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Ensemble Averaging Filter for Noise Reduction

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Abstract: Noise is the extraneous information that changes the original signal information. It is not possible to completely suppress the noise, but we can reduce it. Signal to noise ratio is very important in studies based on signal. It is a measure of the signal level in the measured waveform. The noise affecting the signal is random in nature. The average value of the random noise affected on a signal at different time instants is zero. Ensemble averaging is one of the best noise filtering methods and is based on the concept of noise random nature. In ensemble average successive sets of collected data are summed point by point. Therefore, a prerequisite for the application of ensemble averaging method is the ability to reproduce the signal many times starting always from the same data point. Signal to noise ratio can be improved in proportion to the square root of the number of repetition of the signal. As the number of repetition increases, the signal to noise ratio also increases. Ensemble averaging filtering can be applied to a number of applications like spectroscopy and non-destructive testing.

Keywords: Ensemble Averaging, FPGA, noise reduction, average filter, noise filter.

I. INTRODUCTION

Noise is the extraneous information that changes the original signal information. It is not possible to completely suppress the noise, but we can reduce it. Signal to noise ratio is very important in studies based on signal. SNR is the ratio of signal level to noise level. It is a measure of the signal level in the measured waveform. More SNR means the signal is more usable. But in most cases the signal level in the measured waveform is not sufficient to give a good measurement. We need some ways to boost the signal level. One of the commonly used methods to get high strength signal is to use amplifiers.

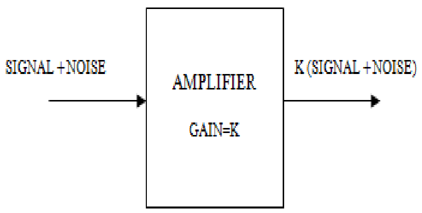

Fig1. Effect of noise on signal Amplification

But the amplifiers do not perform well in many critical applications. The amplifiers have limitations when the gain required is very high. The output measurement from a system is always mixed with noise. Amplifying the measured signal amplifies the noise also. The SNR ratio at the output of the amplifier is worse compared with the input side. We can employ different filtering methods to reduce the noise. But the commonly used filtering method is not suitable for small strength signals as the filter itself remove the significant signal content along with the noise. So we need some other ways to reduce the noise. For a stationary system, the response is expected to be same at different time instants. But in reality, the response from a system is different at different time instants because of the noise. The sources of noise are many including power supply variations, temperature, electromagnetic interference etc. We can reduce the noise by cutting the noise at the source itself. But it is not possible to completely eliminate the noise sources. The noise affecting the measured signal is random in nature. The average value of the random noise affected on the signal at different instants of time is zero. Sampling the signal and taking the average of samples at different time instants will result in the cancellation of noise component. We can employ several methods to get high quality signal.

Ensemble averaging is one of the noise filtering methods which is based on the concept of random noise cancellation. Ensemble is the collection of signals over the same time domain or frequency domain. Real time ensemble filtering of noise from the signal requires device which can handle huge amount of data samples. The massive parallel processing capability of FPGA makes it suitable for the ensemble averaging filter. The memory available in an FPGA is limited and not sufficient to store large number of sample values. For storing the sample values, we need to use external memories like SDRAM. The sampling rate of input signal is very high. Storing and retrieving data in SDRAM memory at very high speed has many limitations. The proposed filter can be implemented either as an IIR filter or as an FIR filter. The infinite impulse response filter has the advantage of very high signal to noise ratio compared to FIR filter. But the response of IIR filter to real world input signals is very slow and is not desirable. FIR filter can be used to obtain very fast response.

II. ENSEMBLE AVERAGING CONCEPTS

In ensemble averaging, we create multiple models and combine them to produce a desired output. An ensemble of models is good when compared with individual model,

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because the errors of the models "average out". In ensemble average successive sets of collected data are summed point by point. Therefore, a prerequisite for the application of ensemble averaging method is the ability to reproduce the signal many times starting always from the same data point.

Consider we are summing n measurements to obtain the ensemble average. The signal Si adds for each repetition. The total signal S_n is given by

$$S_n = \sum_{i=1}^{n} S_i = nS_i$$

For the noise, the variance is additive. The total Variance is

$$\sigma_n^2 = \sum_{i=1}^{n} \sigma_i^2 = n\sigma_i^2$$

The standard deviation or the total RMS noise, is

$$\sigma_n = \sqrt{n}\sigma_i = \sqrt{n}N_i$$

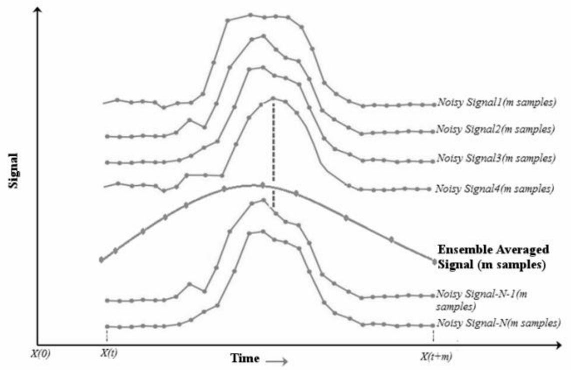

Fig. 2 Ensemble Averaging of N signals

The Signal to noise ratio after n repetitions is given by,

$$\left(\frac{S}{N}\right)_n = \frac{nS_i}{\sqrt{n}N_i} = \sqrt{n}\left(\frac{S}{N}\right)_i$$

Signal to noise ratio at the output of the filter can be increased by increasing the number of repetitions.

III. APPLICATIONS

Ensemble averaging can be used in Nuclear magnetic resonance (NMR) spectroscopy and Fourier transform infrared (FTIR) spectroscopy, where the final spectrum is the result of averaging hundreds of individual spectra. NMR spectroscopy technique uses the magnetic properties of atomic nuclei. The NMR spectroscopy is used to investigate the properties of organic molecules. It determines the physical and chemical properties of atoms in which they are contained. FTIR technique is used to get an infrared absorption or emission spectrum of a solid, liquid or gas. An FTIR spectrometer collects a wide spectral range data of high spectral resolution. Non-destructive testing is another area which finds the application of ensemble averaging filter. It is a technique to find the quality of a material without doing destruction to the structure under test.

IV. RELATED WORK

P.J.M. Kerstens and D. Rockwell in “Ensemble-averaging and correlation techniques for flow visualization images”, proposed a visual-ensemble-averaging technique. In that paper the timeline positions are tracked and averaged in successive images. The phase reference for the averaging process can take the form of an analog pressure, velocity, or displacement signal, or a recurring coherent portion of the image. Global correlations of the timeline patterns are obtained using the same timelines defined for the ensemble-averaging process. A new type of visual correlation function, giving the correlation between two timelines in a given image or successive images, is proposed.

In 2004 Taikang Ning in “An ensemble average approach to remove adverse effects on power spectral estimation due to sampling jitters”, in 'ISCAS (3)', IEEE, pp. 585-588, examines the effects of random jitters in sampling locations upon power spectrum estimation. Random jitters in sampling locations introduce phase shifts in corresponding Fourier coefficients and lead to, among other distortions, attenuation in power spectral estimation. If the probability density function of random jitters is known, then the attenuation can be correctly delineated as a modulation curve which is more severe in higher frequencies. To alleviate attenuation, an ensemble average approach is suggested. It can accurately restore the power spectrum suffered from attenuation due to random jitters. In addition, it can also reliably compute useful statistical parameters of a given random jitter distribution when the statistics is only partially known. Simulation tests were conducted to illustrate the effects of sampling jitters and to demonstrate the effectiveness of this new ensemble average algorithm.

V. IMPLEMENTATION DETAILS

A. Proposed System

The Proposed systems block diagram is shown in figure 4. The design of ensemble average filter started with the selection of proper devices. Spartan 6 FPGA was selected for filtering purpose. The block diagram shows the main components used for the work. Analog to digital converter (ADC) converts the input signal to digital form and given as the input to the FPGA.

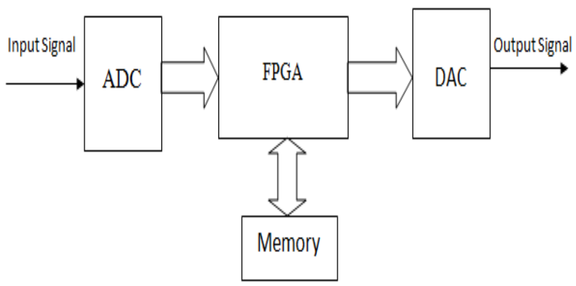

Fig. 4 Proposed System

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B. MATLAB Implementation

The feasibility of the ensemble average filter was checked using MATLAB simulation. The input sine wave was mixed with random noise to generate noisy signal. The corresponding positions of the noisy signals are averaged to obtain the filtered signal. The results gave a clear indication to continue the research work. The result also has an indication that as the number of noisy signals increases the noise in filtered output reduces. Figure shows the MATLAB simulation with 8 noisy signals. The noise content in the output signal is less compared to the individual noisy signals.

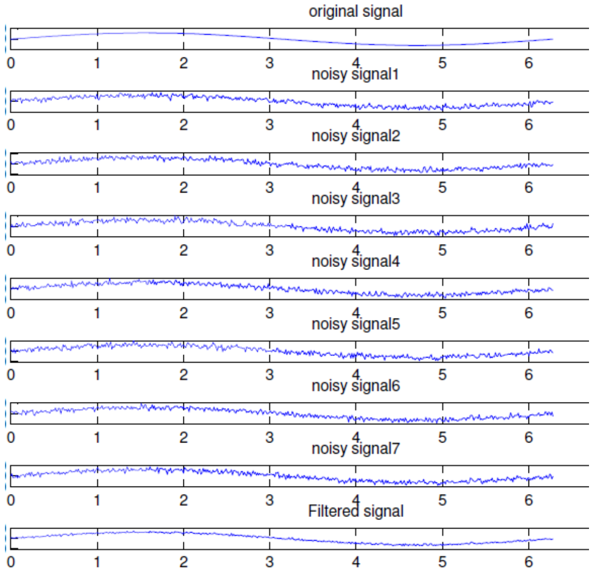

Fig. 5 MATLAB Simulation Result

C. FPGA Implementation

Moving window approach is adopted to design the ensemble averaging filter. In this approach, we can define a window with size N which decides the effectiveness of the filter. Here N is the number of signals to ensemble. As the size N increases the filter will be more and more dependable. If the window size is 32, we need to ensemble 32 noise affected signals. Each noisy signal has m samples and each sample is of w bits wide. The starting point of each noisy signal must be the same for avoiding alignment error.

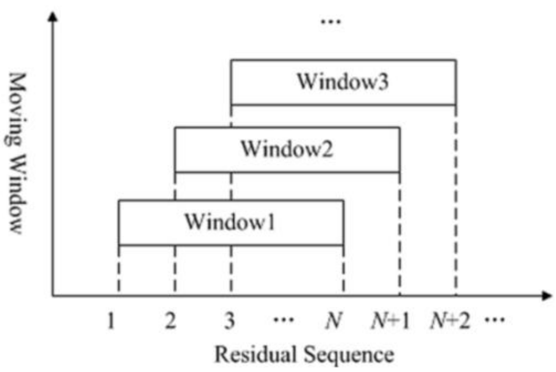

Fig 6 Moving window approach

All the noisy signals represent the same information as the system measures the same information. In ideal case without noise, the response from the system is free from noise. But in practical case, there are some variations in the response signal. But the ensemble of the noisy signals gives a near to original system response.

Figure 6 shows the moving window of N signals. Only N noise signals are needed for taking ensemble average. Here N represents the window size. One of the signals from the window should be replaced with the new noisy signal in first in first out manner. The ensemble of the signals in a moving window is taken as the filtered signal.

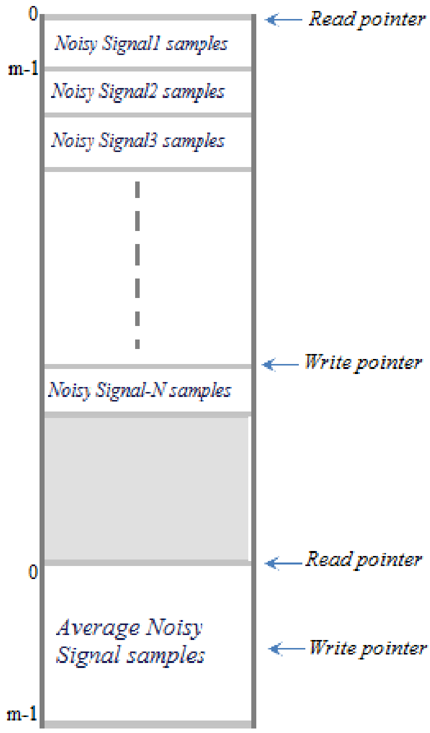

Fig7 Memory mapping

The figure 7 shows memory mapping of SDRAM. The noisy signals are stored in consecutive memory positions. Depending on the moving window size, N such signals are stored. The same memory is reused for the next N signals. If each noisy signal have m samples, m memory locations are required for each noisy signal. Reading and writing agents are used for storing and retrieving the signal information. Each agent uses a read pointer and write pointer for the purpose of memory mapping.

VI. RESULTS AND DISCUSSION

The filter was designed using Spartan6 board and coded in Verilog HDL using Xilinx ISE Design Suit 14.1. The output was observed using a digital oscilloscope. The filtered digital signal from the FPGA is converted using a DAC and given to the oscilloscope. Figure 8 shows the signal affected by the noise and Figure 9 shows the noise filtered signal using ensemble averaging.

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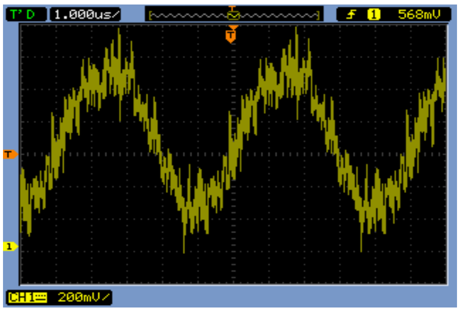

Fig. 8 Signal affected by random noise

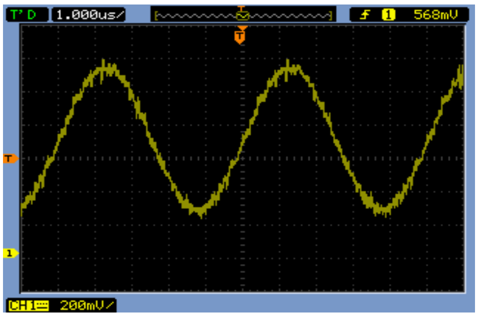

Fig. 9 Filtered signal output

From the figures it is very clear that there is a significant improvement in SNR and the noise is reduced in a large extend. A more smooth noise free waveform is possible with increasing the number of signals used for ensemble average.

VII. CONCLUSION

In brief this paper presents an effective noise reduction method which can be applied to a number of spectroscopy applications. In this paper an Ensemble averaging filter was designed using FPGA which uses SDRAM external memory to store the signal sample values. Signal to noise ratio can be improved in proportion to the square root of the number of signals to be taken for ensemble averaging. The design was implemented using Spartan6 board and coded in Verilog HDL using Xilinx ISE Design Suit 14.1. The filter was found to be very successful for noise diminution in different low signal applications.

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REFERENCES

[1] "Ensemble-Averaging and Correlation Techniques for Flow Visualization Images" P. J. M. Kerstens and D. Rockwell, Experiments in Fluids, Vol. 6, No. 6, pp. 409-419
[2] "An Ensemble Average Approach To Remove Adverse Effects On Power Spectral Estimation Due To Sampling Jitters" Taikang Ning, Ph.D. Trinity College Department of Engineering 300 Summit St., Hartford, CT 06106 USA.
[3] "FPGA Implementation of a Median Filter" Gavin L. Bates & Saeid Nooshabadi School of Electrical Engineering, Northern Territory University, N.T. 0909.
[4] "Efficient Design and FPGA Implementation of Digital Filter for Audio Application" Gopal S. Gawande Asso. Professor, Dept. of E&TC SSGM College of Engineering, Shegaon, Maharashtra State, India , Dr. K.B. Khanchandani Professor, Dept. of E&TC SSGM College of Engineering, Shegaon, Maharashtra State, India.
[5] James C Kennedy, "Electronic signal processing techniques in Non-destructive Testing", Phase III Semi Annual Report , The Boeing Company, June 1971.
[6] Gopika Syam , Sadanandan G.K ," Flaw Detection using Split Spectrum Technique , International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 3, March 2014.

BIOGRAPHY

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