AURALiC Flexible Filter Mode Explanation

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Digital filter is the essential part of oversampling D/A and A/D converters. Hi-End DACs in nowadays usually employ several digital filter options with various input response to satisfy different subjective listening requirements. However, most of the DACs are using one single filter algorithm for all sampling rates in one option, such way may be not ideal for the playback demand of today's high resolution music.

AURALiC hence has invented the Flexible Filter Mode technology, with which, we use a group of different filters optimized for different sampling rates in each mode. As a result, the DAC's performance at all sampling rates has been optimized. Since every filter has been fine-tuned base on AURALiC's mathematician models combining subjective auditory sense and objective measurement data, the result in listening experience, especially at high sampling rate, is dramatically improved.

This article takes AURALiC VEGA Digital Audio Processor's filter parameters as an example to explain the principle of Flexible Filter Mode technology.

The Flexible Filter Mode integrated in VEGA has six options: four of them are designed for PCM signal, the rest two are for DSD stream. Though more setting options are possible, and we do have designed more in the development stage, these six received highest scores during the subjective evaluation with clear sound characters difference from one to another so as to satisfy different requirements.

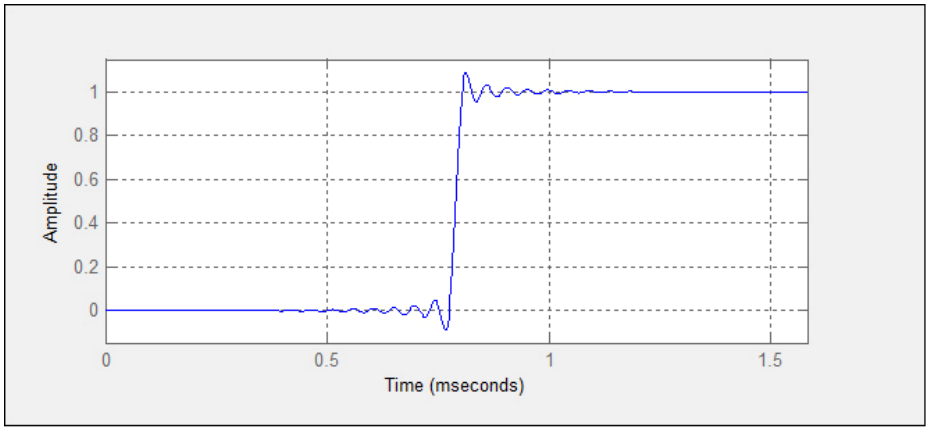
MODE 1

MODE 1 is the 'traditional' filter design which means it uses one single filter algorithm for all sampling rates. This mode offers best measurement performance: flat frequency response well extends to Nyquist frequency at all sampling rates, with very small pass-band ripple and large stop-band attenuation. However, the group delay of MODE 1 is the largest among all four PCM modes which exceeds 794us at 44.1K sampling rate. It means the pre-echo and ringing are not minimized, such behavior may not satisfy subjective listening requirements. Because of the flat frequency response, some modest recordings may sound painful when replay using this mode. But MODE 1 is quite fit for the requirements of studio monitoring. The parameters and impulse response of MODE 1 are shown in Table 1 and Figure 1:

Table 1: Parameters of VEGA Filter MODE 1

Fs	Pass-band(-3dB) (ripple)	Stop-band (attention)	Group Delay
44.1K-384K	0.49*fs (+/-0.003dB)	0.55*fs (110dB)	35/fs 794us@44.1K 397us@88.2K 198us@176.4K 99us@352.8K

Figure 1: Impulse response of VEGA Filter MODE 1



Fs: 44.1K

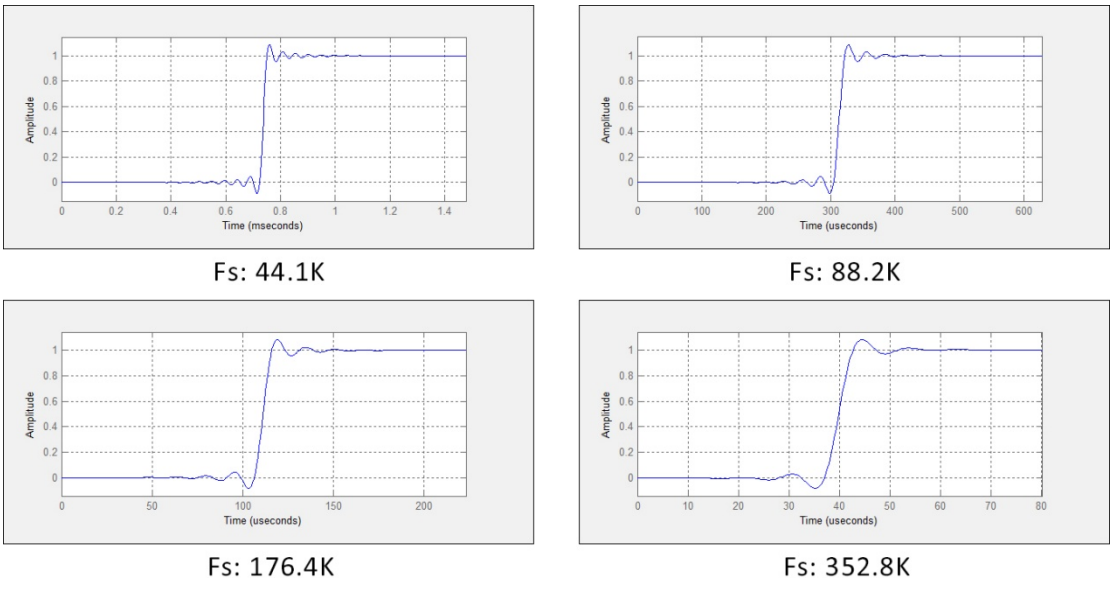
MODE 2

The objective of MODE 2 is to achieve perfect balance between measurement performance and subjective listening experience. MODE 2 maintains same pass-band and stop-band performance as MODE 1 but achieves less group delay. At lower sampling rates of 44.1K and 48K, it allows small attenuation at treble which result in a 0.25dB roll-off at 20K(Fs=44.1K); at higher sampling rates, the group delay is much reduced while the frequency response is still flat to ultrasonic. MODE 2 is reported to be best for replay orchestral and chamber music, piano solo and some music genres with large dynamic range. The parameters and impulse response of MODE 2 are shown in Table 2 and Figure 2:

Table 2: Parameters of VEGA Filter MODE 2

Fs	Pass-band(-3dB) (ripple)	Stop-band (attention)	Group Delay
44.1K-48KHz	0.47*fs (+/-0.001dB)	0.54*fs (110dB)	32/fs 725us@44.1K
88.2K-96K	0.38*fs (+/-0.00001dB)	0.48*fs (140dB)	28/fs 315us@88.2K
176.4K-192K	0.34*fs (+/-0.00001dB)	0.48*fs (140dB)	20/fs 110us@176.4K
352.8K-384K	0.28*fs (+/-0.00001dB)	0.48*fs (140dB)	14/fs 40us@352.8K

Figure 2: Impulse response of VEGA Filter MODE 2



Fs: 44.1K

Fs: 88.2K

Fs: 176.4K

Fs: 352.8K

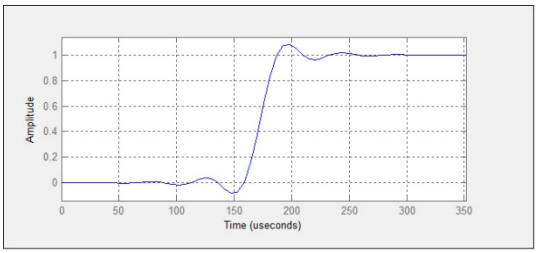
MODE 3

MODE 3 is designed to achieve minimum pre-echo and ringing effects. The slow roll-off filters inside this mode show a moderate pass-band and stop-band performance, however the group delay is reduced to minimum. MODE 3 should be used with caution at lower sampling rates such as 44.1K and 48K because of the aggressive roll-off at treble(-3.2dB at 20K with Fs=44.1K), some ambiance and details in certain music may disappear, it however will not affect sampling rates at 88.2K and higher. MODE 3 is reported to be best for vocal, pop music and some kind of jazz. The parameters and impulse response of MODE 3 are shown in Table 3 and Figure 3:

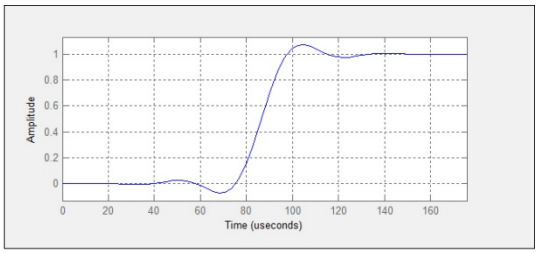
Table 3: Parameters of VEGA Filter MODE 3

Fs	Pass-band(-3dB) (ripple)	Stop-band (attention)	Group Delay
44.1K-48KHz	0.45*fs (+/-0.1dB)	0.66*fs (100dB)	7.7/fs 176us@44.1K
88.2K-96K	0.29*fs (+/-0.1dB)	0.51*fs (100dB)	7.7/fs 88us@88.2K
176.4K-192K	0.25*fs (+/-0.1dB)	0.46*fs (100dB)	7.7/fs 44us@176.4K
352.8K-384K	0.25*fs (+/-0.1dB)	0.46*fs (100dB)	7.7/fs 22us@352.8K

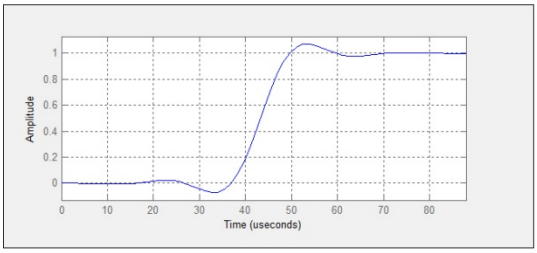
Figure 3: Impulse response of VEGA Filter MODE 3



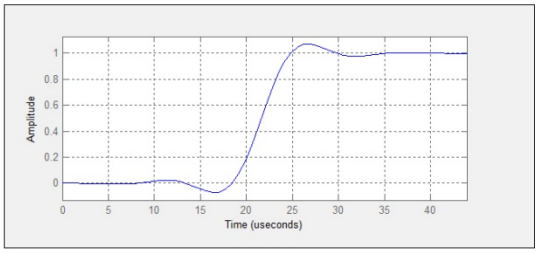
Fs: 44.1K



Fs: 88.2K



Fs: 176.4K



Fs: 352.8K

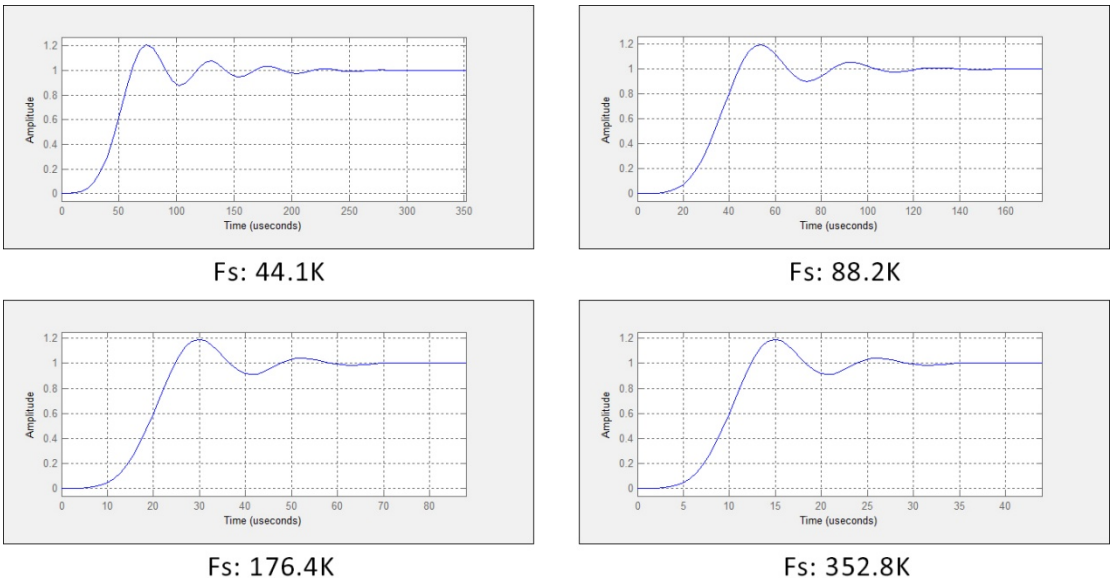
MODE 4

MODE 4 received the highest score during our subjective listening evaluation at development stage. All filters in this mode are minimum phase type which means there is no pre-echo effect at all. We have also designed the filters with very small group delay so as to eliminate the ringing. MODE 4 , as same as MODE 3, should be used with caution at lower sampling rates such as 44.1K and 48K because of the aggressive roll-off at treble(-3.0dB at 20K with Fs=44.1K), some ambiance and details in certain music may disappear, it however will not affect sampling rates at 88.2K and higher. MODE 4 is reported to be the 'all-best' option for music enjoyment. The parameters and impulse response of MODE 4 are shown in Table 4 and Figure 4:

Table 4: Parameters of VEGA Filter MODE 4

Fs	Pass-band(-3dB) (ripple)	Stop-band (attention)	Group Delay
44.1K-48KHz	0.44*fs (+/-0.1dB)	0.63*fs (100dB)	2.15/fs 49us@44.1K
88.2K-96K	0.29*fs (+/-0.1dB)	0.49*fs (100dB)	3.14/fs 36us@88.2K
176.4K-192K	0.25*fs (+/-0.1dB)	0.45*fs (100dB)	3.53/fs 20us@176.4K
352.8K-384K	0.25*fs (+/-0.1dB)	0.45*fs (100dB)	3.53/fs 10us@352.8K

Figure 4: Impulse response of VEGA Filter MODE 4



Fs: 44.1K

Fs: 88.2K

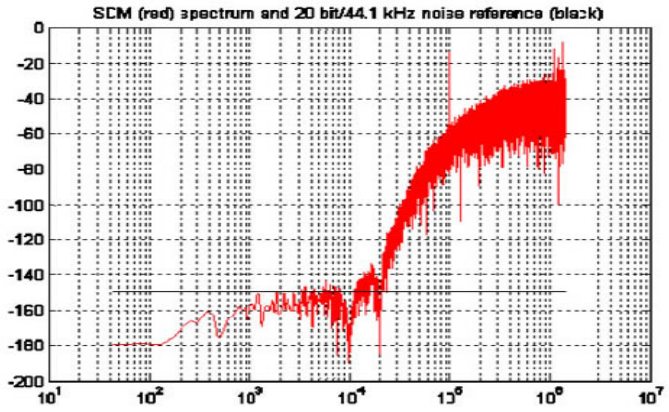
Fs: 176.4K

Fs: 352.8K

MODE 5 & MODE 6

The Direct Stream Digital (DSD) allows very large dynamic range within human hearing range but result in high level ultrasonic noise as byproduct. Shown in Figure 5, the ultrasonic noise raises quickly from only -140dBFS at 20K to almost full scale at the sampling frequency. It is necessary to remove such noise so as to avoid any potential damage to the power amplifier and loudspeakers.

Figure 5: 2.8224MHz DSD quantization noise (Source: HDTracks)



In VEGA's filter design, we use IIR low pass filter at digital domain to control the stop-band noise. The -3dB cut-off frequency of MODE 5 and MODE 6 are 70K and 50K with a general slope at 18dB/oct. The frequency response of MODE 5 and MODE 6 are shown in Figure 6.

Figure 6: Frequency Response of VEGA Filter MODE 5 and MODE 6