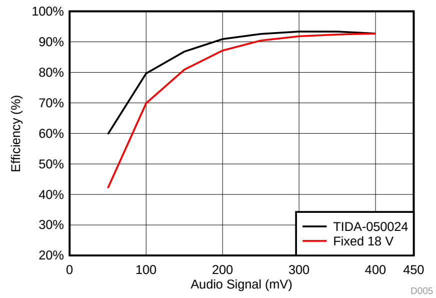

図 13. Efficiency Comparison Result With TPA3126D2 (V_{IN} = 7.2 V, R_{OUT} = 3 Ω)

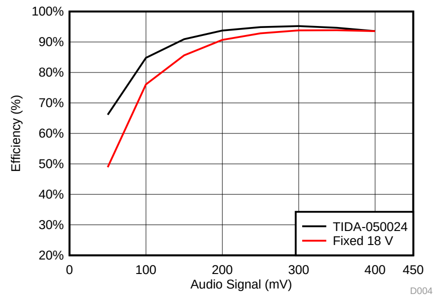

図 14. Efficiency Comparison Result with TPA3126D2 (V_{IN} = 7.2 V, R_{OUT} = 2 Ω)

図 15 shows the waveforms across a 2-Ω load at the one-cell Lithium battery-input application.

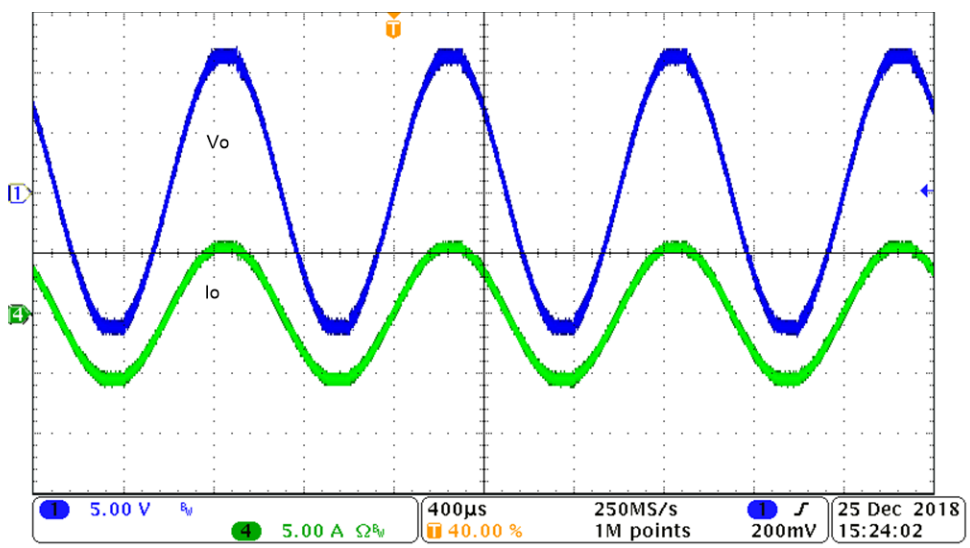

図 15. Waveforms Across the 2-Ω Load

4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-050024.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-050024.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-050024.

4.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050024.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-050024.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-050024.

5 Related Documentation

1. Texas Instruments, *Envelope-tracking power supply for audio power amplifiers TPS61088 design guide*
2. Texas Instruments, *PMP15036 test results technical reference*
3. Texas Instruments, *Low quiescent current synchronous boost DC-DC controller with wide VIN range*
4. Texas Instruments, *TPS61322xx 6.5-μA quiescent current, 1.8-A switch current boost converter*
5. Texas Instruments, *TLV906x 10-MHz Low-noise, RRIO, CMOS operational amplifiers for cost-sensitive systems*
6. Texas Instruments, *Ultra-low voltage processor supervisory circuits*

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6 About the Author

Helen Chen has more than 15 years' application experience in power-supply product design. She is familiar with various topologies such as RCC, buck-boost, full-bridge, half-bridge, flyback, CCM PFC, and DCMB PFC. She is also familiar with the magnetic components design, PCB layout, and EMI solutions.

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