

Using the ADAU1787 Limiter in SigmaStudio

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When using SigmaStudio in conjunction with the ADAU1787, one of the dynamic processing blocks in the FastDSP core that can be employed is the Limiter. This block will limit the signal to a defined threshold level, in accordance with the settings for its five key parameters: Attack Step, Decay Step, Threshold, Min Gain and Max Gain.

This document describes the steps required to use the FastDSP Limiter in a SigmaStudio project for the ADAU1787 low-power, low-latency CODEC. This document also details how to use the External Detect Limiter with the ADAU1787.

NOTE: In all examples and plots in this document, the signal path is I2S Serial Port → Interpolator → FDSP [Limiter] → DACOUT. The Serial Port sample rate is 48kHz and the FDSP/DAC sample rate is 384kHz. The gain of this system with no limiter is 0dB.

USING THE LIMITER

See Figure 1 for an image of the Limiter Block as it is displayed in SigmaStudio. The Attack and Release Steps are entered as dB/sample step sizes by default, but can be changed to linear scale. The Threshold, Min Gain and Max Gain sliders are all in units of dB.

In addition, there is the option to use the limiter in RMS mode or Peak mode. Note this selection only pertains to the threshold used for Decay. For Attack, the peak value is always used. It should be understood that for RMS or Peak Mode, the amplitude that triggers the limiter release for a given signal will be the same. In RMS mode, the peak threshold is internally converted to an equivalent RMS value, and the calculations are then done in RMS values moving forward. Hence, RMS mode will not change the amplitude necessary to trigger release for the limiter, but can provide smoother decay transitions for real audio.

There is an option to specify that the limiter will only adjust gain on zero crossings, denoted by the “ZeroX” check box.

In all plots in this document, RMS Mode is used and the ZeroX setting is not used.

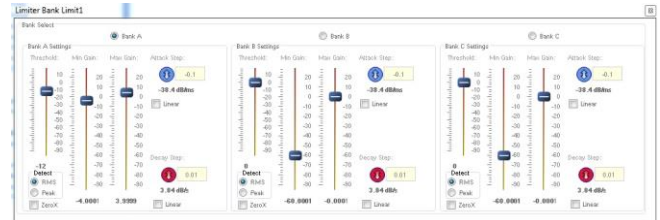


Figure 1. Limiter Block

When the output of the Limiter is below the effective Threshold, the gain of the Limiter is equal to the Max Gain setting.

Once the Threshold has been crossed, the Limiter enters its active region. While active, the Limiter will hard-limit the output level to equal the Threshold value. The active region of the Limiter is equal to the difference between the Max Gain and Min Gain.

If the input continues to increase beyond the level calculated using: $[\text{Input Level} = \text{Threshold} + (\text{Max Gain} - \text{Min Gain})]$, then the Limiter will keep applying the Min Gain setting beyond this point.

Figure 2 shows an example of Limiter operation where Threshold = -12dB, Min Gain = -4dB and Max Gain = 4dB. For easier comparison, an input-to-output plot without the limiter is included.

When the output is less than -12dB [Limiter Threshold], the Limiter Gain is equal to the Max Gain setting of 4dB. After the Threshold has been reached, the Limiter is active and limits the output level to the Threshold of -12dB. The Limiter is active for the next 8dB of input, which is the difference between the Max Gain and Min Gain. After this 8dB region, the Limiter Gain is equal to the Min Gain setting of -4dB.

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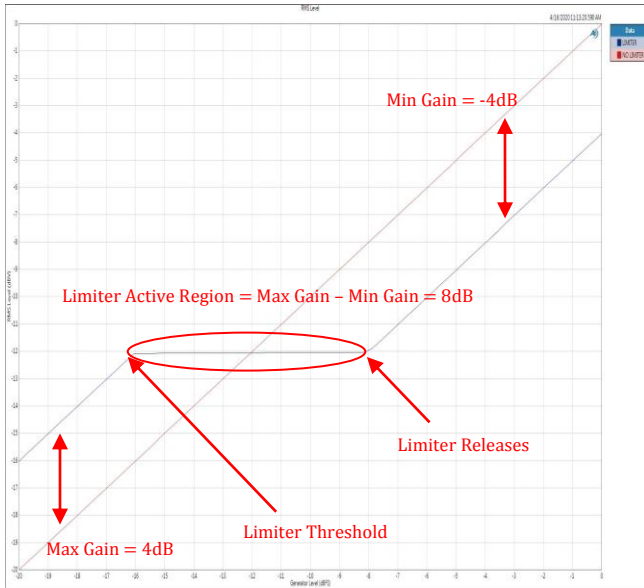


Figure 2. Limiter Operation

Threshold

The Limiter will activate when the output is greater than the Threshold value. Figure 3 shows a plot of Output Level vs. Input Level with varying Threshold levels and -2dB Min Gain, 0dB Max Gain.

The Threshold number entered into the SigmaStudio Limiter Block will be converted into unsigned 2.23 format, and then written to the FDSP. The range of acceptable values for the Threshold is 12dB (max) to -90dB (min).

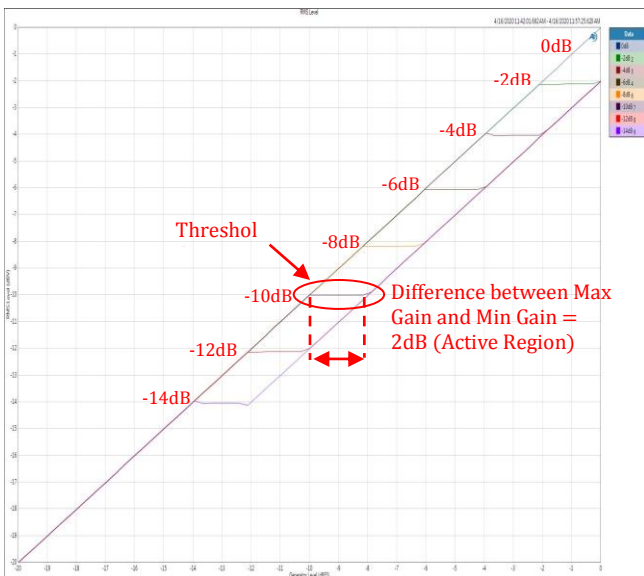


Figure 3. Threshold Variation (-2dB Min Gain, 0dB Max Gain)

Min Gain

When the input level is greater than the Threshold + (Max Gain - Min Gain), the Limiter will apply the Min Gain setting.

See Figure 4 for a plot of Output Level vs. Input Level for varying Min Gain levels and -10dB Threshold, 0dB Max Gain.

The Min Gain number entered into the SigmaStudio Limiter Block will be converted into unsigned 4.15 format, and then written to the DSP. The acceptable range of values for the Min Gain is 24dB (max) to -90dB (min).

Note that when the Min Gain = 0dB, the Limiter gain simply equals 0dB. This is because the difference between the Max Gain and Min Gain = 0dB, so the active region for the Limiter is 0dB.

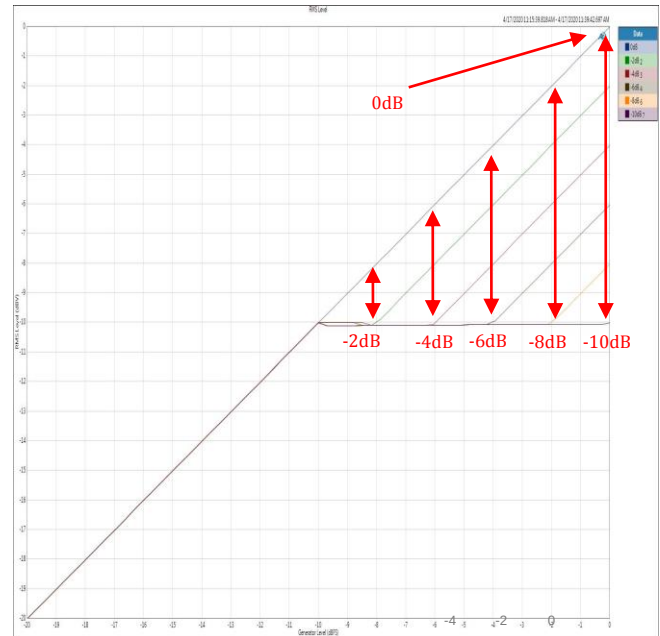


Figure 4. Min Gain Variation (-10dB Threshold, 0dB Max Gain)

Max Gain

When the output level is less than the Threshold value, the Limiter gain will equal the Max Gain setting.

See Figure 5 for a plot of Output Level vs. Input Level with varying Max Gain levels and -10dB Threshold, -2dB Min Gain.

The Max Gain number entered into the SigmaStudio Limiter Block will be converted into unsigned 4.15 format, and then written to the DSP. The acceptable range of values for the Min Gain is 24dB (max) to -90dB (min).

When the output level is below -10dB, the Limiter gain is equal to the Max Gain setting. Once the Threshold of -10dB has been crossed, the Limiter enters the active region.

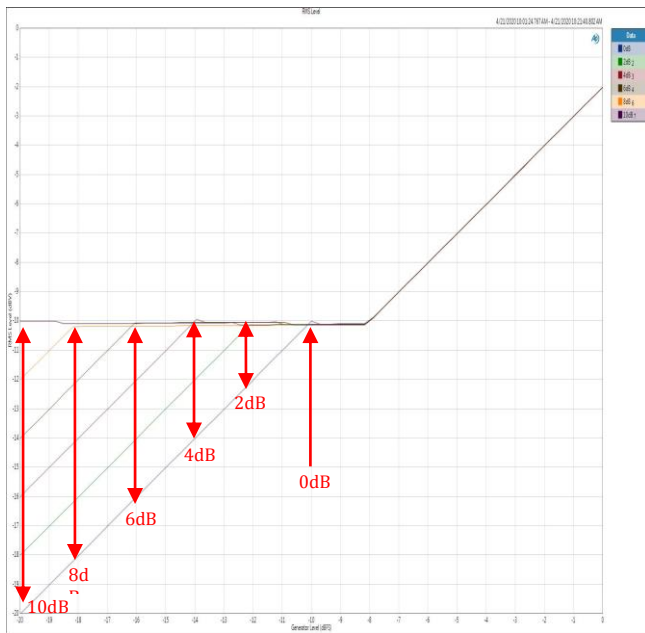


Figure 5. Max Gain Variation (-10dB Threshold, -2dB Min Gain)

Attack Step

The attack step is the speed at which the limiter activates after the threshold has been exceeded. This value is expressed in dB/sample or a linear value per sample. The larger the number, the faster the attack time. The smaller the number, the slower the attack time.

Figure 6 shows the Attack Step value in dB/sample, in the text box. If entering the value in dB mode, the SigmaStudio GUI will also translate that value to dB/mS below the text box. This value is dependent on the FDSP sampling rate. In this instance, the value is -0.10003 dB per sample. The sample rate is 384kHz, so this translates to:

$$\text{Attack Rate} = -0.10003\text{dB} \times 384\text{kHz} = -38.4\text{dB/mS}$$

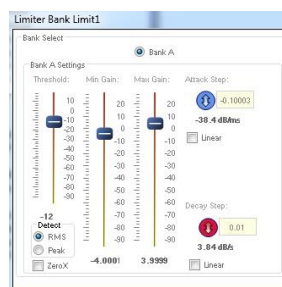


Figure 6. Attack Step Value (dB)

If the “Linear” checkbox is clicked, the same value will now be displayed as a linear gain value to be applied to each sample. Figure 7 shows the value in linear gain = 0.9885. This is equal to -0.10003dB per sample.

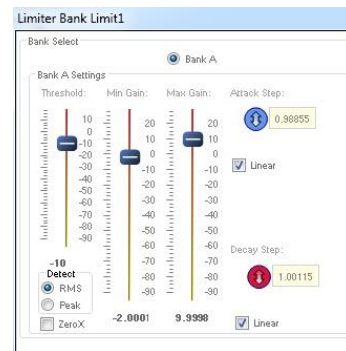


Figure 7. Attack Step Value (Linear)

The attack time scales linearly with the FDSP sample rate. For example, if the FDSP sample rate were increased from 384kHz to 768kHz, the effective Attack Step value per mS should be double its' value at 384kHz.

The Attack Step number entered into the SigmaStudio Limiter Block will be converted into unsigned 1.15 format, and then written to the DSP. In SigmaStudio, the maximum value for the Attack Step is limited from -6dB/sample to 0dB/sample.

Decay Step

The Decay Step is the speed at which the limiter will release the signal to its max gain setting after the signal has fallen below the threshold, expressed in dB per 1000 samples. The larger the number entered, the faster the Decay Step. The smaller the number entered, the slower the Decay Step.

Figure 8 shows the Decay Step value in dB/sample, in the text box. If entering the value in dB mode, the SigmaStudio GUI will also translate that value to dB/mS below the text box. This value is dependent on the FDSP sampling rate. In this instance, the value is 0.01 dB per sample. The sample rate is 384kHz, so this translates to 3.84dB/S decay rate.

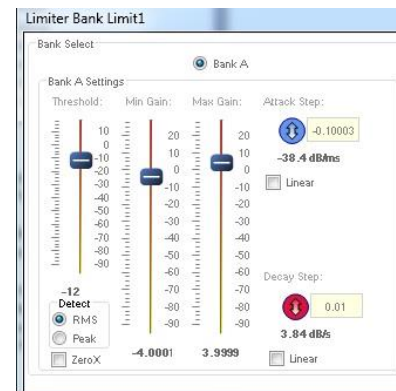


Figure 8. Decay Step Value (dB)

If the “Linear” checkbox is clicked, the same value will now be displayed as a linear gain value to be applied to each sample. Figure 7 shows the value in linear gain = 1.00115. This is equal to 0.01dB per sample.

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Figure 9. Decay Step Value (Linear)

The decay time scales linearly with the FDSP sample rate. Thus if the FDSP sample rate were increased from 384kHz to 768kHz, the Release Step should be double of its value at 384kHz.

The Decay Step number entered into the SigmaStudio Limiter Block will be converted into 2.15 format, and then written to the DSP. In SigmaStudio, the maximum value for the Decay Step is limited from 12dB/sample to 0dB/sample.

EXTERNAL DETECT LIMITER

When using the ADAU1787 in conjunction with SigmaStudio, an External Detect Limiter block can be used in lieu of the regular Limiter block. The External Limiter works almost identically to the Limiter block. The Threshold, Max Gain, Min Gain, Attack Time and Decay Step all function in the same manner. The External Detect Limiter simply uses another external reference input to compare to the Threshold value, rather than comparing the original input to the Threshold value.

A typical working External Detect Limiter schematic is shown in Figure 10.

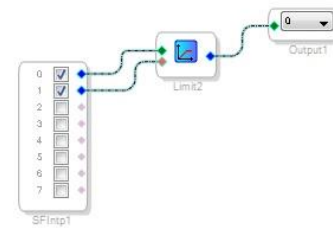


Figure 10. ADAU1787 External Detect Limiter

In this instance, Channel 0 will be the signal that is Limited in accordance with the Max / Min Gain settings. However, it will do so based on whether Channel 1 has gone above or below the Threshold value.

See Figure 11 for a plot of the External Detect Limiter response when Threshold = -12dB, Min Gain = -4dB and Max Gain = 4dB.

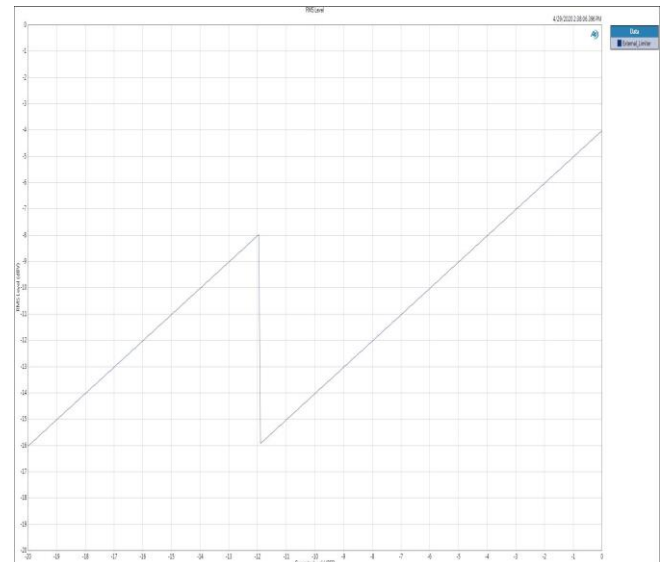


Figure 11. External Detect Limiter