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Vybrid ASRC Performance

Audio Analyzer Measurements

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This bulletin contains performance measurement data of the Asynchronous Sample Rate Converter (ASRC). The ASRC is used in several Freescale products including DSP, i.MX, and Vybrid products as a part of the audio subsystem. Measurements were performed on an Audio Precision instrument with integrated generator and signal analyzer.

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1 ASRC

The ASRC converts a signal with a sampling rate associated with an input clock to a signal associated with a different output clock. The converter is designed as a coprocessor in hardware, with minimal platform intervention required.

The ASRC supports concurrent sample rate conversion of up to 10 channels with performance THD+N of about -120 dB across a wide dynamic range. The ASRC supports up to three sampling rate pairs. The incoming audio data to this chip may be received from various sources at different sampling rates. The outgoing audio data of this chip may have different sampling rates and it can also be associated with output clocks that are asynchronous to the input clocks.

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1.1 ASRC Features

The Asynchronous Sample Rate Converter has the following features:

- 10 contiguous channels
- 3 sampling rate pairs
- 8/16/24 -bit width of input data
- 16/24 -bit width of output data
- Conversion between 44.1 kHz, 32 kHz, 48 kHz, 96 kHz, and 192 kHz with useful signal bandwidth below 24 kHz
- Other rates with less desirable band width
- Clock signals from ESAI, SAI, SPDIF, and so on
- DMA and interrupt data transfer
- User-programmable threshold for the input/output FIFOs

1.2 Measurement description

The measurements were performed using an Audio Precision (AP) instrument (2700 series) with optical input and output.

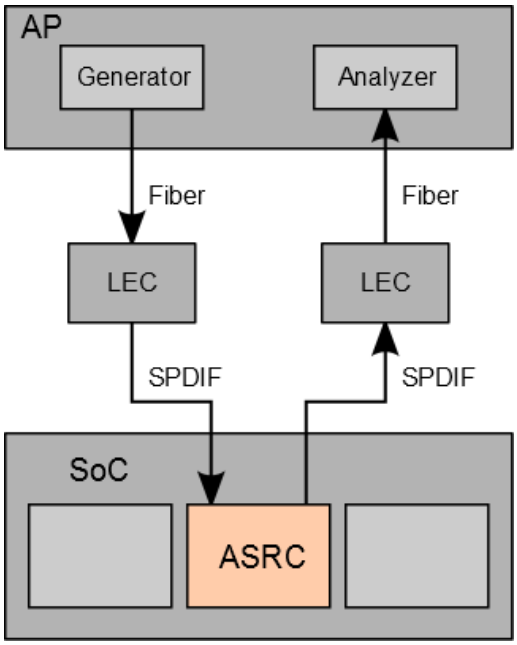

Figure 1. ASRC measurement configuration

Figure 1 shows the configuration of the test environment to collect the measurements. The signal from the AP generator's optical output is transmitted through optical fiber to the onboard light-to-electric converter (LEC). The converted input signal in the electric domain is sent through the SPDIF interface to the device-under-test, which is the ASRC on the System-on-Chip (SoC) by DMA. The signal is converted in the ASRC and sent through the second SPDIF interface by DMA. The output electric signal is converted to an optical signal in the second onboard LEC and is transmitted into the second optical fiber and optical

input of the AP analyzer. The clock of the input signal (AP clock) is not synchronized with the clock of the output signal (SoC clock). The ASRC works in auto-selection mode. Measurements were performed at 16,384 points with Kaiser (7) windowing.

1.3 Measuring terms

FFT Fast Fourier Transform.

IMD Intermodulation Distortion—Creation of additional signals at harmonics frequencies or at sum or difference frequencies of the input signals.

D-D Dynamic Distortion—Dynamic distortion caused by a linearity error.

THD+N Total Harmonic Distortion plus Noise—Unwanted addition of new tones to the audio signal. These tones are harmonically related to the original signal plus noise.

dBFS Decibel Full Scale—Signal amplitude compared to full scale of the device.

2 ASRC Performance Data

The following measurements were performed to test ASRC performance. Tests included different input and output sample rates, signal frequencies and signal levels:

- Wideband FFT on 1 kHz, 20 kHz, and 80 kHz
- IMD of 10 kHz and 11 kHz signals
- Pass-band ripple
- Dynamic distortion
- THD+N

2.1 Wideband FFT 1 kHz

Figure 2 through Figure 13 show the frequency spectrum of measured signals on the ASRC output after conversion. Sample rates are denoted as “input sample rate:output sample rate” in the title under each figure.

The input signal is 1 kHz sine wave at two amplitude levels - 0 dB (Figure 2 to Figure 7) and - 60 dB (Figure 8 to Figure 13).

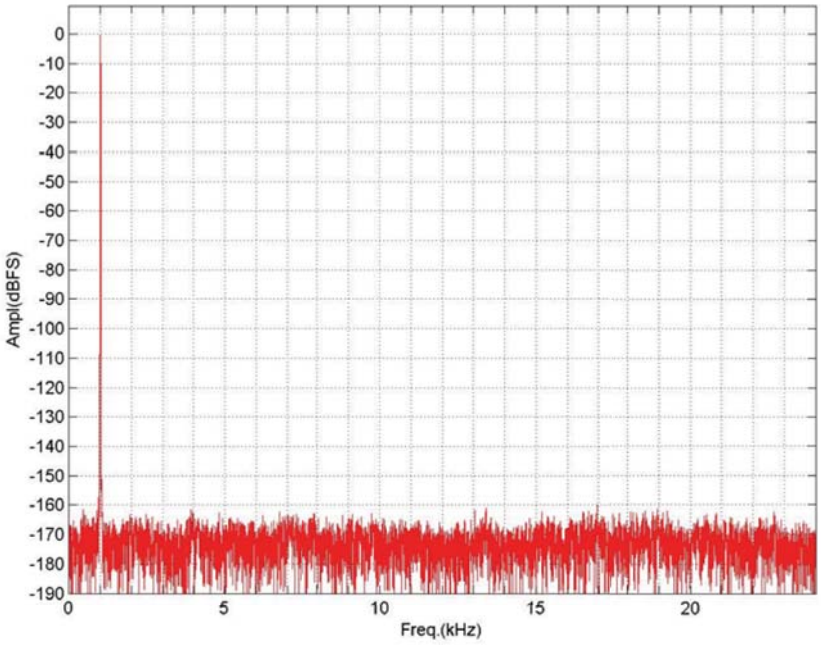

Figure 2. Wideband FFT Plot (0 dBFS 1 kHz Tone, 48 kHz:48 kHz)

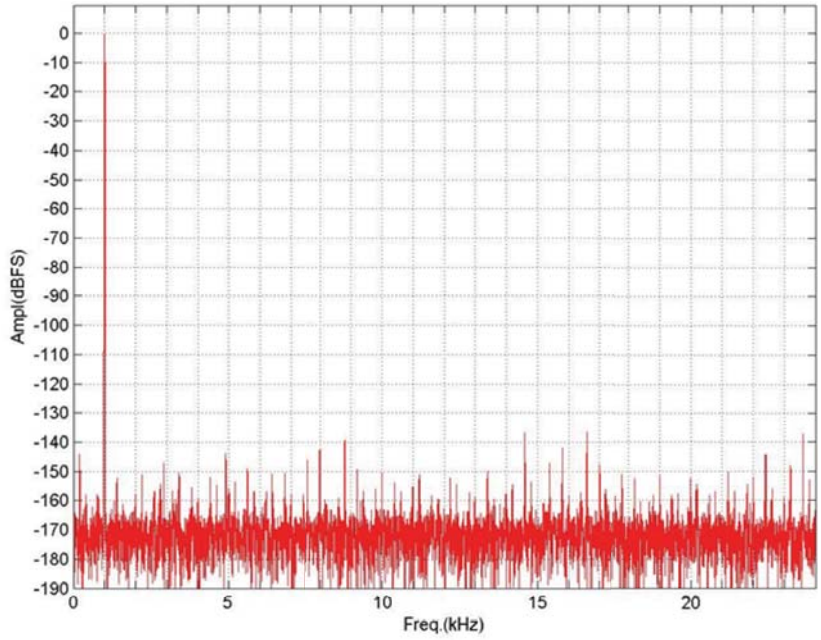

Figure 3. Wideband FFT Plot (0 dBFS 1 kHz Tone, 44.1 kHz:48 kHz)

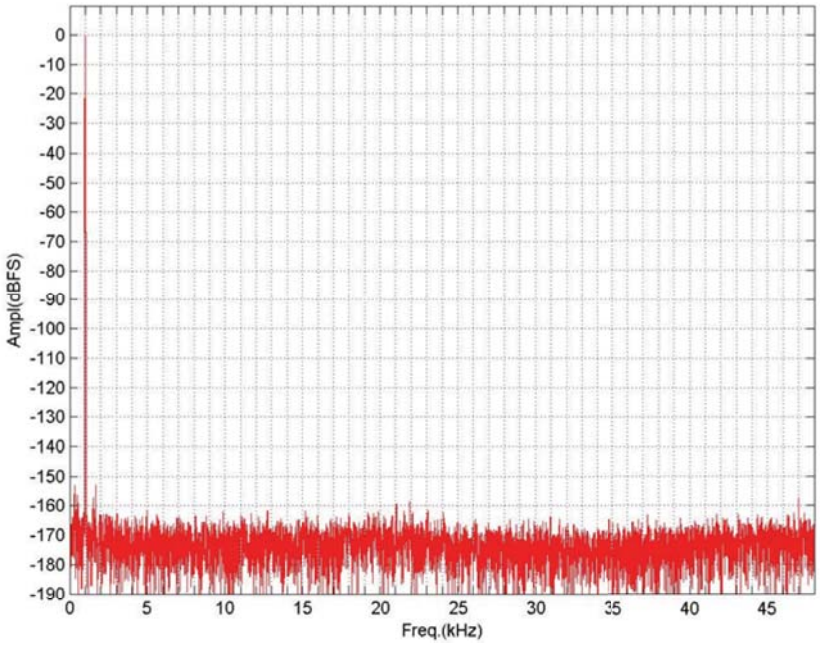

Figure 4. Wideband FFT Plot (0 dBFS 1 kHz Tone, 48 kHz:96 kHz)

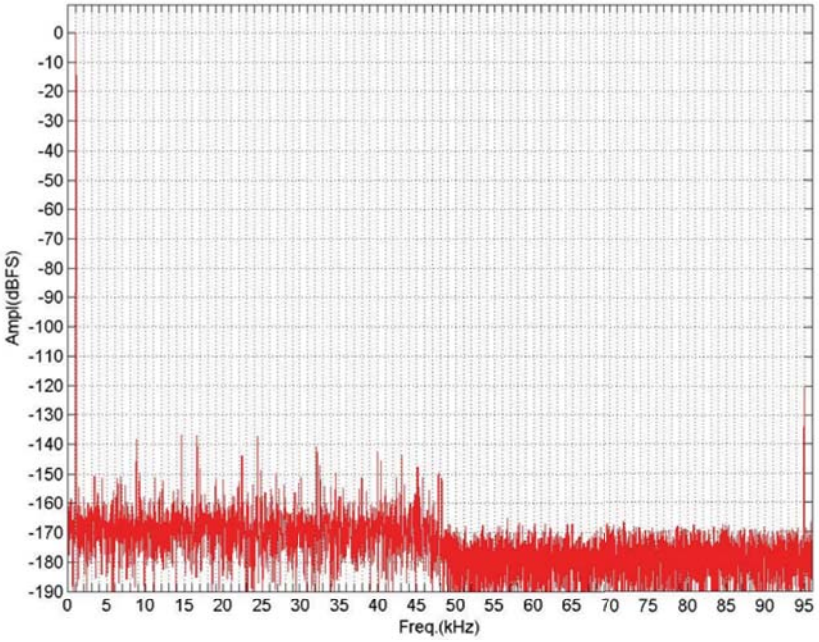

Figure 5. Wideband FFT Plot (0 dBFS 1 kHz Tone, 44.1 kHz:192 kHz)

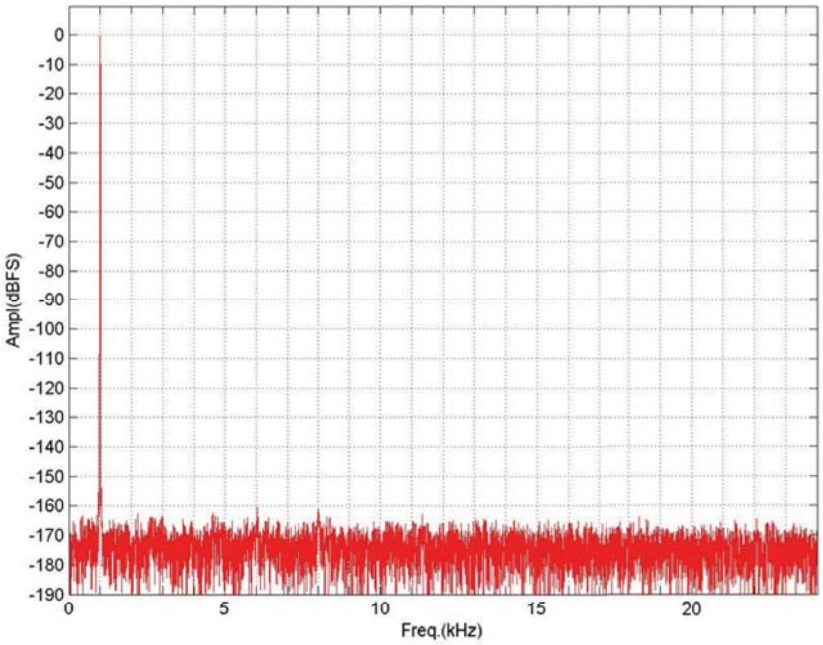

Figure 6. Wideband FFT Plot (0 dBFS 1 kHz Tone, 96 kHz:48 kHz)

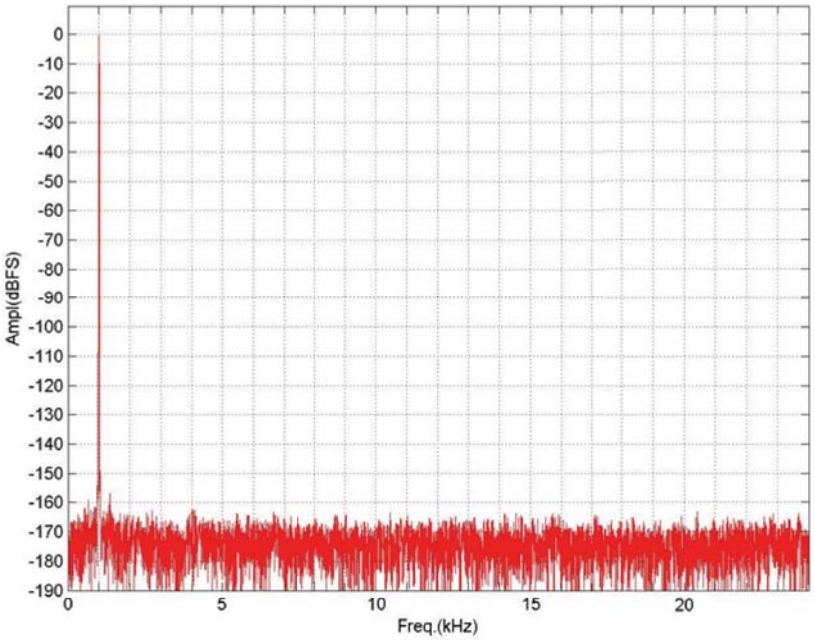

Figure 7. Wideband FFT Plot (0 dBFS 1 kHz Tone, 192 kHz:48 kHz)

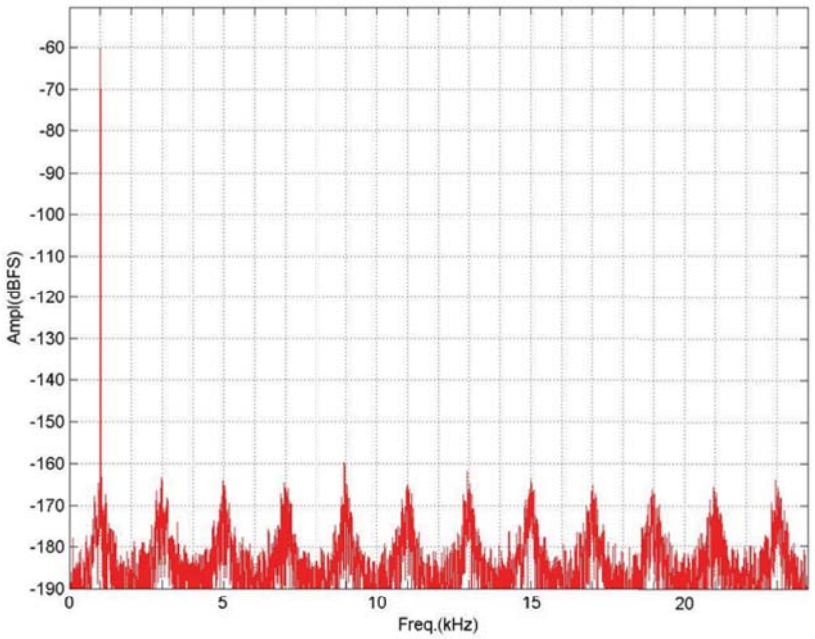

Figure 8. Wideband FFT Plot (-60 dBFS 1 kHz Tone, 48 kHz:48 kHz)

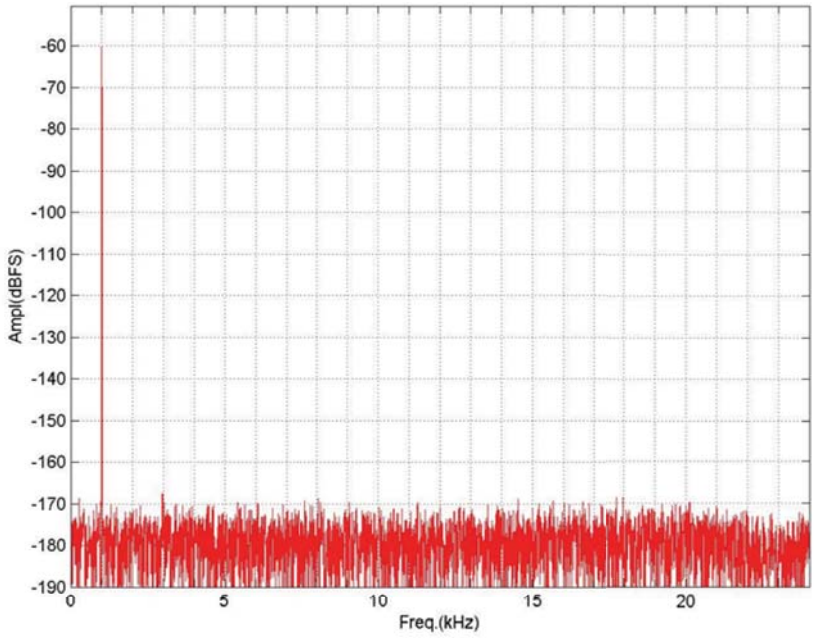

Figure 9. Wideband FFT Plot (-60 dBFS 1 kHz Tone, 44.1 kHz:48 kHz)

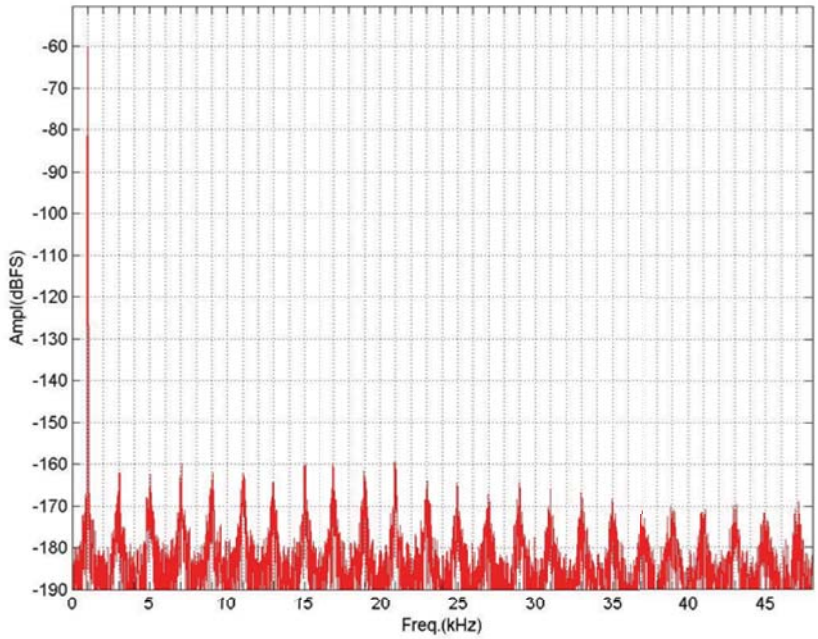

Figure 10. Wideband FFT Plot (-60 dBFS 1 kHz Tone, 48 kHz:96 kHz)

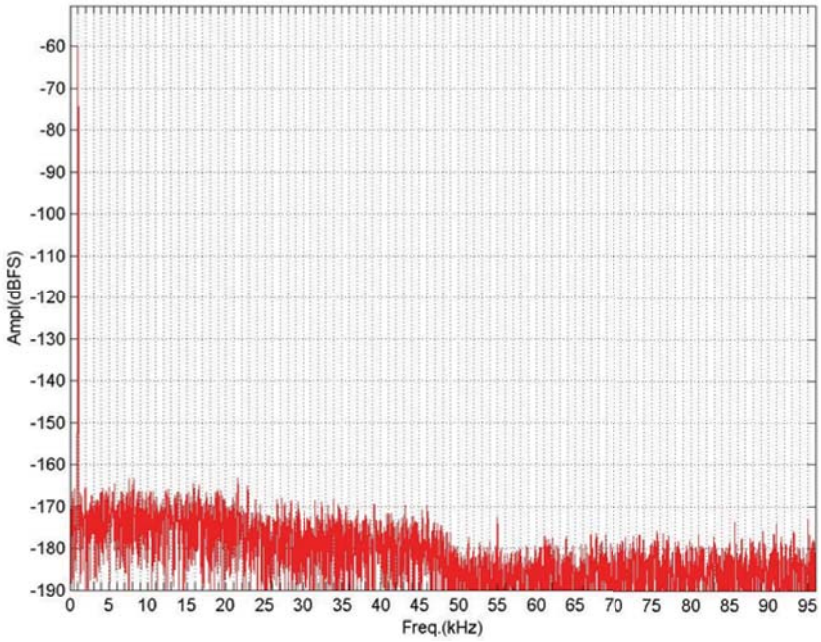

Figure 11. Wideband FFT Plot (-60 dBFS 1 kHz Tone, 44.1 kHz:192 kHz)

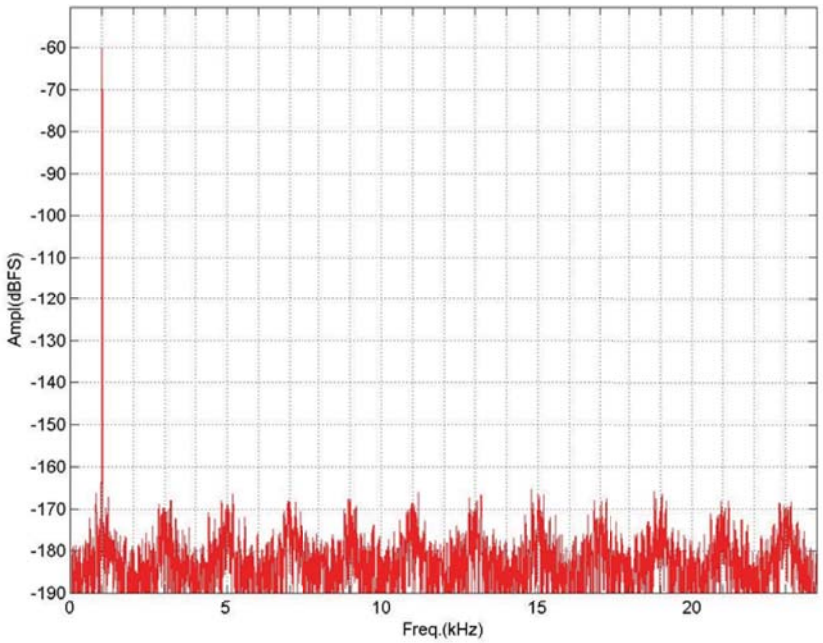

Figure 12. Wideband FFT Plot (-60 dBFS 1 kHz Tone, 96 kHz:48 kHz)

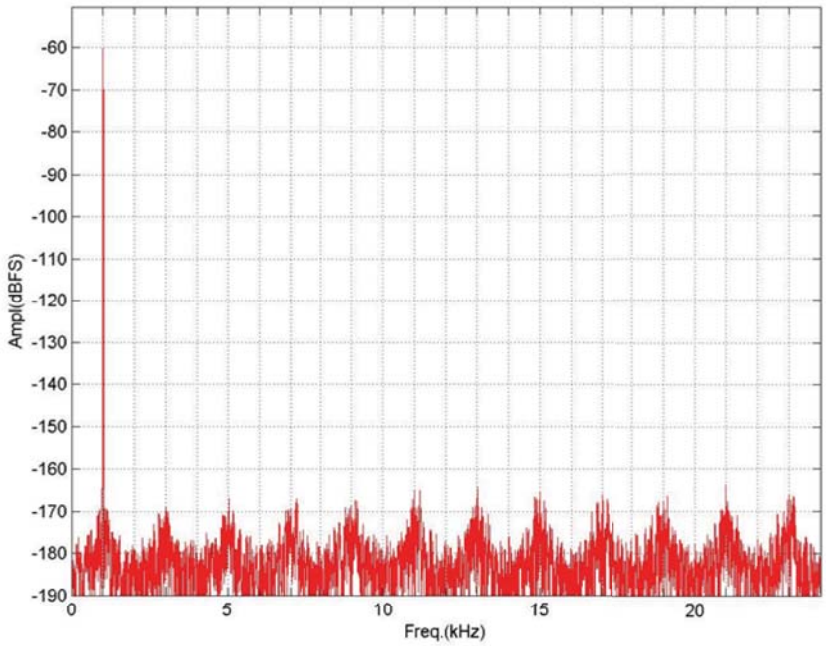

Figure 13. Wideband FFT Plot (-60 dBFS 1 kHz Tone, 192 kHz:48 kHz)

2.2 IMD

Figure 14 and Figure 15 show the frequency spectrum of the measured signal on the ASRC output. Sample rates are denoted as “input sample rate:output sample rate” in the title under each figure. The input signal is the combination of two sine wave signals—10 kHz and 11 kHz, at 0 dB total level. The measurement shows intermodulation distortion of the two input signals. The amplitude of each signal is -6 dB (1/2).

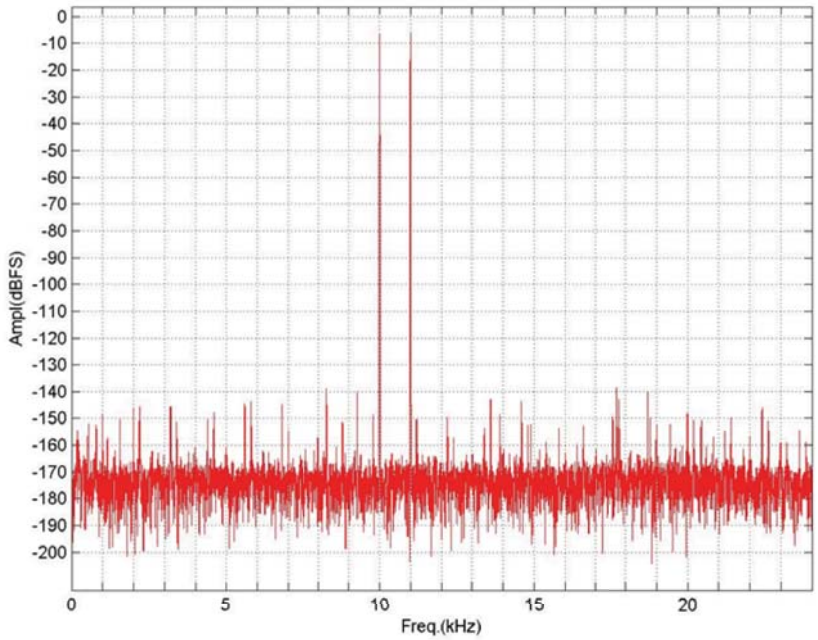

Figure 14. IMD, 10 kHz and 11 kHz, 0 dbFS Tone, 44.1 kHz:48 kHz

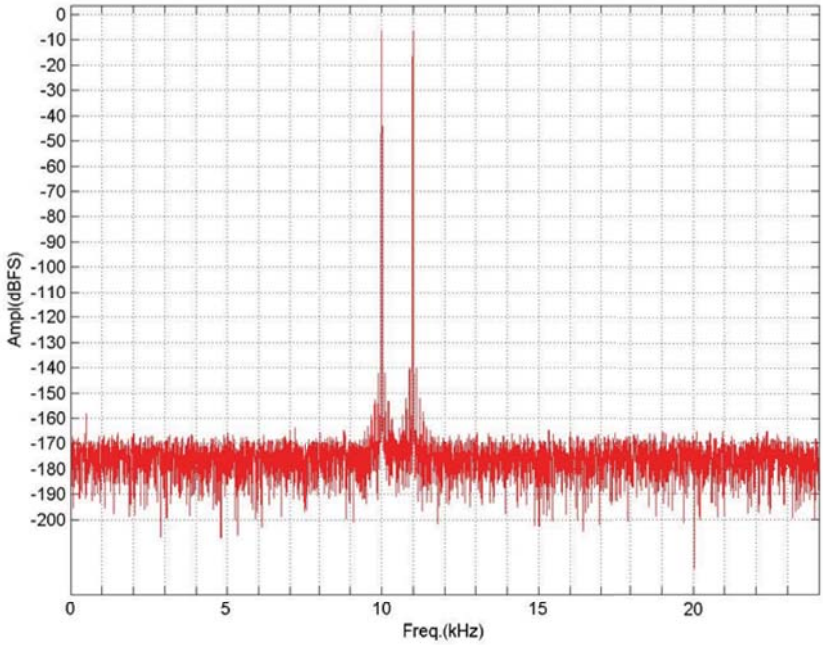

Figure 15. IMD, 10 kHz and 11 kHz, 0 dBFS Tone, 96 kHz:48 kHz

2.3 Wideband FFT 20 kHz and 80 kHz

Figure 16 through Figure 20 show the frequency spectrum of the measured signal on the ASRC output. Sample rates are denoted as “input sample rate:output sample rate” in the title under each figure. The input signal is a 20 kHz sine wave, which is still within the 24 kHz bandwidth, and 80 kHz which is beyond the ASRC bandwidth. Both are at 0 dB amplitude level.

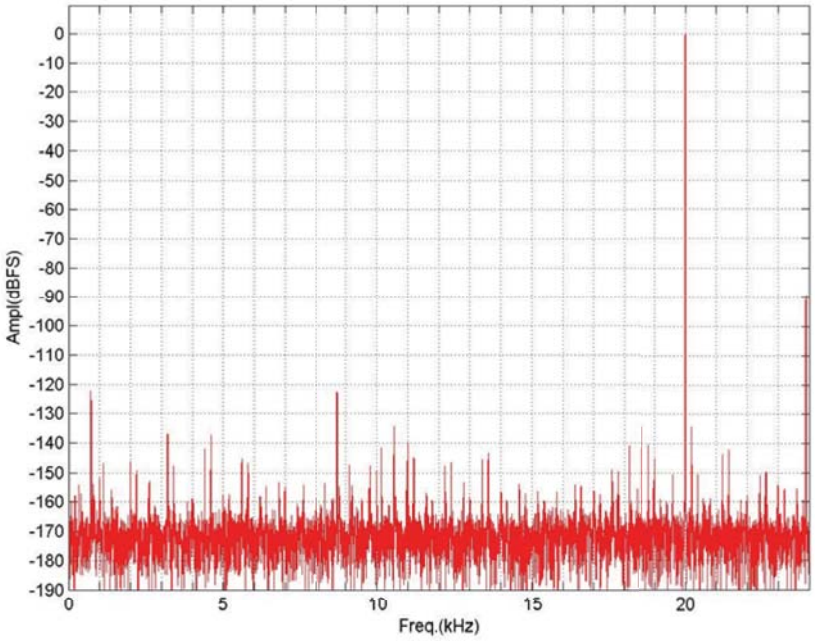

Figure 16. Wideband FFT Plot (0 dBFS 20 kHz Tone, 44.1 kHz:48 kHz)

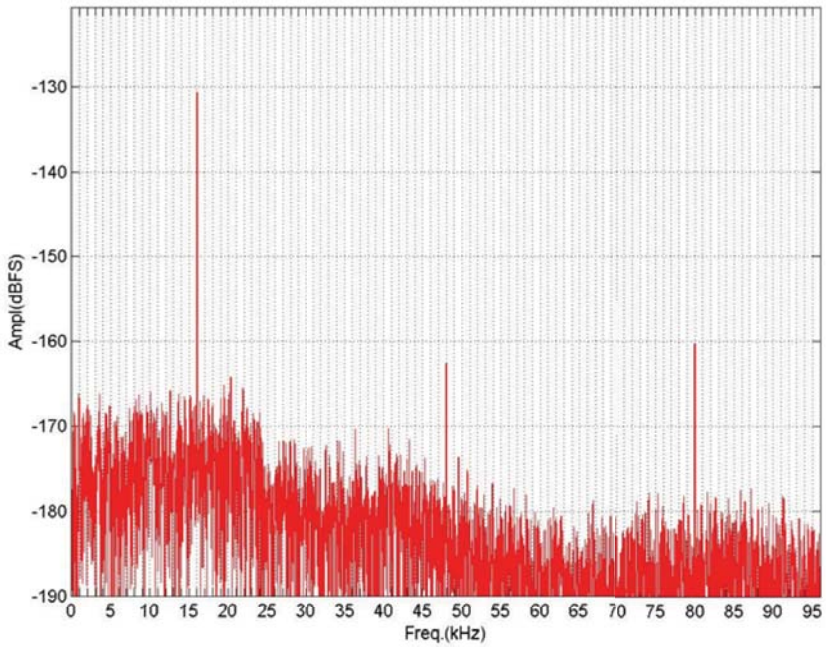

Figure 17. Wideband FFT Plot (0 dBFS 80 kHz Tone, 192 kHz:192 kHz)

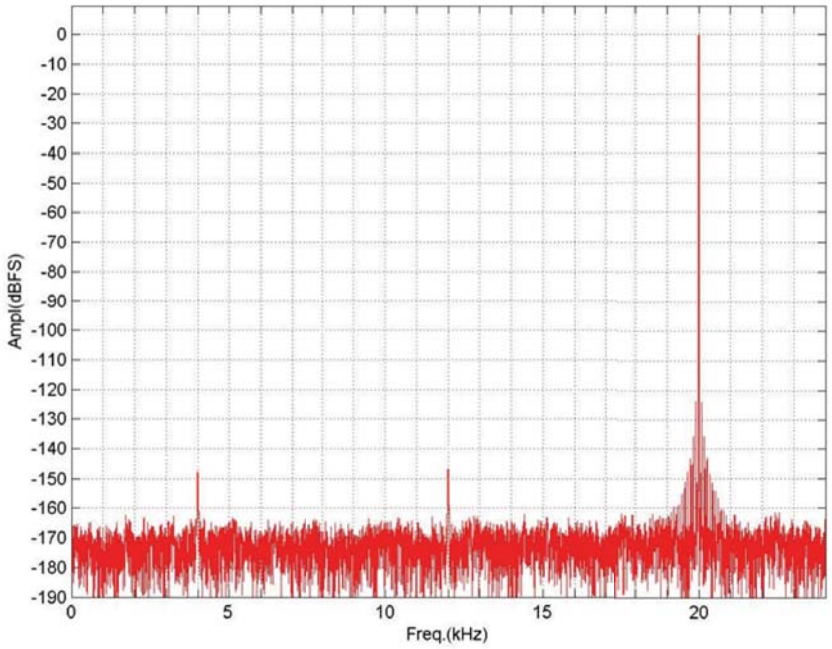

Figure 18. Wideband FFT Plot (0 dBFS 20 kHz Tone, 48 kHz:48 kHz)

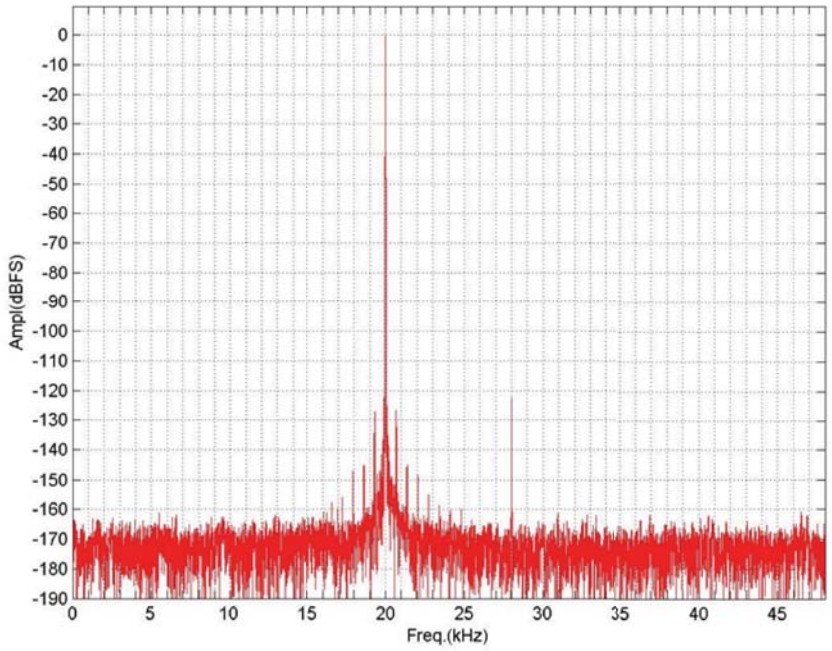

Figure 19. Wideband FFT Plot (0 dBFS 20 kHz Tone, 48 kHz:96 kHz)

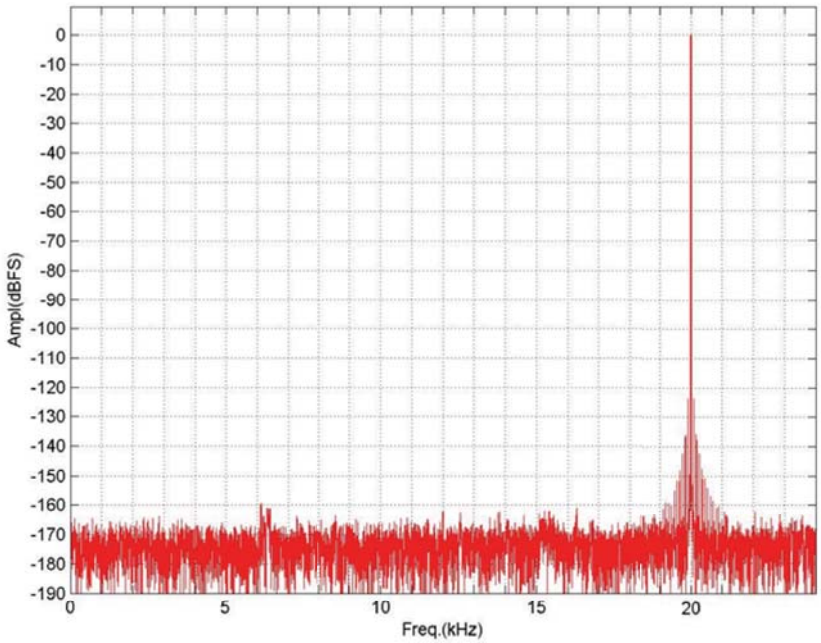

Figure 20. Wideband FFT Plot (0 dBFS 20 kHz Tone, 96 kHz:48 kHz)

2.4 Pass-Band Ripple

Figure 21 shows the frequency spectrum of the measured signal on the ASRC output.

The input signal is 0–25 kHz sine wave at 0 dB amplitude level. The measurement shows the frequency response of the ASRC. The input signal is sampled at 192 kHz and converted to 48 kHz on the output.

The bandwidth of the low-pass pre-filter (see the *ASRC Signal Processing Flow* chapter in the associated product reference manual) is set to 0.25 × Fs, where Fs is sampling rate of the input signal. In this case ×0.5 down-sampling is used, so sampling rate of the input signal is 192 × 0.5 = 96 kHz.
Fs = 0.25 × 96 = 24 kHz.

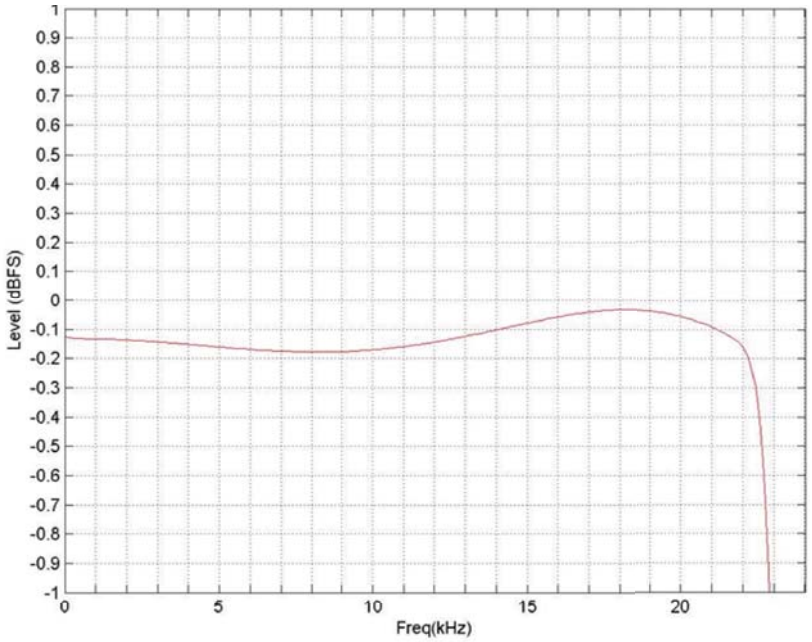

Figure 21. Pass-Band Ripple, 192 kHz:48 kHz

2.5 D-D Linearity Error

Figure 22 through Figure 26 show the amplitude spectrum of the measured signals on the ASRC output after conversion. Sample rates are denoted as "input sample rate:output sample rate" in the title under each figure. The input signal is 200 Hz sine wave at an amplitude level range from -140 dB to 0 dB. The measurements show linearity error proportional to signal input level.

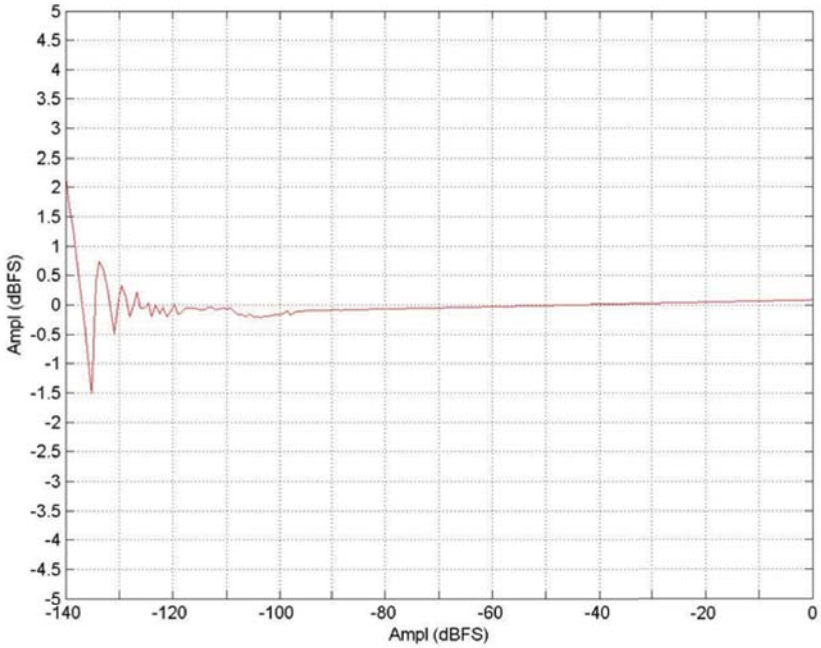

Figure 22. D-D Linearity Error, 48 kHz:48 kHz, 0 dBFS to -140 dBFS Input, 200 Hz Tone

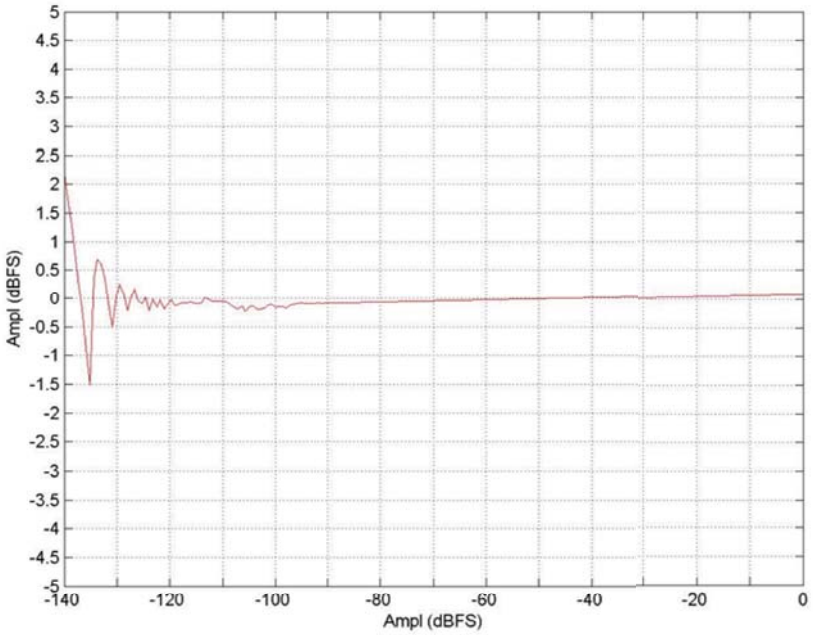

Figure 23. D-D Linearity Error, 96 kHz:48 kHz, 0 dBFS to -140 dBFS Input, 200 Hz Tone

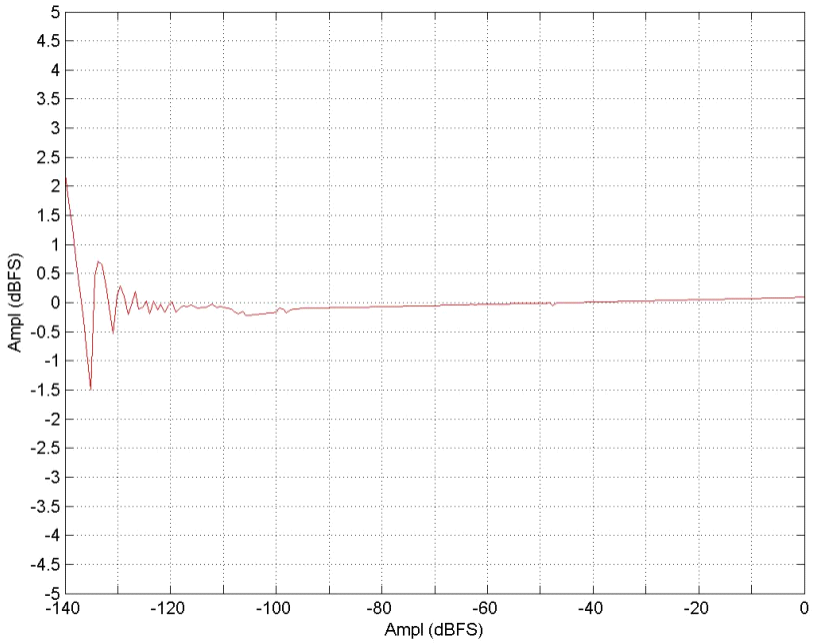

Figure 24. D-D Linearity Error, 44.1 kHz:48 kHz, 0 dBFS to -140 dBFS Input, 200 Hz Tone

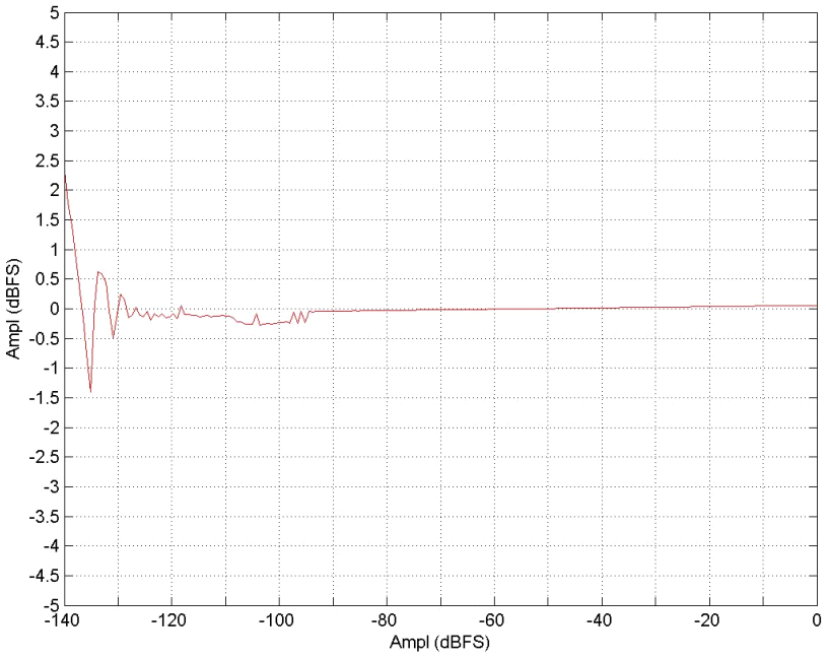

Figure 25. D-D Linearity Error, 48 kHz:96 kHz, 0 dBFS to -140 dBFS Input, 200 Hz Tone

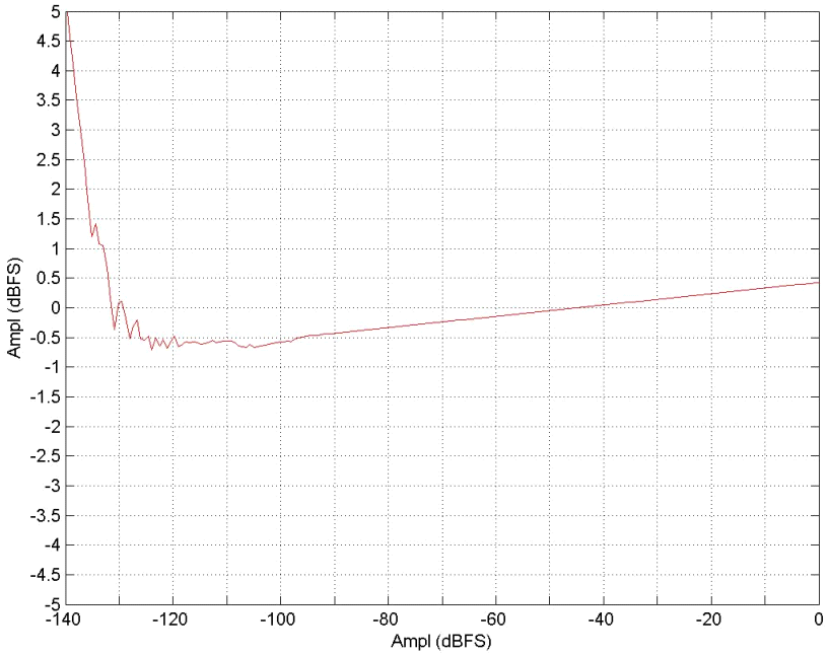

Figure 26. D-D Linearity Error, 44.1 kHz:192 kHz, 0 dBFS to -140 dBFS Input, 200 Hz Tone

2.6 THD+N

Figure 27 through Figure 31 show the amplitude spectrum of measured signals at the ASRC output after conversion. The figures show total harmonic distortion plus noise (THD+N) levels proportional to the amplitude level of the 1 kHz input signal in the range from -140 dB to 0 dB.

Figure 32 through Figure 34 show the frequency spectrum of measured signals at the ASRC output after conversion. The figures show total harmonic distortion plus noise (THD+N) levels proportional to the frequency of the input signal at 0 dB level in the range from 0 to 24 kHz. Sample rates are denoted as "input sample rate:output sample rate" in the title under each figure.

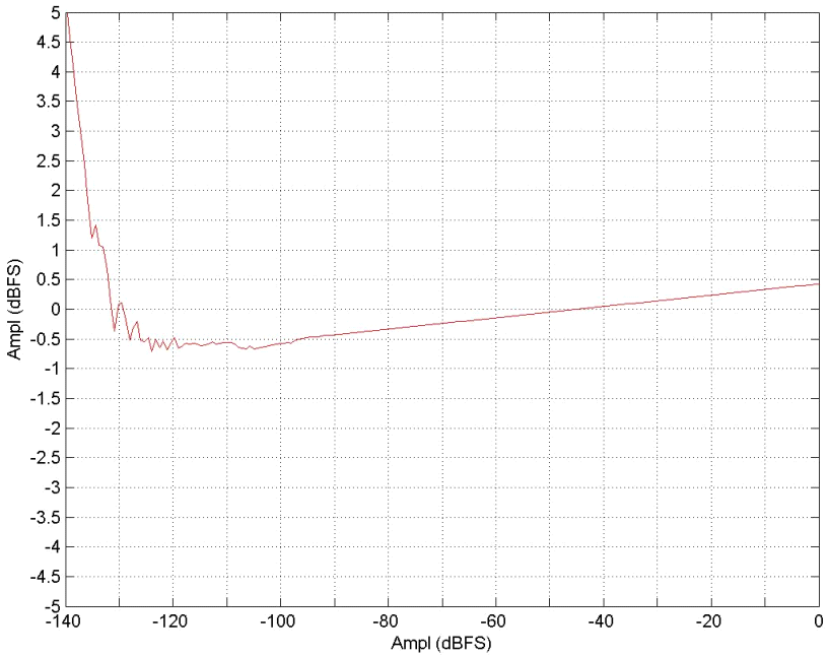

Figure 27. THD+N vs. Input Amplitude, 96 kHz:48 kHz, 1 kHz Tone

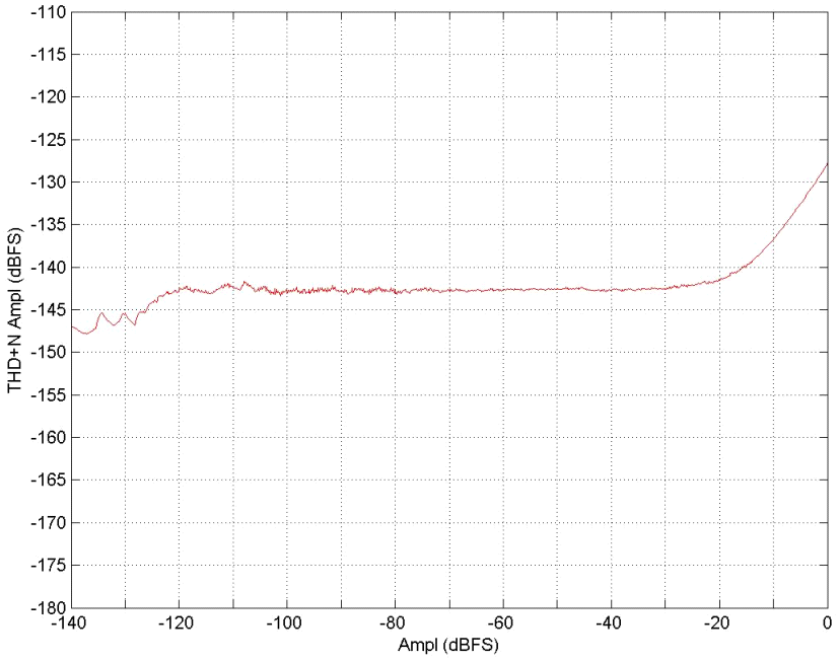

Figure 28. THD+N vs. Input Amplitude, 44.1 kHz:48 kHz, 1 kHz Tone

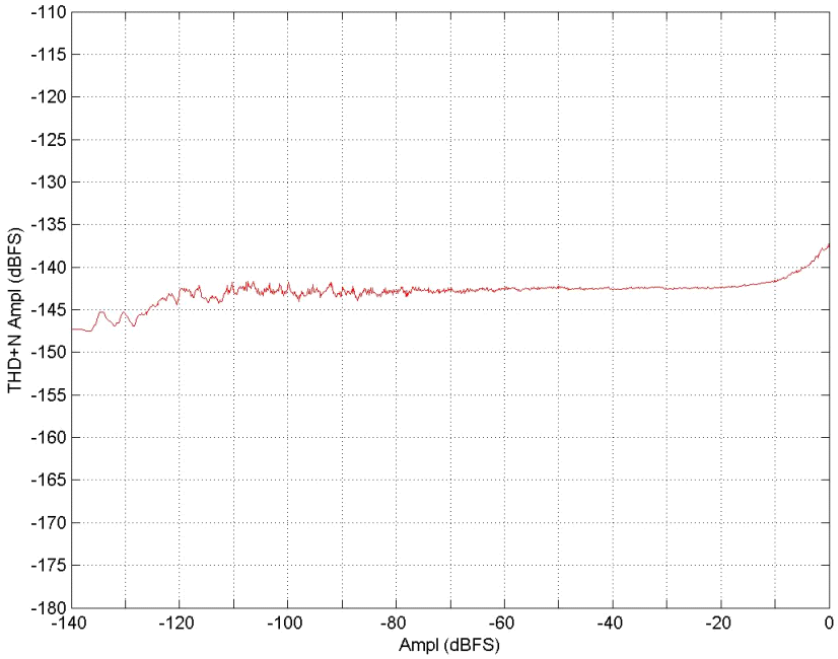

Figure 29. THD+N vs. Input Amplitude, 48 kHz:96 kHz, 1 kHz Tone

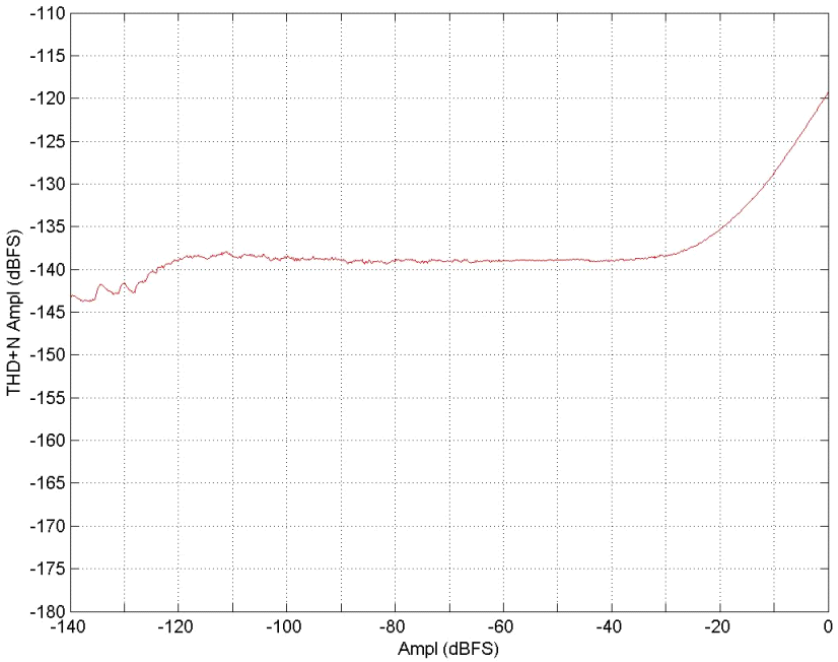

Figure 30. THD+N vs. Input Amplitude, 44.1 kHz:192 kHz, 1 kHz Tone

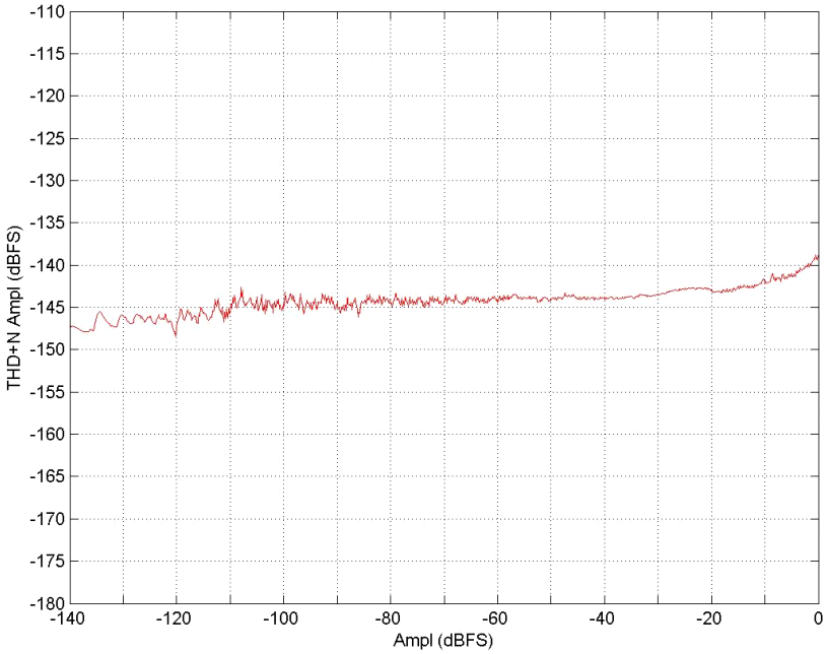

Figure 31. THD+N vs. Input Amplitude, 192 kHz:48 kHz, 1 kHz Tone

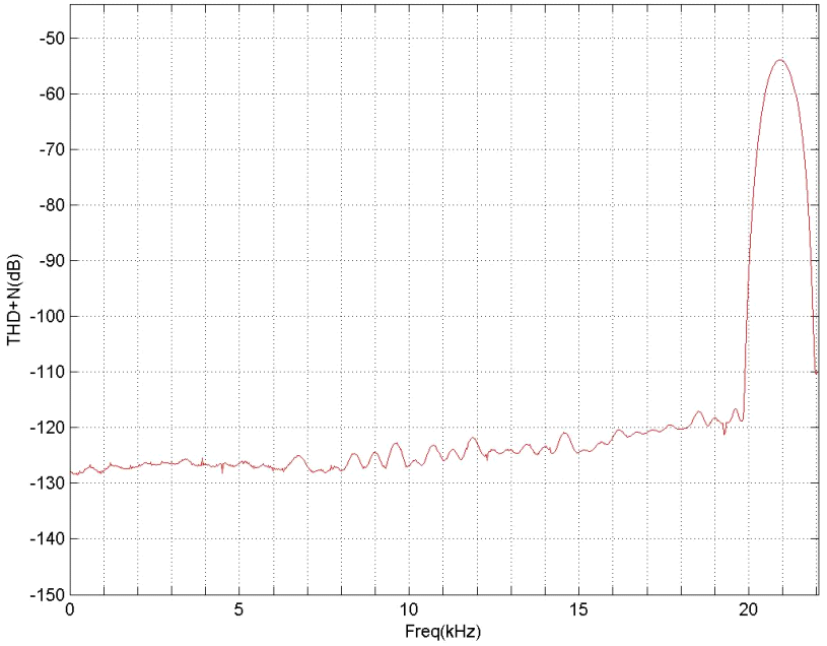

Figure 32. THD+N vs. Frequency Input, 44.1 kHz:48 kHz, 0 dBFS

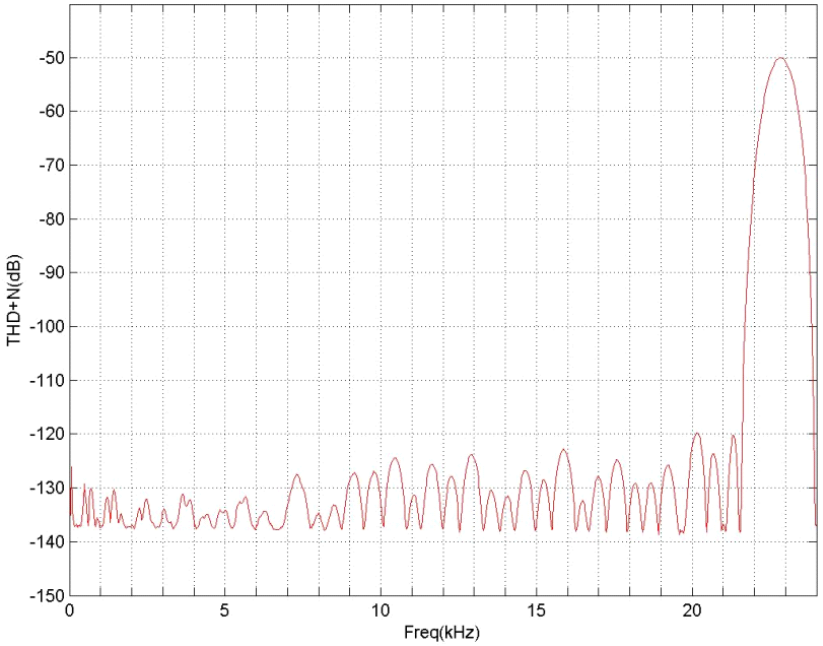

Figure 33. THD+N vs. Frequency Input, 48 kHz:96 kHz, 0 dBFS

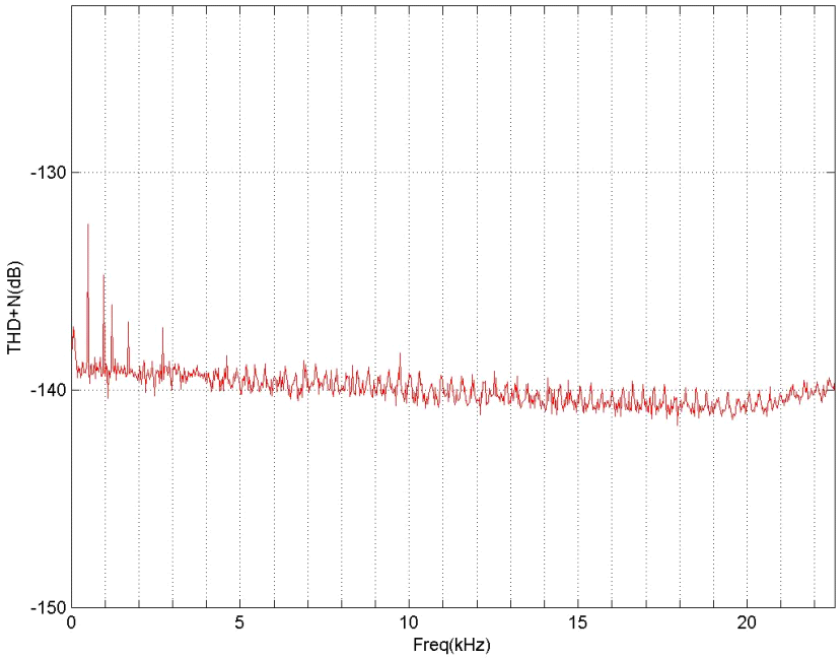

Figure 34. THD+N vs. Frequency Input, 96 kHz:48 kHz, 0 dBFS

3 Conclusion

We have seen ASRC performance results at different signal frequencies, levels and transfer rates.

It is clear that the best results are achieved when:

- Input sample rate equals the output sample rate—for example, 48 kHz: 48 kHz. This mode is used to eliminate the inaccuracy and jitter of input and output clocks. For example, in Figure 2 the signal to noise ratio is better than 160 dB (1 / 100,000,000),
- Output sample rate to input sample rate ratio is a whole number. For example, 48 kHz: 96 kHz (1:2) in Figure 4.
- Input sample rate to output sample rate ratio is a whole number. For example, 192 kHz: 48 kHz (4:1) in Figure 7.

If the input sample rate to output sample rate ratio is not a whole number, we see unwanted harmonics at frequencies of the sum of, or the difference between, the sample rate and the input signal. For example, in Figure 3 we see peaks at 14.6 kHz and 16.6 kHz which are at (48 kHz – 44.1 kHz) × 4 ± 1st harmonic. Those peaks are still at -140 dB level, which is 1 / 10,000,000 of the input signal.

IMD tests show additional harmonics at frequencies which are a combination of the input harmonics difference and whole-number multiple of the difference of sample rates, etc. For example, in Figure 14 we see peaks at 13.6, 14.6, 16.6, and 17.6 kHz which is (48 kHz – 44.1 kHz) × 4 ± 1st harmonic ± (11 kHz – 10 kHz) or the signal at 17.8 kHz which is (48 kHz – 44.1 kHz) × 2 + 10 kHz. Those unwanted harmonics are still at -140 dB level.

Frequency response in Figure 21 shows 0.18 dB linearity error mainly in the integrated low-pass pre-filter of the ASRC.

The worst case of dynamic distortion is in the ±0.6 dB range for input signals down to -130 dB for 44.1 kHz:192 kHz.

THD+N was in all cases better than the specified -120 dB. The worst case is again at 44.1 kHz:192 kHz conversion.

In Figure 32 and Figure 33 we see the effect of the low-pass pre-filter on frequencies above 20 kHz (Fs = sampling rate × divider × 0.25). In the range of 0 to 20 kHz THD+N is less than the specified level -120 dB.

These module performance measurements demonstrate the ability of the Freescale ASRC module to convert signals at different input sample rates to signals at different output sample rates with high dynamic range, high linearity and low THD+N.

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