PSRR for PurePath Digital™ Audio Amplifiers

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ABSTRACT

This document describes how power-supply ripple and noise components affect a PurePath Digital audio amplifier. The document identifies a way to measure power-supply rejection ratio (PSRR).

The document also shows PSRR measurement for the TAS5086-5142V6EVM. The result can also be related to the output stages TAS5111, TAS5112, TAS5122, TAS5142, TAS5152, and TAS5182 when using the modulators TAS5028, TAS5066, TAS5076, TAS5086, TAS5508, and TAS5518.

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1 Introduction

PurePath Digital audio amplifier technology is a direct high-power PCM-to-PWM converter without feedback; this requires adequate decoupling and an adequate power supply to achieve good performance. The power-supply voltage would normally be regulated because the H-bridge is switching the supply level directly to the outputs via the output reconstruction filter.

The power supply in a PurePath Digital amplifier can in a way be regarded as a voltage reference in a DAC.

2   PSRR for Class D Amplifiers

Power-supply rejection ratio (PSRR) is well known for normal class-A/B amplifiers and can be used also for analog-input class-D amplifiers with feedback.

PurePath Digital amplifiers do not use feedback; the PSRR term is therefore different.

The PurePath Digital amplifier switches the power-supply voltage directly into the output filter.

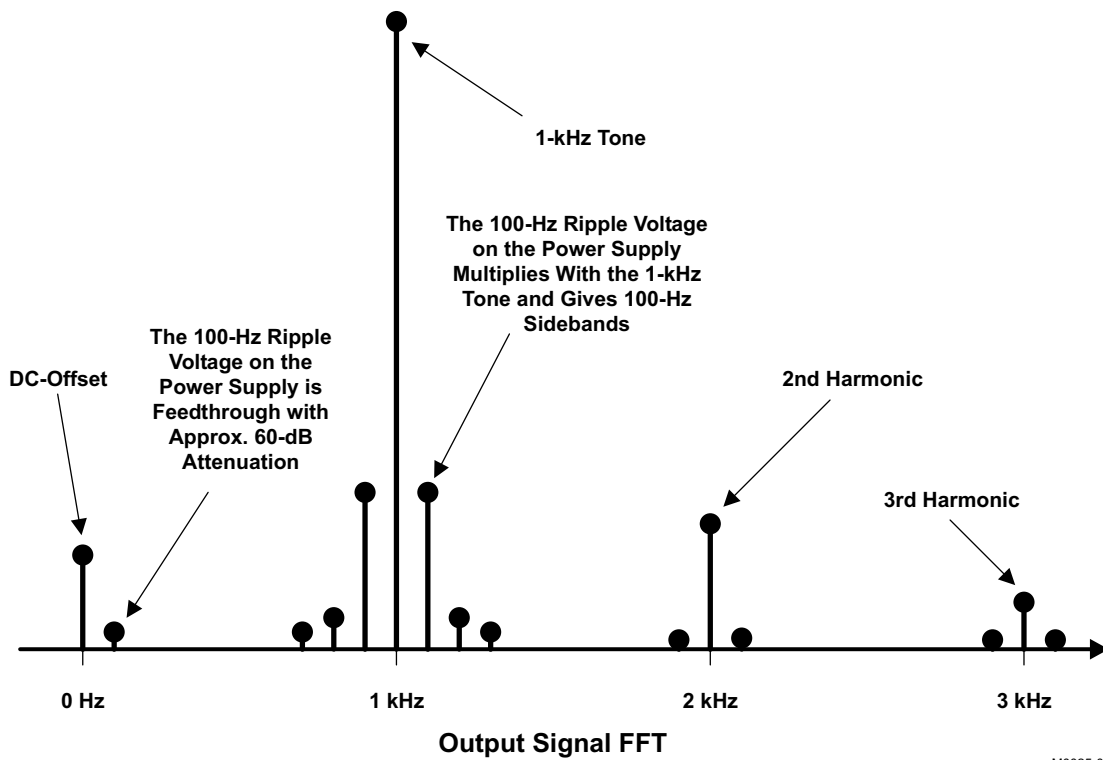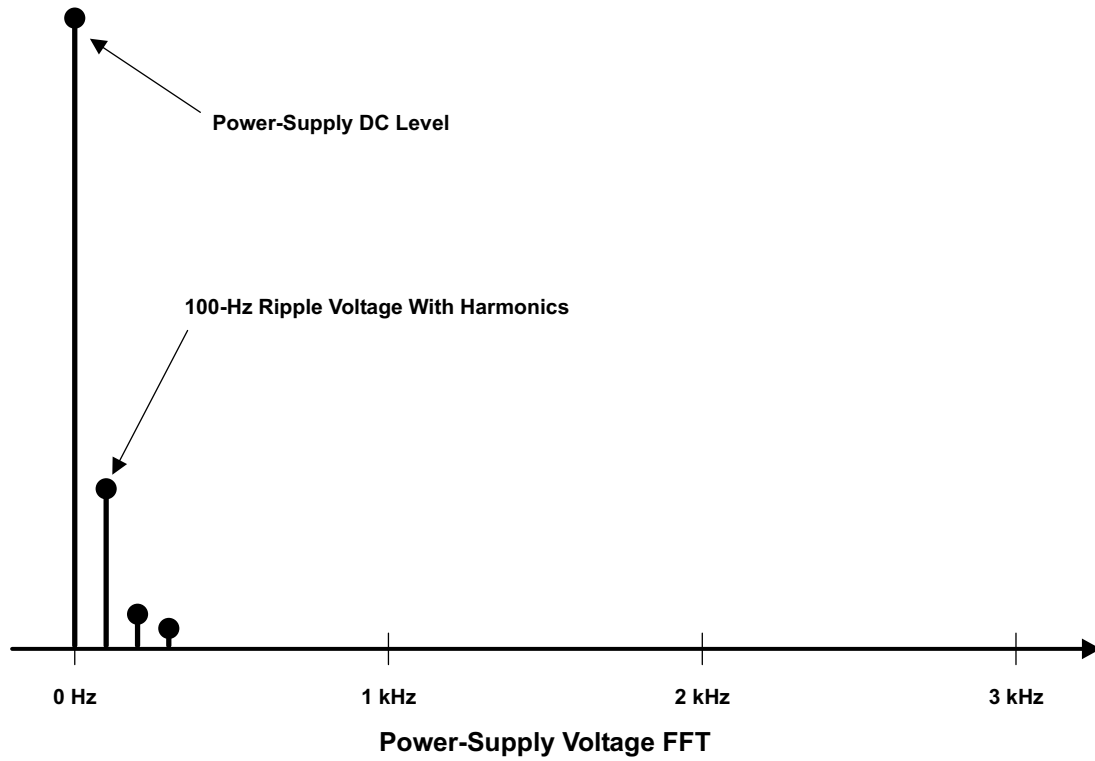A simplified expression of the output signal is:

$$V_{OUT}(t) = V_{PSU}(t) \times Duty(t)$$

where $V_{PSU}(t)$ is the power-supply voltage, and Duty(t) is the duty cycle of the PWM signal as function of time. For a full-scale 1-kHz output signal, Duty(t) is a sine wave with an amplitude of 1.

$V_{PSU}(t)$ can be split into a dc value and an ac signal, representing the ripple and noise voltage.

If a 50/60-Hz main transformer is used, the rectified output is a dc voltage with a 100/120-Hz ripple voltage and the harmonics thereof.

Then, if a full-scale, 1-kHz signal is output, an error coming from the multiplying term shown in the foregoing equation produces sidebands 100/120 Hz from the fundamental tone. This is illustrated in Figure 1.

Figure 1. FFT of PSU With 50/60-Hz Main Transformer and Amplifier

Figure 1 shows the FFT of the voltage and the FFT of the output signal. The FFT of the power-supply voltage consists of a dc term, a 100-Hz ripple voltage with higher harmonics coming from the rectification.

The output signal FFT shows several tones.

- The audio 1-kHz signal
- Harmonic distortion of the 1-kHz signal (second and third harmonics shown)
- Sidebands to the 1-kHz tone (and to the harmonics) coming from the multiplication of the 100-Hz ripple voltage and the 1-kHz audio signal and its harmonics
- Feedthrough of the 100-Hz signal, with a approximately 60-dB attenuation
- Output dc-offset voltage

The noise is not illustrated, but excessive noise on the power-supply voltage also is multiplied on the audio signal.

The tones shown are not to scale, but are shown for explanation only.

If a switch-mode power supply (SMPS) is used, there is no 100/120 Hz ripple voltage, but there can be a switching-frequency ripple voltage. This is normally well above the audio band and low-amplitude (less than 100 mV); therefore, no audible tones are produced. Figure 2 shows the FFT.

A point to be aware of regarding the SMPS is to use a good low-pass filter on the voltage reference for the regulation so that the short-term stability is good. A second-order filter with a cutoff frequency below 10 Hz is normally adequate.

An example for an adequate reference voltage is the Texas Instruments shunt regulator TL431 with the addition of the low-pass filter. The TL431 family is widely used in SMPS designs.
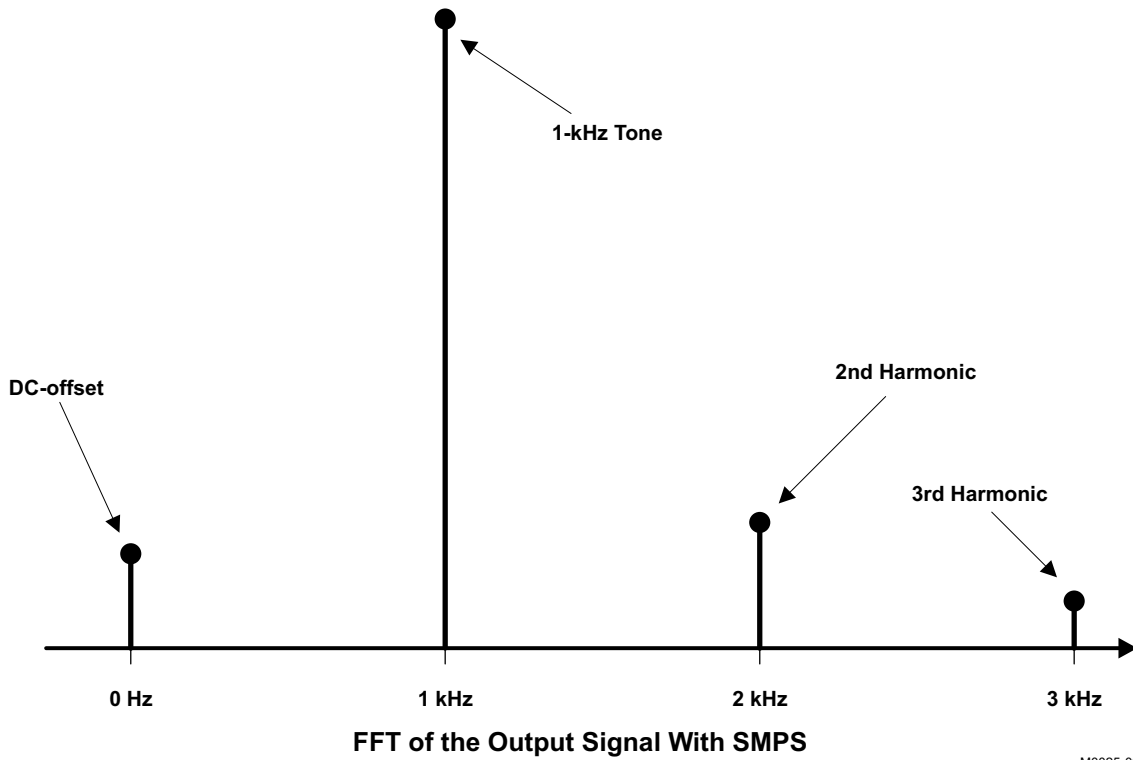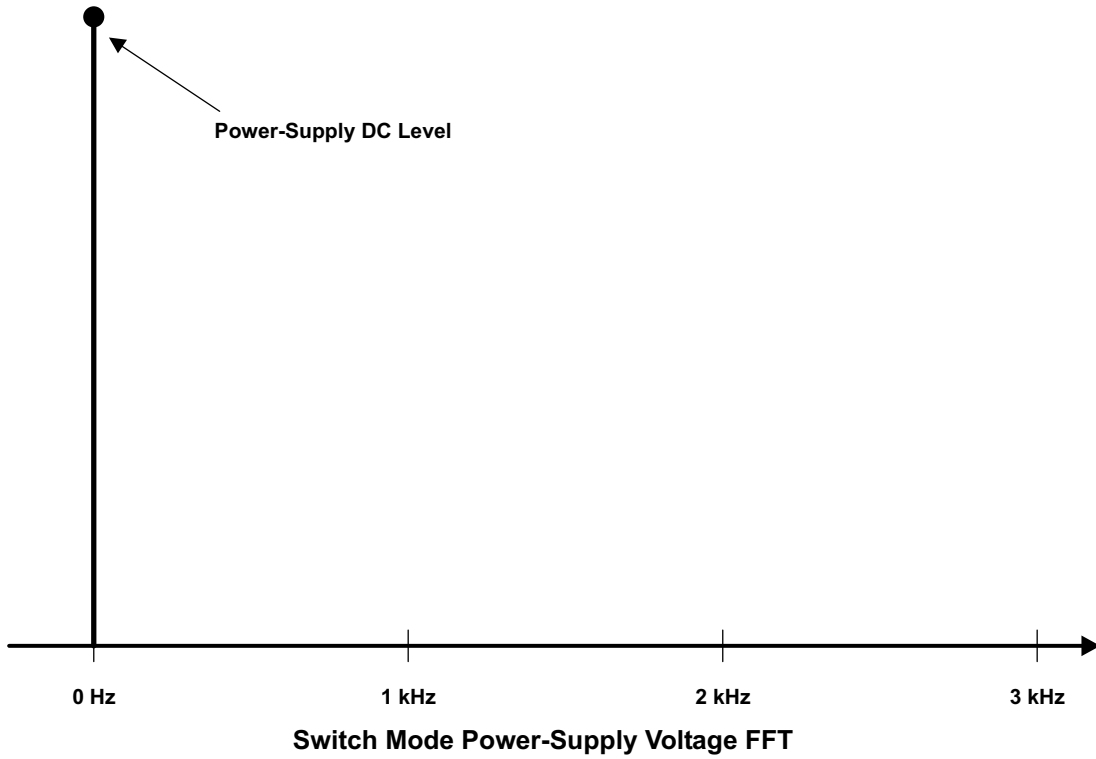
Figure 2. FFT of PSU With SMPS and Amplifier

3 PSRR Test Set-Up

PSRR can be measured in different ways. One uses standard analog generators and RMS voltmeters, and another could be to use an audio analyzer and an external amplifier.

The power supply is fed to the device under test (DUT) through a big resistor or inductor. This is to provide high ac impedance to the power supply. The inductor or resistor must have at least 10× higher impedance than the signal generator. The ac signal is then injected into the supply line through a capacitor. The test setup is shown in Figure 3.
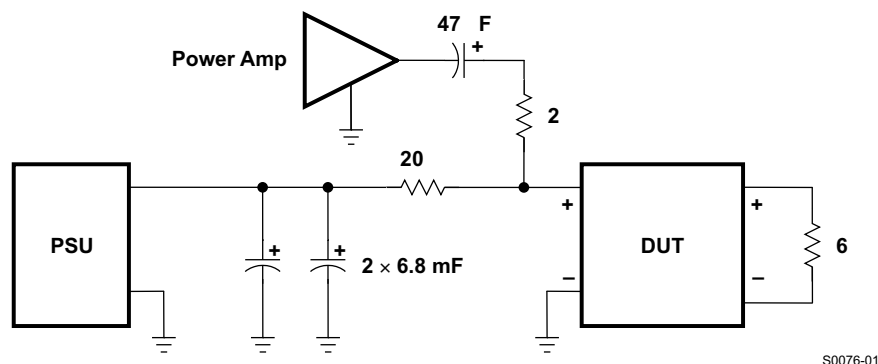

Figure 3. PSRR Test Setup 1

A different way is to use a transformer to inject the ac signal. A transformer is placed in series with the power supply. This transformer must be able to handle the dc current drawn by the DUT. A capacitor is placed in parallel with the power supply to give an ac-signal path to GND. The ac signal is then injected into the supply line via the transformer. The test setup is shown in Figure 4.
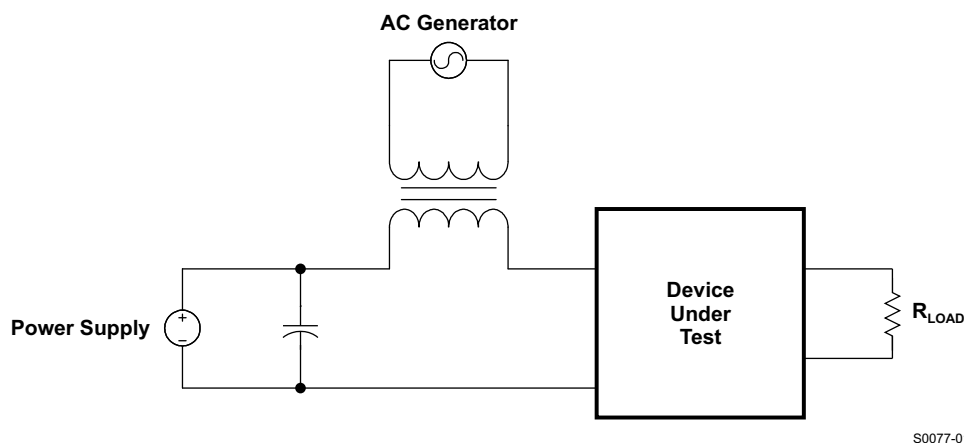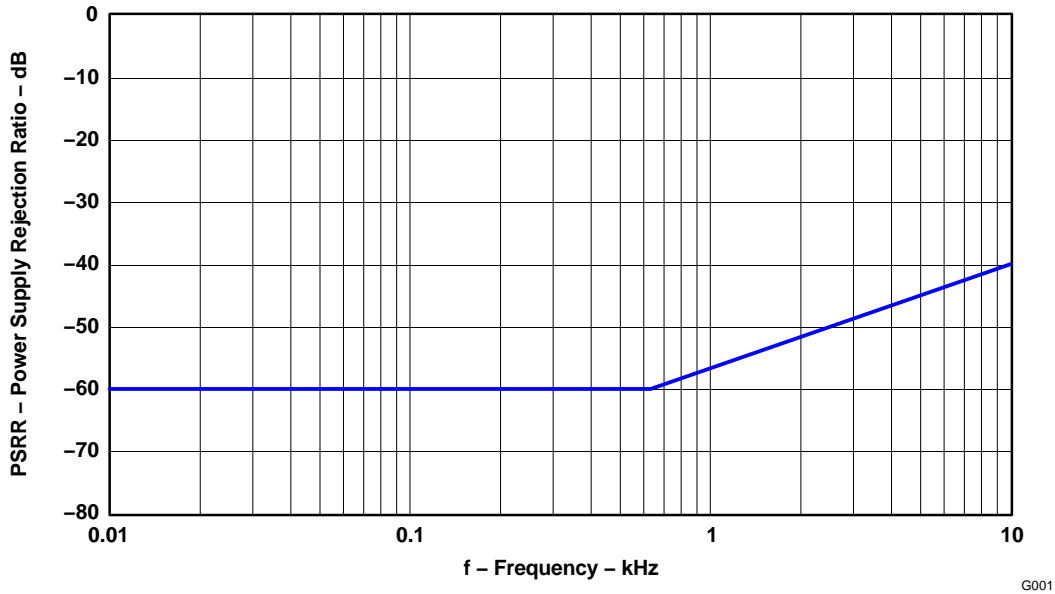

Figure 4. PSRR Test Setup 2

Running the amplifier at 50% duty cycle (mute) makes it possible to measure the PSRR. This is calculated as:

$$PSRR(f) = 20 \times \log \frac{V_{OUT}(f)}{V_{INJECT}(f)}$$

Typical PSRR with the amplifier muted is shown in Figure 5.

Figure 5. Typical PSRR vs Frequency

The PSRR is approximately –60 dB up to approximately 800 Hz, and then it rises to –35 dB at 20 kHz. The rise at higher frequencies is due to non-ideal behavior of the output stage and the parasitic capacitors and inductors.

The normal decoupling of the power-supply voltage provides a filter whereby the noise injected into the power-supply line is filtered at higher frequencies. Therefore, the rise at high frequencies does not contribute to a perceived higher noise at the output.

4   PSRR Measurement

PSRR has been measured using the TAS5086-5142V6EVM and Audio Precision analyzer as shown in Figure 6.
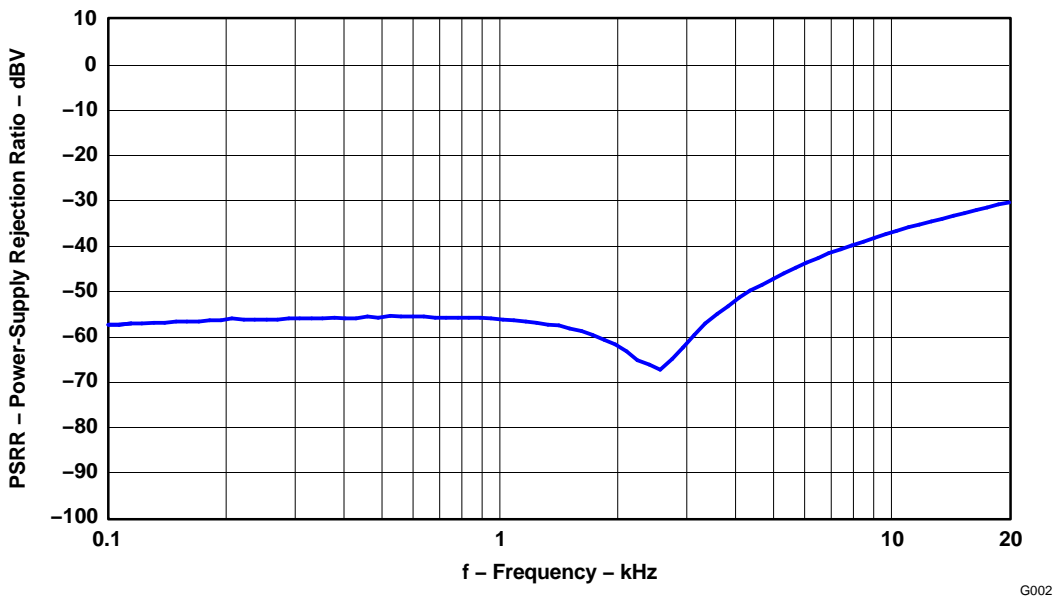
Figure 6. PSRR Measurement

The PSRR is approximately –58 dB from 20 Hz to 3 kHz. It then rises to –30 dB at 20 kHz. The rise at higher frequencies is due to non-ideal behavior of the output stage and parasitic capacitors and inductors.

Normal decoupling of the power-supply voltage provides a filter whereby the noise injected into the power-supply line is filtered at higher frequencies. Therefore, the rise at high frequencies does not contribute to a perceived higher noise on the output, due to the total system noise response.

5   References

1. *System Design Considerations for True Digital Audio Power Amplifiers* (SLAA117)
2. *Digital Audio Measurements* (SLAA114)

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