PSRR and Measurement of PSRR in Class-D Audio Amplifiers and LDOs

Introduction

This application note explains the importance of PSRR and shows how to calculate and measure it. Two examples using the AAT5101 Class D audio amplifier and the AAT2868 CABC Compatible 4 Channel Backlight Driver with Dual LDO Regulators are used to explain how to measure the PSRR of a Class D audio amplifier and a low dropout regulator (LDO). Additionally, a non-inverting amplifier adder circuit used in PSRR measurement is introduced at the end of this note.

What is PSRR?

Power Supply Rejection Ratio (PSRR) is the ratio of the output ripple voltage to the power supply ripple voltage; PSRR indicates how well a circuit rejects ripple coming from the power supply input at various frequencies. PSRR is an important parameter of amplifier and LDO performance in many applications, especially RF and wireless application.

The Importance of PSRR

In a typical portable RF application, the RF amplifier is turned on/off at a rate of 217Hz. At each of these events, a high current (typically, up to 1.7A) is drawn from the power supply, creating a sudden voltage drop (about 200mV) through the battery’s equivalent series resistance (ESR) as shown in Figure 1. The battery also provides power to other devices such as an audio amplifier. The supply ripple caused by the RF amplifier will be injected into the audio amplifier, which then will appear at the same frequency as a voltage ripple in the audio amplifier output. Since 217Hz is within the audio bandwidth (20Hz to 20kHz) the ripple can be heard by the human ear as is observed as a fixed-frequency noise. The level of this noise depends on the PSRR performance of the audio amplifier. With excellent PSRR, the 217Hz noise will be rejected well and not disturb the audio performance.

![Figure 1: RF Subsystem Diagram.](image-url)
Calculating PSRR

The PSRR of the audio amplifier can be calculated using Equation 1:

\[
\text{Eq. 1: } \text{PSRR} = 20 \cdot \log\left(\frac{V_{\text{RIPPLE(OUT)}}}{V_{\text{RIPPLE(IN)}}}\right)
\]

For example, if there is 200mV peak-to-peak ripple in the power supply input and the same frequency voltage ripple in the amplifier output at 200μV peak-to-peak.

The PSRR of the LDO can then be calculated using Equation 2:

\[
\text{Eq. 2: } \text{PSRR} = 20 \cdot \log\left(\frac{200 \cdot 10^{-6}}{200 \cdot 10^{-3}}\right) = -60\text{dB}
\]

However, in an LDO, the PSRR is always expressed as a positive value.

Measuring PSRR

As shown previously, when the amplitude of the input ripple and relative output ripple are known, the device PSRR can be calculated easily.

The common way to perform the PSRR measurement is to add a fixed amplitude sinusoid ripple on the power supply input and measure the amplitude of the same frequency ripple on the output. The PSRR can then be calculated using Equation 1 or 2.

An Audio Precision audio analyzer or a network analyzer is needed to perform the PSRR measurement. The PSRR value can be expressed in dB directly by using the crosstalk or A/R function in the measurement instrument instead of calculating it.
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PSRR Measurement of Class D Audio Amplifier

Figure 3 shows the PSRR measurement set-up for the AAT5101 Class D audio amplifier. In this case, the DC power supply, non-inverting amplifier adder, an 8Ω load, 30kHz low pass filter, and Audio Precision analyzer AP-SYS2722 are needed.

![Figure 3: AAT5101 PSRR Measurement Set-up.](image)

The inputs of the AAT5101 should be AC grounded as shown. A 200mV peak to peak sinusoid ripple generated from the Audio Precision analyzer output is added onto the power supply input through the non-inverting amplifier adder. The output ripple can be measured by the Audio Precision (AP) analyzer through a 30kHz low pass filter (LPF). Connect the power supply input (V\textsubscript{DD}) to the AP’s channel A and connect the output of the low pass filter to the AP’s channel B. Choose the crosstalk function and scan frequency from 20Hz to 20kHz, then a resulting curve of PSRR over the audio bandwidth will be measured as shown in Figure 4. Adjust the power supply DC value to the intended system operating range.

Figure 4 shows the AAT5101 PSRR measurement results for DC input values of V\textsubscript{DD} at 2.5V, 3.6V and 5V.

![Figure 4: AAT5101 PSRR Result.](image)
PSRR Measurement of LDO

Figure 5 shows the PSRR measurement set-up for the AAT2868 which contains two LDO regulators. In this example, the DC power supply, non-inverting amplifier adder, DC electronic load, and a network analyzer such as the Agilent 4395A are needed.

![Figure 5: AAT2868 LDO Part PSRR Measurement Set-up.](image)

A 200mV peak-to-peak sinusoid ripple waveform generated from network analyzer output is added onto the power supply input (INLDO) through the non-inverting amplifier adder. The output voltage can be measured by the network analyzer. Connect the LDO input to the network port INA and connect the LDO output to the network port INR. Chose the A/R function and a scan frequency from 100Hz to 100kHz. Adjust the power supply DC value to the intended system operating range.

Figure 6 shows the PSRR measurement result using the AAT2868 LDO for the condition: $V_{IN} = 3.6V$, $V_{RIPPLE} = 200mVpp$, $I_{LOAD} = 10mA$.

![Figure 6: AAT2868 LDO PSRR Measurement Result.](image)
Design and Application of the Non-inverting Amplifier Adder

To generate a DC power with a certain sinusoid ripple waveform added, a non-inverting amplifier adder is adopted. The output of the adder will be DC+AC as shown in Figure 7.

![Adder for PSRR Measurement](image)

**Figure 7: Adder for PSRR Measurement.**

Figures 8 and 9 show the schematic and board picture of the non-inverting amplifier adder used in the PSRR measurement.

![Schematic of the Non-inverting Amplifier Adder in PSRR Measurement](image)

**Figure 8: Schematic of the Non-inverting Amplifier Adder in PSRR Measurement.**
Connect ±12V DC power to +12V and -12V on the board. Connect the power supply input voltage of the test device to VDD. Connect the output of audio precision or network analyzer to In to supply the desire sinusoid ripple. The DC+AC voltage of VDD + In signal will be generated at OUT.

Figure 10 shows the system connecting of the set-up described above.

The yellow curve on the scope is the sinusoid ripple waveform before the non-inverting amplifier adder and the blue curve is the DC+AC signal of the Adder output.
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Conclusion

The PSRR measurement indicates how well a circuit rejects ripple or noise from the power supply input. When making a PSRR measurement, the biggest challenge is that the output ripple amplitude is very small. This makes it difficult to measure accurately using common equipment such as an oscilloscope or multi-meter. An Audio Precision analyzer (e.g. AP-SYS2722) or a network analyzer (e.g. Agilent 4395A) is necessary to do the measurement correctly.

Table 1 shows the required equipment and calculations for the Class D audio amplifier and the LDO PSRR measurement.

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>PSRR Calculation</th>
<th>Measurement Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class D Audio Amplifier</td>
<td>PSRR = 20 · log (V_{RIPPLE(OUT)}) / V_{RIPPLE(IN)}</td>
<td>Audio Precision (e.g. AP-SYS2722), Adder</td>
</tr>
<tr>
<td>LDO</td>
<td>PSRR = 20 · log (V_{RIPPLE(IN)}) / V_{RIPPLE(OUT)}</td>
<td>Network Analyzer (e.g. Agilent-4395A), Adder</td>
</tr>
</tbody>
</table>

Table 1: PSRR Calculation Equation and Measurement Equipment.