- 2700 Series
- ATS-2
- APx500 Series

Measuring Power Supply Rejection Ratio (PSRR)

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About This Technote

In this technote we describe and compare two different methods to measure PSRR. Then we give instructions for using the APx PSRR Measurement Utility, which simplifies the calculations and graphing on APx analyzers.

Introduction

Power Supply Rejection Ratio (PSRR) is a measure of a device's ability to reject noise from the supply used to power it. It is defined as the ratio of the change in supply voltage to the corresponding change in output voltage of the device.

$$PSRR = 20 \cdot \log\left(\frac{\Delta V_{in}}{\Delta V_{out}}\right)$$

PSRR is often expressed in dB, where ΔV_{IN} is the change in voltage input and ΔV_{OUT} is the change in voltage output. However, due to lack of standardization, the ratio is sometimes inverted, and the value in dB is sometimes expressed as a negative number.

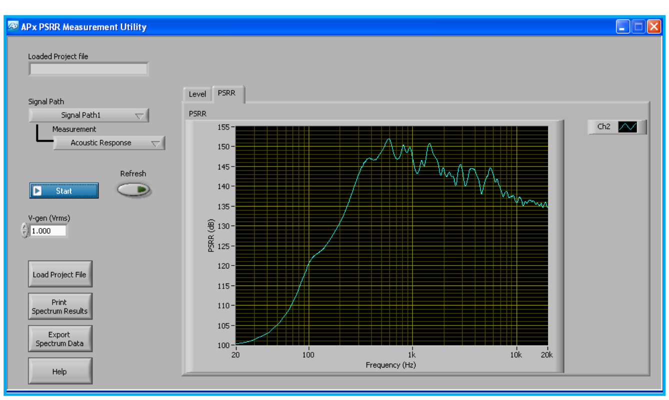


Figure 1. The APx PSRR Measurement Utility in spectrum mode.

PSRR measurements are typically made for ICs and other functional assemblies. To measure such a device's power supply rejection, we need to insert an AC signal (ΔV_{IN}) in series with the DC voltage from the supply and examine the device's output (ΔV_{OUT}) for the presence of the signal. It is often desirable to measure PSRR over a range of frequencies and to produce a spectrum plot of PSRR versus frequency.

PSRR Measurement Methods

The problem with conducting a PSRR test with a DC supply is that most signal generators (including the generator in AP audio analyzers) cannot be connected directly in series with a DC power supply. First, the DC current drawn from the power supply to the device must flow through the signal generator, and this current could be substantial. In addition, the output impedance of most signal generators is likely to cause an excessive voltage drop, and very few signal generators can be floated to typical DC voltages.

There are three possible solutions to these problems:

- Build a transformer circuit to couple the AC test signal in series with the power supply.
- Use a special power supply that is capable of combining an arbitrary AC signal with DC power.
- Use a DC-coupled power amplifier.

This technote will investigate the first two solutions in further detail with practical examples.

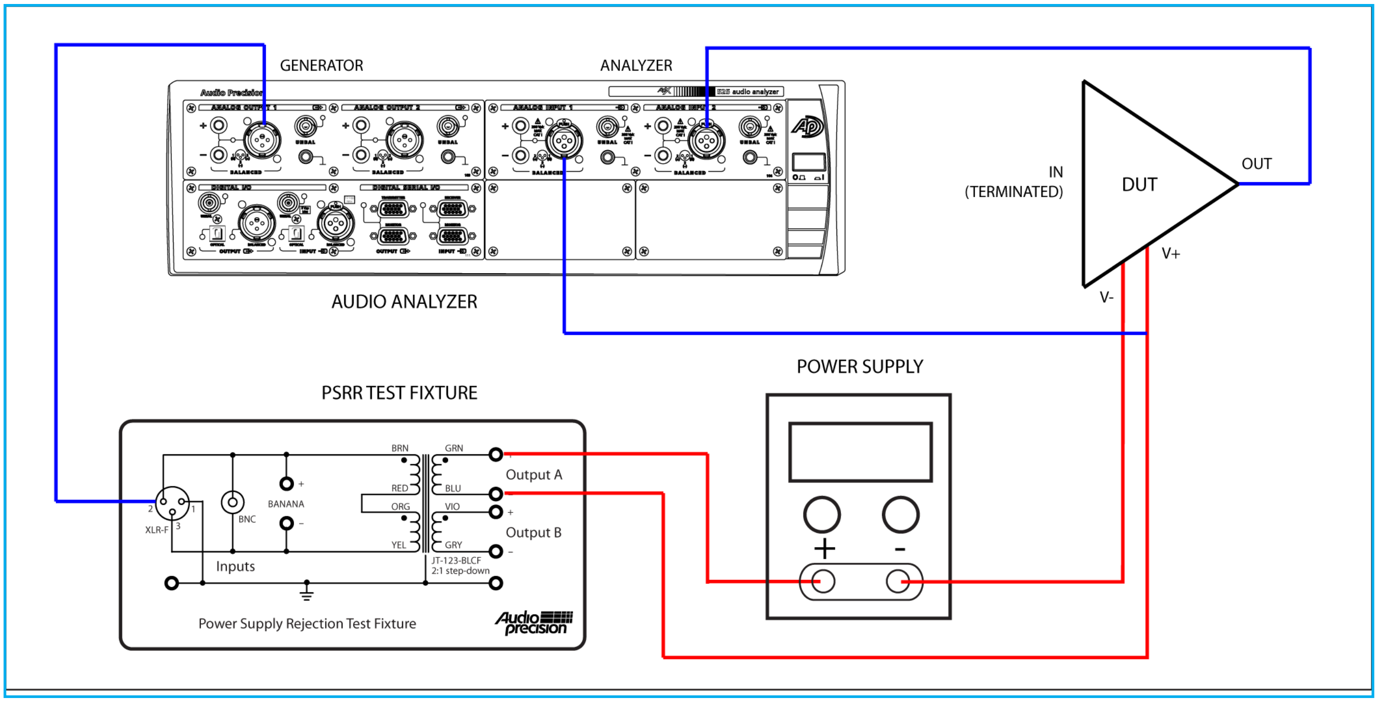


Figure 2. *Connections using the PSRR transformer test fixture.*

Transformer Circuit

By attaching a signal generator to a transformer primary and running DC through the secondary, we can couple an AC voltage onto the DC supply. The test configuration is shown in Figure 2 above.

For convenience, we built the transformer circuit into a project box with appropriate input and output connectors. The primary windings have been connected in series, to provide an input impedance of approximately 600 Ω. The secondary windings can be connected in series for a 1:1 voltage ratio, or we can connect to just one for a 2:1 ratio.

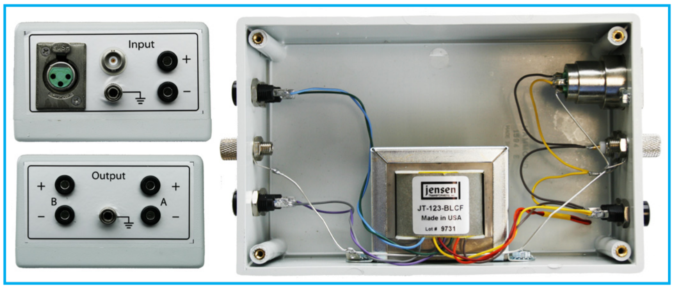


Figure 3. *Completed PSRR test fixture.*

We selected a Jensen JT-123-BLCF transformer, due to its low distortion, flat frequency response, and split winding flexibility. One of the pitfalls of using a transformer in this application is that excessive DC current can saturates the core, causing the AC signal to distort.

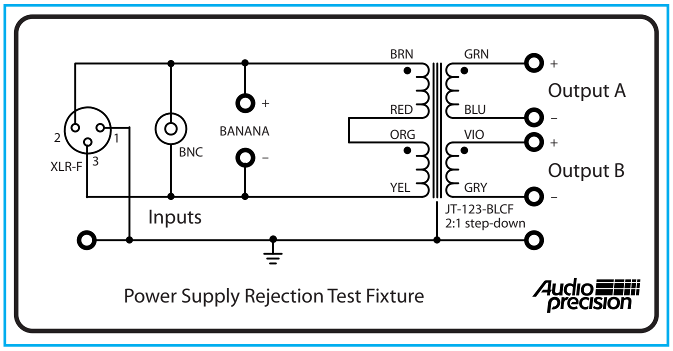


Figure 4. *PSRR test fixture schematic.*

To determine its current capacity, we measured the distortion of a 20 Hz sine wave coupled to a DC voltage at a number of different current levels. As seen in Figure 5, the distortion begins to rise sharply as the current exceeds about 500 mA DC.

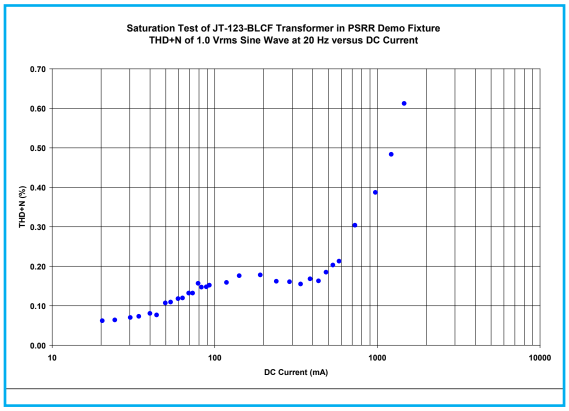


Figure 5. *Transformer distortion vs. DC current.*

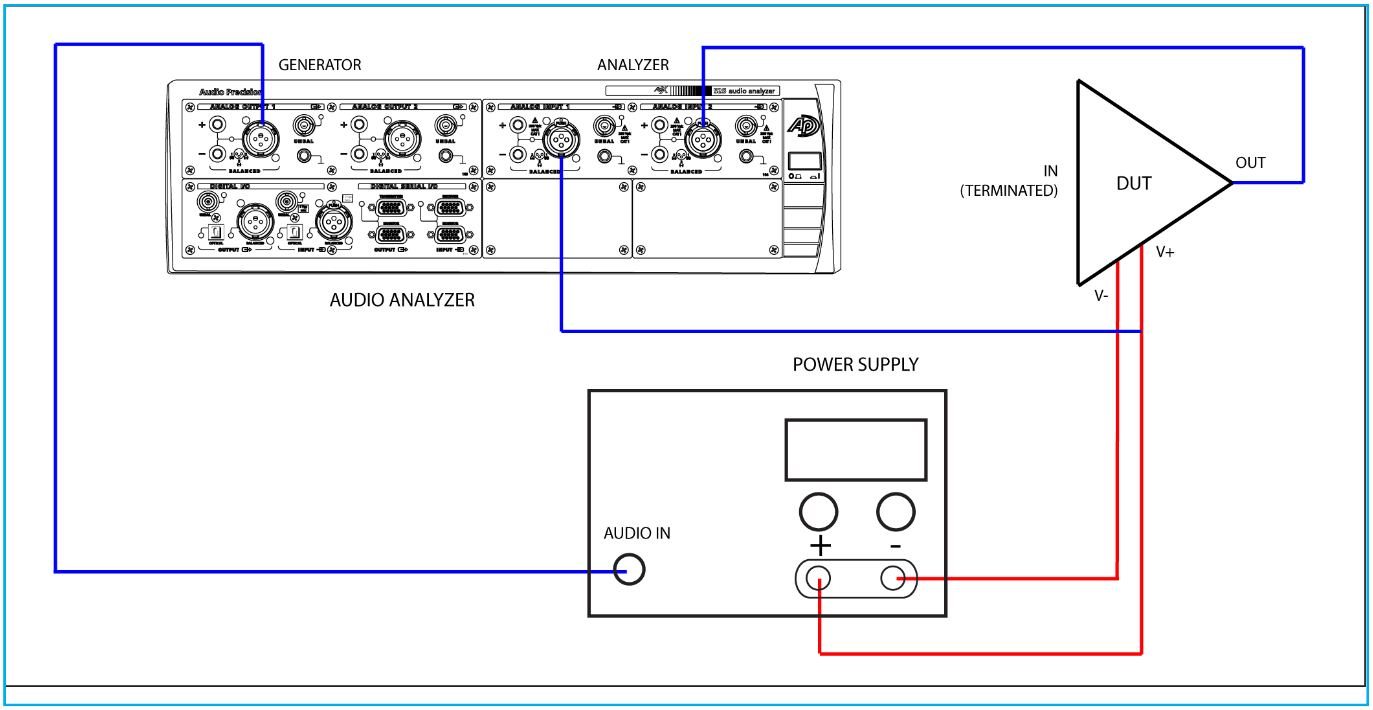


Figure 6. Connections using the DC + AC power supply.

Power Supply with DC and AC Output

A special power supply with the ability to add an AC signal to its DC output is used for this method. One example in this category is the Kepco BOP series, a high-powered operational amplifier / power supply with outputs capable of both sustained DC and arbitrary AC waveforms. Additionally, the outputs can operate as a sink as well as a voltage and current source.

After selecting the required DC voltage, we connect the signal generator output of an audio analyzer to the Voltage Programming Input on the front panel of the power supply. The input has a fixed gain of 2.0 to 20.0, depending on the model. This gain must be considered when selecting the audio analyzer generator voltage.

APx PSRR Measurement Utility

For APx500 Series instruments, we have created the APx PSRR Measurement Utility to simplify measurement and calculation. We apply an AC signal from the audio analyzer's generator into the DUT's DC power supply, using either of the two methods described above. Since the actual AC voltage seen at the power input terminals of the DUT is unknown and may vary with frequency, we connect channel 1 of the analyzer to this point and use it as our reference level. The other channel will be used to measure the DUT output voltage (V_{OUT}). PSRR is then calculated using the equation on page 1. For a 2700 Series or ATS-2 analyzer, the PSRR can be derived using the Compute Delta feature, if the voltages are in read in dBV.

The utility works in two modes: discrete frequency, and spectrum.

Discrete Frequency Mode

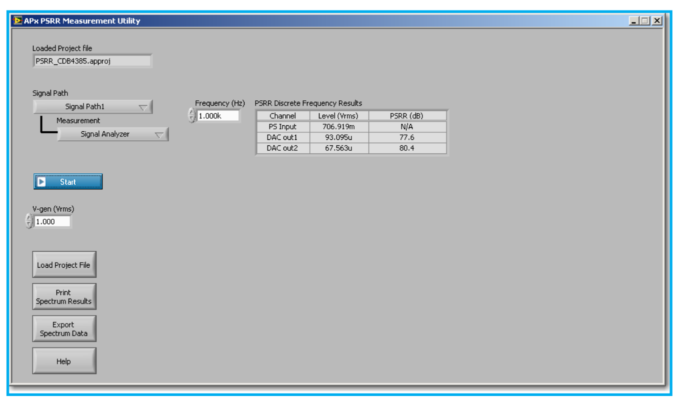


Figure 7. The APx PSRR Measurement Utility in discrete frequency mode.

In discrete frequency mode, the Signal Analyzer measurement is used to measure PSRR at a single frequency. If the Signal Analyzer is not an available choice in the utility, add it to the measurement navigator in the APx500 measurement software and click refresh in the utility to update its list. In discrete frequency mode, the utility retrieves the levels of the input channels at the generator frequency and calculates the PSRR using the equation.

Note that a standard PSRR reading is a measurement of the DUT output voltage at the same frequency as the stimulus signal. In practice, however, the mechanisms that couple power supply variations to the output can be decidedly non-linear, resulting in harmonics at significant levels. Since the Signal Analyzer in APx500 displays a full spectrum FFT, it is easy to see if these signals are present. Measuring them is relatively easy—set the dBrA reference in APx500 to equal the Vrms level of channel one, as shown in the utility, and then change the Y-axis of the FFT Spectrum view to read in dBrA.

Spectrum Mode

In spectrum mode (Figure 1), the utility measures the spectrum of the input channels, using any of the three APx frequency response type measurements (Frequency Response, Continuous Sweep, or Acoustic Response). It then calculates a PSRR spectrum by applying the equation.

PSRR Test Examples

In our first example, we'll test a D/A converter evaluation module using the transformer test fixture. This module has three power supply inputs: +12, –12, and +5 VDC. You can (and should) conduct a PSRR measurement on each of the supply inputs. In this case, we're testing the +12 VDC input.

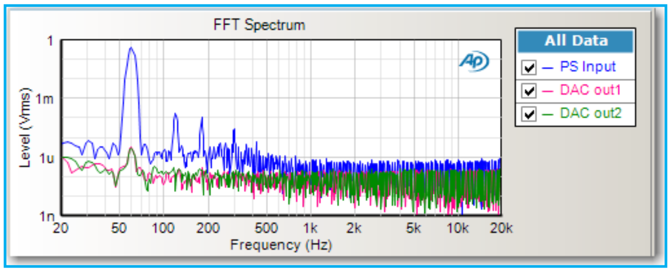
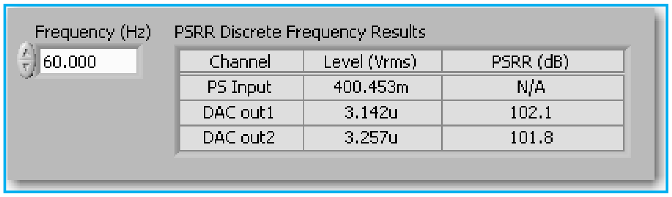


Figure 8. FFT level spectra of the power supply input and signal output channels of a DAC, 1.0 Vrms stimulus at 60 Hz.

Figure 8 shows the level spectra measured with the PSRR utility in descrete frequency mode and the APx generator set to 1.0 Vrms at 60 Hz. From the FFT, you can see that the signal input to the DUT (PS Input) is about 0.4 Vrms, and the DAC output signals are at about 3 µV.


Frequency (Hz) 60.000

PSRR Discrete Frequency Results

Channel	Level (Vrms)	PSRR (dB)
PS Input	400.453m	N/A
DAC out1	3.142u	102.1
DAC out2	3.257u	101.8

Figure 9. PSRR results for DAC at 60 Hz.

As shown in Figure 9, the APx PSRR Measurement Utility accurately retrieves the levels at the generator frequency and performs the PSRR calculation.

Figure 10 shows the level spectra measured with the PSRR utility in spectrum mode and the generator set to 1.0 Vrms. Note that at low frequencies, the measured level on the power supply input is approximately 0.5 Vrms, as we would expect for the transformer's 2:1 step-down ratio. However, the level gradually decreases to about 20 mV as the frequency is increased to 20 kHz. This is because the DUT and/or the power supply's impedance decreases with frequency, and therefore the generator cannot maintain a constant voltage. Nevertheless, since we are measuring both the input and output voltages, we can still make valid PSRR spectrum measurements, as shown in Figure 11.

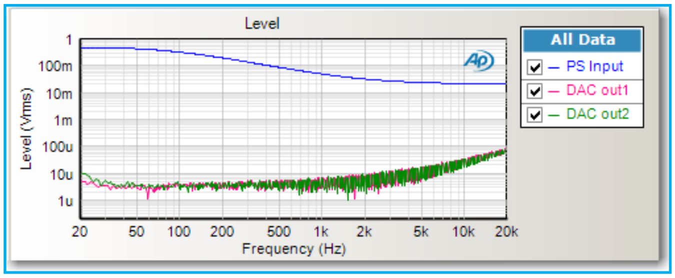


Figure 10. Level spectra of a DAC, Frequency Response measurement.

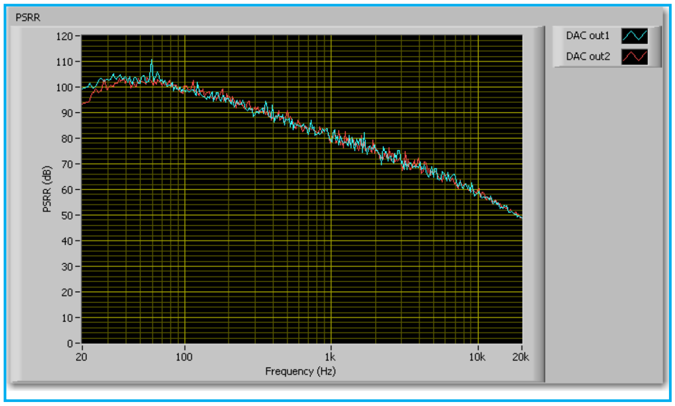


Figure 11. PSRR spectrum derived from Figure 10.

Due to the low levels of the output signals (< 100 µVrms), their level spectra measured with the

Frequency Response measurement are somewhat noisy (Figure 10), resulting in noisy PSRR spectra (Figure 11). A smoother looking curve can be made with APx by using the Acoustic Response measurement (Figures 12 and 13).

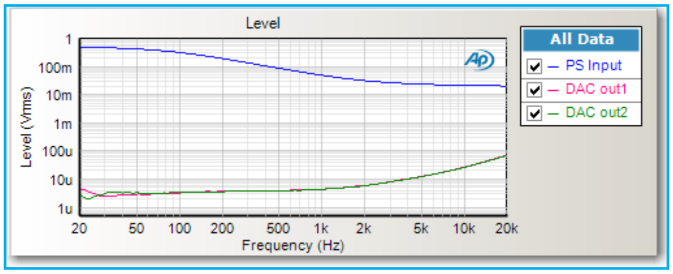


Figure 12. Level spectra of a DAC, Acoustic Response measurement.

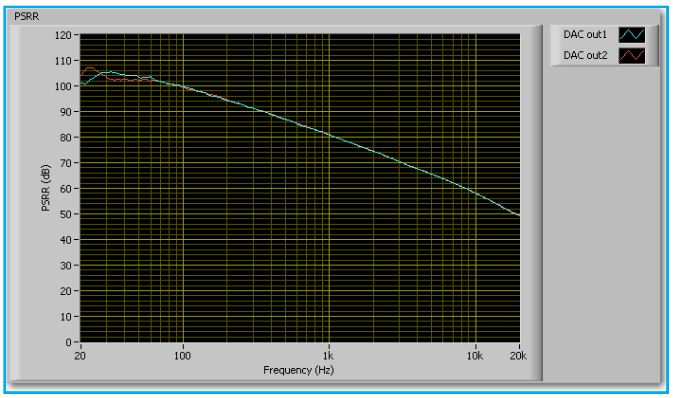


Figure 13. PSRR spectrum derived from Figure 12.

In this case, two features of the Acoustic Response measurement have been used to produce smoother output spectra—averaging, which improves signal to noise ratio, and 1/24-octave smoothing.

Next, we'll test a small Class D amplifier using the transformer test fixture. This DUT requires a 10 to 35 VDC power supply, and has a maximum power rating of 2 x 25 Wrms into 4 Ω. We used a 20 VDC power supply with a 4 Ω resistive load on the output, and set the generator voltage to 1.0 Vrms.

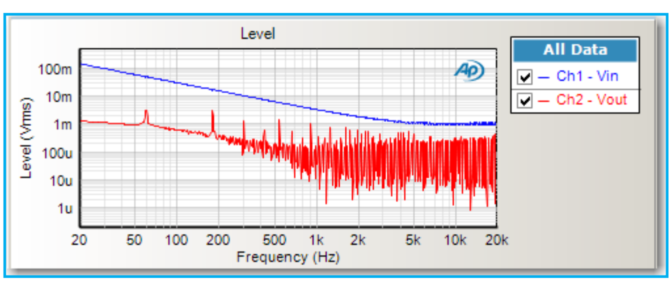


Figure 14. Level spectra for a Class D EVM, Frequency Response measurement.

Figure 14 shows the power supply input (V_{IN}) and signal out (V_{OUT}) levels measured for this device using the APx Frequency Response measurement. There are three things to note about the results:

- In the V_{OUT} signal, harmonics of the 60 Hz power line frequency which corrupt the measurement are clearly visible.
- The input voltage falls off much more rapidly with frequency than the DAC device above, approaching a lower limit of approximately 1 mV above 3 kHz.
- The V_{OUT} signal is very noisy - probably because the AC input voltage is so low that its effect is not discernible above the DUT's inherent noise.

Needless to say, a PSRR spectrum derived by dividing the V_{IN} curve by V_{OUT} the curve in Figure 14 would be very noisy and of limited use.

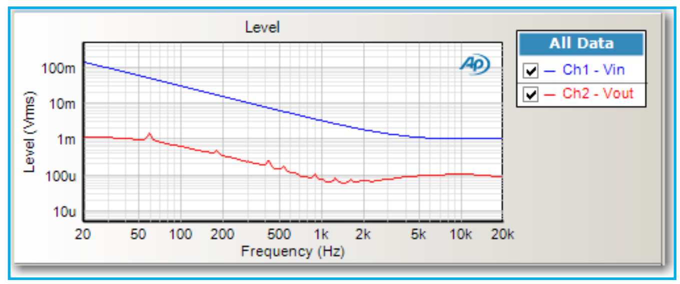


Figure 15. Level spectra for a Class D EVM using Accoustic Response measurement.

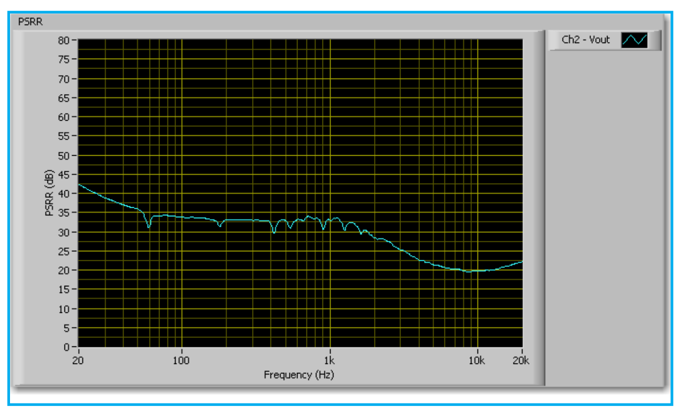


Figure 16. PSRR spectrum derived from Figure 15.

Figure 15 shows the same signal as Figure 14, but this time the Acoustic Response measurement was used with 5 averages and 1/24-octave smoothing. The averaging and smoothing do smooth out the noise in the V_{OUT} curve, to the point where the derived PSRR spectrum (Figure 16) appears reasonable. However, the various peaks in the curve indicate that the measurement still has a relatively low signal-to-nose ratio—i.e., the V_{IN} signal is probably not high enough to achieve an accurate measurement at some frequencies.

Next, for comparison, we test the same Class D amplifier EVM, but this time using the Kepco Model BOP 36-12M power supply with DC + AC output capability. This supply has a gain of 3.6 on the AC input, and a much greater current capacity than the APx generator. To achieve an input voltage of 100 mVrms (approximately the same input voltage applied in the previous test at 20 Hz), the APx's generator was set to 28.2 mVrms.

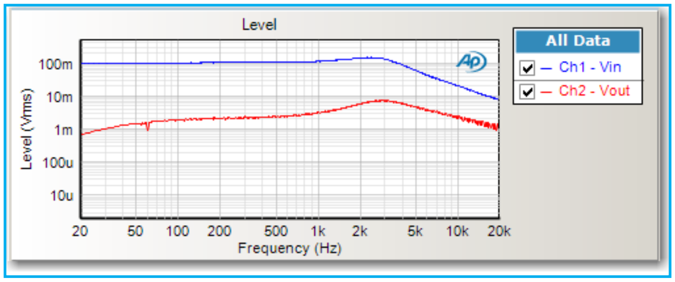


Figure 17. Level spectra for a Class D EVM using the Frequency Response measurement and the DC + AC Kepco power supply.

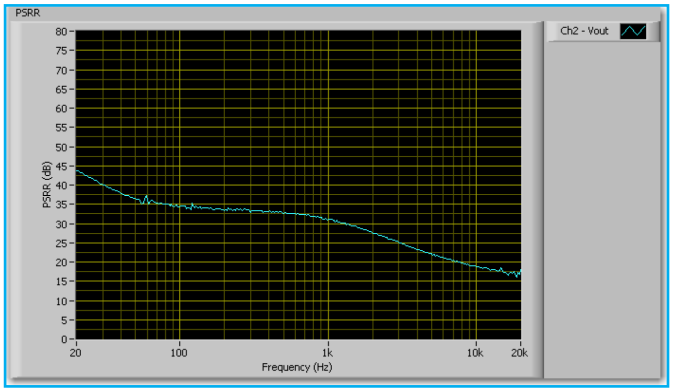


Figure 18. PSRR spectrum derived from Figure 17.

Figure 17 shows the level spectra measured on the Class D amplifier EVM with the Kepco power supply. Note that the voltage input to the DUT remains relatively constant with frequency up to about 3 kHz, and then begins to taper more gradually. Due to this higher voltage, the V_{OUT} curve is much less noisy than when measured with the transformer test fixture. The resulting PSRR spectrum (Figure 18) is also much less noisy.

A comparison of the PSRR spectra for this DUT measured with the transformer test fixture and the special purpose Kepco power supply is shown below.

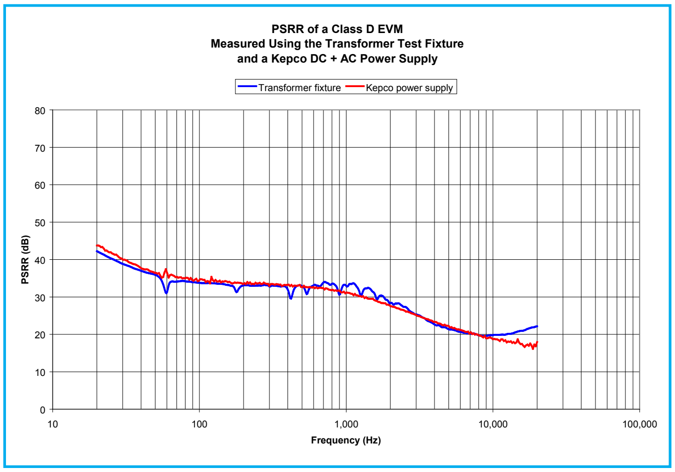


Figure 19. Comparison of PSRR spectra of the Class D EVM.

Obviously, the Kepco power supply is a better choice for testing the PSRR of this device. However, in spite of the higher noise levels present in the measurements with the transformer test fixture, the results are remarkably close. In addition, it should be noted that results measured with the transformer fixture in discrete spectrum mode are probably more accurate than those measured in spectrum mode, due to the inherently higher signal to noise ratio.

Related Downloads:

APx PSRR Measurement Utility
http://ap.com/downloads/splash/443

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