XRDAN28

Frequency Response Effects of Oversampling and Averaging on A/D Output Data

Introduction

EXAR's family of high resolution and high speed analog to digital converters are often used in digital video, digital graphics and other mixed signal sampled data systems where Digital Signal Processing is used to relax analog antialiasing filter requirements. Reducing the effects of aliasing (which is the translation of unwanted out of band noise and signals into the signal band) can require high order lowpass filtering prior to A/D conversion.

The analog filter complexity can be significantly reduced if the data is oversampled, that is, sampled at a higher rate. This raises the Nyquist rate (half sampling frequency) thereby reducing the attenuation required of the analog filter. Typically, doubling the sampling rate cuts the filter order (therefore size) in half. The higher digital output data rate can be reduced by averaging several samples then outputting these computed values at the original lower data rate. This process, called "decimation", provides additional filtering but is also a sampling operation at the decimation frequency. The exact frequency characteristics of the averaging operation (digital filter) is important since it impacts the overall effects of aliasing and modifies the in band response of the system. The transfer function of two commonly occurring cases is presented below.

Example I (*See Figure 1.)*

The input signal for this example is initially sampled at 30 MHz. After conversion, two data words are averaged and the calculated data is output at a rate of 15 MHz. The input pass band is 5 MHz.

An equivalent block diagram of this system is shown in *Figure 1.* The transfer function is also given. Note that in the equivalent circuit, the input signal is delayed by 1/(30 MHz), added to itself, divided by two, then sampled at 15 MHz. The operation and transfer function are typical of finite impulse response discrete filters.

Example II (*see Figure 2.*)

The input signal for this example is initially sampled at 30 MHz. After conversion, four data words are averaged and the calculated data is output at a rate of 7.5 MHz. The input pass band is 2.5 MHz.

A equivalent block diagram of this system is shown in *Figure 2.* The transfer function is also given. Note that in this equivalent circuit, the input signal is delayed down three paths by integer multiples of 1/(30 MHz), these delayed signals are added to the undelayed input, divided by four, then sampled at 7.5 MHz. The operation and transfer function are typical of a higher order (than above) finite impulse response discrete filter.

Results

Frequency response plots for both examples are given in *Graph 1.* Both amplitude responses have zero output at their respective output frequency, which is often called the decimation frequency. Both are periodic about the input sampling frequency. The pass band attenuation for both examples is not insignificant and might require compensation at some point in the signal channel. This can be done as part of other analog or digital signal conditioning functions.

Conclusion

The frequency responses for these discrete filter examples can be considered to be cascaded with the input antialiasing filter. It adds to the low pass attenuation and helps reduce the order of the analog filter. It does not totally eliminate input filtering since it provides little attenuation at half the output sampling frequency. The benefits are realized at the expense of higher conversion speed requirements in the A/D and a small amount of digital signal conditioning.

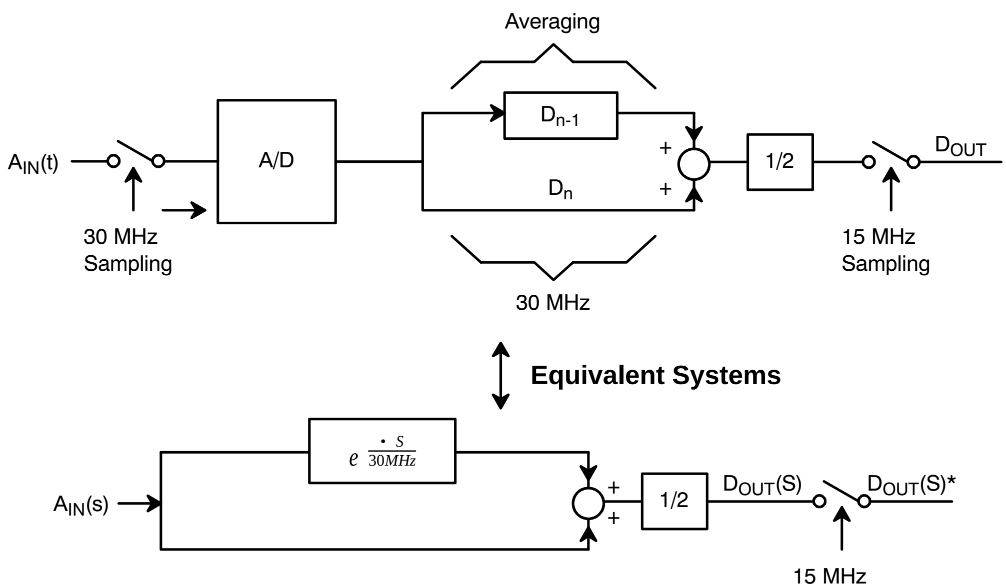
The transfer function can be generalized for other sampling and decimation frequencies as follows:

$$D_{OUT}(s)/D_{IN}(s)=(1\bullet exp(\bullet N*s/F_S))/(N(1\bullet exp(\bullet s/F_S)))$$

where, F_S= sampling frequency (input sampler)

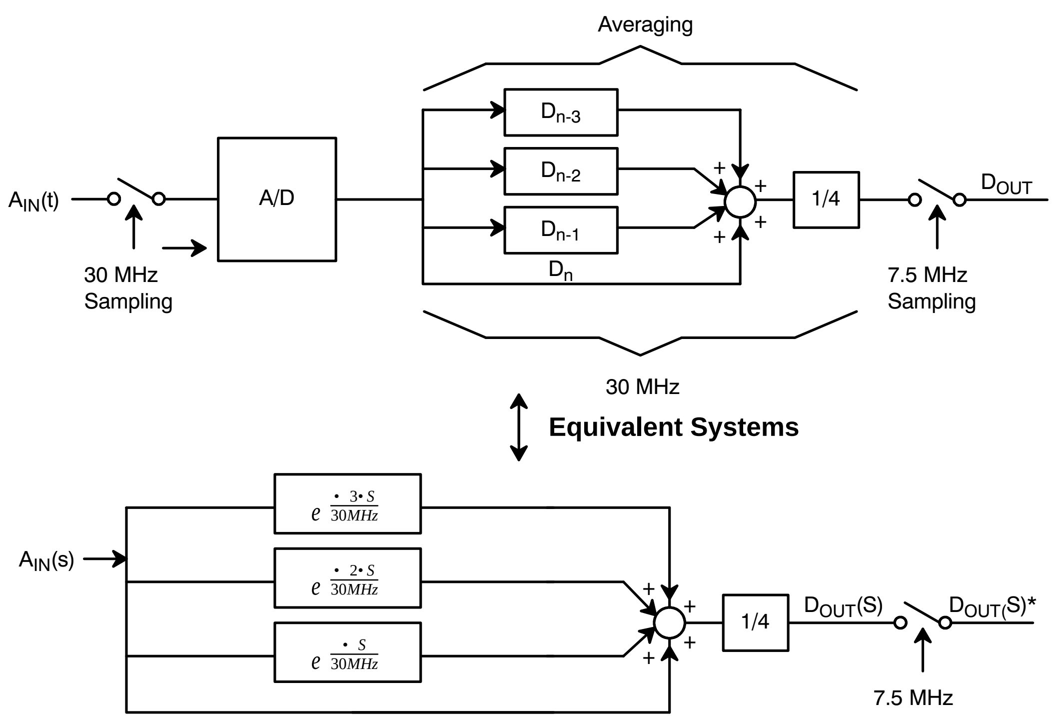
F_d= decimation frequency (output rate)
and, $N= F_S/F_d$

This equation can be used to plot amplitude and phase response for any combination of input and output frequencies. This decimation circuit is common in Delta-Sigma converters.



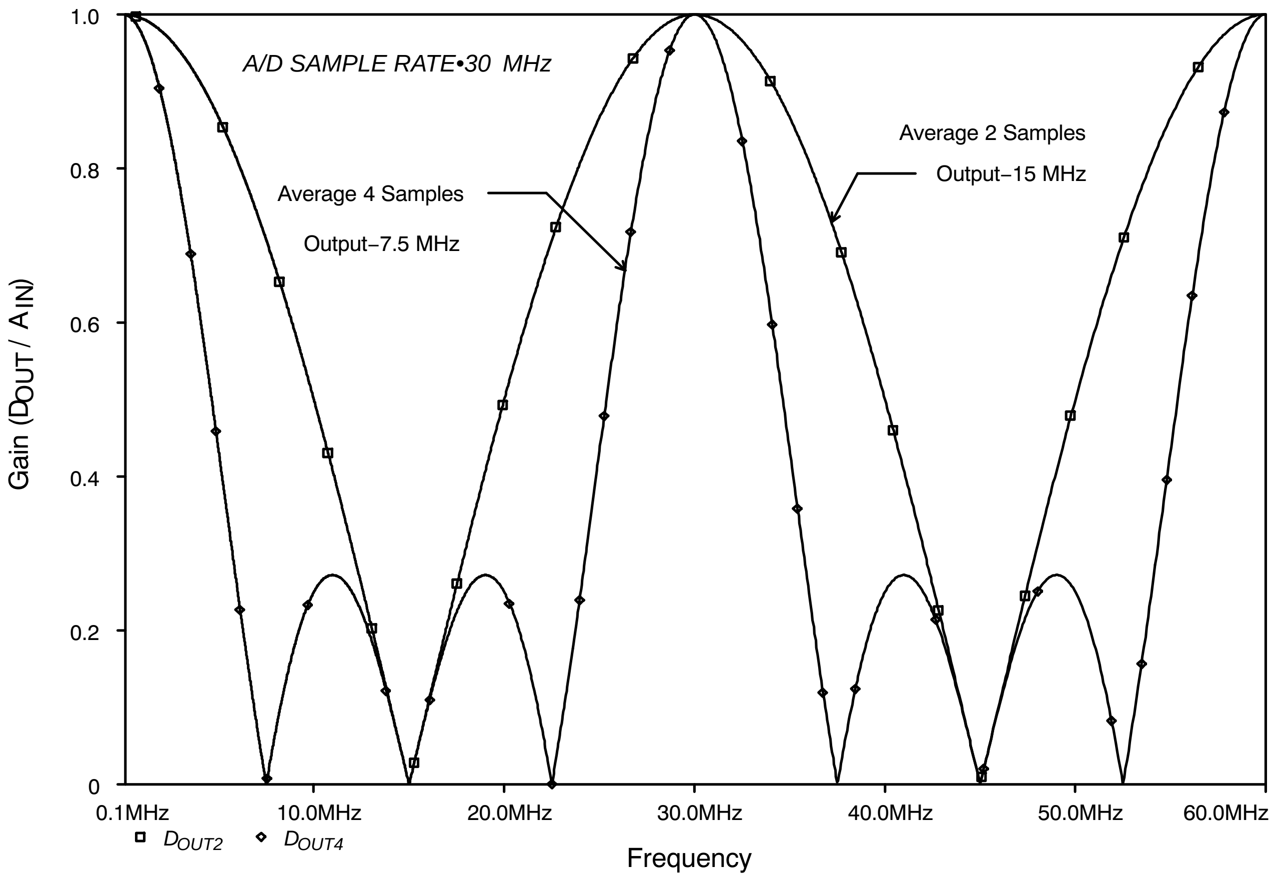
$$\frac{D_{OUT}(S)}{A_{IN}(S)} = \frac{1}{2} \bullet \left(1 + e^{\bullet \frac{S}{30\,MHz}}\right)$$

Figure 1. Two Samples Averaged



$$\frac{D_{OUT}(S)}{A_{IN}(S)} = \frac{1}{4} \bullet \left(1 + e^{\bullet \frac{S}{30\,MHz}} + e^{\bullet \frac{2 \bullet S}{30\,MHz}} + e^{\bullet \frac{3 \bullet S}{30\,MHz}}\right)$$

Figure 2. Four Samples Averaged



Graph 1. Decimation Filter Frequency Response

Notes