Ultimate-Preamplifer

by

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USING THE INTERSAMPLE-OVERS GUARD TO ELIMINATE INTERSAMPLE OVERS

Introduction

Intersample-Overs is an often overlooked and neglected aspect of DAC and Sample Rate Converter (SRC) processes that are used to up-sample or over-sample an incoming audio stream where no in-coming sample exceeds the full-scale word limits. Up-sampling or over-sampling is purely a mathematical process usually achieved by using interpolation techniques of some kind.

For any DAC or SRC that up-samples a low rate digital audio-stream to a higher rate audio-stream, it is inevitable that some of the intermediatory samples may well exceed the numerical limits of the up-sampling hardware and hence drive the interpolator into an overloaded state. How a DAC or SRC handles these intermediatory samples may well determine the overall sound quality of the device and why one device sounds better than another.

According to reference 2 nearly every DAC and SRC that involves some kind of up-sampling or interpolation algorithm suffers from this problem. From reference 1 the best way to avoid overloading a DAC or SRC is to make sure there is sufficient margin so that the resulting intermediatory values are well within the hardware's capability without it going into an overload or undefined state.

The Ultimate-Preamplifier provides two mechanisms to guard against Intersample-Over conditions both of which rely on attenuating the signal before it is allowed to overload the succeeding stages. The conditions of over-drive are slightly different between a stand-alone DAC and digital Preamplifier such as the UP. For a standalone DAC which usually precedes an external preamplifier the DAC is always operated at full scale or full volume whereas a Preamplifer such as the UP, the signal is sufficiently attenuated by the digital volume control so that it is running at least 20 to 30 dB or more attenuation before the DAC interpolator and hence rarely experiences issues with Intersample Overs. However, we have still incorporated a switchable -3.5dB margin for cases such as home theater bypass where the volume control will be operating at 0dB.

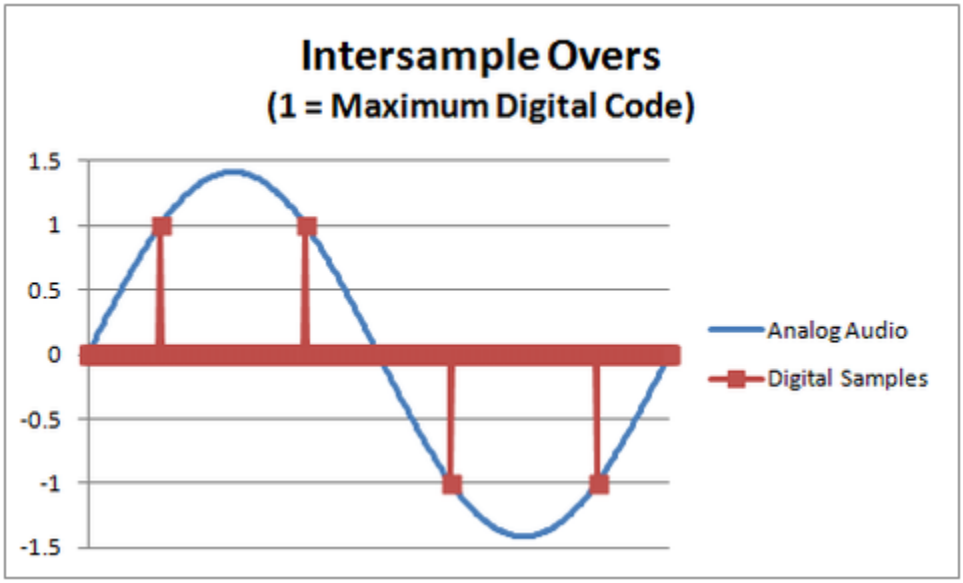
In a preamplifier which features DSP processing a Sample Rate Converter (SRC) is used to convert varying different incoming sample rates to a fixed sample rate which is typically 192kHz. Because the SRC is always running at full scale with no pre-attenuation it is susceptible to being over driven and this may account for adverse reaction of some listeners to the effect of the SRC on the sound quality.

To this end we have designed a very unique system of catching and adjusting for inter-sample overs in real time so that only the necessary amount of attenuation of the incoming signal is used to limit the SRC from being over driven. We also provide a statistics mode which can be used to observed the amount of inter-sample overs on any recording. You will be surprised at how often and the magnitude of these overs occur in standard recordings when up-sampling is being used.

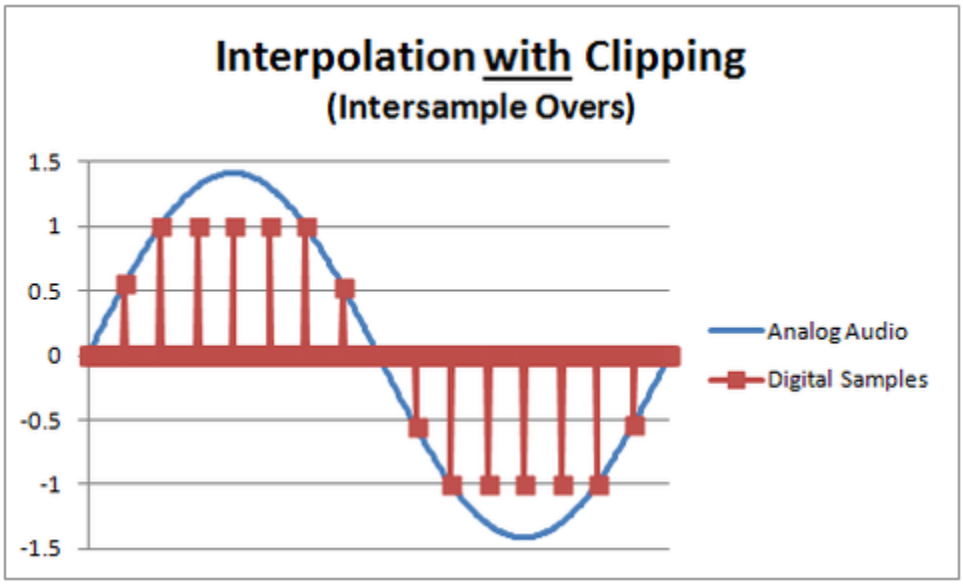
Intersample Overs

Reference 1 covers the theory and explanation of Intersample overs so we will not be covering it here. We have done some of our own testing on the UP and it basically confirms that this phenomenon is real and should be addressed. We have some synthetic test tones which generate intersample overs when fed to an up-sampling DAC or SRC. In an ideal world no clipping or limiting should occur because the original audio-stream samples by definition are all within the maximum full scale limits.

The test tone we are applying is a sinewave at 11.025kHz and sampled at 44.1kHz with full scale sample values. A DAC or SRC which does not overload its interpolator stage should be able to reproduce a higher sample rate version that follows the blue line in the graph below.[1]

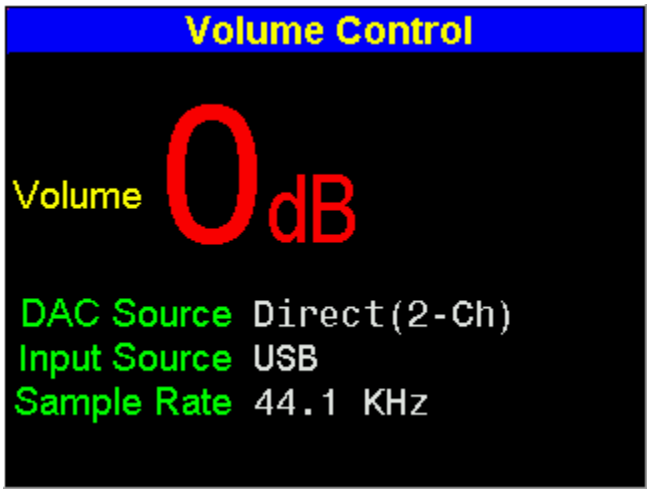


However, a DAC or SRC that overloads will clip or limit the signal as in the following diagram below [1].

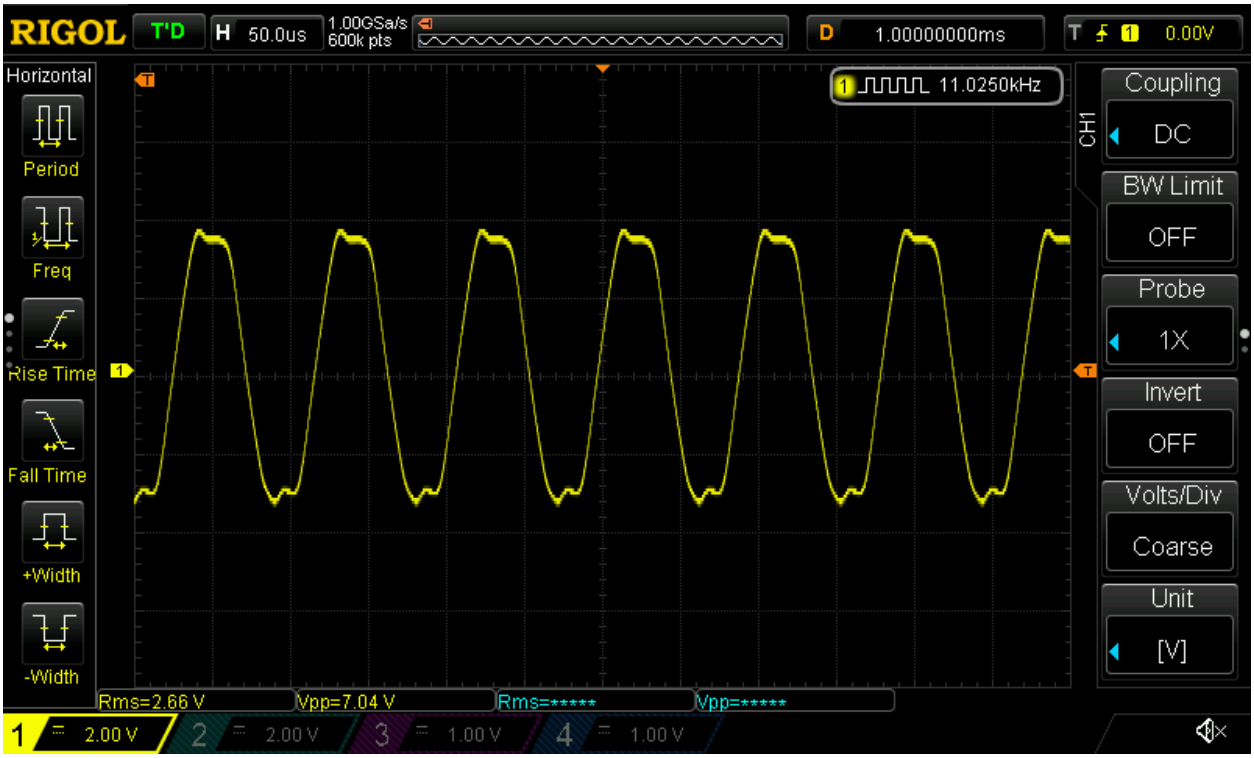


Avoiding Intersample Overs in the DAC

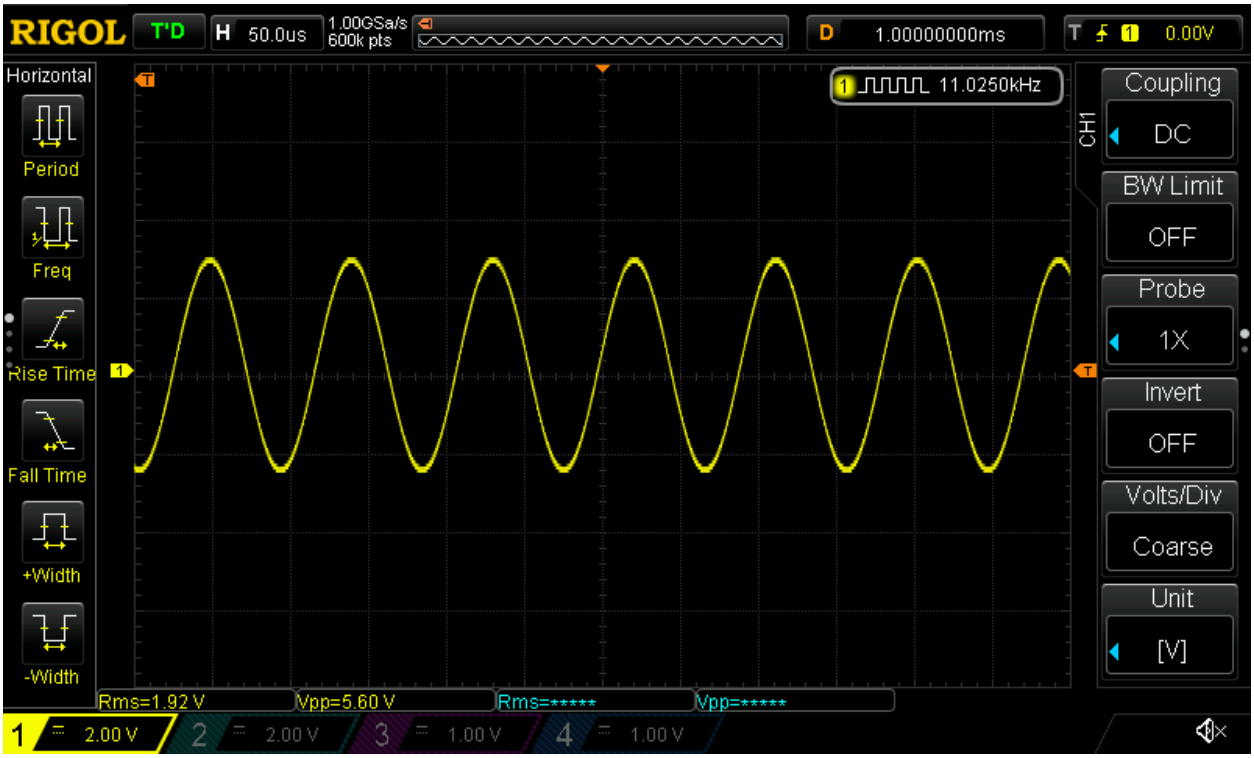
A full-scale 11.025kHz signal sampled at 44.1kHz was fed directly to the DAC and the level adjusted for maximum on the master volume control.



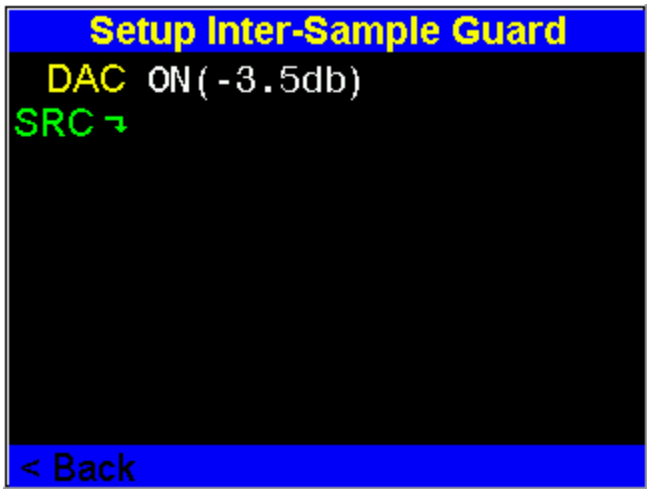
As you can see, even though the samples of the original signal never exceed the full-scale limits the interpolated or up-sampled output from the DAC shows severe compression and limiting.



If we back off the master volume to -4dB everything is ok as can be seen in the following scope shot.

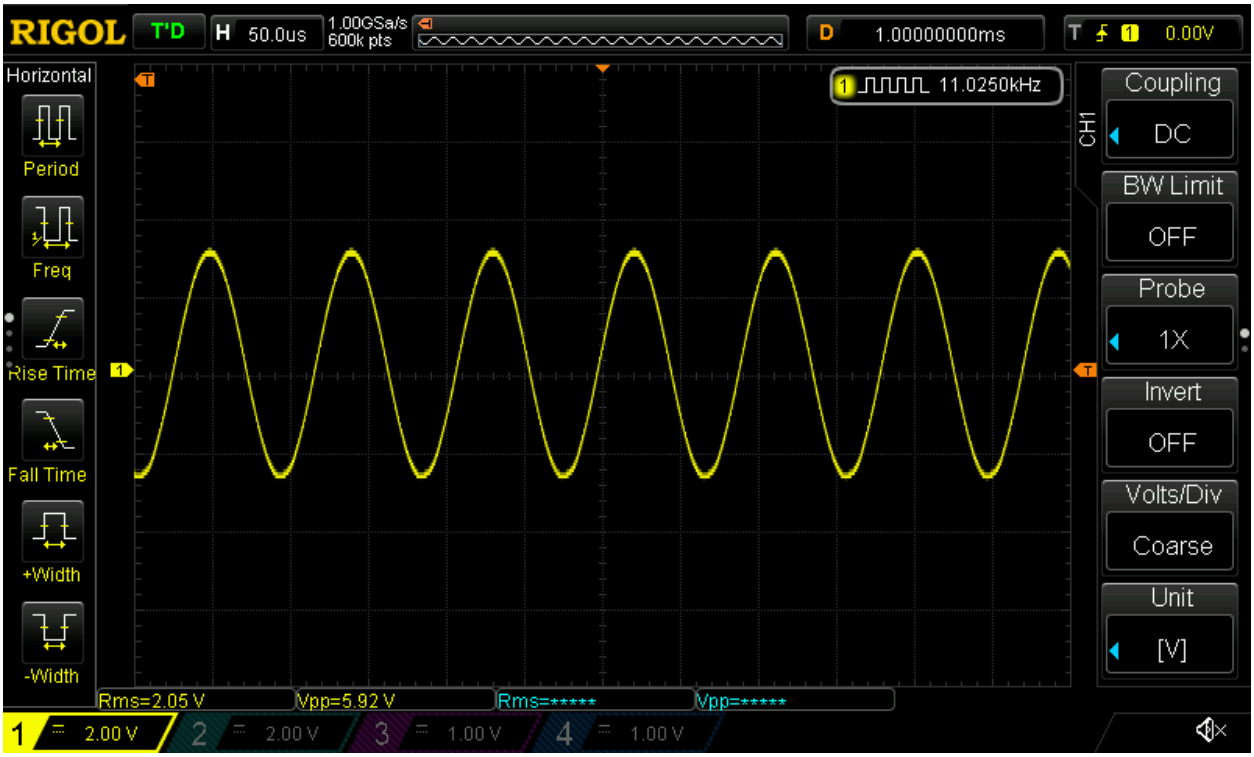


We can also achieve the same thing by turning on the Intersample Over Guard for the DAC which inserts a fixed 3.5dB attenuation on all 8 DAC channels. Ie from the main menu [Main Menu] → [Setup] → [Audio Setup] → [Intersample Guard] → [DAC = ON]



USING THE INTERSAMPLE-OVERS GUARD

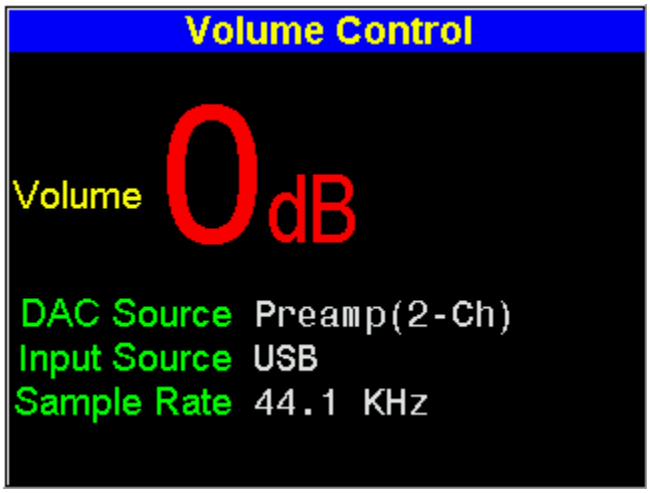
With the master volume set back to 0dB the output is now free of any distortions but the signal level has been reduced by 3.5dB to allow for the worst case Intersample overs. If you are using the preamp as a preamp rather than a stand-alone DAC then this option probably won't be that useful because the master volume is usually set to -20dB or below for normal listening so intersample overs should never be a problem.



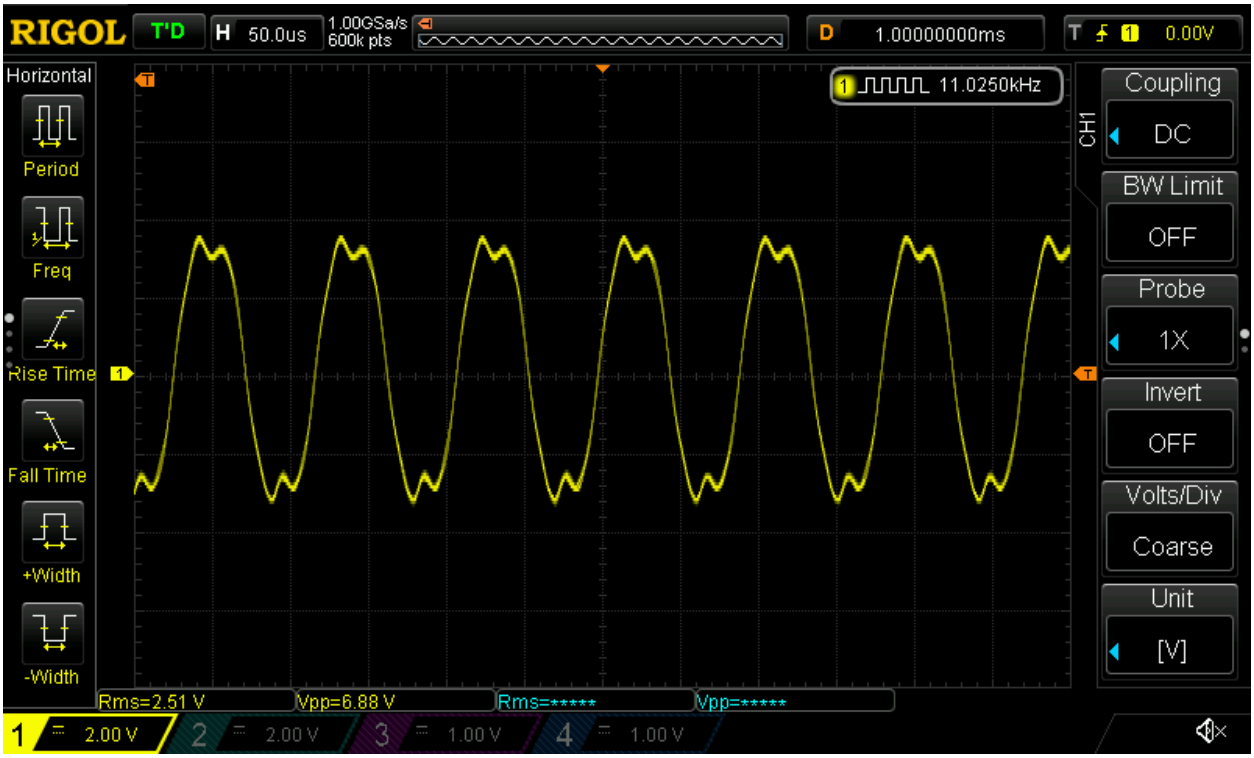
Intersample Overs in the Sample Rate Converter

When the preamp is switched to 2-Channel or Multi-Channel Preamp mode the SRC is used to up-sample all incoming audio-streams to a reference standard of 192KHz for the purpose of applying DSP processing which is always done at a fixed sample rate.

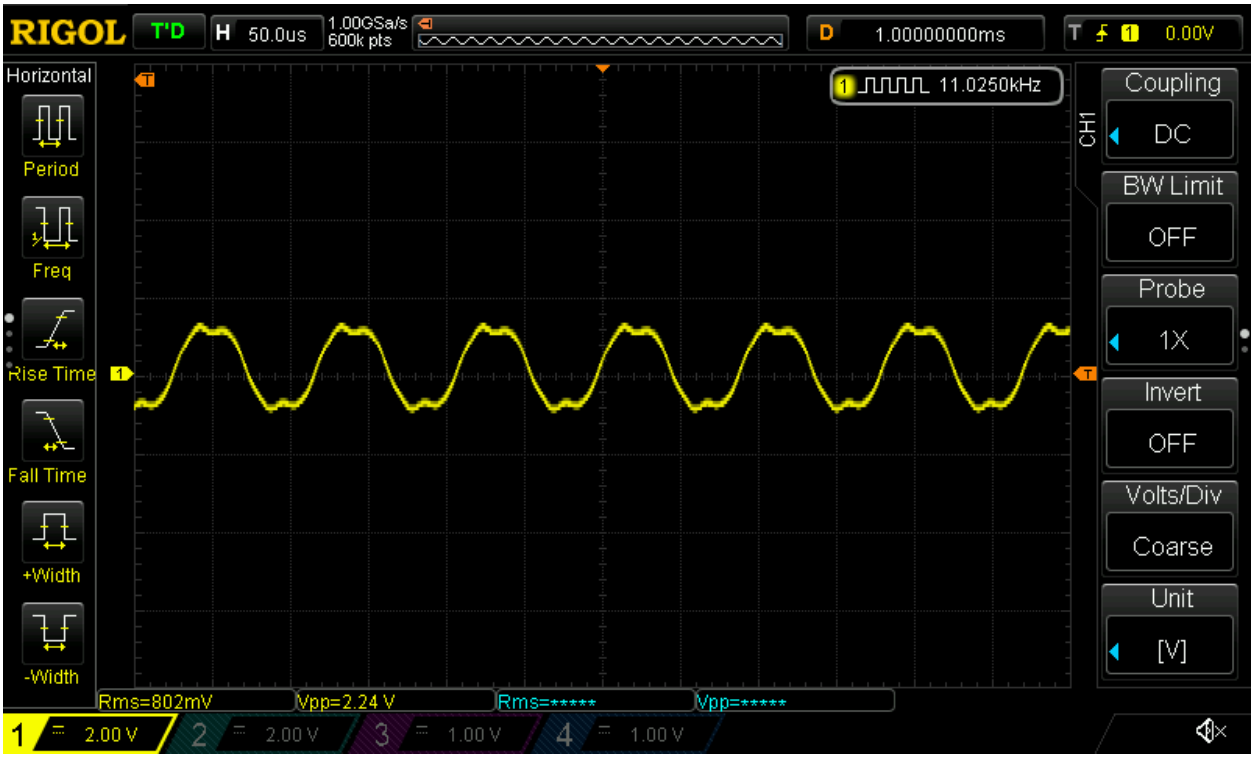
We can apply the same test to the SRC as we did with the DAC. In this case the level of the master volume does not affect the results because the SRC precedes the DAC and always receives the incoming audio stream with no preceding attenuation. However, for comparison with the DAC tests, we shall set the master volume to 0dB to match the levels used in the DAC test.



As you can see in the scope shot below it displays the same kind of overload characteristics that the DAC does.

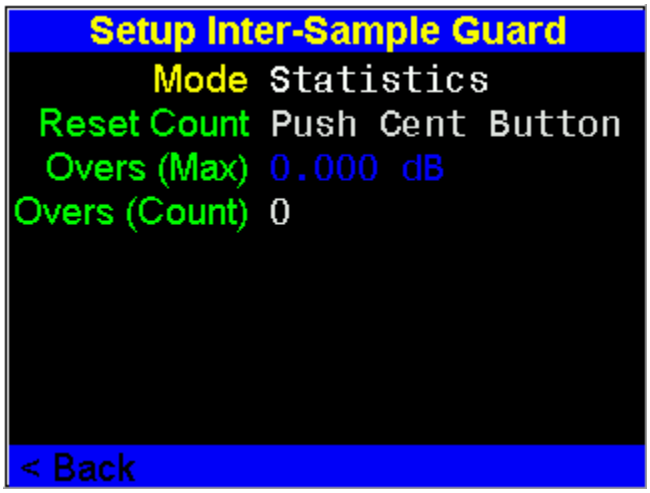


With the master volume set to -10dB we still get the same type of distortion which proves that the distortion is coming from the SRC and not the DAC !

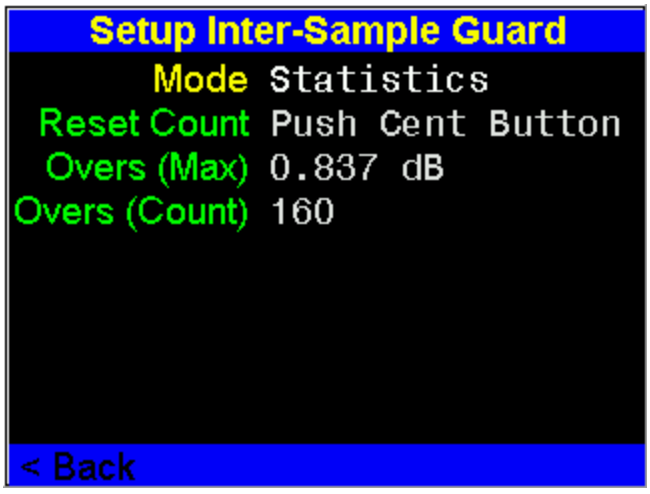


Intersample overs from real world source material

The example test tone used in the previous test is not really indicative of what you would experience playing music so just how much of an issue is it and what can you expect ? To analyse this we built a statistics mode into the SRC Intersample Guard. This mode just looks to see if there are any intersample overs and updates a count value as well as displaying the worst case over in dB. This can be accessed from the Main Menu ie [Main Menu] → [Setup] → [Audio Setup] → [Intersample Guard] -> [SRC] and setting the mode to 'Statistics'. Each time an over is detected the count is incremented and the SRC status LED on the front panel is flashed. If the over is the worst case then the maximum value will be updated.

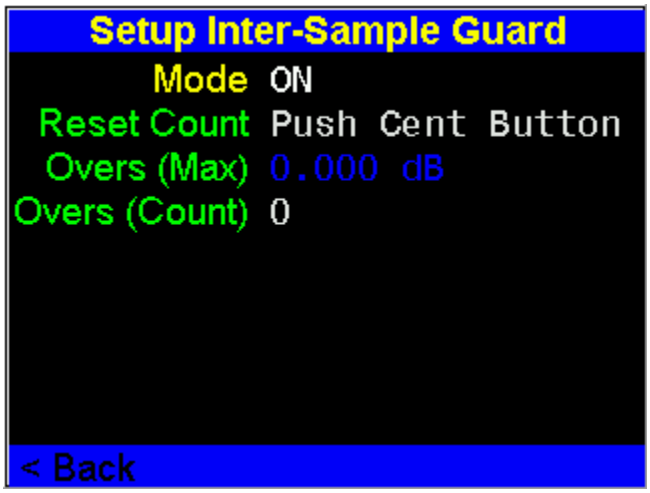


Playing the 'S'Wonderful' track from 'The Very Best of Diana Krall' produced 160 overs with a worst case over of 0.837 dB ! Other tracks on this album weren't so bad but as you can see it is an issue and could very well account for the coloration that some people complain about SRC's.

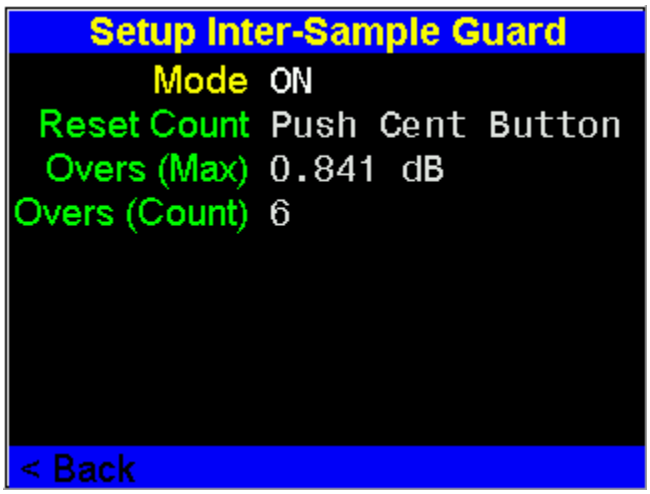


Avoiding Intersample Overs in the SRC using the SRC Guard

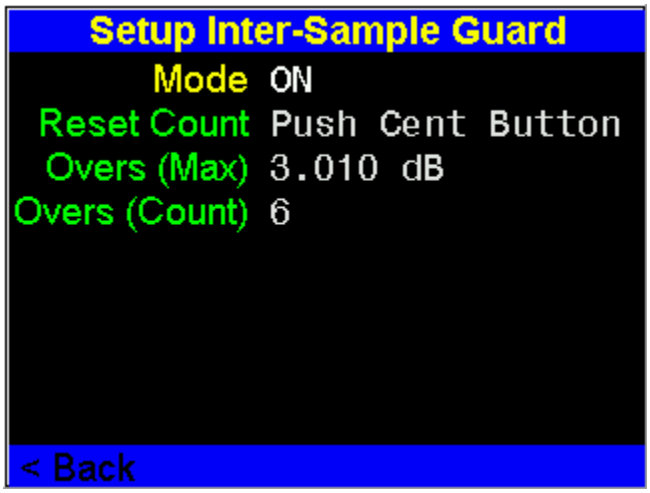
By switching the mode to 'ON' invokes an adaptive intersample over guard that continuously looks for the worst case over and automatically applies the reciprocal attenuation in order to eliminate over driving the SRC. The beauty of an adaptive guard compared to the fixed guard used for the DAC is that the least amount of attenuation is only used to avoid overdriving the proceeding up-sampling hardware.



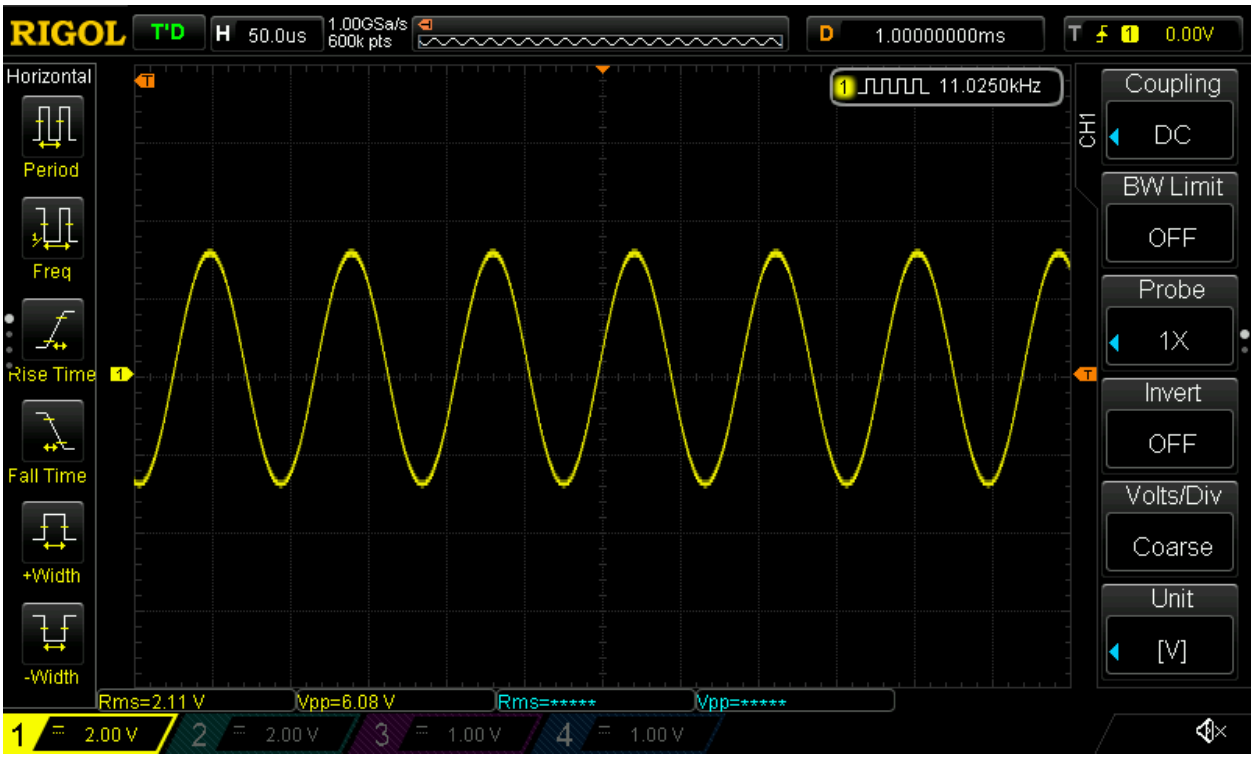
Now lets play the same track again with the guard switched on. As you can see from the screen shot below the guard has worked out the worst case over of 0.841 dB and limited the overs count to 6 compared to 160 ! What this means is that 0.841 dB of attenuation is applied to all of the proceeding samples being fed to the SRC. If however a proceeding over is detected which is larger than the current maximum then the attenuator will be adjusted again. This is done so quickly as to have the minimal impact on the sound and indeed once the maximum envelope has been determined then no further adjustments will be made and the guard will be completely transparent.



And of course lets see what happens when we apply our test tone !



The guard calculated the worst case over to be about 3dB and applied this attenuation to the incoming samples to the SRC. As you can see in the scope shot below the signal is no longer distorted and the guard has done its job with minimal intervention !



Conclusion

Intersample overs are a real phenomenon but have rarely been dealt with in real world hardware. They are a consequence of upsampling algorithm technology used in most DAC's and SRC's. It may very well account for the main difference between the sound of different DAC's and sample rate converters. The current Ultimate-Preamp firmware has been updated with Intersample Guards to avoid intersample overs and overdriving both the DAC and SRC in such a way that this should no longer be an issue !

References

1. INTERSAMPLE OVERS IN CD RECORDINGS by Benchmark Media
2. Are Intersample Overs an actual problem ?