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Oversampling Sigma-Delta Digital to Analog Converter

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Abstract— Oversampling sigma-delta digital-to-analog converters are crucial building blocks for telecommunication applications. To reduce the power consumption, lower oversampling ratios are preferred thus high-order digital sigma-delta modulators are needed to meet the dynamic performance requirements. Only recently have oversampling methods used for high resolution A/D and D/A conversion become popular. The digital to analog converter (digital to analog converter) arrangement can be thought of as open loop with a counter, Sigma, which is preloaded with the number to be converted. The counter is counted down to zero by a series of impulses, delta. As above these impulses are of fixed amplitude and duration. At the start an integrator is set to zero and then integrates the impulses to form the analog voltage equivalent of the starting number.

Keywords— Interpolation Filter, sigma-delta modulator

I. INTRODUCTION

Most of the signals in the real world are continuous in time such as speech, music and images. Increasingly discreet time signal processing algorithms are being used to process such signals and are implemented employing discrete- time analog –to digital and digital to analog interface circuits to convert the continuous time signals into digital form and vice versa. so it is necessary to develop the relations between the continuous time signals and its digital equivalent in the time domain and also in frequency domain.

The interface circuit performing the conversion of a continuous time signal into a digital form is called the analog to digital converter. Likewise, the back operation of converting a digital signal into a continuous time signal is implemented by the interface circuit called digital to analog (D/A) converter. In addition to these two devices several additional circuits are required. If the D/A converter staircase like waveform it is necessary to smoothen the D/A converter output by means of an analog reconstruction (smoothening) filter.

In signal processing, oversampling is the process of sampling a signal with a sampling frequency significantly higher than twice the bandwidth or highest frequency of the signal being sampled. Because of their outstanding linearity, oversampling converters have become a popular technique for data conversion . However, due to the nature of oversampling, these converters are much slower compared to their Nyquist-rate counterparts. Hence, the applications of sigma–delta modulators are usually restricted to low-speed high-linearity applications such as digital audio. Emerging needs have forced designers to seek highly linear converters with broader input bandwidths.

An oversampled signal is said to be oversampled by a factor of β, defined as

$$\beta = fs / 2B$$

Where

- f_s is the sampling frequency.
- B is the bandwidth or highest frequency of the signal.

II. ARCHITECTURE

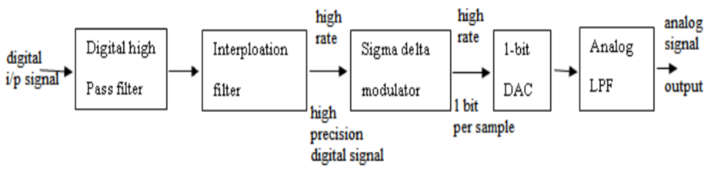

Fig.1 sigma-delta digital to analog converter

The quantizer extracts the MSB from its input and subtracts the remaining LSBs, the quantization noise from its input. The MSB output is then spread into a 1 bit D/A converter and passed through a analog LP reconstruction filter to remove all frequency components beyond the signal band of interest since the signal band occupies the very small position of the baseband of the high sample rate signal, the reconstructed filter in this case can have very wide transition band, permitting its realization with a low order filter that, for example can be implemented by using a Bessel filter to provide an approximately linear phase in signal band.

The spectrum of the quantized 1 bit output of the digital sigma delta quantizer is nearly the same as that of its input.

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More over it also shapes the quantization noise spectrum by moving the noise power out of the signal band of interest.

In this program MATLAB is used to verify the operation of the sigma delta D/A converter for a sinusoidal sequence of frequency 100hertz operating at a sampling rate F_T of 5 KHz. The signal is clearly oversampled since the sampling rate is much higher than the Nyquist rate of 200Hz. Program given below first generates the input digital signal, then generates a two valued digital signal by quantizing the output of the sigma delta quantizer, and finally develops the output of D/A converter by low pass filtering the quantized output. As in the case of the sigma delta converter of the above example, the filtering operation has also been perform in DFT domain due to short length of input sequence.

A. DELTA-SIGMA MODULATION

Delta-sigma (ΔΣ; or sigma-delta, ΣΔ) modulation is a method for encoding high resolution signals into lower resolution signals using pulse-density modulation. This technique has found increasing use in modern electronic components such as analog-to-digital and digital-to-analog converters, frequency synthesizers, switched-mode power supplies and motor controls. One of the earliest and most widespread uses of delta-sigma modulation is in data conversion. An analog to digital converter or digital to analog converter circuit which implements this technique can relatively easily achieve very high resolutions while using low-cost CMOS processes, such as the processes used for designing digital integrated circuits .

Almost all analog integrated circuit vendors offer delta-sigma converters. Given a particular fabrication process, a sigma-delta analog to digital converter can give more bits of resolution than any other analog to digital converter structure, with the only exception of the integrating analog to digital converter structure. Both kinds of analog to digital converters use an analog integrating amplifier to cancel out many kinds of noise and errors.

Sigma-delta digital to analog converters operate very similarly to sigma-delta analog to digital converters, however in a sigma-delta digital to analog converter, the noise shaping function is accomplished with a digital modulator rather than an analog one. A Σ-Δ digital to analog converter, unlike the Σ-Δ analog to digital converter, is mostly digital . It consists of an "interpolation filter" (a digital circuit which accepts data at a low rate, inserts 0's at a high rate, and then applies a digital filter algorithm and outputs data at a high rate), a Σ-Δ modulator (which effectively acts as a low pass filter to the signal but as a high pass filter to the quantization noise, and converts the resulting data into a high speed bit stream), and a 1-bit digital to analog converter whose output switches between equal positive and negative reference voltages. The output is then filtered in an external analog low pass filter. Because of the high oversampling frequency, the complexity of the low pass filter is much less than the case of traditional Nyquist operation.

B. OVERSAMPLING D/A CONVERTER

As indicated earlier the digital to analog conversion process consists of two steps: the conversion of input digital sample into staircase continuous time waveform by means of D/A converter with zero order hold at its output followed by an analog low pass reconstruction low pass filter. If the sampling rate F_T of the input digital signal is the same as Nyquist rate, the analog low pass reconstruction filter must have a very sharp cutoff in its frequency response satisfying the requirements of equation given below.

Hr (jΩ) =’T ‘at $|\Omega| \leq \Omega_T/2$ and ‘0’ at $|\Omega| > \Omega_T/2$

In the case of anti aliasing filter, this involves the design of a very high order analog reconstruction filter requiring high precision analog circuit components to solve the above problem an over sampling approach is often used in which case a wide transition band can be tolerated in the frequency response of the reconstruction filter allowing its implementation using low precision analog circuit components while requiring a more complex digital interpolation filter at the front end.Further improvement in the performance of oversampling D/A is obtained by employing digital sigma 1-bit quantiser at the output of digital interpolator as shown in figure below.

Because of their outstanding linearity, oversampling converters have become a popular technique for data conversion [2]. However, due to the nature of oversampling, these converters are much slower than their Nyquist-rate counterparts. Hence, the applications of sigma–delta modulators are usually restricted to low-speed high-linearity applications such as digital audio. Emerging needs have forced designers to seek highly linear converters with broader input bandwidths. Does the SNR improvement come simply from oversampling and filtering? Note that the SNR for a 1-bit analog to digital converter is 7.78dB (6.02 + 1.76).

Each factor-of-4 oversampling increases the SNR by 6dB, and each 6dB increase is same as gaining one bit. A 1-bit analog to digital converter with 24x oversampling achieves a resolution of four bits, and to achieve 16-bit resolution you must oversample be a factor of 415, which is not realizable. But, sigma-delta converters overcome this limitation with the technique of noise shaping, which enables the gain to be more than 6dB for each factor of 4x oversampling.

C. Noise Shaping

To understand noise shaping, consider the sigma-delta modulator of the first order .It includes a difference amplifier, an integrator, and a comparator with feedback loop

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that contains a 1-bit digital to analog converter. (This digital to analog converter is simply a switch that connects the negative input of the difference amplifier to a positive or a negative reference voltage.) The purpose of the feedback digital to analog converter is to maintain the average output of the integrator near the comparator's reference level.

The density of "ones" at the modulator output is proportional to the input signal. For an increase in input the comparator generates a greater number of "ones," and vice versa for a decreasing input. By summing the error voltage, the integrator acts as a lowpass filter to the input signal and a highpass filter to the quantization noise. Thus, most of the quantization noise is pushed into higher frequencies . Oversampling has changed not the total noise power, but its distribution.

III. RESULTS

The input digital signal applied to the digital to analog converter is shown below with the values

Seq. length=50, Amplitude =1

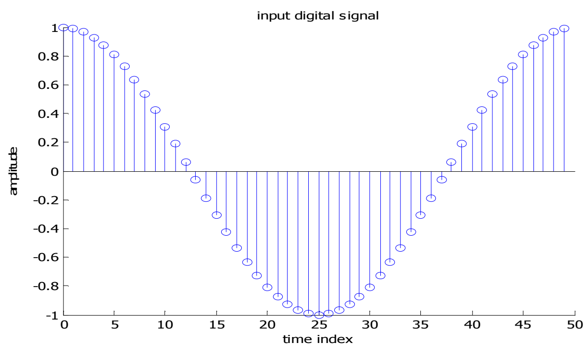

Fig.2 input digital signal

The quantized output for the given input is shown below

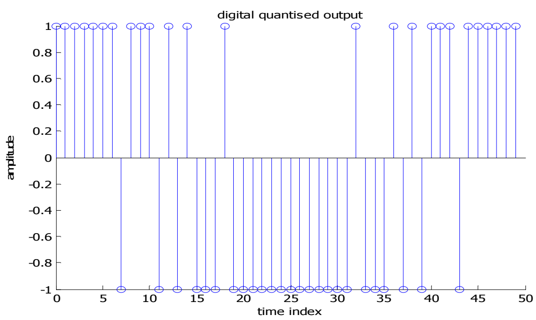

Fig.3 digital quantized output

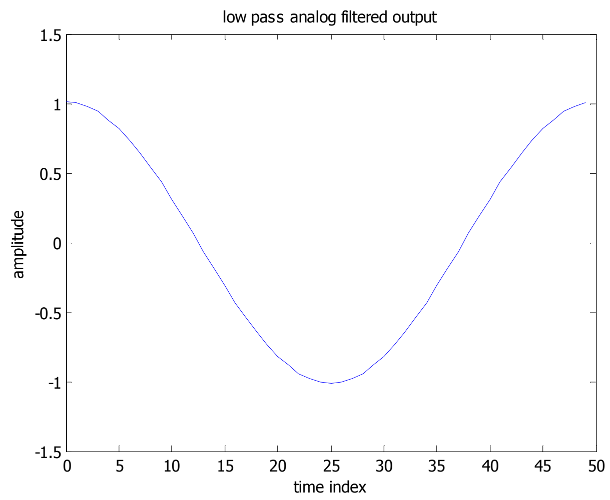

Fig.4 low pass analog filtered output

From the above graph we can see that the low pass filtering is nearly a scaled replica of the desired sinusoidal analog signal.

IV. APPLICATION

One of the most common application of oversampling sigma delta converter is in compact disc (CD) player the below figure depicts a block diagram of basic components in the signal processing part of CD player. The typically a factor of 4-over sampling D/A converter is employed for each audio channel and then converted into analog audio signal.

Motion control systems often require digital-to-analog converters with high resolution but not high accuracy. Because high-accuracy digital to analog converters are expensive and consume valuable board space, a good solution is to extend your digital to analog converter's resolution in software. This paper presents such a technique**.**

Developers of closed-loop control systems often need a digital-to-analog converter (digital to analog converter) whose resolution far exceeds its accuracy. Indeed, when you've got good analog feedback sometimes you'll find that an 8-bit digital to analog converter has more than enough accuracy but not the 16 bits of resolution you need to attain your system performance goals.

The usual closed-loop control system uses a relatively inaccurate device yet achieves high accuracy through good feedback. While high digital to analog converter resolution is often necessary to keep the output steady, digital to analog converter inaccuracies are often insignificant compared to the device's own peculiarities. Cost or size constraints might prevent you from adding a fancy high-precision, high-resolution DAC to your system. you can steal a page from the audio industry and use a software sigma-delta modulator to extend the resolution of a cheap digital to analog

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converter or PWM output. When this technique works well it can give you enormous gains in effective digital to analog converter resolution for a cost-effective improvement in system performance.

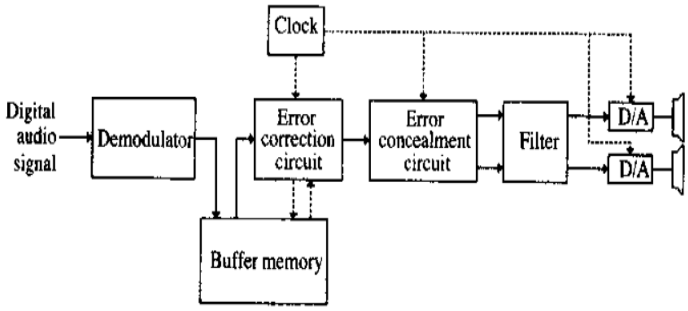

Fig.5 Block diagram of signal processing part of CD player

V. CONCLUSION

Oversampling sigma-delta digital-to-analog converters are crucial building blocks for telecommunication applications. To reduce power consumption, lower oversampling ratios are preferred thus high-order digital sigma-delta modulators are needed to meet the dynamic performance requirements. In this program the operation of the sigma delta D/A converter is verified by using MATLAB for a sinusoidal sequence of frequency 100hertz operating at a sampling rate F_T of 5 KHz. The signal is clearly oversampled since the sampling rate is much higher than the Nyquist rate of 200Hz. As can be seen from these plots, the low pass filtering is nearly a scaled replica of the desired sinusoidal analog signal.

REFERENCES

[1]. Samba Sesay, Zonngai and Jianhua He "A Survey on Mobile Ad-Hoc wireless Network", Information Technology Journal 3(2), 2004, Dept of telecommunication and Information Technology, Huazhong University of Science and Technology Wuhan, People's Republic of China.
[2]. Ram Ramanathan and Jason Redi "A Brief Overview Of Ad-Hoc Networks: Challenges and Directions", IEEE Communications Magazine 2002, BBN Technologies.
[3]. Dr Carlo Kopp "Ad-Hoc Networking", NCW 101 Networked Operations Journal, pp. 60-64.
[4]. Mohamed Aboudina, Behzad Razavi "A New DAC Mismatch Shaping Technique for Sigma–Delta Modulators ", IEEE Transactions On Circuit And Systems—II, Vol. 57, No. 12,December 2010.
[5]. Timir Nandi, Karthikeya Boominathan, And Shanthi Pavan, "Continuous- Time Modulators With Improved Linearity And Reduced Clock Jitter Sensitivity Using The Switched-Capacitor Return-To-Zero DAC" Ieee Journal Of Solid-State Circuits, Vol. 48, No. 8, August 2013.
[6]. Khiem Nguyen, Robert Adams and Karl Sweetland "A 11 3db SNR OVERSAMPLING SIGMA-DELTA DAC FOR CD/DVD APPLICATION" IEEE Transactions on Consumer Electronics, Vol. 44, No. 3, AUGUST 1998.