TI Designs: TIDA-01414
TPA3244 Dolby Atmos® Soundbar Reference Design

Description

This reference design combines ultra-high-definition (HD) audio and high dynamic range to create a room-filling audio experience from a small form-factor (SFF) system. The design leverages TI's high-performance TPA3244 amplifier, PCM5252 high-performance DAC with processing, and an integrated system-on-chip (SoC) for decoding and rendering Dolby Atmos®. The soundbar reference board provides ten digital-to-analog converter (DAC) amplifier channels using TI's integrated audio digital signal processing (DSP) for independent channel processing, which includes digital active crossovers, digital room correction (DRC), and biquads to support the 5.1.2 soundbar output configuration. The design uses the 66AK2G audio SoC for Dolby Atmos decode and rendering.

Resources

TIDA-01414	Design Folder
TPA3244	Product Folder
PCM5252	Product Folder
66AK2G	Product Folder

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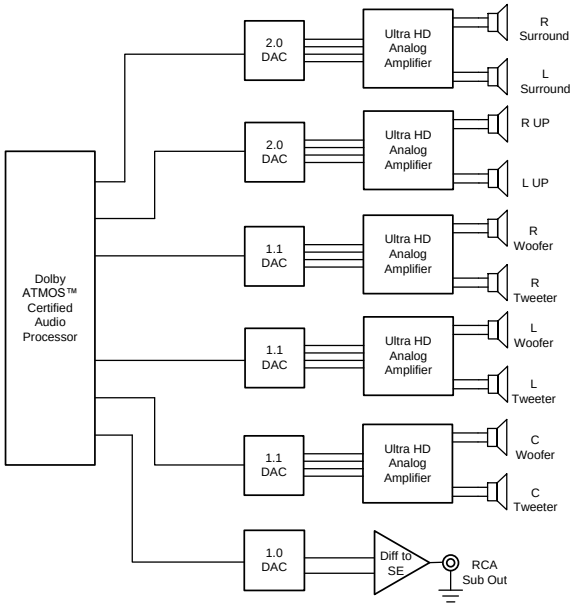
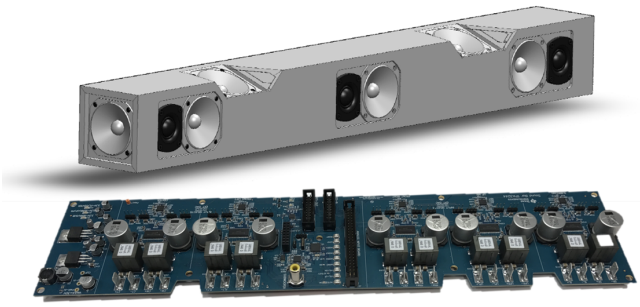
Features

- 5.1.2 Dolby Atmos Soundbar
- Ten Class-D Amplifier Channels from Five TPA3244 in Bridge-Tied Load (BTL)
- Immersive, Three-Dimensional (3-D) Ultra-HD Audio
- DAC-Integrated DSP Audio Processing for Active Crossover, Equalization, and Bass Enhancement
- Single-Chip SoC Dolby Atmos Solution
- Digital and Analog Subwoofer Outputs

Applications

- High End Soundbar
- Home Theater Systems
- Audio/Video Receiver (AVR)
- Low-End Soundbar





1 System Description

This 5.1.2 Dolby Atmos® soundbar reference design uses the new TPA3244 ultra-HD analog input Class-D amplifier in conjunction with the PCM5252 digital-to-analog converter (DAC). With seamless integration between these devices, the user can realize an immersive HD audio experience. The TPA3244 offers 60-W root mean square (RMS) of continuous audio while delivering 110-W RMS peaks without a heat sink using a pad-down package, which is perfect for small form-factor (SFF) products like soundbars and active speakers. Audio artifacts are non-existent with 0.005% total harmonic distortion (THD) + noise (N) at 1 W and 110-db signal-to-noise ratio (SNR).

This design implements a new 1.1 active crossover-processing flow with the new PCM5252 Burr-Brown DAC, which eliminates the passive crossovers for the left, right, and center two-way channels. The designer can implement equalization and fully customizable crossovers between the woofer and tweeter to obtain a flat frequency response. The SmartBass enhancement further extends the low-frequency response of the woofers for better integration, or for complete removal of the subwoofer.

High-end and low-end soundbars combine multiple audio channels in a small for factor bar to enhance the audio experience significantly when compared to regular TV speakers. The input signal is often provided in a digital format through HDMI, Bluetooth or other AV connectors and requires the signal chain to support an I^2S-input. The performance can range from a simple stereo 2.0 system to a room filling 7+ channel soundbar with integrated or external subwoofer for a full surround sound experience.

Audio/video receivers (AVRs) are the king of home entertainment with a main focus on excellent sound. These systems combine the highest audio performance with a high channel count to create the most advanced sound and video experience. High output power, low distortion, and high signal-to-noise ratios are key requirements for AVR.

Home theater systems, also known as home theater-in-a-box (HTiB), enable affordable surround sound for consumers. Multiple speaker are driven by a host unit that contains all audio processing and amplification. HTiB systems deliver a good performance from a minimal footprint.

1.1 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
Amplifier channels	Ten
Speaker channels	Seven
Output power per channel	60-W stereo and 110-W peak
THD+N at 1 kHz	–83 dB
SNR	–107.11 dB A
Input voltage	30 V
Crossover for left, right, and center channels	Active
Required heat sink	None

2 System Overview

2.1 Block Diagram

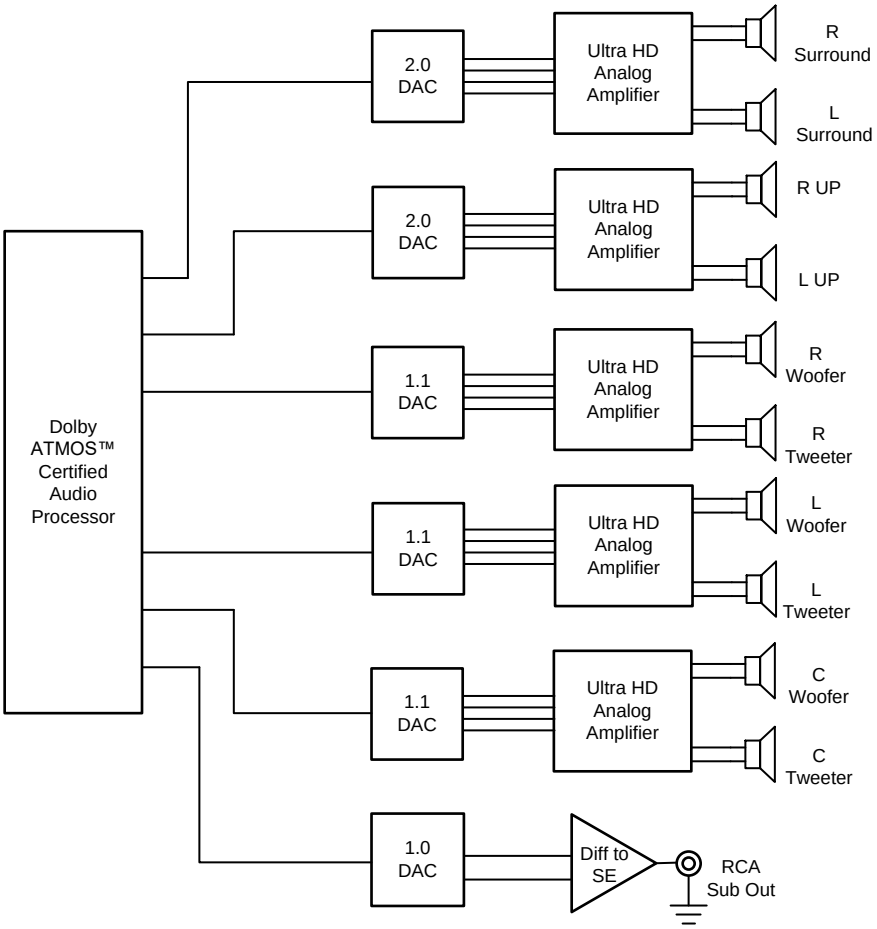


Figure 1. TIDA-01414 Block Diagram

2.2 Highlighted Products

2.2.1 TPA3244 60-W Stereo, 110-W Peak PurePath™ Ultra-HD Pad-Down Class-D Amplifier

- 100-kHz audio bandwidth support for ultra-HD sound
- Analog input
- Pad-down design does not require heat sink
- High power output: 60-W continuous, 110-W peak
- > 85% efficient into 4-Ω load
- Self-protecting design including undervoltage, overtemperature, clipping, and short-circuit protection with error reporting

Figure 2 shows the TPA3244 block diagram.

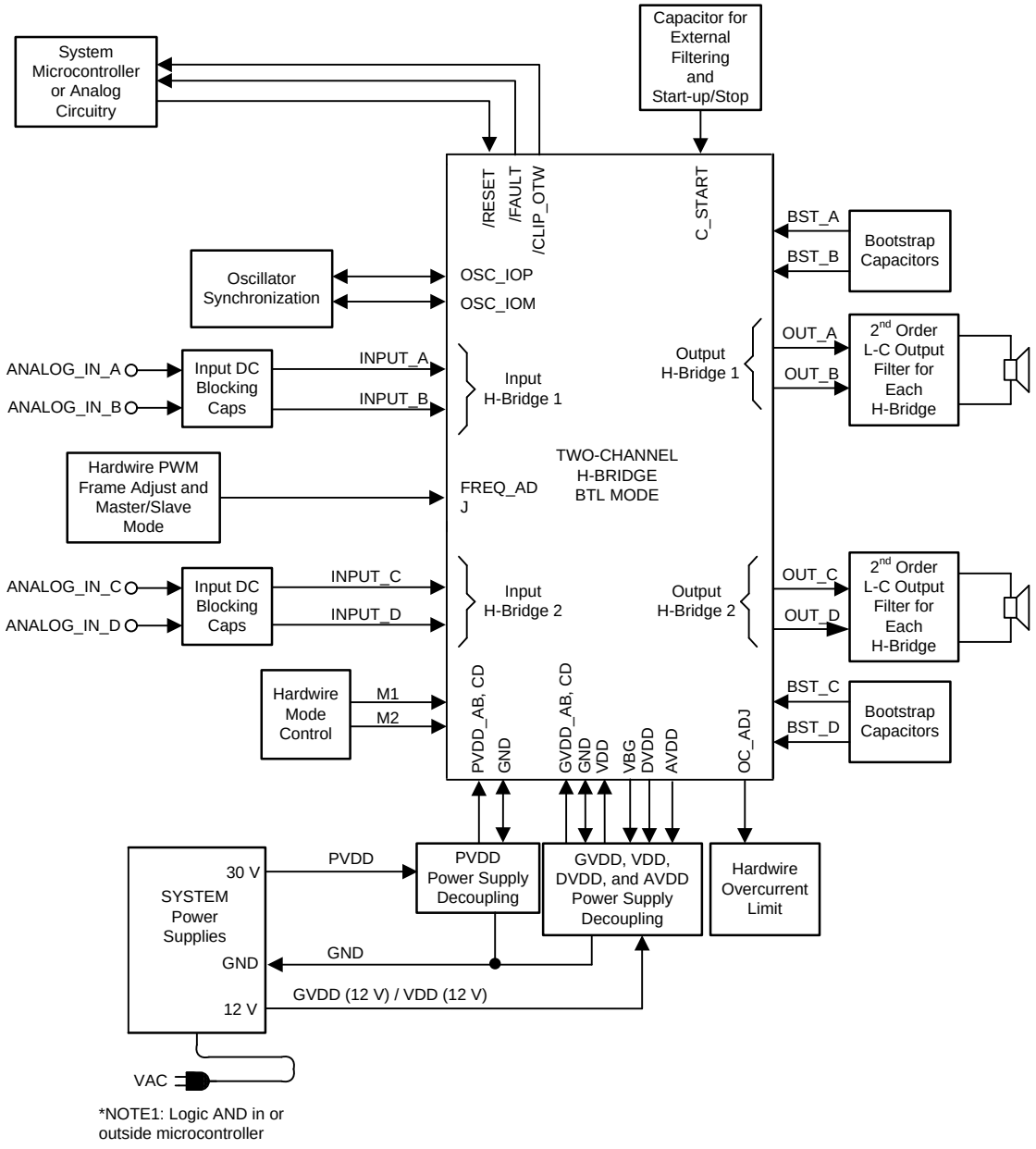


Figure 2. TPA3244 Block Diagram

2.2.2 PCM5252 PurePath™ SmartAmp 4.2-V_{RMS} DirectPath™, Audio Stereo Differential Output DAC

- Differential DirectPath™ ground-biased outputs
- DAC outputs connect directly to TPA3244 without operational amplifiers (op amps)
- 114-dB SNR
- Smart amplifier technology
- MiniDSP on chip
- Ultra-HD

Figure 3 shows the PCM5252 block diagram.

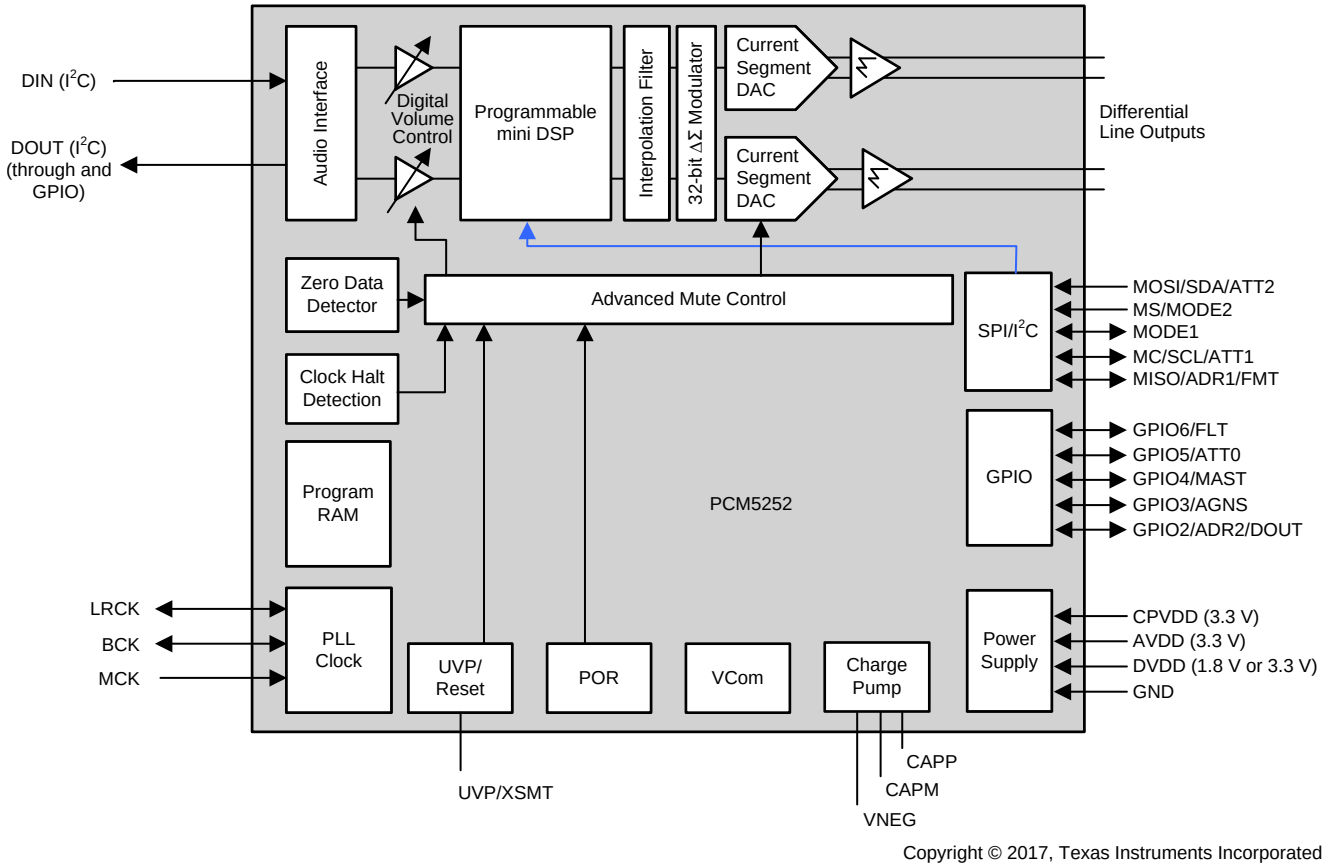


Figure 3. PCM5252 Block Diagram

2.2.3 66AK2G Audio SoC

- C66x DSP core with 1MB of L2 memory
- ARM Cortex-A15 core with 512kB of L2 memory
- 1MB shared L2 RAM
- 3x multichannel audio serial port (McASP) with up to six clock zones and 32 data pins
- Single-chip solution for Dolby Atmos and DTS:X™

2.3 Additional Products

Table 2 lists the additional products and their function in the design.

Table 2. Additional Products

PART	FUNCTION IN DESIGN
TCA6408A	General-purpose input/output (GPIO) expander used to control amplifier reset
MSP430F234	Microcontroller (MCU) for taking user input, displaying light-emitting diodes (LEDs), and configuring DACs
TCA9548A	I^2C expander to control five DACs from single I^2C line from MCU
SN74LVC1G125	Clock driver and buffer
NE5532	Operational amplifier used to do differentia-to-single-ended conversion for analog subwoofer output
TPS54340	30-V to 15-V step-down converter
LM2940C	15-V to 12-V low dropout regulator (LDO)
TLV1117	12-V to 3.3-V LDO

2.4 System Design Theory

The soundbar design classifies into three major components: the DSP, amplifier printed-circuit board (PCB), and speaker enclosure.

2.4.1 Audio Processor

Before playback can occur, Dolby Atmos content must be decoded and then rendered. This soundbar design uses the 66AK2G ("K2G" for short) for such purposes (see Figure 4). The design uses the following hardware platform: 66AK2G EVM with the additional 66AK2G Audio Daughter Card.

The demonstration also requires high-definition multimedia interface (HDMI) functionality, which is enabled by the TI DA-10X Board Kit from Momentum Data Systems. For more details on this processor, contact Momentum Data Systems.

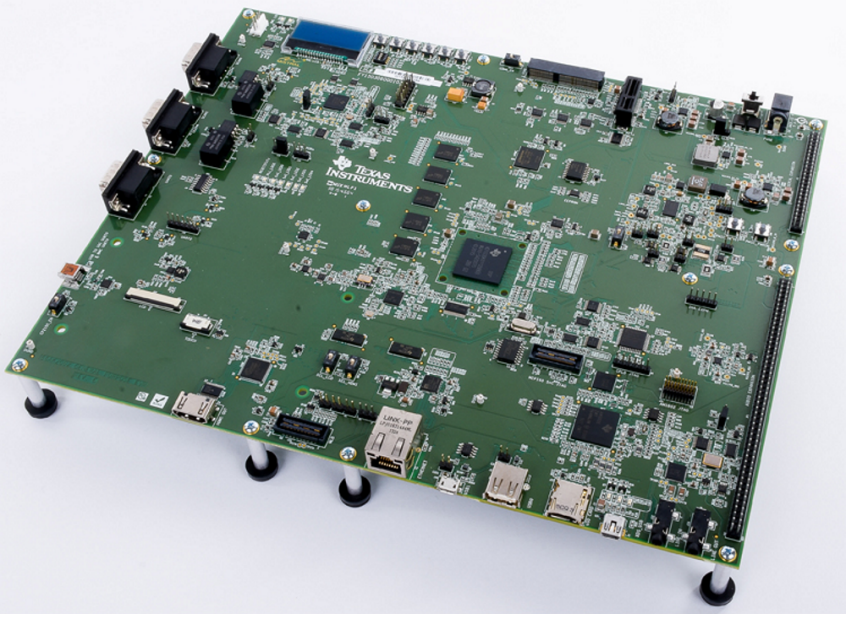


Figure 4. 66AK2Gx EVM

The K2G is a DSP + ARM device which contains a C66x DSP core and an ARM Cortex-A15 core. The device is a single-chip solution for Dolby Atmos and DTS:X and has been designed for multichannel audio applications in general.

The signal flow for the Dolby Atmos demonstration is as follows:

Auto-Detection → Decode → Render → Post-processing

- The C66x core examines the incoming data and determines which decoder to use, such as the Dolby Digital Plus™ decoder, Dolby TrueHD, and so forth. The C66x then passes the data to the A15 core through inter-processor communication (IPC).
- The A15 decodes the bitstream and passes the decoded data back to the C66x core.
- The C66x renders the decoded audio data; rendering is the process by which the audio content is mapped to the available speakers. In the case of this design, this is a 5.1.2 soundbar configuration, see further details in *Speaker Enclosure*.
- The C66x core additionally applies a suite of Dolby® post-processing technology including, which includes a surround virtualizer for the rendered audio content. This feature allows the listener to enjoy a surround-sound experience with sounds moving around and above them, even though the speaker bar is at the front of the room.
- After all decode, render, and post-processing operations have been performed, the audio data is transmitted to the amplifier PCB through a ribbon cable.

NOTE: Although TI employees may demonstrate this system to a customer, Texas Instruments can only provide Dolby Atmos software to a customer that is a Dolby Atmos licensee. Please contact your TI sales associate for additional details.

2.4.2 Amplifier and DAC PCB

The amplifier and DAC PCB is designed to have a SFF, high power, high dynamic range, and immersive ultra-HD sound. To obtain these objectives, this design pairs the differential output PCM5252 DAC and the ultra-HD, high-performance TPA3244 audio amplifier (see Figure 5).

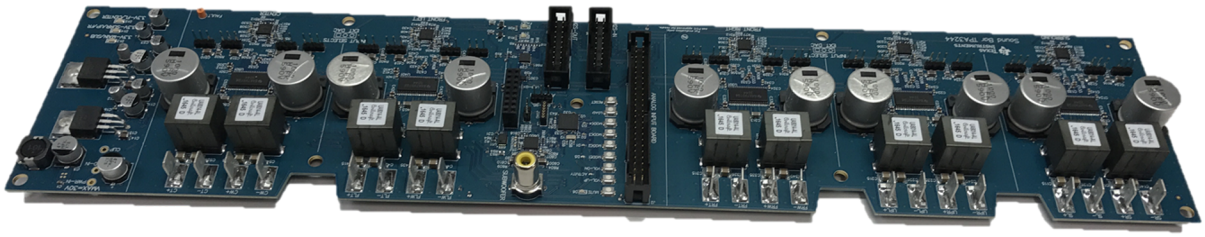


Figure 5. Amplifier and DAC PCB

The amplifier board receives I^2S signals from the DSP board using the "I^2S DSP Board Connector" J3. From this point, the I^2S signals are fanned out to six DACs. Each DAC applies equalization and enhancement. This low-frequency extension provides stunning bass performance for relatively-small speakers by safely pushing the speakers to their full potential. The left, center, and right channels both have a tweeter and woofer that use two DAC and two amplifier channels to create an active crossover. The remaining channels: surround left, surround right, up-firing left, up-firing right, only have a woofer speaker each and require only one channel of the DAC and amplifier.

Figure 6 shows the 1.1 DAC configuration used for the left, center, and right channels on the soundbar. Figure 7 shows the 2.0 DAC configuration used for the surround left, surround right, up-firing left, and up-firing right channels on the soundbar.

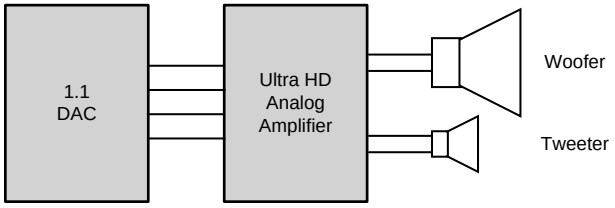


Figure 6. Amplifier and DAC in 1.1 Configuration (Left, Center, and Right Channels on Soundbar)

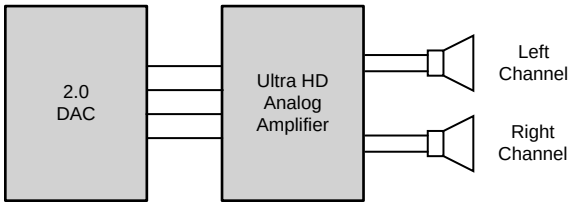


Figure 7. Amplifier and DAC in 2.0 Configuration (Surround Left, Surround Right, Up-Firing Left and Up-Firing Right on Soundbar)

Each TPA3244 is configured for a two-channel, bridge-tied load (BTL) and either drives a left and right speaker or a tweeter and woofer depending on the DAC configuration. One additional DAC is available for creating an analog subwoofer channel; however, this is not required on the soundbar if using a wireless subwoofer module that accepts I^2S inputs. The designer can implement a wireless subwoofer design to support a wireless subwoofer.

The TPA3244 offers best-in-class THD+N and is extremely efficient. Take advantage of the fact that audio consists of a small number of peaks with low average power by using the PCB as a heat sink. This space-saving pad-down design does not require additional heat sinks and ultimately allows the amplifier PCB to fit neatly behind the soundbar.

Figure 8 shows the benefits of a space-saving pad-down design for the TPA3244 amplifier.

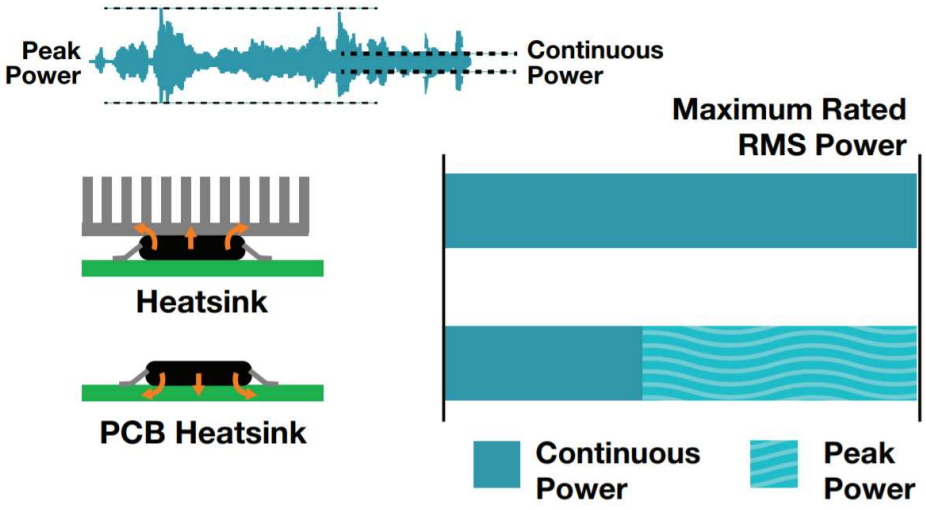


Figure 8. TPA3244 Pad-Down Benefits

As with all Class-D amplifiers, the performance of the LC filter determines the limits of the system audio performance. Typically a trade-off exists between size, cost, performance, and idle power. Selecting the right inductor for the LC filter plays a critical role in improving the efficiency and overall sound quality of the system. A smaller, surface mount inductor is used to keep a SFF for the amplifier board. A inductor has been developed by Coilcraft (UA8014-ALD) specifically for use with the TPA3244 and TPA3245. A single shielded package contains two coils with a very-low coupling coefficient ($k < 0.001$) between the two inductors. The single package is 14 mm by 15.5 mm. A good linearity of the inductor saturation current and ultra-low core losses minimize the impact of the THD+N, which greatly improves the audio quality. Use 1-µF XR7 capacitors for the extremely small 1210 package size, despite the fact that doing so somewhat limits THD+N performance. To enhance the performance of the soundbar, use metallized film capacitors, such as the capacitors used on TPA3244EVM - part number: PHE426HB7100JR06.

Two LEDs serve to monitor the warning and error pins, CLIP/OTW and FAULT, on all of the amplifiers. If just one amplifier goes into a condition causing CLIP/OTW, the CLIP/OTW LED turns ON. The same is true for the FAULT pin.

An MSP430™ MCU functions to send mute, reset, and volume commands to all six DACs. The MSP430 also loads the DAC configurations and controls the reset of the five amplifiers. An I^2C expander (TCA9548A) sends mute, reset, and volume commands to these six DACs. A GPIO expander (TCA6408A) sends reset commands to the five amplifiers.

This design only requires a single rail 27-V to 30-V power supply, which simplifies power supply requirements for the user. This 27-V to 30-V rail goes directly to the PVDD pin on the TPA3244 and a few converters create 12 V for the GVDD pin on the TPA3244 and 3.3 V for the DACs and MSP430. The amplifier PCB is designed to fit neatly behind the DSB5 Soundbar Speaker Enclosure. Mounting holes and standoffs attach the amplifier PCB to the soundbar. Connect the speakers to the amplifiers using the male spade connectors on the PCB.

2.4.3 Speaker Enclosure

Triad Speakers Inc has developed a custom soundbar specifically designed to meet criteria established by Dolby and TI. The speaker enclosure, DSB5, is a 5.1.2 speaker box that supports Dolby Atmos® and is not available to order (see Figure 9).

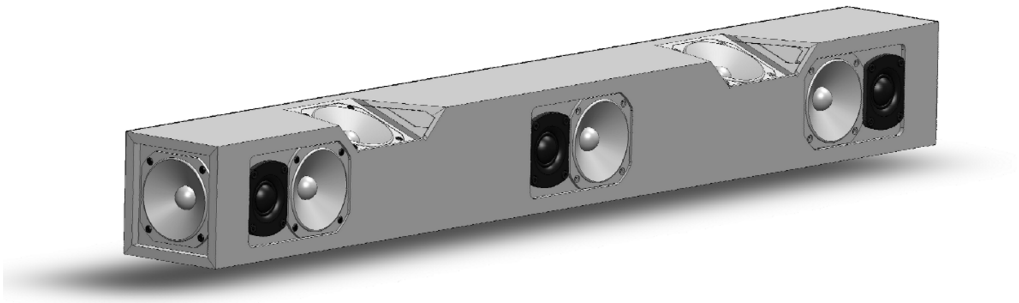


Figure 9. Soundbar DSB5

The DSB5 channels consist of:

- Three channels for left, right, and center channels:

  These channels are designed as a two-way (woofer + tweeter) for highest fidelity. Instead of large, bulky passive crossovers, active crossovers are implemented in the DSP of the PCM5252 DAC. This implementation not only saves space, but allows for a custom state-of-the-art equalization that flattens the total response and enhances the bass, pushing the speakers to their full potential.
- Two surround channels:

  These channels are side-firing drivers that use wall reflections to create a surround effect.
- Two up-firing channels (height left top middle and height right top middle channels):

  These channels are up-firing drivers that use ceiling reflections to create overhead content.
- One channel for the line-level subwoofer out

For clarity, this Dolby Atmos soundbar design is only one example of many. The acoustic specification for a Dolby Atmos soundbar is flexible and can support a variety of soundbar form factors. For more information, contact Dolby Labs.

3 Getting Started

3.1 Hardware

The following steps detail how to set up the TPA3244 soundbar amplifier board to play audio.

1. Attach the speakers to the speaker terminals.
   a. Using spade connectors, connect the speaker terminals on the soundbar to the speaker terminals on the amplifier PCB.
2. Attach the DSP.
   a. Connect the DSP to the amplifier PCB using the digital input connector labeled I2S-IN on the amplifier PCB (see Figure 10).

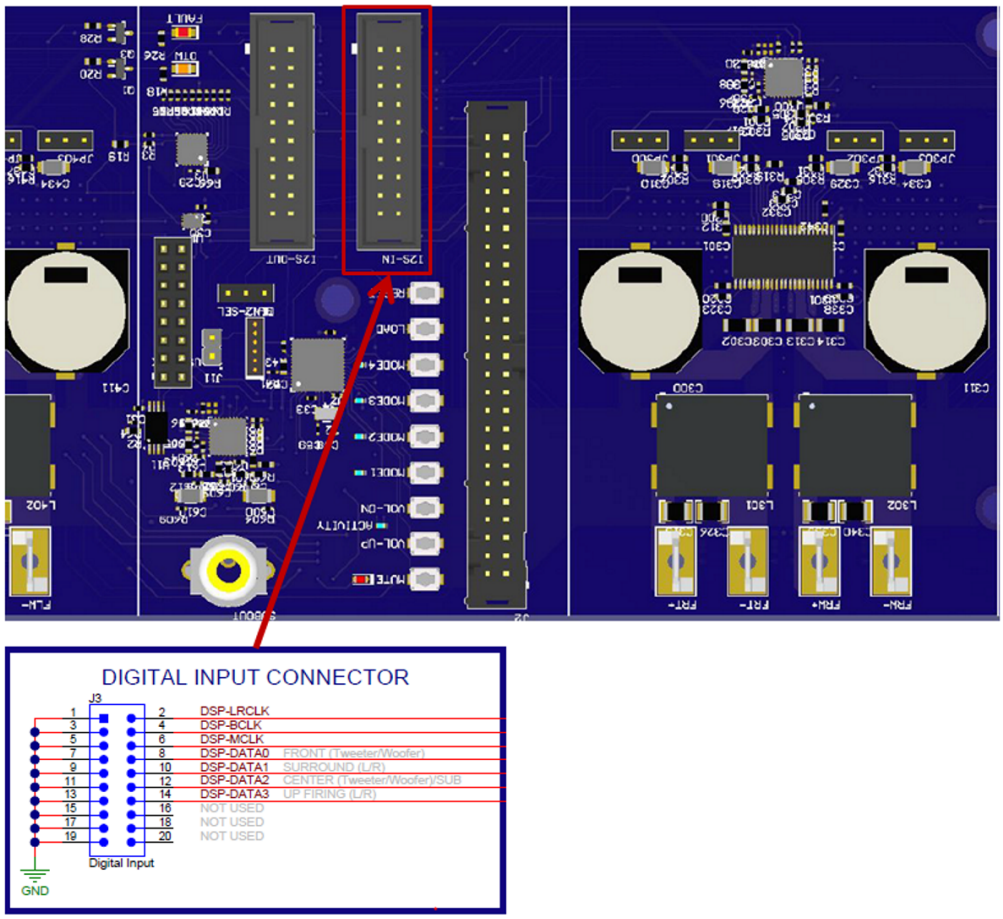


Figure 10. DSP Hookup

3. Attach the power supply.
   a. Connect a 30-V power supply to the amplifier PCB using the connections PWR-IN for +30 V and GND-IN for GND (see Figure 11).

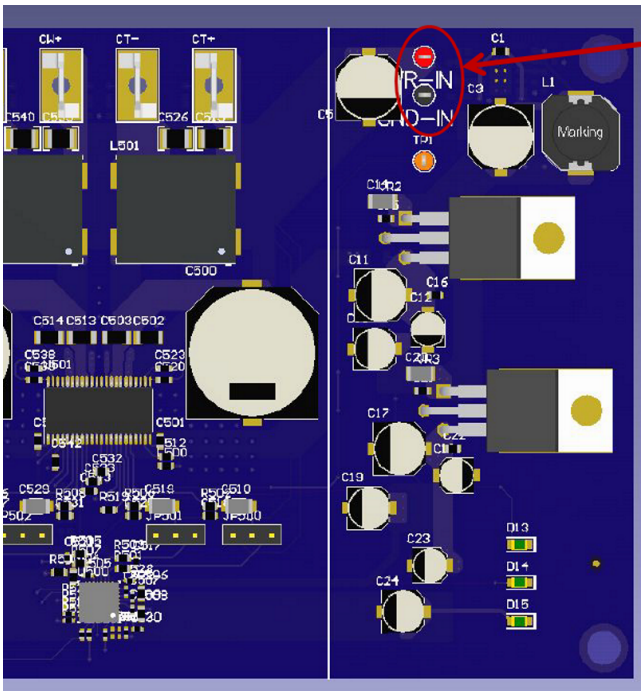


Figure 11. Power Supply Hookup

3. Power on the amplifier.
   a. Turn on the power supply.
4. Unmute the amplifiers.
   a. Upon power up, the amplifiers default into mute mode. Press the mute button once to unmute the amplifiers (see Figure 12). The red indicator LED should shut off when the amplifiers are out of mute mode.

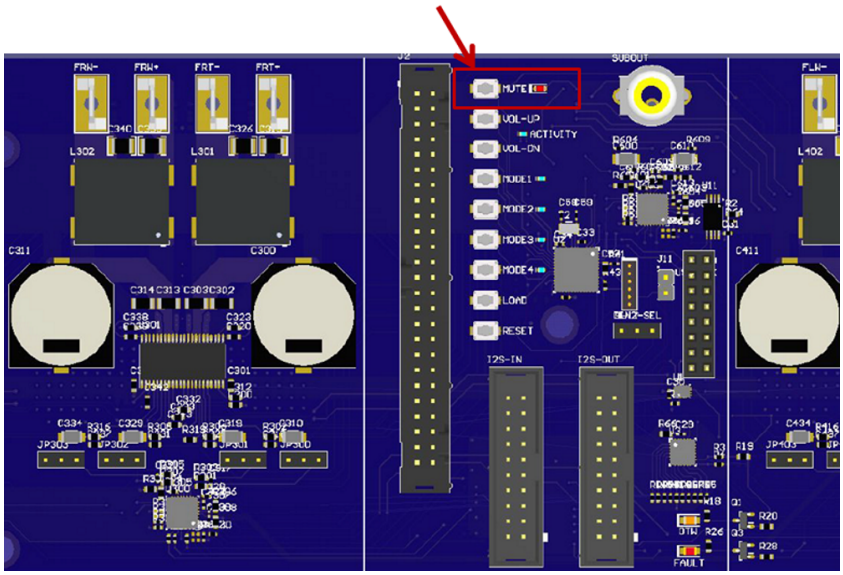


Figure 12. Mute Button Location

5. Play the audio.
   a. Play the audio through the DSP into the amplifier PCB.
6. Adjust the volume as necessary.
   a. Adjust the volume on the amplifier PCB by pressing VOL-UP and VOL-DN (see Figure 13).

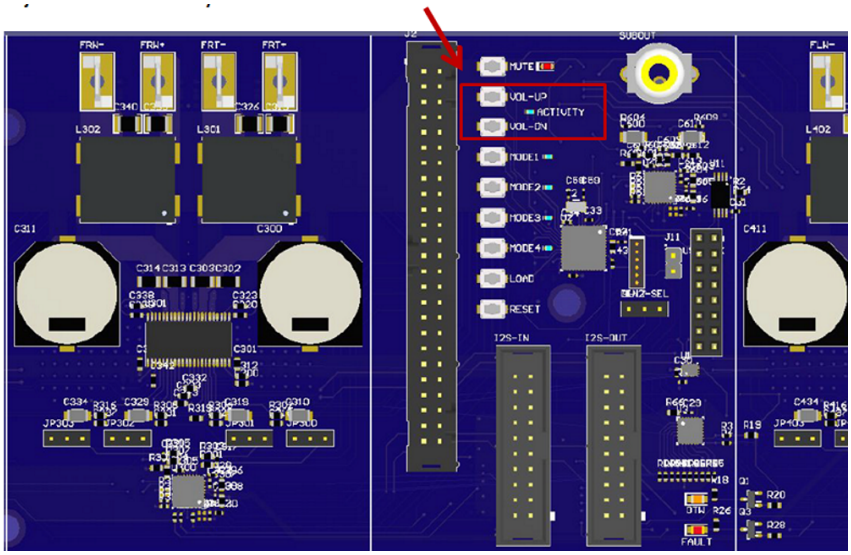


Figure 13. Volume Button Location

4 Testing and Results

Several audio performance metrics were tested on the TPA3244 Dolby Atmos Soundbar. These tests use an audio precision bench tester to input digital sine waves to the board, during which the analog output is analyzed. An Audio Engineering Society (AES) filter is utilized on the analog output of the device. A bench power supply is used to power the board.

Figure 14 shows the soundbar test setup.

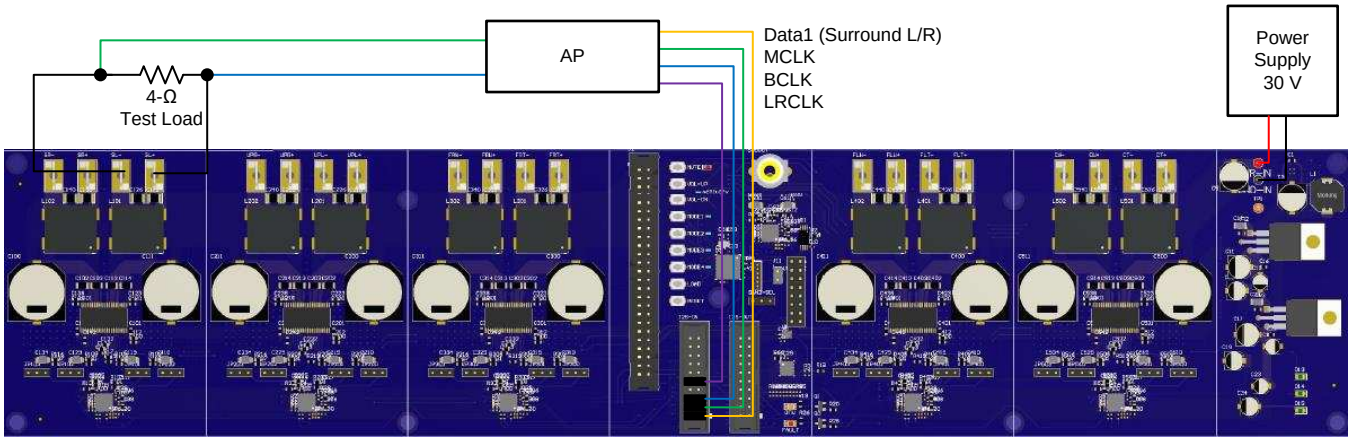


Figure 14. Soundbar Test Setup

The frequency response is an important metric for determining how well the soundbar is capable of passing audio frequencies at the same level. The more flat the frequency response curve is, the better frequency response the soundbar has (see Figure 15).

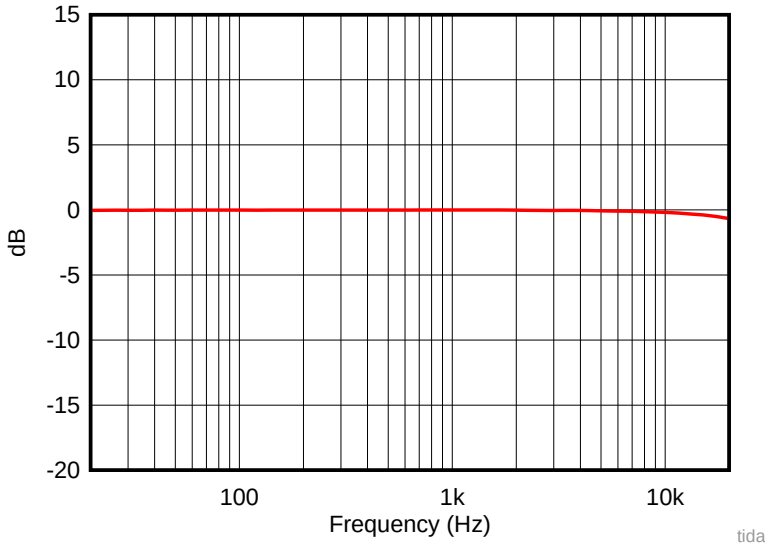


Figure 15. Soundbar Frequency Response

The THD+N is an audio measurement of how much distortion and noise is present for a given signal. By keeping distortion and noise levels low (less than 0.01%), the TPA3244 offers extremely-high quality audio. Two tests are primarily used when determining THD+N: THD+N versus frequency and THD+N versus power. THD+N versus frequency shows the THD+N across a frequency for a particular power level. The following Figure 16 shows the TPA3244 test results for 1 W, 10 W, 20 W, and 50 W. Notice that the THD+N is less than 0.03% for all frequencies and reaches as low as 0.002% for lower frequencies.

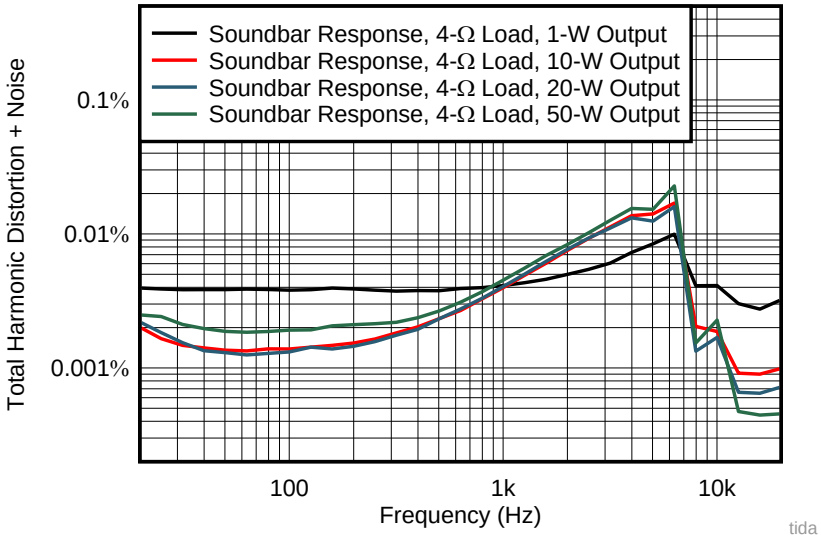


Figure 16. Total Harmonic Distortion + Noise versus Frequency

THD+N versus power shows how the distortion and noise changes across power at a particular frequency. The standard frequency to run this test at is 1 kHz. Notice that the TPA3244 device produces less than 0.004% THD+N for power levels between 1 W and 50 W (see Figure 17). This power range is incredibly important for the everyday consumer because it allows the user to easily hear distortion.

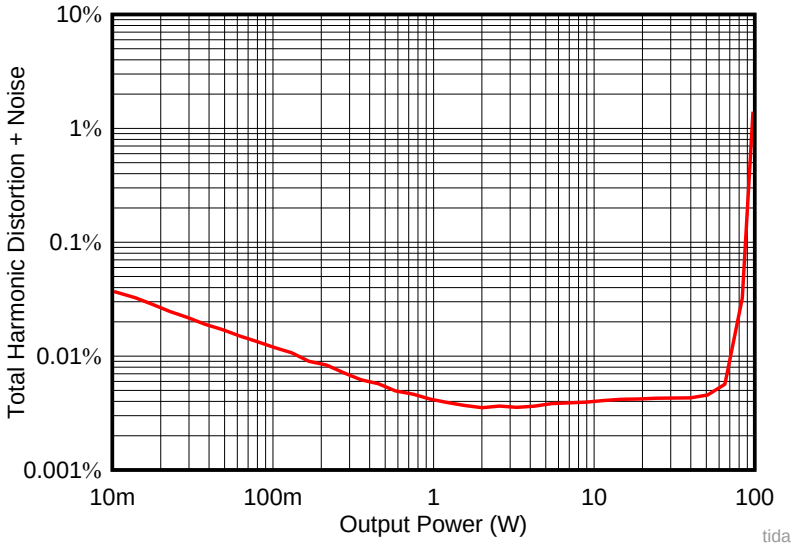


Figure 17. Total Harmonic Distortion + Noise versus Power

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-01414.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01414.

5.3 PCB Layout Recommendations

5.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01414.

5.4 Altium Project

To download the Altium project files, see the design files at TIDA-01414.

5.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01414.

5.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01414.

6 Software Files

To download the software files, see the design files at TIDA-01414.

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