Improving Audio Converters Performance

Tahar Allag, Analog Power Applications Engineer, Texas Instruments

Introduction

Most modern audio is stored in digital formats such as pulse code modulation (PCM), and MP3s. This provides lossless data storage, perfect copies without quality degradation, indefinite storage, flexibility, and compatibility with other digital systems. An audio DAC converts these digital formats into analog signals that drive speakers which create audio sounds or analog waves. Audio amplifiers magnify the converted audio sounds so that speakers can deliver these sounds to the audience.

Sound is an audio system’s final outcome. Its quality depends on the entire audio system. This includes the original digital code quality, audio DAC device, audio power amplifiers, and loudspeakers or headphones.

For an audio DAC, performance depends on its quality, plus other external factors. High-performance audio DACs are sensitive to external noise that penetrates the audio band during the conversion process. The noise can come from AC power supply ripple, radio frequency interference, switching noise, and thermal noise from the audio system’s other circuit components. This article explores ways to improve DAC power supply voltage noise quality and audio converter noise performance.

Audio performance specifications

To quantify a sound system’s noise quality, certain specifications are measured. Total harmonic distortion (THD) measures the amount of undesirable signal produced by an audio converter during the audio signal play-back. Audio converters are non-ideal and non-linear devices with single or multiple inputs and outputs. They always distort some of the original input signal. This distortion is usually added at the original input signal harmonics. THD represents the original signal distortion amount, and is a good specification to measure audio DAC performance.

THD alone does not incorporate other non-distortion-related noise in the output signal generated by the DAC. Therefore, total harmonic distortion is combined with noise to construct another standard of measurement, THD+N. This specification accurately quantifies all noise coming out of a DAC not related to the input signal. The noise comes from power supply AC ripple, radio frequency interference, switching noise, vibrations, and the audio system’s circuit component thermal noise.

While THD+N can help specify the device’s audio DAC performance, it does not provide insight into a DAC’s performance across its frequency band. A fast Fourier transform (FFT) analyzer plot analyzes the analog audio signal quality over its frequency band. This analyzer takes the time varying analog audio output signal and converts it into its frequency spectrum. It measures the audio converter’s

performance over its entire 1–20 kHz frequency range, showing both noise and harmonic distortion.

Power supply affects audio performance

Most home audio systems are powered from an AC adapter that provides a 12V bus. The 12V bus must be converted to 5V or 3.3V. This conversion can be accomplished using either a switching or linear regulator. Switching regulators are desirable because they are highly efficient. Typical efficiencies of 80-95 percent minimize power loss and system heat. However, switchers suffer from switching noise plus AC ripple voltage on top of their DC output voltage. These side effects reduce audio DAC performance. **Figure 1** shows the typical output voltage of a switching converter.

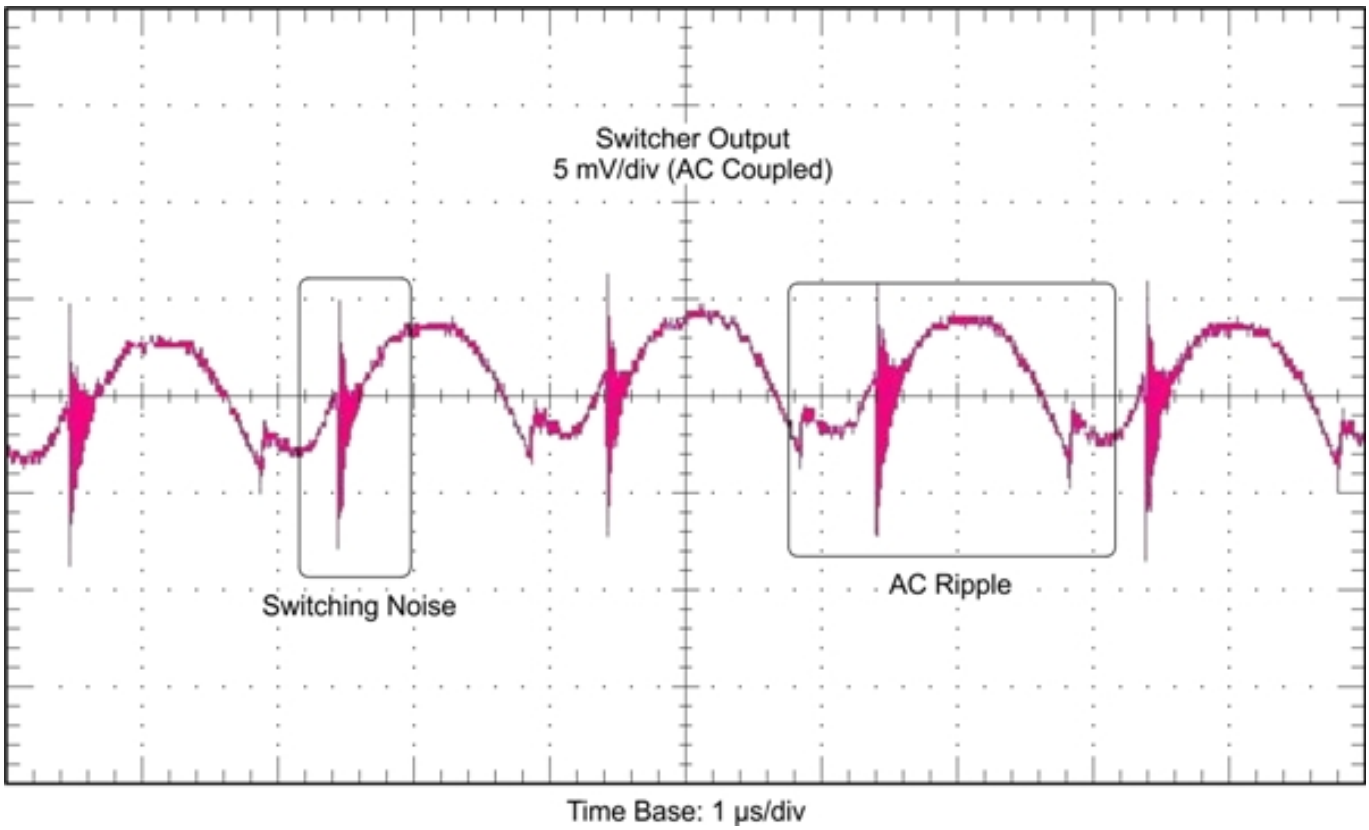

Figure 1: Typical output voltage ripple of a switcher.

The higher the power supply's AC ripple and noise, the more it negatively affects sound quality. Input noise and ripple can penetrate the IC and affect performance by getting into the audio band during conversion, interfering with internal bias voltages, clocks, oscillators, and so on. They also can be coupled to the output through the board layout. Moreover, the performance of the whole audio system, including power audio amplifiers and speakers, are affected. Power supply noise downgrades audio output sound quality significantly.

Figure 2 shows an audio DAC's performance, powered directly by a 3.3V switching regulator. Testing is performed with a standard 1-kHz test tone applied to the DAC's digital input. Measurements are taken using the audio precision (AP) analyzer test

equipment. Here, the analog audio output signal FFT plot shows deference between the left and right channels due to differences in noise floors on both channels. The THD+N result reveals that a noisy power supply degrades the output audio signal quality significantly.

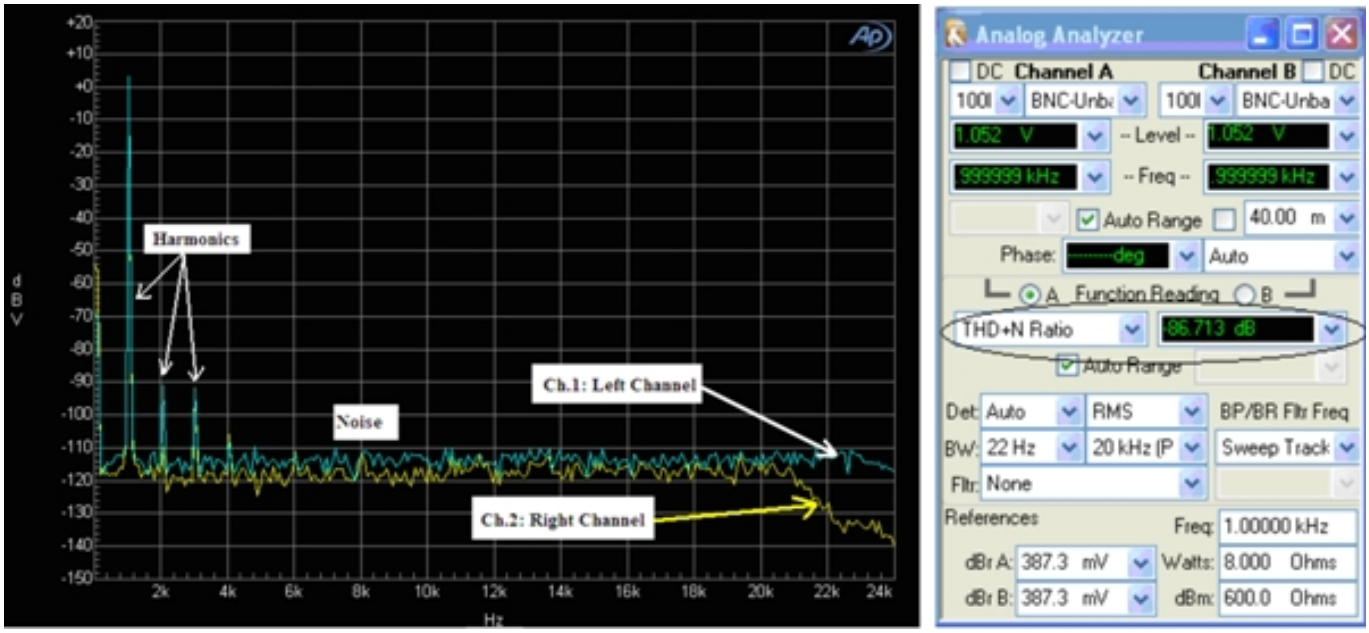

Figure 2: FFT spectrum analysis plot and THD+N measurements with sine wave audio signal powered from a switcher.

Isolating the switching noise and ripple from the DAC's power rails achieves higher audio performance. Adding additional filtering to the switcher's output helps to reduce some noise. But some sophisticated filters are expansive, complicated, and space-consuming solutions. Also, most filters suffer from power loss, load regulation issues, and poor transient response. Converting the 12-V input bus to 3.3V using a linear regulator (LDO) significantly reduces ripple and noise, which results in improved audio performance. The drawback of using an LDO is reduced efficiency and higher power dissipation in the design.

Figure 3 shows the FFT plot for the audio DAC powered by an LDO. As in the previous test, a 1-kHz sinusoidal audio signal is applied to the DAC's optical input, under the same conditions, and using the same audio precision test equipment as a measurement tool.

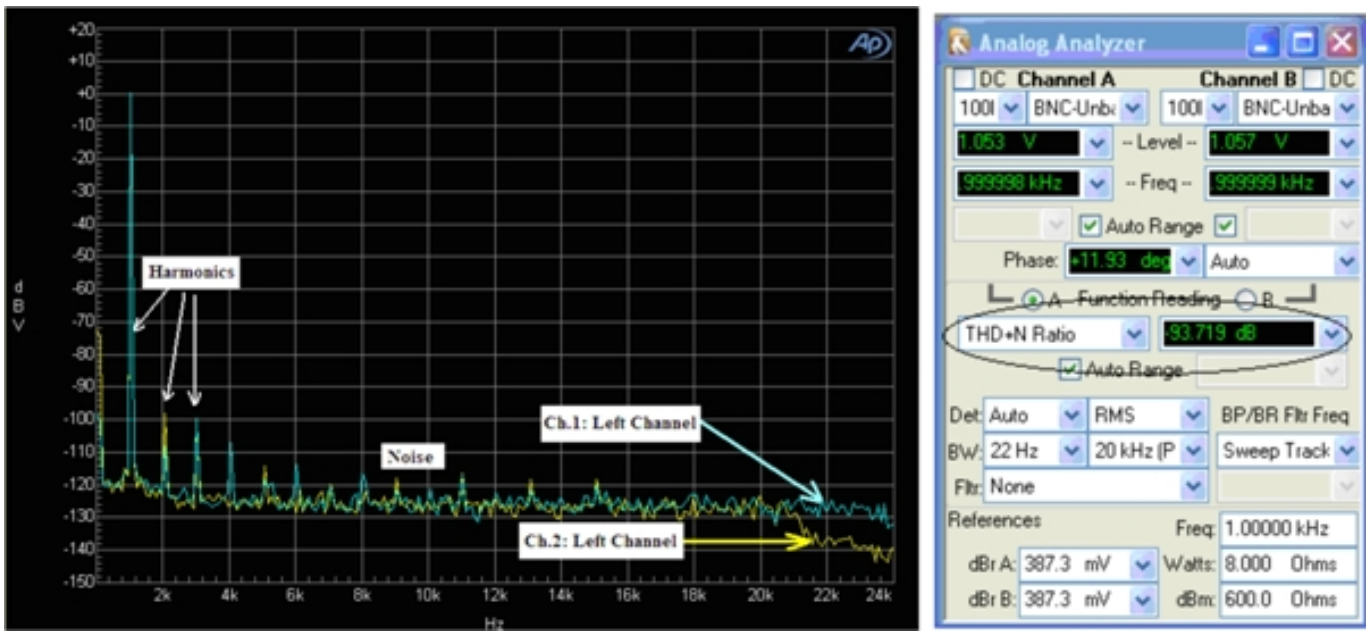

Figure 3: FFT plot spectrum analysis and THD+N measurements of the audio DAC with sine wave audio signal powered from an LDO.

The LDO's cleaner power rail improves sound quality by almost 8 dB. **Figure 3** shows the THD+N to be more than 93 dB. Looking at the FFT spectrum analyzer graph, the noise floor is reduced significantly. The harmonics are easily distinguishable, and are due to the device performance. In most of its frequency bandwidth, the noise floor is kept below the –120 dBV level versus –110 dBV (**Figure 2**). This result confirms that using a clean power supply rail on an audio converter improves its performance.

While LDO power solutions provide a cleaner output voltage over a switcher, efficiency is low and causes system thermal issues. Thus, an ideal solution is to combine the switcher's high efficiency with the linear regulator's cleaner output performance, such as the TPS54120. This combination achieves an efficient and clean power solution.

In **Figure 4**, an integrated switcher and LDO regulator are used to power the audio DAC. A 12-volts input voltage is used at the regulator's input. The results obtained are the same as in **Figure 3**.

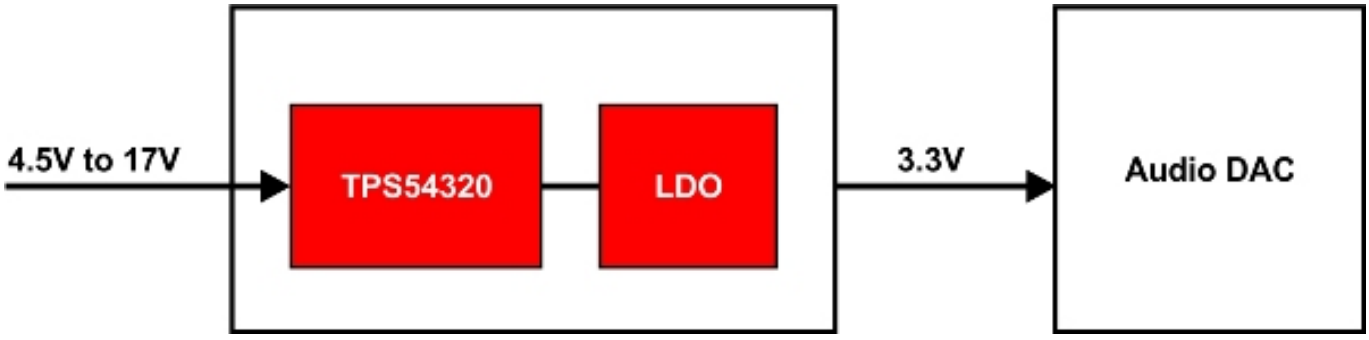

Figure 4: Schematic diagram of audio DAC powered by an integrated switcher and LDO regulator.

When comparing different solutions by cost, board space, efficiency and performance, the integrated switcher with LDO provides good performance with high efficiency.

Conclusion

AC ripple and switching noise generated by switching power supplies have negative effects, which reduces the quality of audio DAC output. Several filtering techniques can isolate the audio converter from these noise sources. Besides noise, efficiency, cost, and board space of the filter in an audio system are also important factors. Combining the switcher's high efficiency with the ultra-low noise of an LDO is an ideal solution. Moreover, the integrated solution of a switcher plus LDO has advantages over a discrete solution by further reducing cost and savings board space.

About the Author

Tahar Allag is an analog power applications engineer with TI's power management group. He received his BSEE and MSEE from the Rochester Institute of Technology, New York. Tahar can be reached at ti_taharallag@list.ti.com [1].

Links:
[1] mailto:ti_taharallag@list.ti.com