Application Note

Microphone Interface with TAX5XXX Devices

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ABSTRACT

The analog front end module (ADC) of the TAX5XXX devices (TAC5212, TAC5211, TAA5212, TAC5412, TAC5411, TAA5412, TAA5242, TAC5242) is designed in a new architecture with 118dB Dynamic Range performance in the AC-Coupled differential input configuration. There are other device variants (TAC5112, TAC5111, TAC5312, TAC5311, TAC5142) which incorporated the same architecture with standard performance of 100dB Dynamic Range. These Dynamic Range performances are with A-weighted filter.

In this new architecture, the commonly known Programmable Gain Amplifier (PGA) is now integrated into the ADC module. The PGA gain amplification is no longer available and when additional gain is needed, the gain is applied in the digital through the Digital Volume (DVOL) register.

This application notes addresses the following questions by comparing two different architectures:

1. Can the lowest signal of a condenser microphone such as ECM be captured by the TAX5XXX front end without additional external amplification?
2. Are the performances affected in the new architecture without PGA?

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Trademarks

1 Introduction

The TAX5XXX are TI audio devices where a new Analog Digital Converter (ADC) architecture is introduced without the Programmable Gain Amplification (PGA). This new ADC architecture integrates the PGA into the ADC module, thus removing the PGA block which normally used for additional amplification. This integration allows us to increase the performance of the signal chain as if the PGA is present. When additional gain or attenuation is needed, the device has DVOL register that provides gain from -80dB to 47dB with a 0.5dB step. This new architecture gives a dynamic range of 118dB in the AC-Coupled differential input configuration with 2 Vrms full-scale input. Normally in an audio application, the front-end connection of the audio converter is a microphone or line input. Microphone such as the Electret Condenser Microphone (ECM) or the HD-Series Microphone has Signal Noise Ratio (SNR) in the 50dB-70dB range and the maximum input level (AOP) is much lower than the converter full range input. Thus, amplification is added to increase the input level into the converter full-scale level. We can look at some examples of interfacing these microphones to these converters in this appliation note.

2 ADC Front End Block Diagram

Here is a simplified block diagram of an ADC front-end of converter with PGA versus the TAX5XXX front-end which is without the PGA block. The difference is the PGA and ADC are now integrated and optimized in the new feedback DAC block of the new architecture.

The integration of the PGA on the new architecture is implemented in the DAC path of the ADC block. ADC front-end is a class B DAC, which behaves similar to PGA's RFB block in Figure 2-1. The detail of the new RFB DAC architecture is not the scope of this application note.

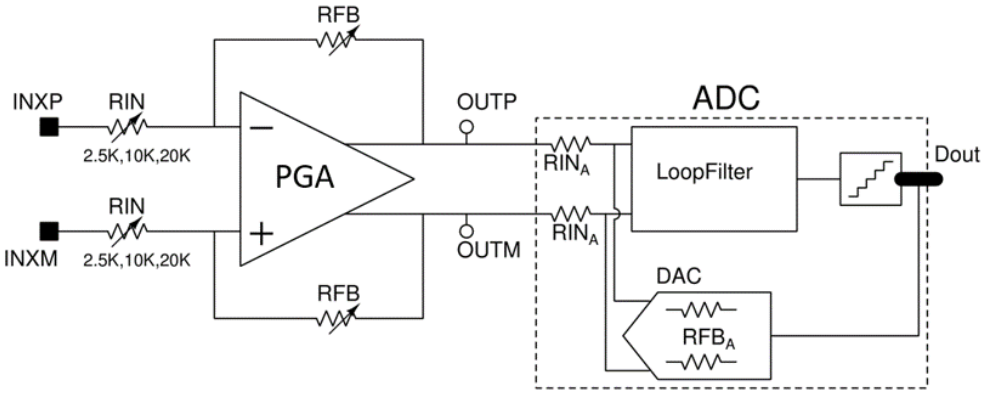

Figure 2-1. ADC Front-End With PGA

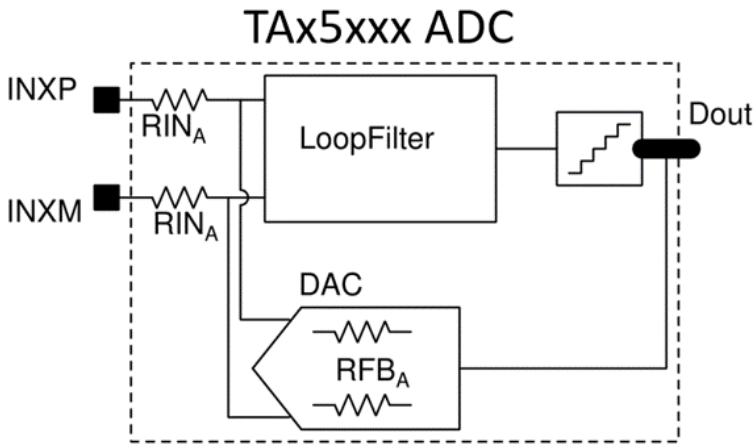

Figure 2-2. ADC Front-End With PGA Integrated Into the ADC

3 Application Example

The following are two different Microphones used in this application examples; POM-2242P-C33-R and POM-2730L-HD-R. Using the microphone information from the data sheet, tests are run on converter devices that has PGA and TAX5XXX converter which has the new ADC front-end architecture.

In each of the microphone case, the following test conditions were run:

- From the smallest input signal level the microphone is able to capture, use an instrument like Audio Precision AP555 to generate a tone of that level and analyze the digital signal output from the converter.
- From the largest input signal (AOP) the microphone is able to capture, use an instrument like Audio Precision AP555 to generate a tone of that level and analyze the digital signal output from the converter.
- From the AOP of the microphone, add the necessary gain in the converter to achieve the converter input full-scale level. The gain is added up to -1dBr of the full-scale per the converter THDN specification.

From each of the test cases above, the performance is compared between the 2 converter devices.

The device we use with PGA integrated is TLV320ADC6120; a high performance audio analog-to-digital converter (ADC) with 123dB Dynamic Range with DRE enable and 113dB with DRE disabled in the AC-Coupled differential input and TAA5212; a low-power high-performance stereo audio ADC with 118dB dynamic range in the new ADC front-end architecture.

3.1 MIC 1: POM-2242P-C33-R Microphone

The data sheet of this microphone is shown in Figure 3-1 with the respective sound to electrical signal level.

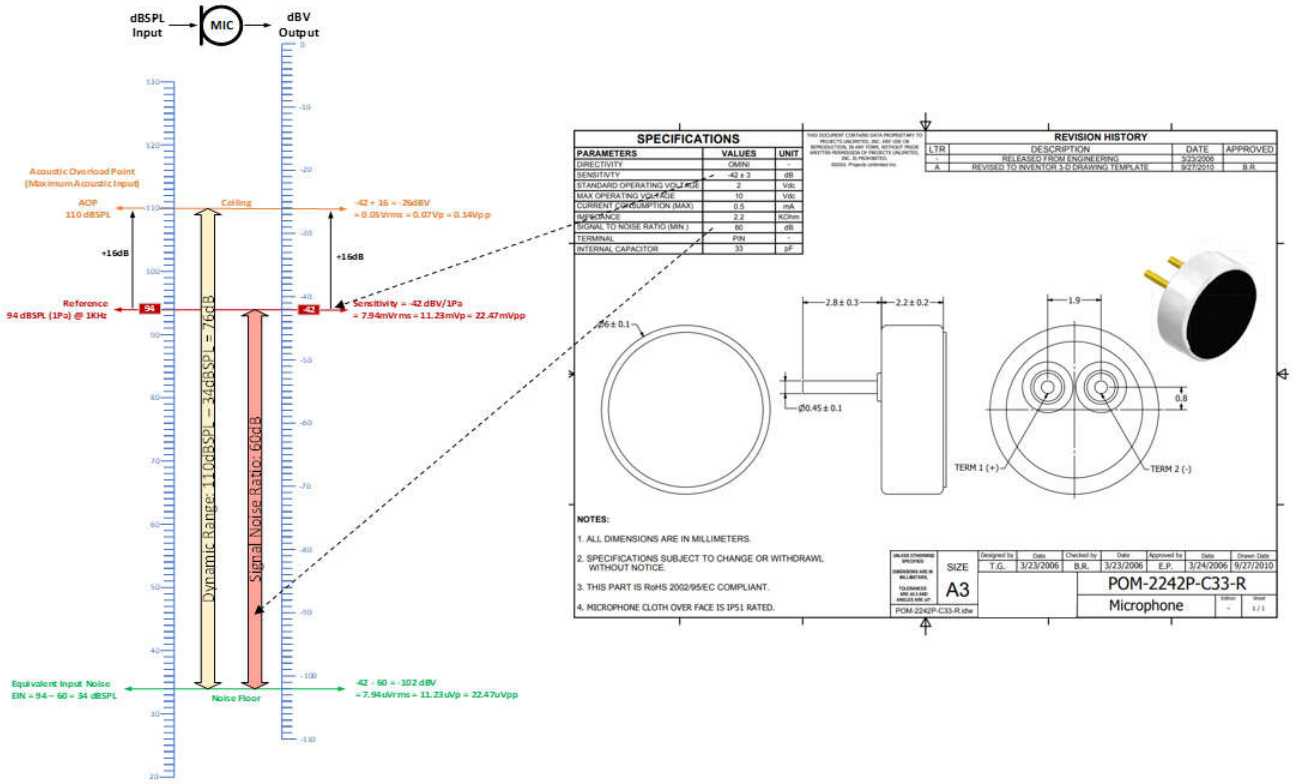

Figure 3-1. POM-2242P-C33-R Sound to Electrical Signal Level

Based on the microphone Sensitivity, Maximum Acoustic Input Level (AOP approximately Acoustic Overload Point) and SNR, the electrical rms/peak-peak voltages are calculated. These voltages are applied to the instrument input level in each test case respectively.

3.1.1 Test Case 1: Microphone Minimum Input Level

From the microphone Sensitivity of -42dBV and SNR of 60dB, the lowest or smallest input level the microphone can record is -102dBV which is equivalent to 7.94µVrms single-ended. A 1KHz tone with 7.94µVrms is applied to the analog AC-Coupled differential inputs of the device under test (DUT) with 0dB gain setting and the digital output is captured with Audio Precision. In ADC6120, we run with and without Dynamic Range Enhancer (DRE) for comparison. DRE is a feature which basically amplify low level signal with the low noise PGA when the feature is below the DRE threshold. This DRE feature is available only in the ADC with PGA converter and not available in the new architecture ADC.

Figure 3-2. TAA5212 Captured of Minimum Mic Input

Figure 3-3. ADC6120 Captured of Minimum Mic Input With DRE Disable

Figure 3-4. ADC6120 Captured of Minimum Mic Input With DRE Enable

As shown in the previous results, the two devices are capable of capturing the microphone lowest level of -108dBr without any amplification needed. The rms level of the converters shows a 6dB delta due to the

differential configuration setting and the dynamic range of the un-weighted test is about 2dB down from the A-weighted setting as expected. Also, the DRE feature in the ADC6120 shows an increase in the dynamic range at this low signal level compare to DRE disable.

Table 3-1. MIC 1 Minimum Input Level

	Analog Input Vrms [dBr(2Vrms)]	Spec DR A-Weighted (dB)	Measured DR Un-Weighted (dB)
TAx5xxx	7.94µV [-108dBr]	118	116
ADC6120	7.94µV [-108dBr]	113	111
ADC6120-DRE	7.94µV [-108dBr]	123	121

3.1.2 Test Case 2: Microphone Maximum Input Level

From the microphone Sensitivity of -42dBV and AOP of 110dBSPL given by the manufacturer, the largest input level the microphone can record is -26dBV which is equivalent to 50mVrms single-ended.

AOP is the maximum sound level pressure (SPL) a microphone can handle before the AOP starts to distort the audio signal. This AOP is defined as SPL that causes 10% THD in the microphone's output at 1KHz frequency. A higher AOP is desirable as it allows the microphone to record loud sounds without distortion. Dynamic microphone has a higher AOP than the Condenser microphone, but lower sensitivity level. In this application notes, we are using the AOP for the maximum test case.

A 1KHz tone with 50 mVrms is applied to the analog differential inputs of the device under test (DUT) with 0dB gain setting and the digital output is captured with Audio Precision APx555. The following are the results taken on these two devices.

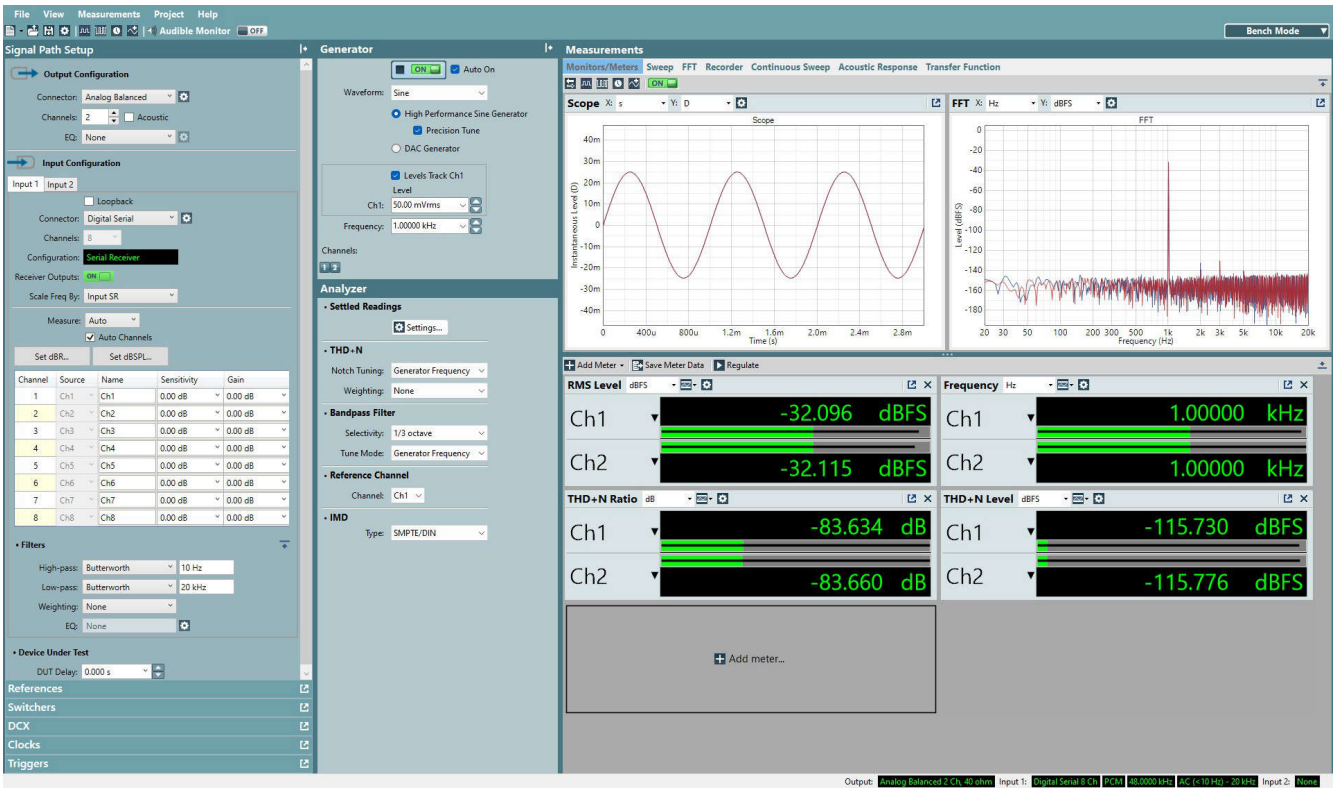

Figure 3-5. TAA5212 Captured of Maximum mic Input

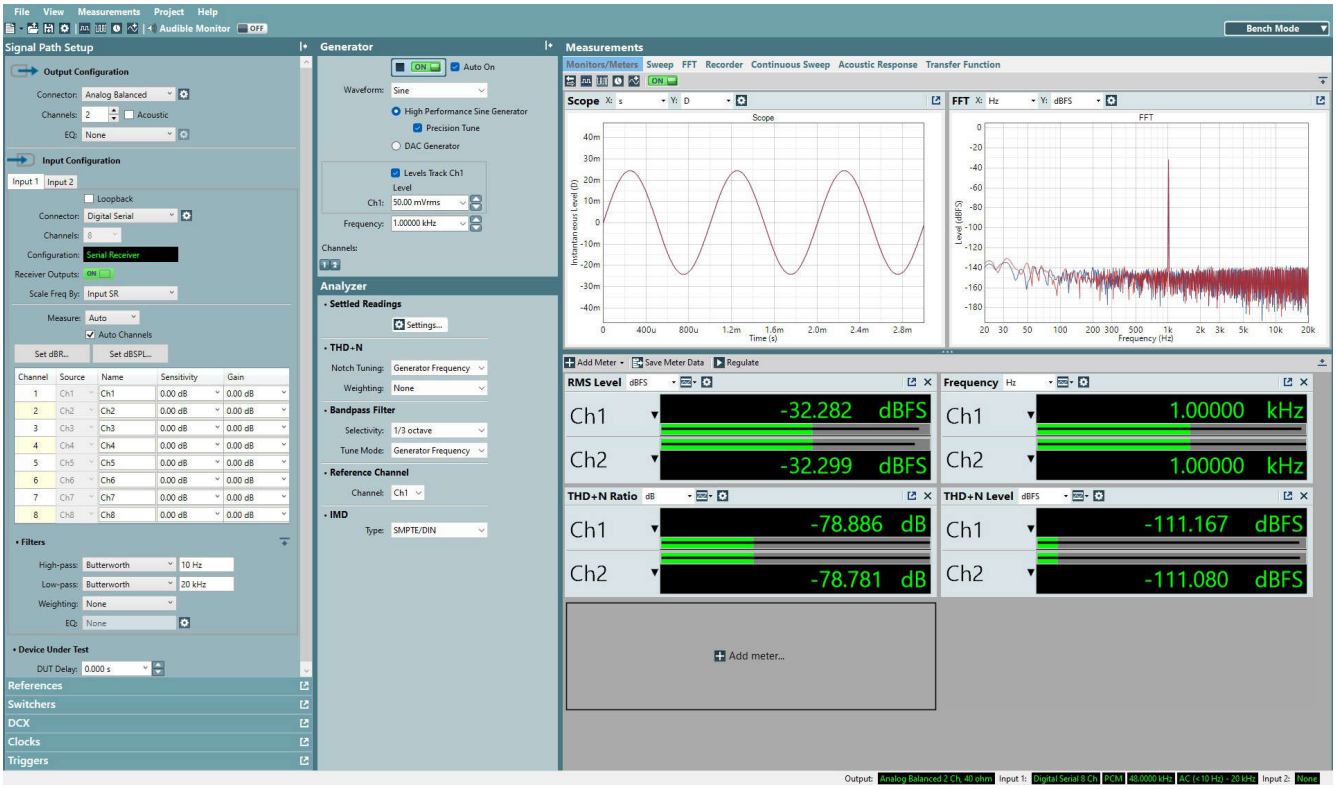

Figure 3-6. ADC6120 Captured of Maximum mic Input With DRE Disable

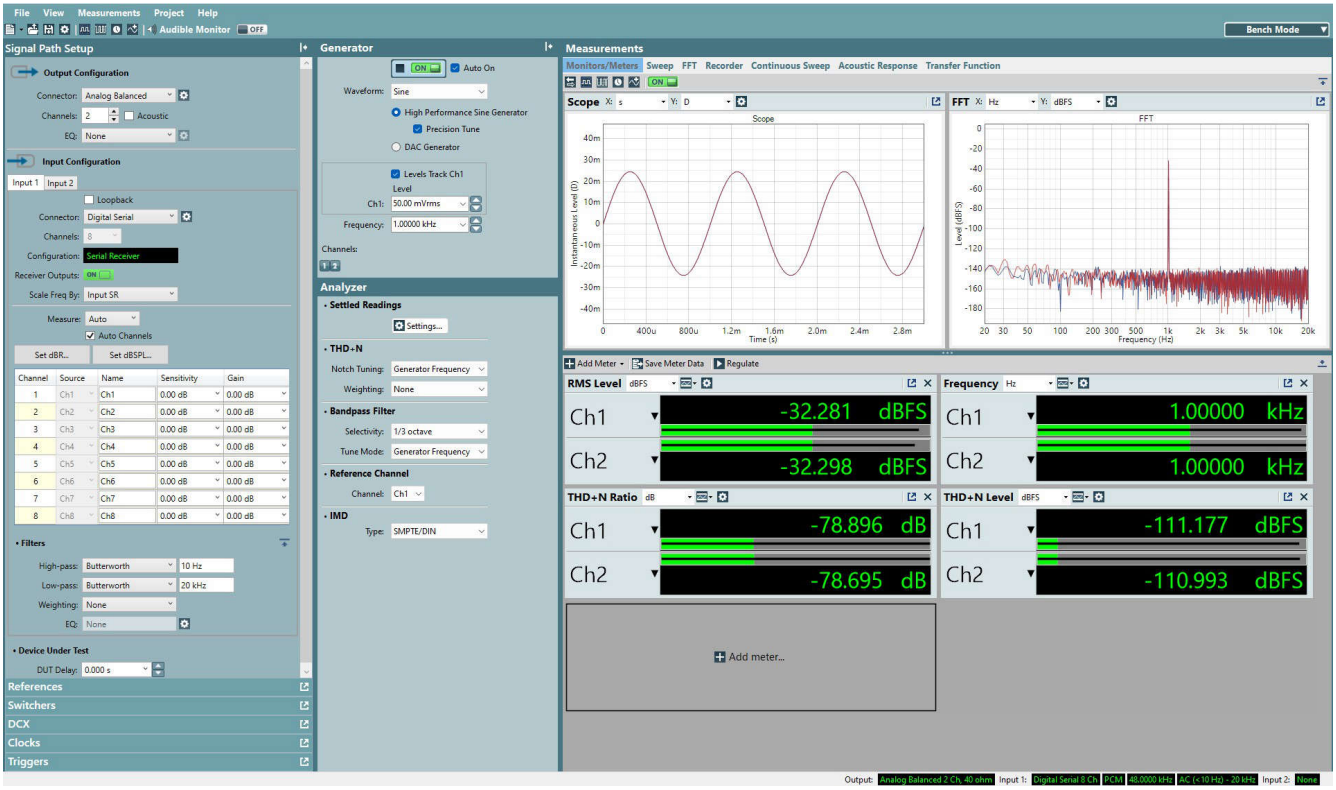

Figure 3-7. ADC6120 Captured of Maximum mic Input With DRE Enable

Here we can see the recorded input level of the microphone maximum level is -32dBFS for differential configuration from the converter full-scale. Based on the un-weighted Dynamic Range (DR) of the converter, the THDN is calculated by Equation 1 and summarized in Table 3-2 for these devices.

$$THDN \cong Unweighted\ Dynamic\ Range\ (DR) - Input \quad (1)$$

Table 3-2. MIC 1 Maximum Input Level

	Analog Input Vrms [dBr(2Vrms)]	Spec DR A-Weighted (dB)	Measured DR Un-Weighted (dB)	Calculated THDN Ratio (dB)	Measured THDN Ratio (dB)
TAx5xxx	50mV [-32dBr]	118	116	-84	-84
ADC6120	50mV [-32dBr]	113	111	-79	-79
ADC6120-DRE	50mV [-32dBr]	113(1)	111	-79	-79

(1) Use DRE disable DR as level if above DRE threshold

3.1.3 Test Case 3: Microphone Maximum Input Level with Gain

In this test case, we add gain from the audio device to -1dBr of the device full-scale and check the performance. This -1dBr input is used to avoid clipping due to gain error. In the TAX5XXX device, the gain is set through Digital Volume (DVOL) and for ADC6120 device, the gain is set through the PGA register.

From the maximum input level of the microphone measured previously, we apply +31dB to increase the record audio path level to -1dBr of input full-scale.

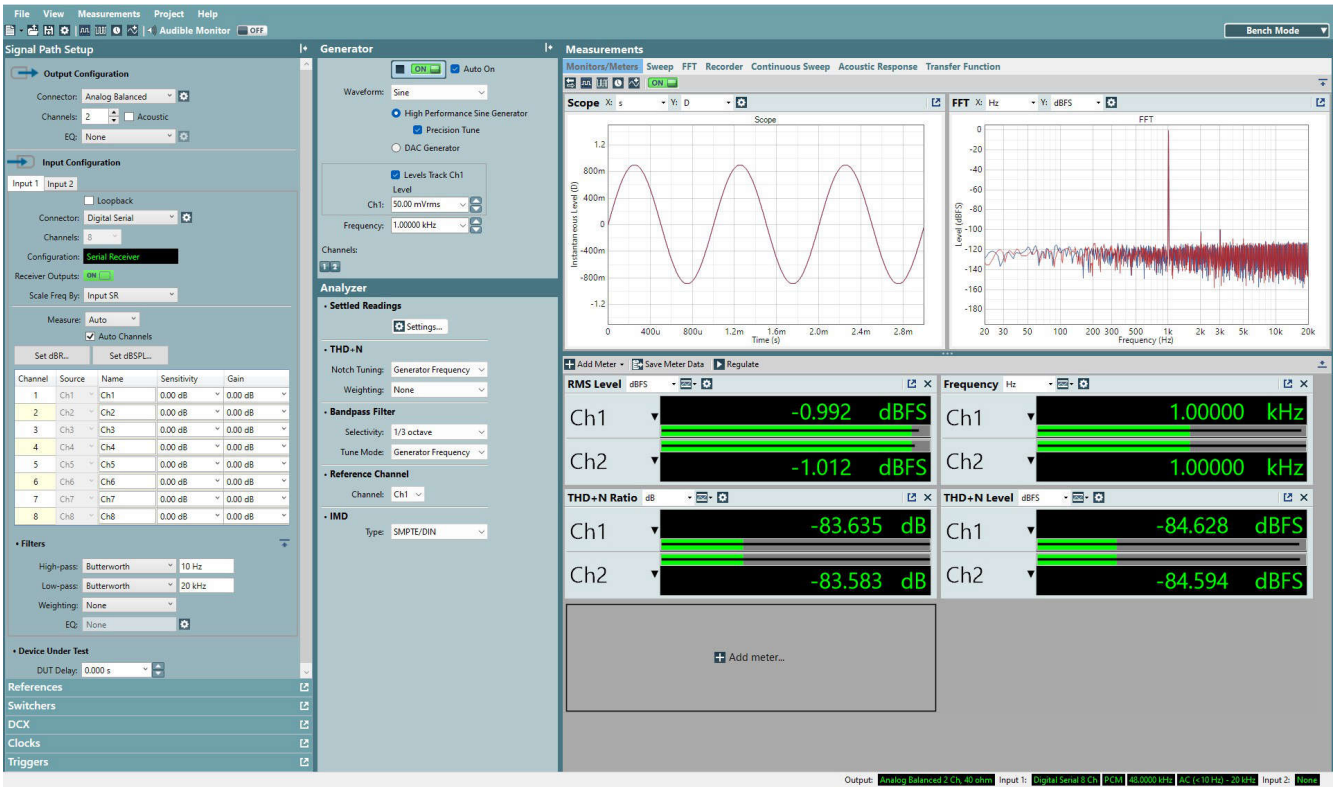

Figure 3-8. TAA5212 Captured of Maximum mic Input With +31dB Gain

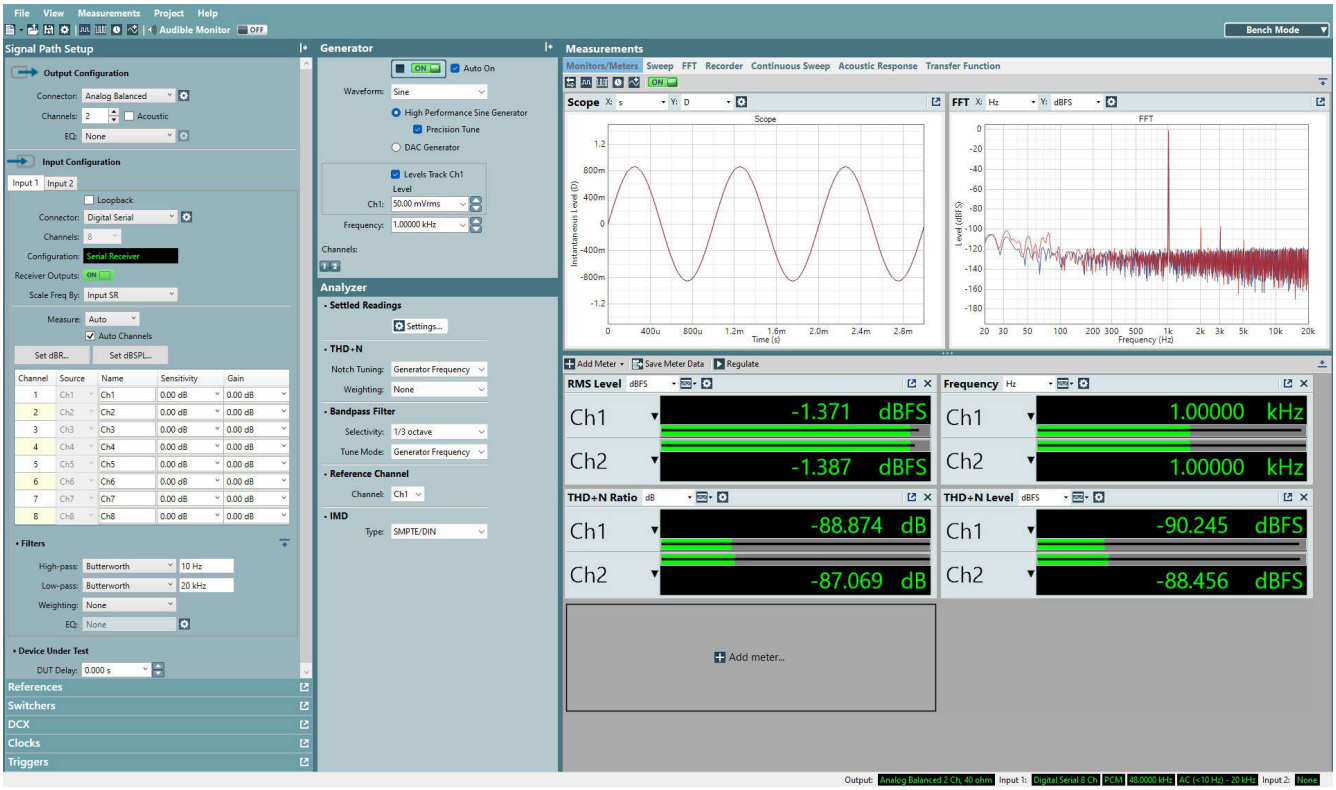

Figure 3-9. ADC6120 Captured of Maximum mic Input With +31dB Gain

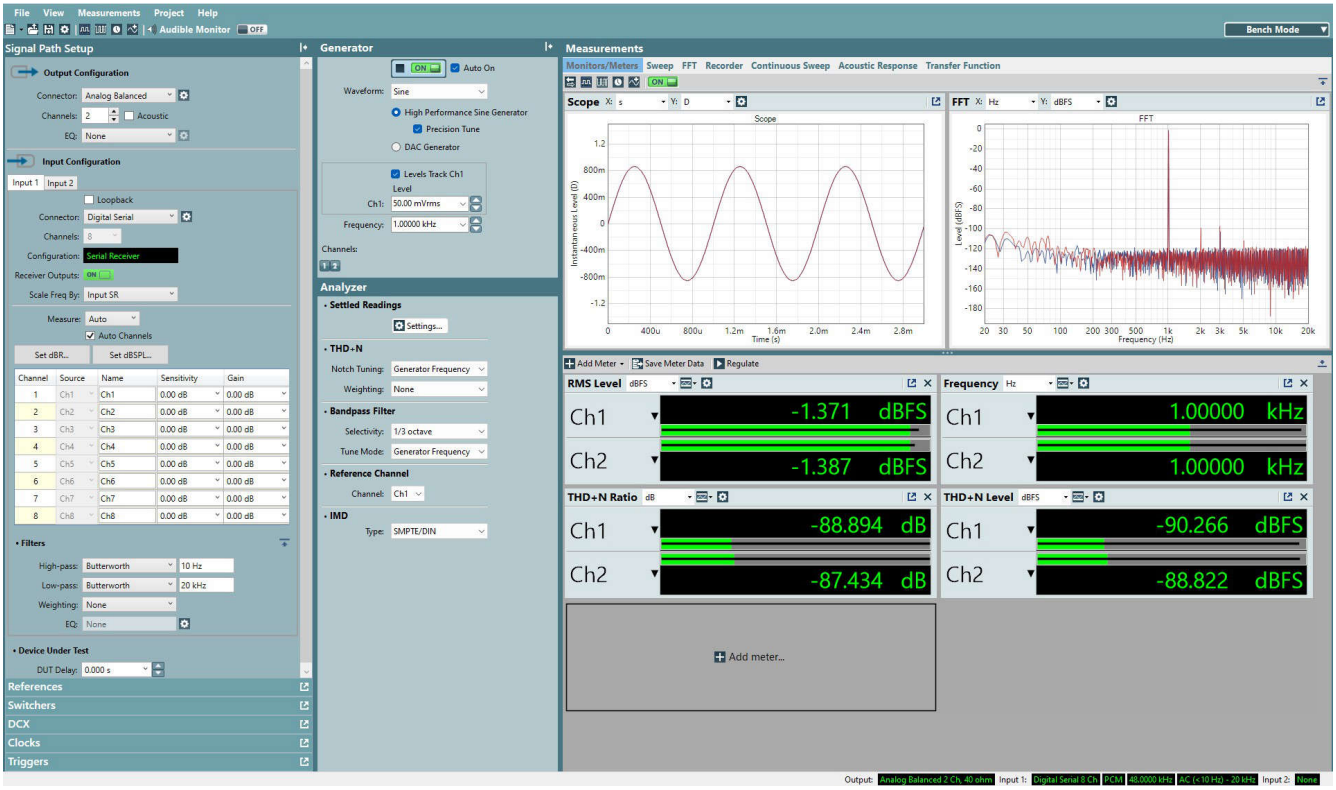

Figure 3-10. ADC6120 Captured of Maximum mic Input With +31dB Gain and DRE Enable

In TAX5XXX, adding the DVOL gain to the input level does not change the THDN level, but in the ADC6120 device PGA gain improves THDN. This improvement is because the ADC noise is less dominant than the PGA thus THDN is better.

Table 3-3. MIC 1 Maximum Input Level With +31dB Gain

	Analog Input Vrms [dBr(2Vrms)]	Calculated THDN (dB)	Measured THDN Ratio without Gain (dB)	Measured THDN Ratio with Gain (dB)
TAx5xxx	50mV [-32dBr]	-84	-84	-84
ADC6120	50mV [-32dBr]	-79	-79	-89
ADC6120-DRE	50mV [-32dBr]	-79	-79	-89

3.2 MIC 2: POM-2730L-HD-R Microphone

The data sheet parameter of this microphone is shown in Figure 3-11 with the respective sound to electrical signal level conversion. This microphone has better Sensitivity and SNR than the ECM, thus is a good microphone to test as well. The higher the sensitivity, the greater the electrical output the microphone can produce, though the AOP is the same as the ECM microphone.

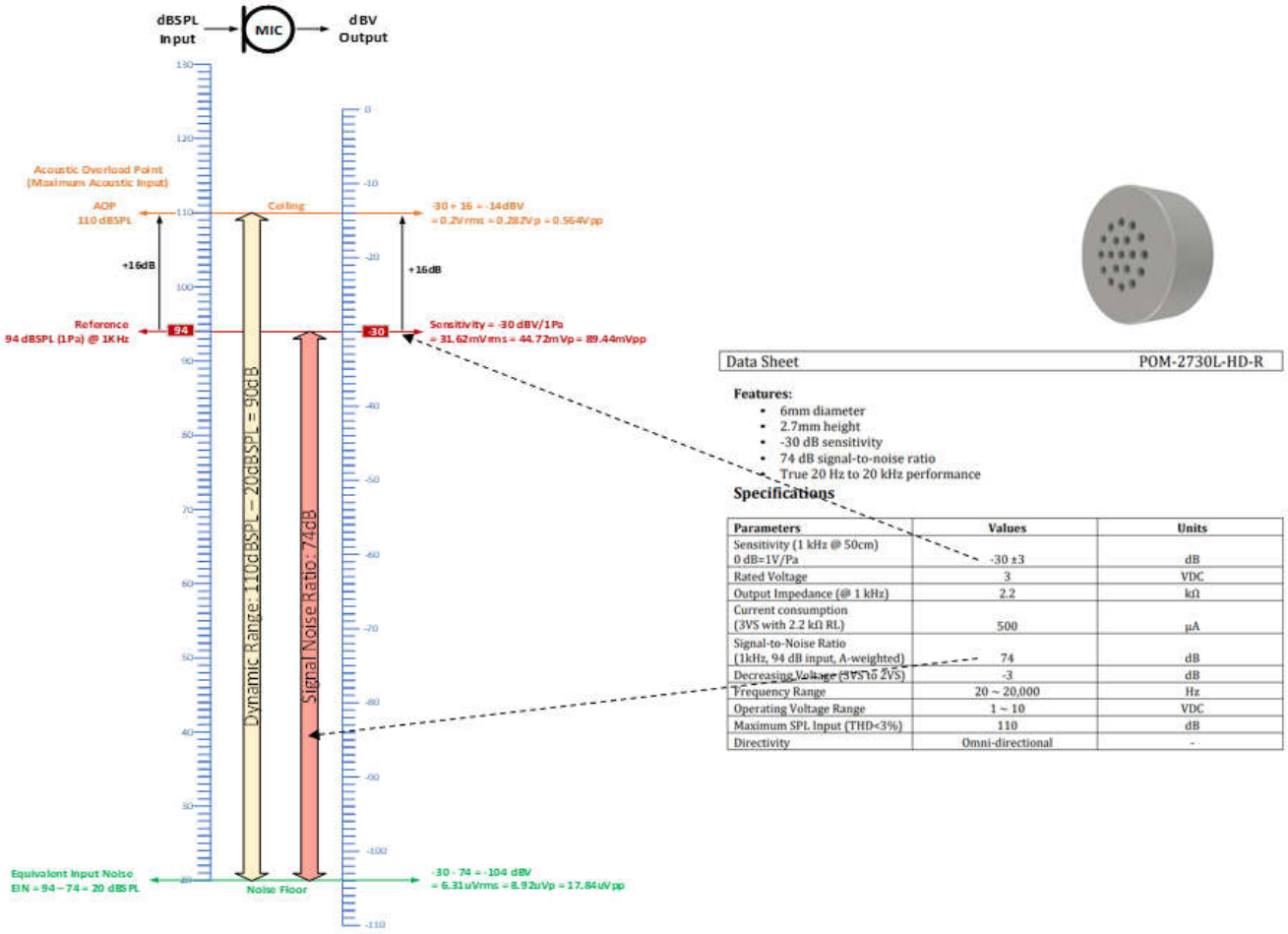

Figure 3-11. POM-2730L-HD-R Sound to Electrical Signal Level

From the conversion, the voltages are used and applied in the instrument input level of the test cases.

3.2.1 Test Case 1: Microphone Minimum Input Level

From the microphone Sensitivity of -30dBV and SNR of 74dB, the smallest input level the microphone can record is -104dBV which is equivalent to 6.31µVrms single-ended. A 1KHz tone with 6.31µVrms is applied to the

analog differential inputs of the device under test (DUT) with 0dB gain setting and the digital output is captured with Audio Precision APx555. The following are the results taken on these 2 devices.

Figure 3-12. TAA5212 Captured of Minimum Mic Input

Figure 3-13. ADC6120 Captured of Minimum Mic Input With DRE Disable

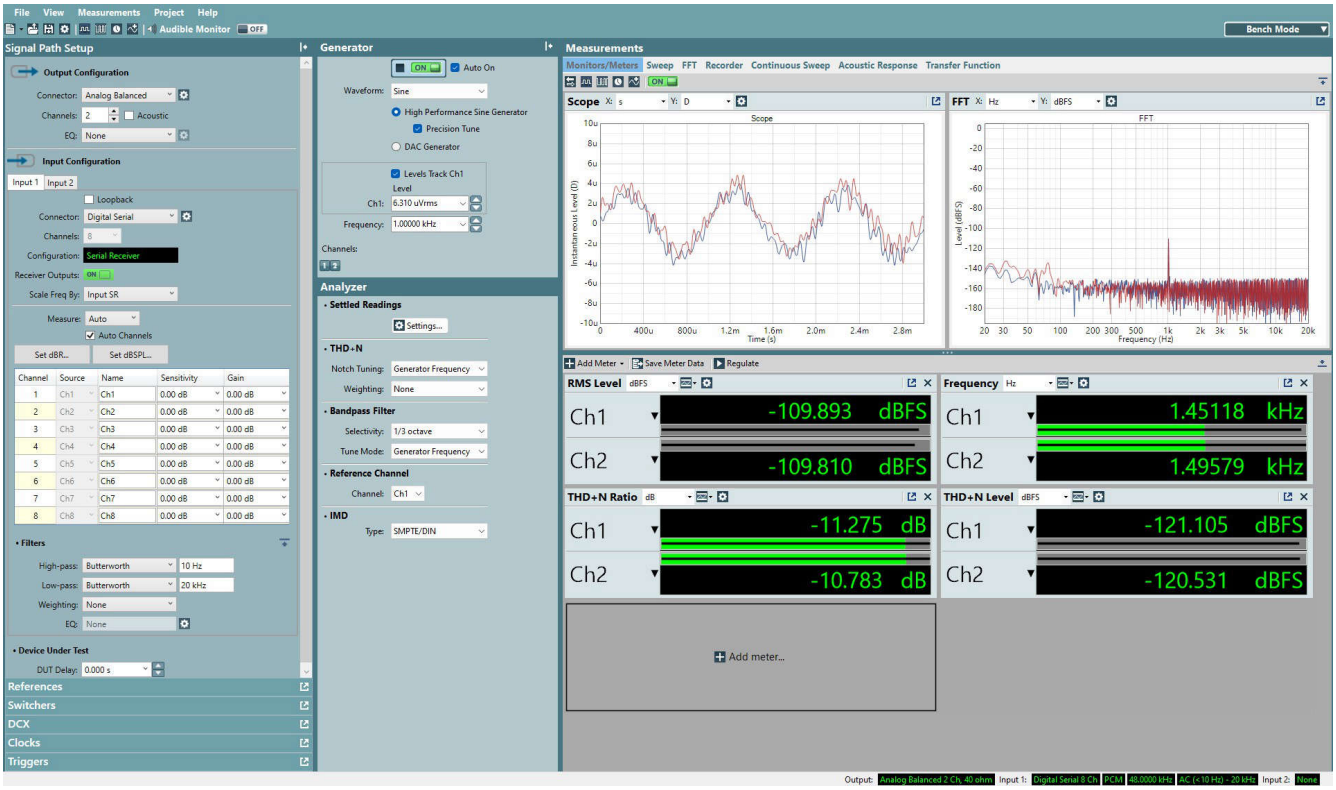

Figure 3-14. ADC6120 Captured of Minimum Mic Input With DRE Enable

As shown, these devices are capable of capturing the lowest level at -110dBr from this microphone input without any amplification. The DRE result shows an increase in dynamic range at this signal level and is below the DRE threshold setting.

Table 3-4. MIC 2 Minimum Input Level

	Analog Input Vrms [dBr(2Vrms)]	Spec DR A-Weighted (dB)	Measured DR Un-Weighted (dB)
TAx5xxx	6.31µV [-110dBr]	118	116
ADC6120	6.31µV [-110dBr]	113	111
ADC6120-DRE	6.31µV [-110dBr]	123	121

3.2.2 Test Case 2: Microphone Maximum Input Level

From the microphone Sensitivity of -30dBV and AOP of 110dBSPL, the largest input level the microphone can record is -14dBV which is equivalent to 199 mVrms single-ended. A 1KHz tone with 199mVrms is applied to the analog differential inputs of the device under test (DUT) with 0dB gain setting and the digital output is captured with Audio Precision APx555. The following are the results taken on these two devices.

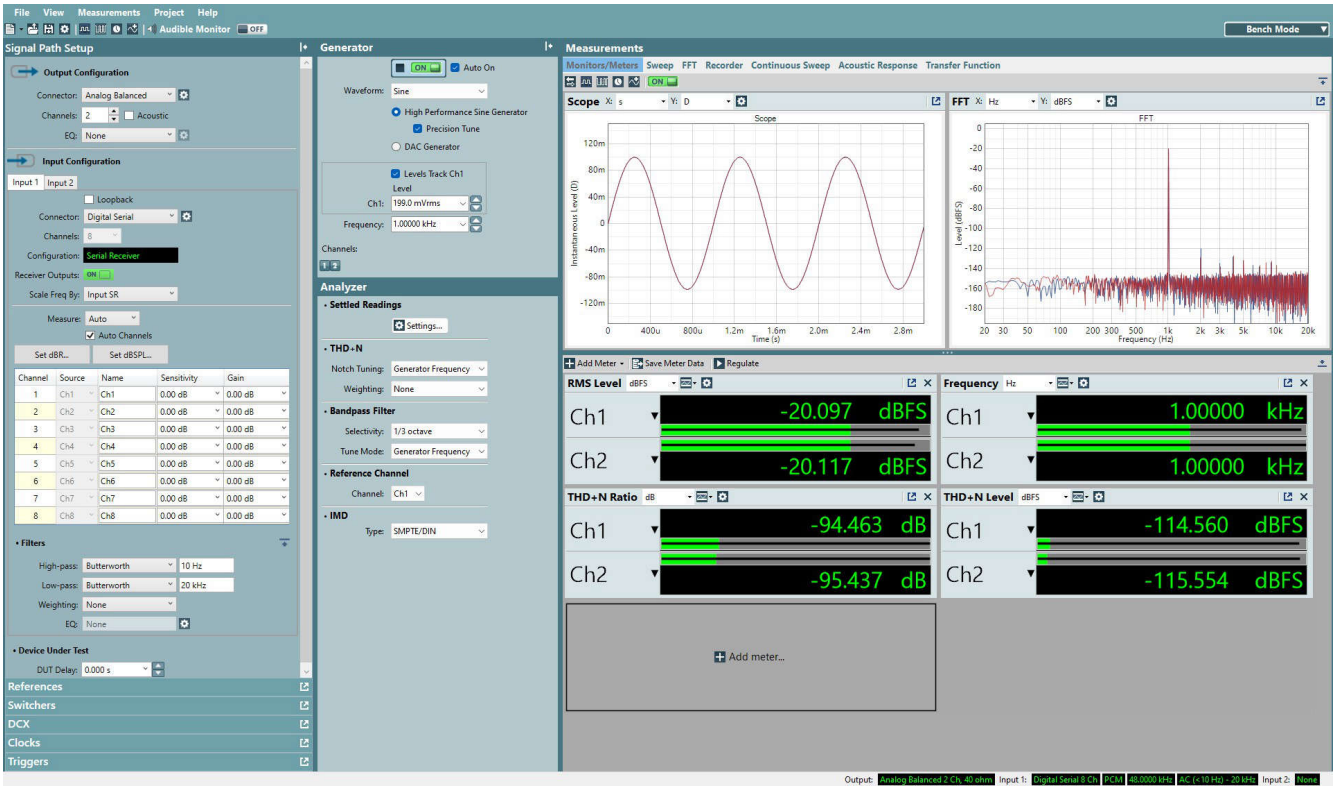

Figure 3-15. Test Case 2: Microphone Maximum Input Level

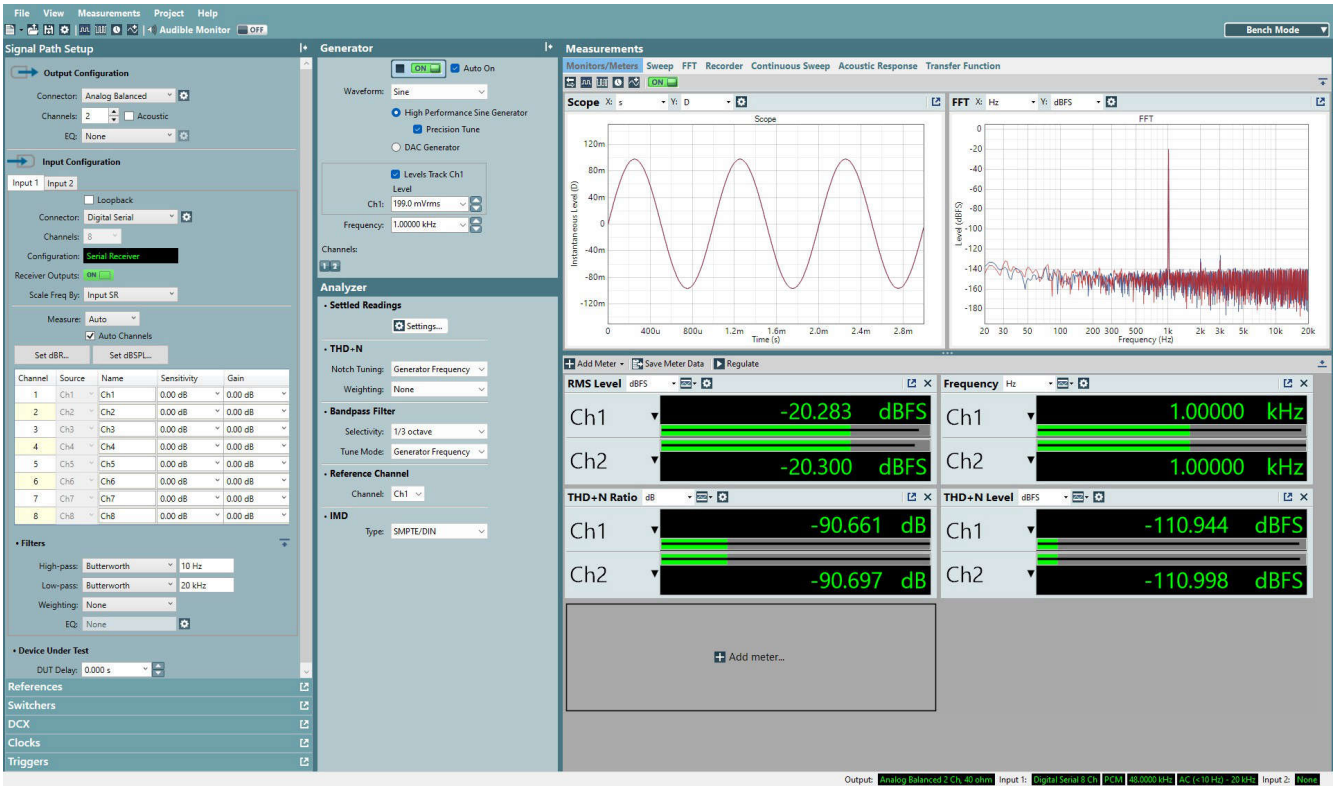

Figure 3-16. ADC6120 Captured of Maximum mic Input With DRE Disable

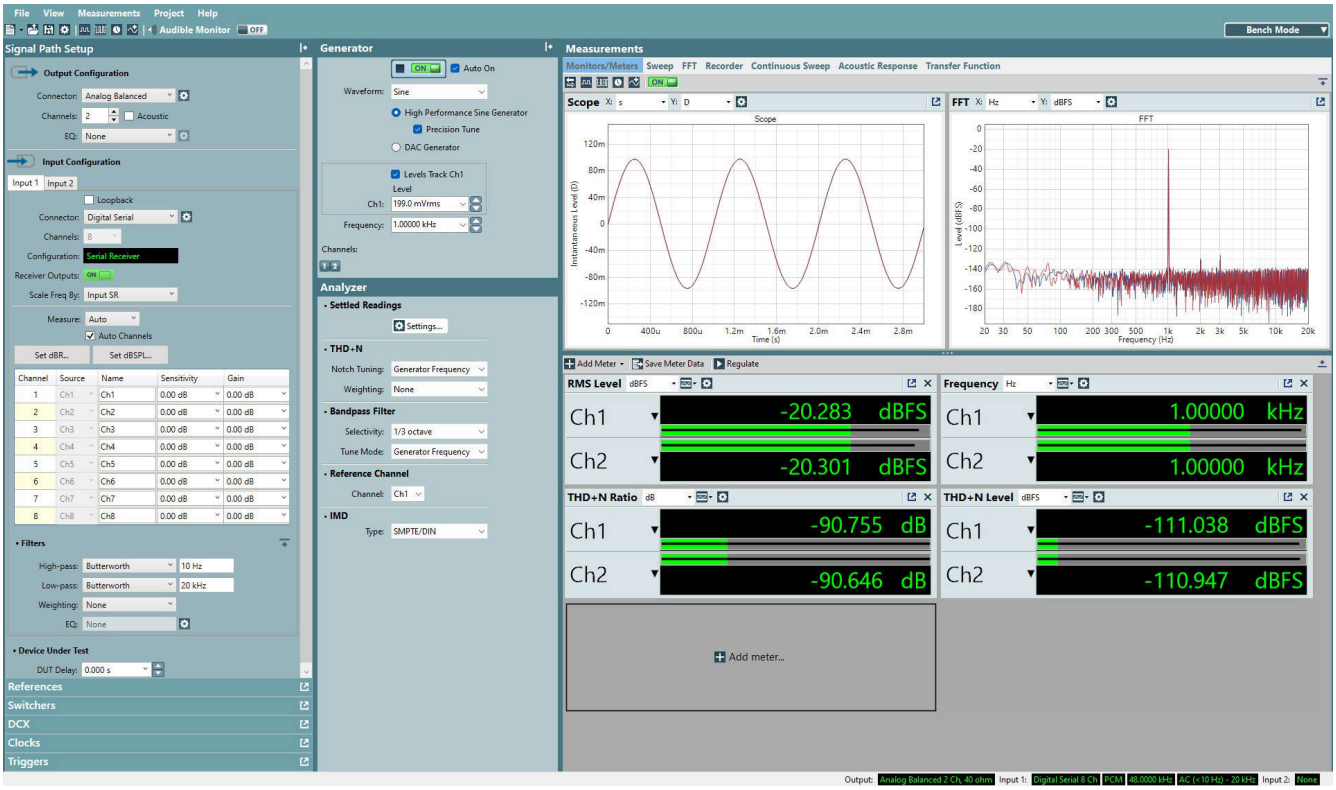

Figure 3-17. ADC6120 Captured of Maximum Mic Input With DRE Enable

Here, the digital output level of the microphone maximum level is -20dBFS for differential configuration from the converter's full-scale. Based on the un-weighted Dynamic Range (DR) of the converter, the THDN is calculated by Equation 1 and summarized in Table 3-5 for these devices.

Table 3-5. MIC 2 Maximum Input Level

	Analog Input Vrms [dBr(2Vrms)]	Spec DR A-Weighted (dB)	Measured DR Un-Weighted (dB)	Calculated THDN Ratio (dB)	Measured THDN Ratio (dB)
TAx5xxx	199mV [-20dBr]	118	116	-96	-95
ADC6120	199mV [-20dBr]	113	111	-91	-91
ADC6120-DRE	199mV [-20dBr]	113(1)	111	-91	-91

(1) Use DRE disable DR as level if above DRE threshold

3.2.3 Test Case 3: Microphone Maximum Input Level with Gain

In this test case, we add gain from the audio device to -1dBr of the device input full-scale. In the TAX5XXX device, the gain is set through Digital Volume (DVOL) and for ADC6120 device, the gain is set through the PGA register.

From the maximum input level of the microphone measured previously, we apply +19dB gain to bring the record audio path level to -1dBr of full-scale.

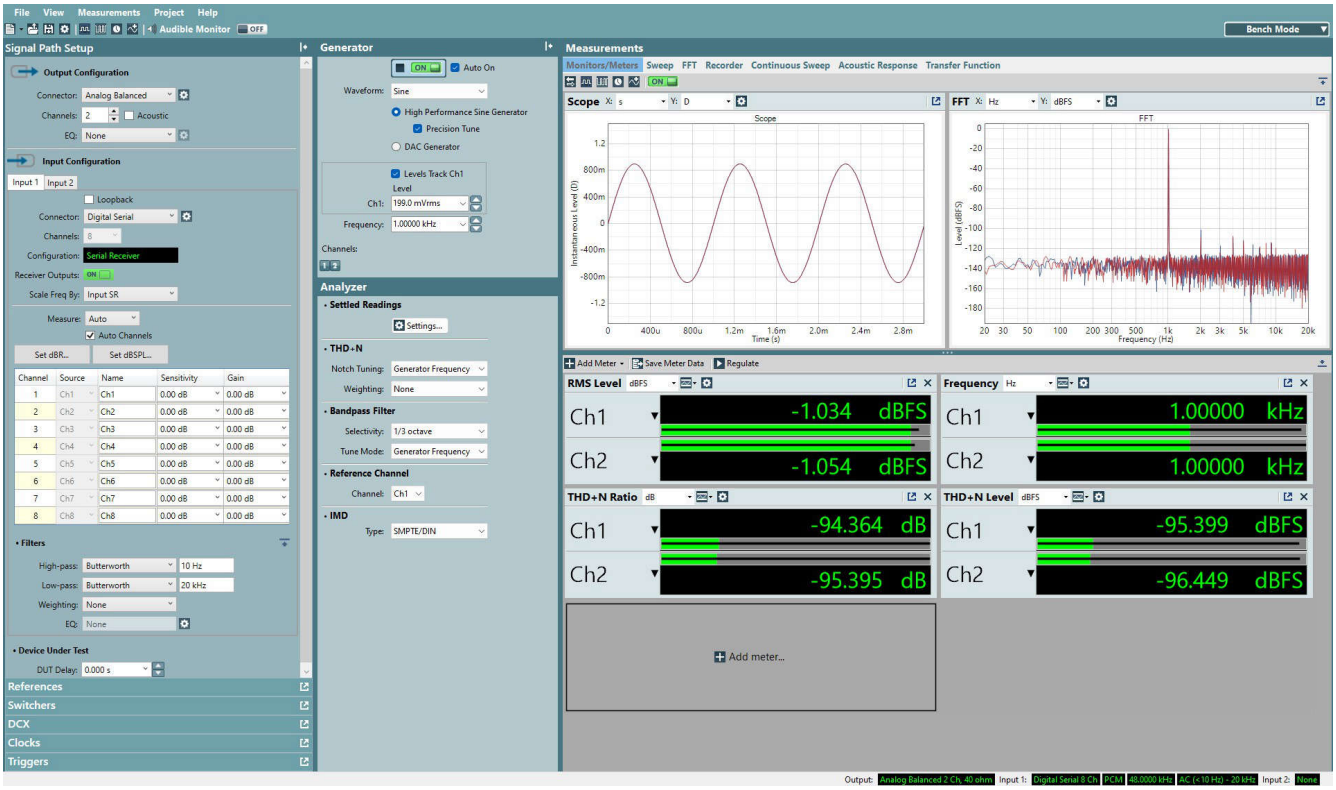

Figure 3-18. TAA5212 Captured of Maximum Mic Input With +19dB Gain

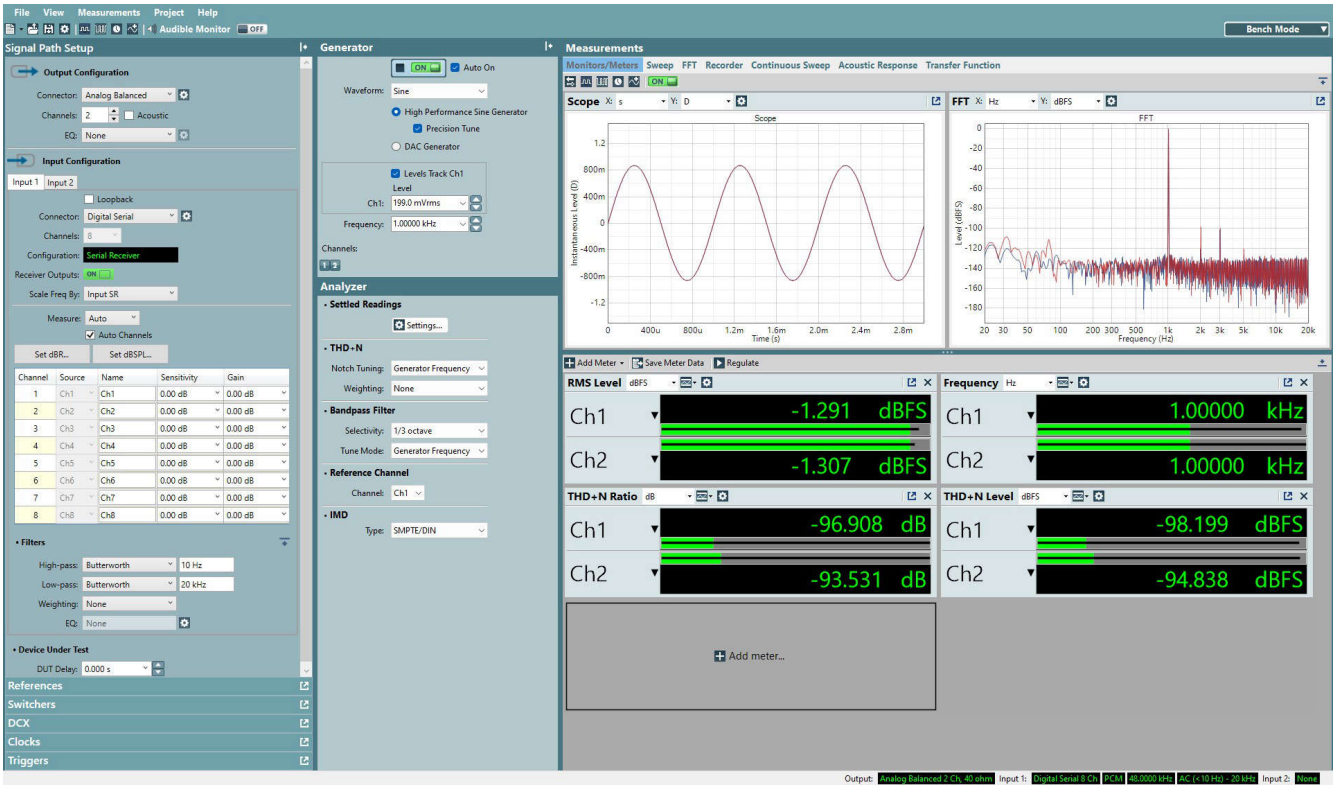

Figure 3-19. ADC6120 Captured of Maximum Mic Input With +19dB Gain

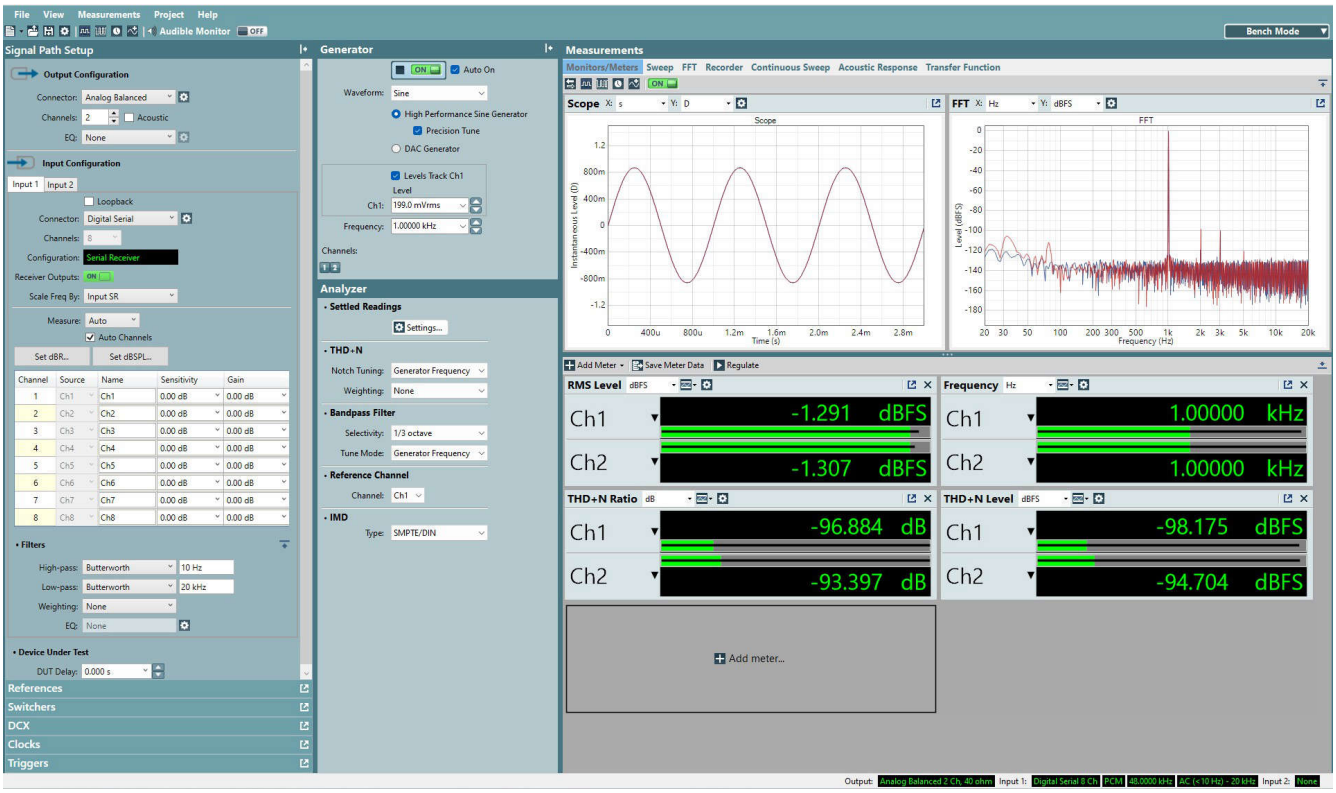

Figure 3-20. ADC6120 Captured of Maximum Mic Input With +19dB Gain and DRE Enable

In TAX5XXX, adding the DVOL gain to the input level does not change the THDN level, but in the ADC6120 device with PGA gain it improves THDN. This increase is due to ADC noise is less dominant than the PGA thus THDN is better.

Table 3-6. MIC 2 Maximum Input Level With +19dB Gain

	Analog Input Vrms [dBr(2Vrms)]	Calculated THDN (dB)	Measured THDN Ratio without Gain (dB)	Measured THDN Ratio with Gain (dB)
TAx5xxx	199mV [-20dBr]	-96	-95	-95
ADC6120	199mV [-20dBr]	-91	-91	-97
ADC6120-DRE	199mV [-20dBr]	-91	-91	-97

4 Summary

From the test cases conducted in this application note, the TAX5XXX audio devices which are designed without a PGA, is able to record or capture sound of any microphones due to the high dynamic range and when amplification is needed, the digital gain can be applied through digital volume (DVOL) without degradation.

5 References

- Texas Instruments, *TAA5212 Low-Power High-Performance Stereo Audio ADC With 115dB Dynamic Range*, data sheet.
- Texas Instruments, *TLV320ADC6120 2-Channel, 768-kHz, Burr-Brown™ Audio ADC*, data sheet.

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