APPLICATION NOTE AN06

MEASURING PSRR AND PSR+N ON THE APx525

Special attention to details is required to properly measure the Power Supply Rejection Ratio (PSRR) and Power Supply Rejection (PSR+N) performance of SiSonic™ microphones. This is especially true for new generations of microphones with better performance.

PSRR AND PSR+N DEFINITION

PSRR (Power Supply Rejection Ratio) is commonly defined as 20log(Vdd_Signal/OUT_Signal). It is a measure of how signals on the power supply are rejected at the output. That is, when Vdd is perturbed it measures how much of the perturbation shows up at OUT. If the signal on OUT is very small then PSRR will be a big positive number indicating very good performance. Microphones are often placed in environments with very noisy supply lines and it is undesirable to have this noise corrupt the output signal. All other things being equal, a microphone with large PSRR will outperform a microphone with lower PSRR.

The PSRR perturbation test signal is a sinewave which is swept across a frequency range. PSRR can then be plotted in a way similar to Frequency Response. Datasheets often only specify PSRR at 1kHz which is an easy to use figure of merit.

While PSRR accurately reflects the microphone's rejection of signals on Vdd, it doesn't model the typical use cases very well. In a cellphone, for example, Vdd is often supplied from a battery which also supplies the RF power amplifier, the biggest drain on the battery. The legacy GSM system transmits RF in bursts with a 1/8 duty cycle operating at 216.6667 Hz (often rounded to 217 Hz). Each burst uses a great deal current, causing the battery voltage to droop during the transmit cycle. The waveform of the battery voltage looks like a 7/8 duty cycle 217 Hz rectangular wave. Since the microphone Vdd is derived from this, it will also have a 7/8 duty cycle 217Hz waveform superimposed on it. This is the Vdd perturbation test signal used for PSR+N measurements.

Not only is the perturbation test signal different from PSRR, but PSR+N is not a ratio like PSRR but a measure of the actual output level. In addition, the measurement is PSR+N, not just PSR. The noise floor is included in the measurement and because of this the whole measurement is A-weighted. For analog microphones the unit is dBV(A). For digital microphones the unit is dBFS(A). A large negative number indicates a very small output level, which is good.

PSRR and PSR+N are two ways to measure the same thing. When interference adds noise and signals to the Vdd line, how much does the microphone output degrade?

TEST SETUP

The microphone must be placed in a very quiet environment to keep ambient noise from corrupting the measurements. Microphones with good PSRR can easily have their PSRR output signal buried in the noise floor.

CONNECTIONS TO THE APX525

Connection to the APx525 is illustrated in the figures below and summarized in the table:

APx525	Analog	Digital
PDM Vdd Supply	Vdd	Vdd
Analog Input 1	Out	nc
PDM Input	nc	Data
PDM Bit Clock	nc	Clock

nc = no connection

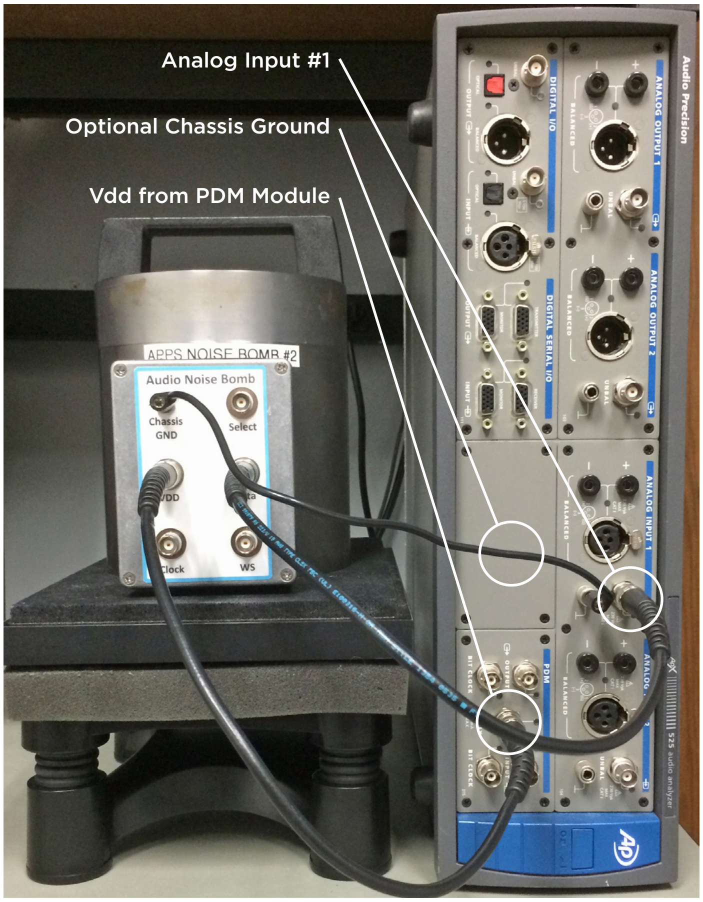
The chassis ground connection shown in the figures may be required to keep 50/60 cycle interference of the power mains from corrupting the measurement.

If the PDM module is not available to provide Vdd then it is best to construct the Vdd waveform by using an Arbitrary Waveform Generator. Microphone current requirements are so small that the Vdd line can be easily driven. However, most generators have a 50 ohm output impedance which will have to be taken into account.

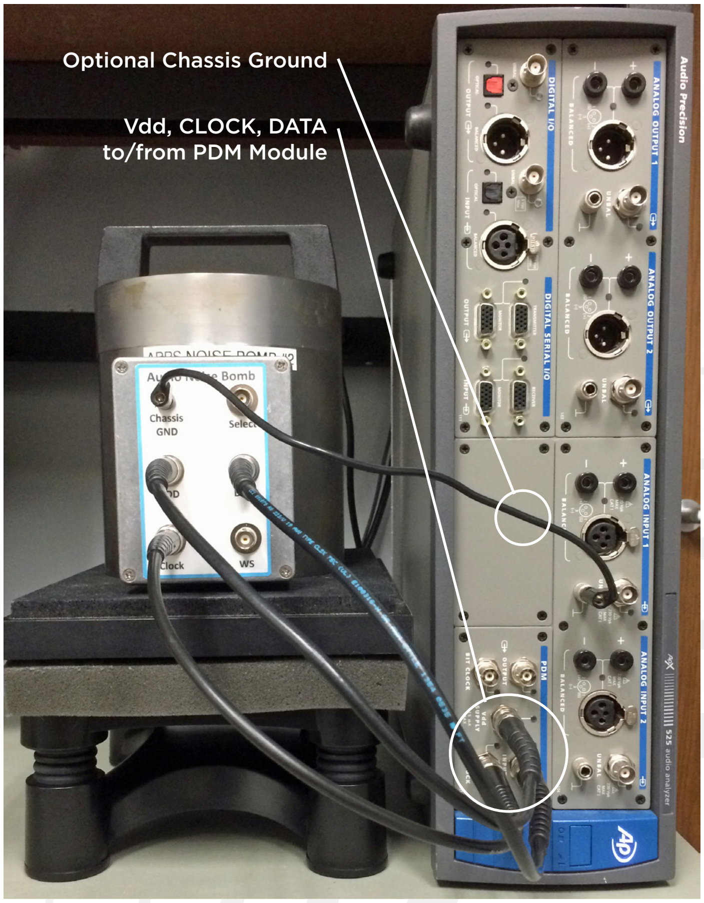
Since microphones with very good PSRR performance have output signals close to the noise floor during a PSRR measurement, they are placed in an isolation cavity with sufficient sound pressure attenuation to remove the effects of ambient noise from corrupting the measurement. For example, the noise floor of a 65dB(A) SNR microphone is 29dB(A) SPL. That means the noise level of test environment needs to be 19-23dB(A) SPL. That is very, very quiet and is difficult to achieve. As seen in the these figures, Knowles uses a custom fixture called an Audio Noise Bomb. It sits on isolation pads commonly used in recording studios to isolate monitor systems. This helps keep desktop movements such as mouse clicks and keyboarding from coupling into the system, degrading the noise floor even further.

A PSRR measurement consists of applying a 100mVpp sinewave to Vdd and reading the level of the signal seen at OUT. 100mVpp is small enough to be considered small signal and not disrupt microphone operation when Vdd is 1.8v. However, for microphones with very good PSRR the resulting output signal could be buried in the noise. In this case the perturbation test signal can be increased to 200mVpp in order to increase the output signal, hopefully raising it out of the noise floor. With this larger signal care must be taken to insure the microphone is still kept within its normal operating range.

APx Connection for an Analog Microphone



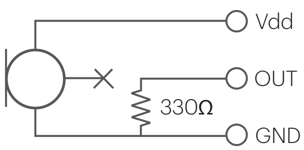
APx Connection for a Digital Microphone



TESTING THE SYSTEM CAPABILITIES

To test the capabilities of the measurement setup, an analog microphone measurement is made using a special test board to properly terminate the Vdd and OUT cables. The schematic of the board is shown to below and consists of a normal microphone FR4 coupon or flex circuit but with the microphone OUT disconnected from the edge connector. To properly load the OUT cable, a 330 ohm resistor is placed between OUT and GND to replicate the output impedance of the microphone which has been disconnected. In this way both the Vdd and OUT cables are properly loaded just as if a microphone were normally installed.

Schematic of PSRR System Test Circuit

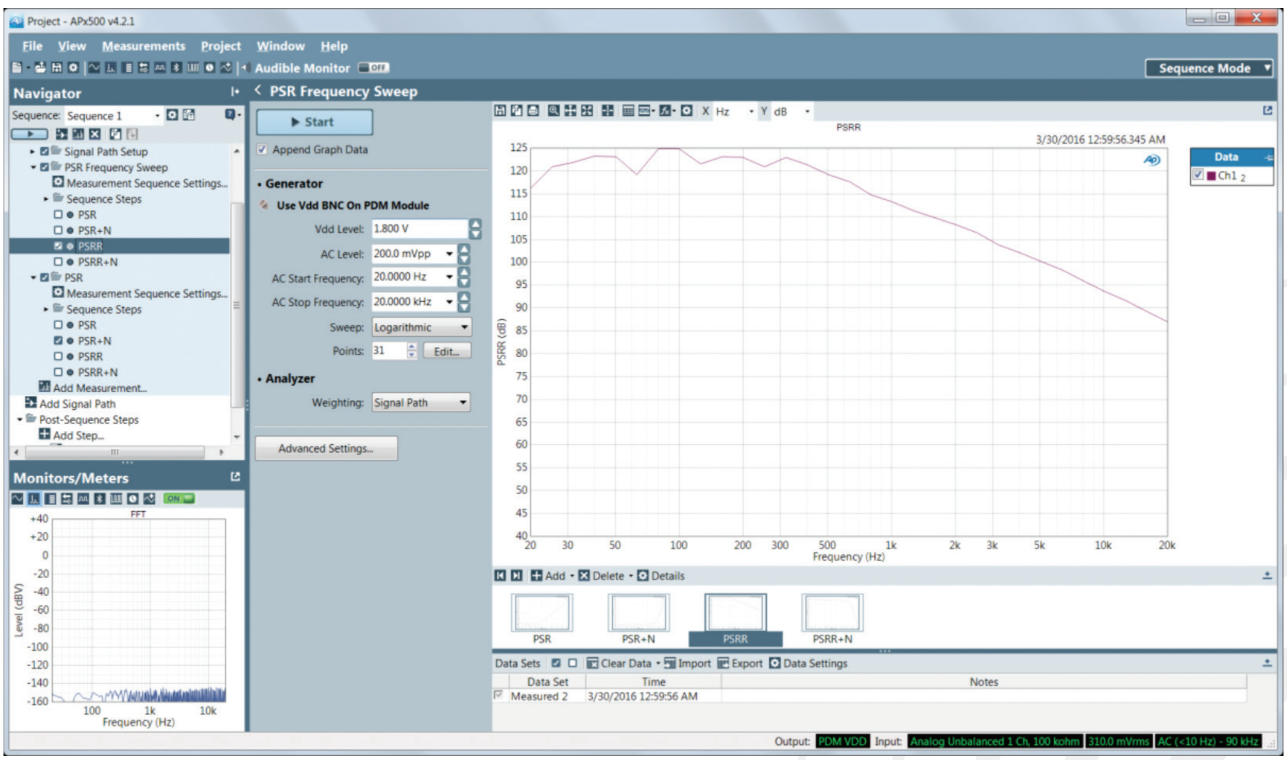


The PSRR result of the test system using this test board is shown in the figure below. A 200mVpp perturbation signal was used because the output signal was expected to be very small and difficult to see above the noise. Even with this larger perturbation signal it is still impossible to measure PSRR below 300 Hz. This test system has very good results and will be capable of measuring very high levels of PSRR.

In the test setup the stray leakage path from Vdd to OUT is thru the cables, the Audio Noise Bomb wiring, the coupon, and internally thru the APx525. It is not through the microphone since its output has been disconnected. This leakage path can be modeled as stray coupling capacitance and forms a stray RC highpass filter from Vdd to OUT.

The high frequency rolloff is 20dB/decade, indicating that the single pole RC highpass filter is an appropriate model (at first glance the response looks like a lowpass filter but the output signal appears in the denominator of PSRR so at high frequencies there is MORE signal - i.e., it's a highpass filter). This highpass RC filter has 100dB of attenuation at 5 kHz and, since R = 330 ohms, total stray C can be calculated from $10^{-100/20} \sim 2\pi f RC$. In this case stray C ~ 1pF which is outstanding. This test setup was very good.

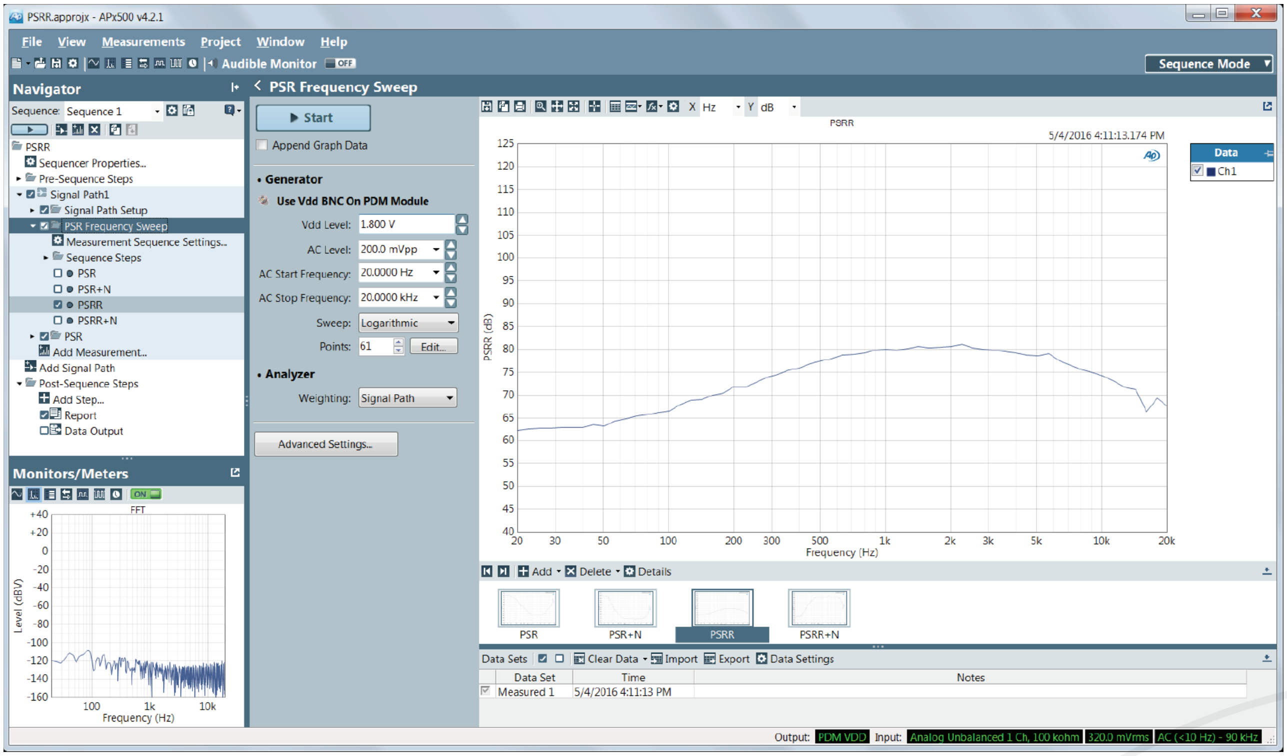
APx v4.2.1 PSRR Result Using PSRR System Test Circuit



MEASURING PSRR AND PSR+N ON ANALOG MICROPHONES

PSRR setup and results for an analog microphone are shown below. During the sweep the response should be monitored in the lower left window to see if the signal stays above the noise floor. If it gets too low then increase the signal to 200mVpp, which is what occurred in this case.

APx v4.2.1 PSRR Result For Analog Microphone

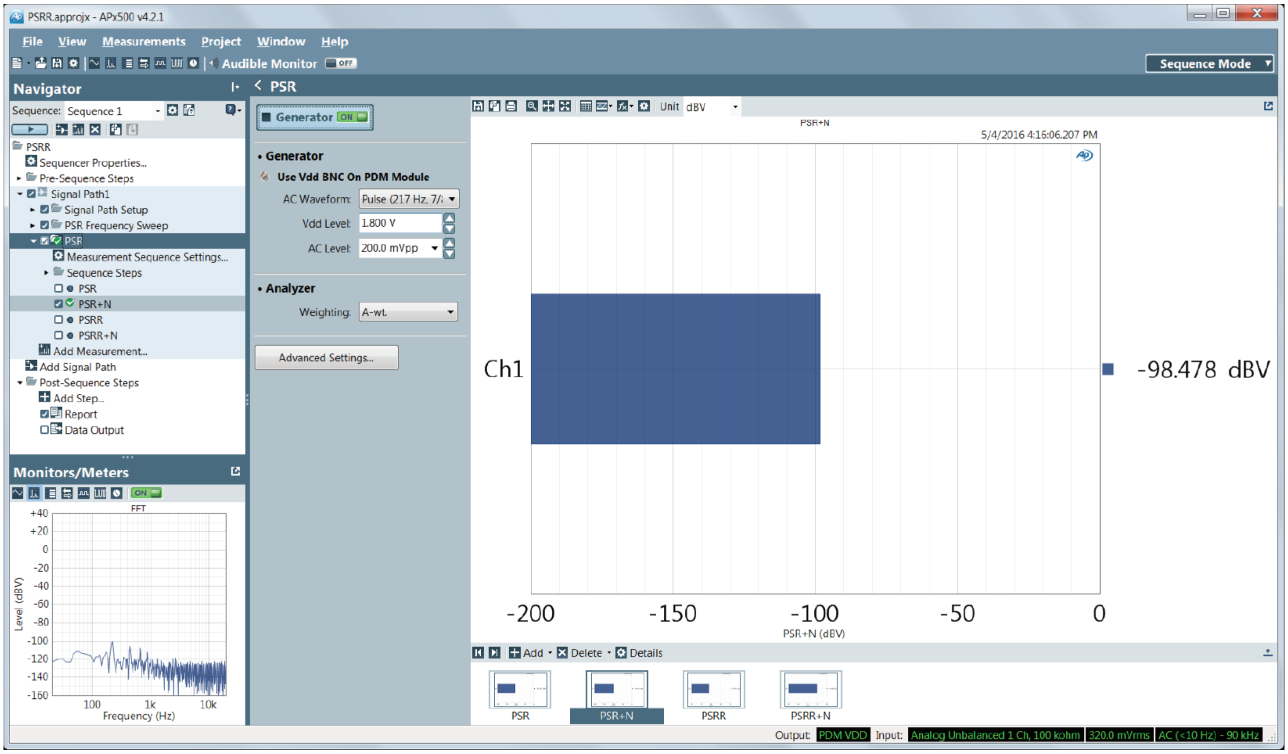


NOTE:

This part has a PSRR of 80dB at 1kHz

PSR+N setup and result for an analog microphone are also shown below. The spectrum of the 7⁄8 duty cycle rectangular waveform on OUT can be seen in the monitor window in the lower left. If it appears too close to the noise floor, or if the numeric result is not stable enough for a good reading, increase the signal level to 200mVpp as was done in this case.

APx v4.2.1 PSR+N Result For Analog Microphone



NOTE:

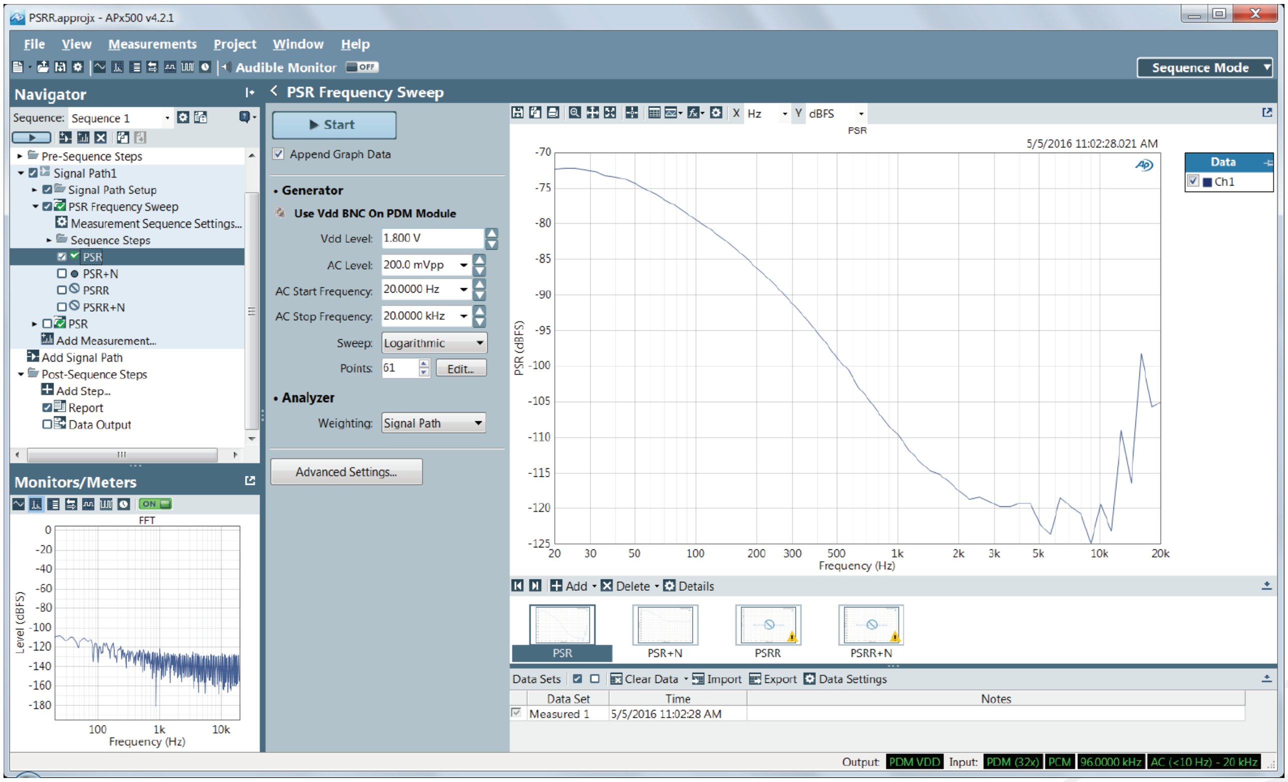
This part has a PSR+N of -98.5 dBV(A) when using a 200mVpp squarewave.

MEASURING PSRR AND PSR+N ON DIGITAL MICROPHONES

The native APx PSRR measurement is not available for digital microphones because PSRR is a ratio of Input to Output. For analog microphones these both have units of Volts while for digital microphones the input is in Volts and the output is some fraction of fullscale. The units are not the same and the APx does not know how this should be handled. Instead of measuring the ratio, the APx measures just the output.

PSRR setup and result for a digital microphone are shown below. During the sweep the response can be monitored in the lower left window to see if the signal stays above the noise floor. If it gets too low then increase the signal to 200mVpp as was done in this case. In addition, care must be taken in choosing OSR and CLK since Sigma-Delta noise shaping can easily corrupt the PSRR signal at high frequencies.

APx v4.2.1 PSRR Result For Digital Microphone



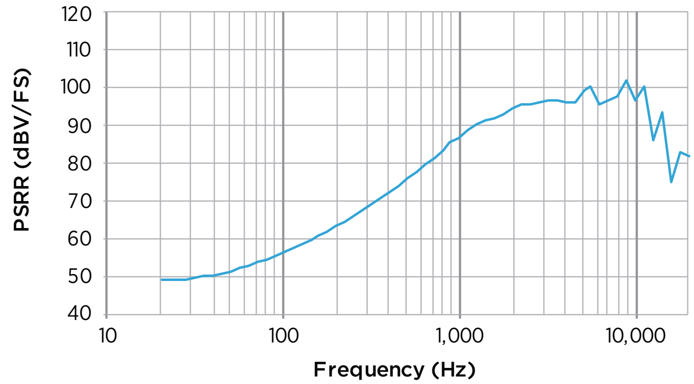
The input is the same sinewave used for analog microphones. The output is a graph in dBFS showing the output of the microphone. The ratio is then manually calculated by using PSRR = Input Test Signal (dBV) – Measurement (dBFS) and will have units of dBV/FS. The input test signal can be expressed in dBV according to the Table to the right.

Vin (Vpp)	Vin (dBV)
100mVpp	-29dBV
200mVpp	-23dBV

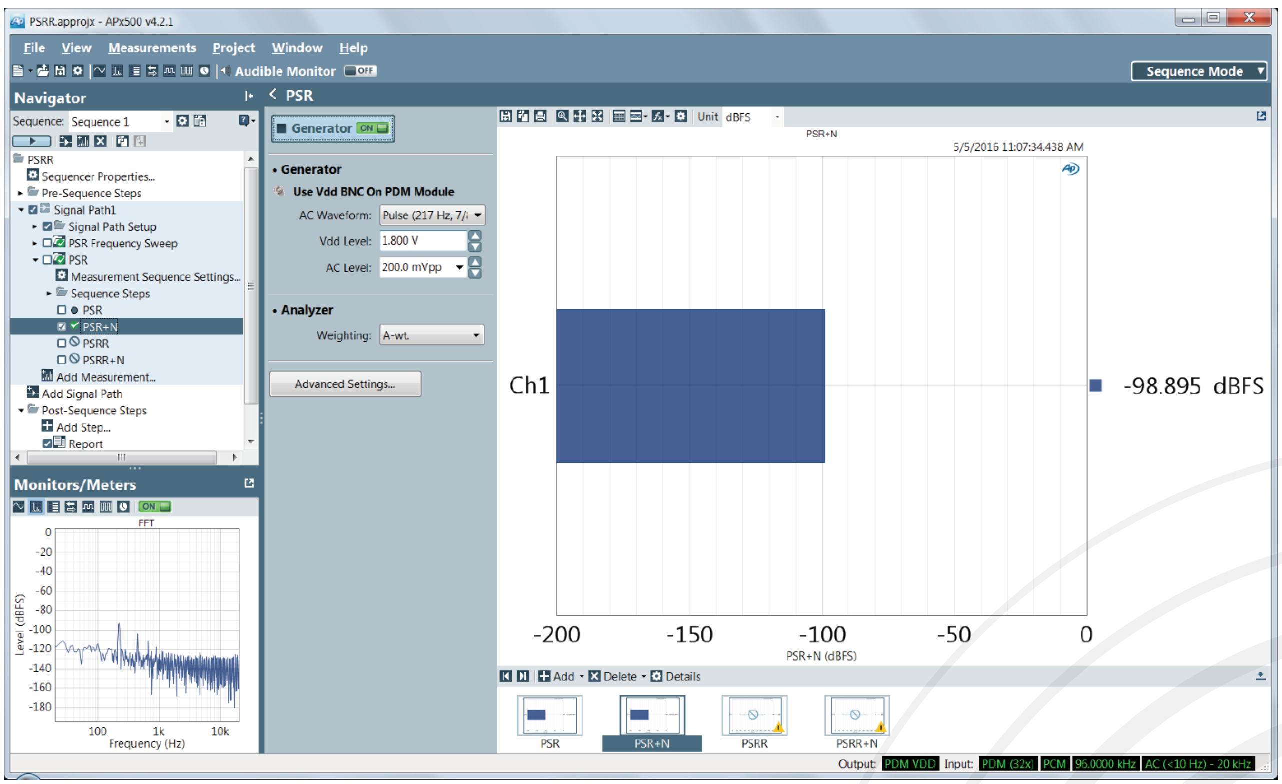
PSRR can then be calculated in a post-processing step. For example, the APx measurement shown in the table to the right is -110dBFS at 1kHz. The input signal is 23dBV so the PSSR calculation gives -23 – (-110) = 87dBV/FS. When applied to the entire spectrum the PSSR graph looks like the graph to the right.

PSR+N setup for digital microphones is identical to that used for analog microphones. A typical result is shown below:

APx v4.2.1 PSRR Response For Digital Microphone



APx v4.2.1 PSR+N Result For Digital Microphone



NOTE:

This part has a PSR+N of -98.9 dBFS(A) when using a 200mVpp squarewave.

SUMMARY

The procedure for measuring PSRR and PSR+N for both analog and digital microphones has been described with special attention being given to obtaining high performance measurements. Descriptions of how to connect and configure the APx v4.2.1 were also shown as well as the post-processing required for digital microphone PSRR measurements.

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