AN001 - C60 Application Note

Time delays

A digital audio device was driven by the C60. The signal was converted by an ADC into a 24 bit digital data stream and then reconverted back into an analogue signal with a DAC. This loop back test reveals some of the perils of high quality digital audio systems. Both conversion processes send the data through long transversal digital filters (Figure 1) that shape the signal and noise spectrums and also recover the analogue signal. This filtering takes time to process the signals, in this case 3.1 milliseconds. The input signal was resistively mixed with the non-inverted delayed signal as shown in Figure 2. If the two signals have the same amplitude, then a cosine comb response is produced. At 161Hz on the graph, the first notch appears. A frequency of 161Hz has a period of 6.2mS. However, a delay of half of 6.2mS will produce a delayed sine wave output that is in anti phase with the input signal. When these two signals are added together they cancel each other out, producing a notch in the frequency response. So, the delay time of the unit is 6.2/2 = 3.1mSec.

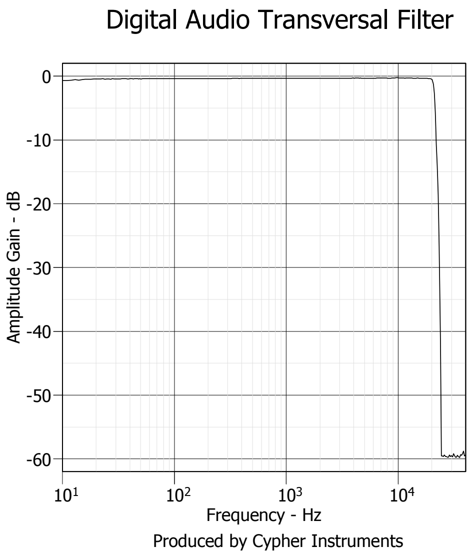

Figure 1. Frequency response

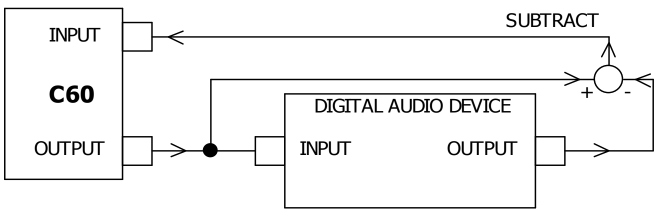

Figure 2. Measurement of time delay

The notches repeat every 322Hz. There are 62 of them going all the way up 20KHz (Figure 3). This is a nightmare for the audio industry. Imagine sending a signal off to a digital effects unit, and then mixing it back in with the source signal. Often, the resultant mix will have a 'drain pipe' quality to it, caused by the inadvertent comb filtering.

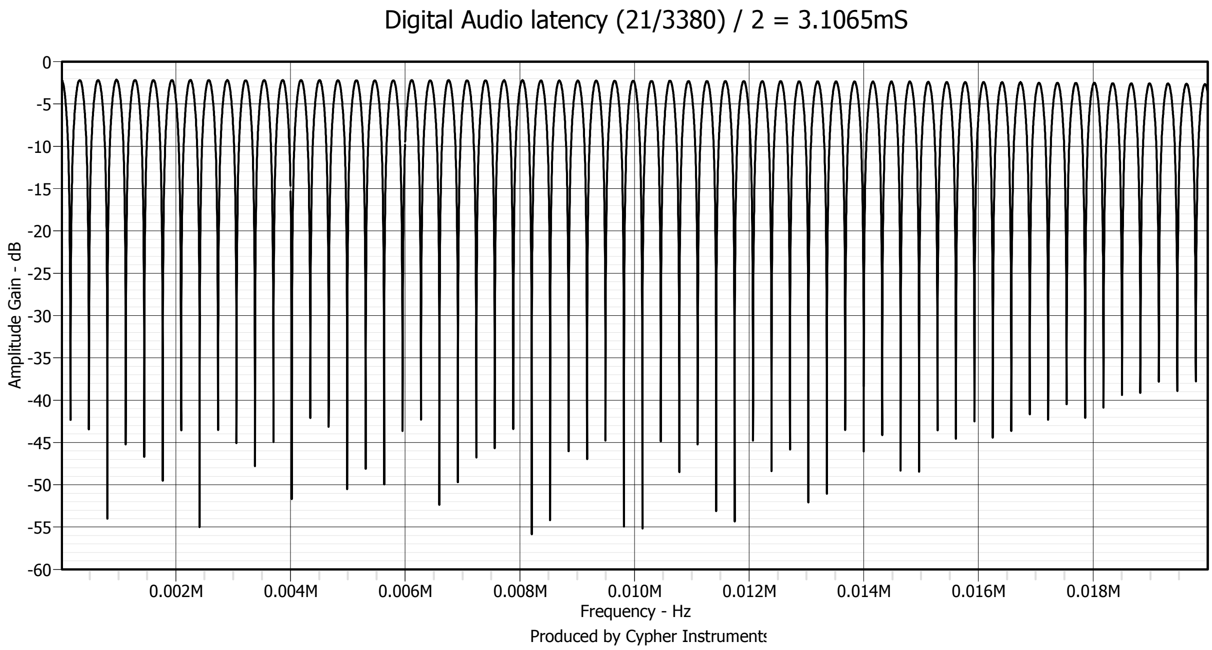

Figure 3. Comb filter response

The phase response is the classic saw tooth shape. To obtain this shape, the frequency axis has to be linear. At 0Hz, the input and output are in phase with each other, and so the phase shift is zero. As the frequency increases, the phase swings linearly towards -90^{o}, and then flips around by 180^{o} (at the zero) and continues to ramp downwards. The phase detector and the sign detector are operating in near ideal conditions. The signals are low frequency (20KHz max) and large (2Vpp). Compare this with a 2MHz sine wave at -60dB. The frequency is 100 times faster and the signal is 1/1000th of the level.

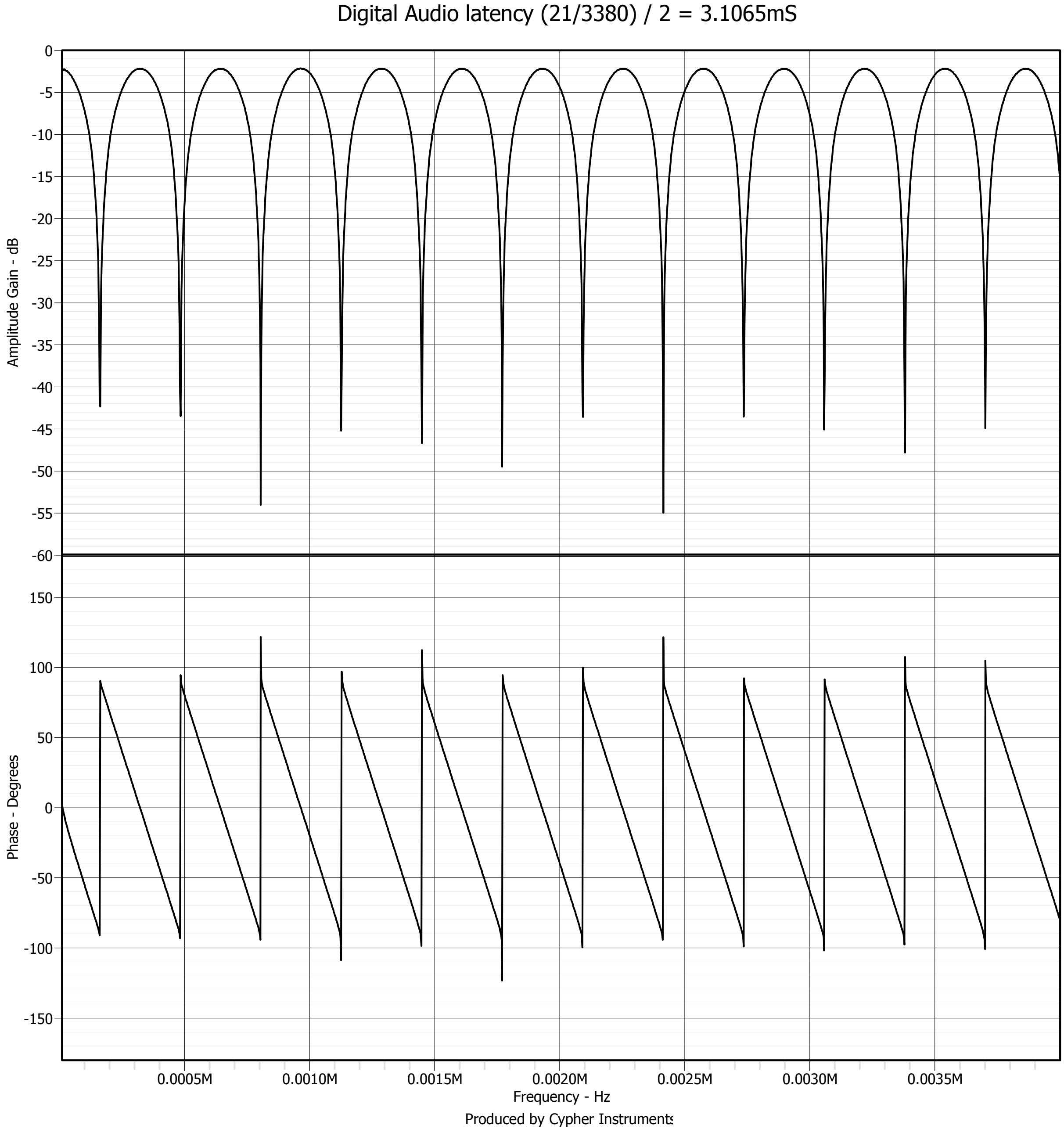

Figure 4. Measuring digital audio latency