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Implementation of LMS and NLMS Filters For Noise Cancellation in ECG Using TMS320c5505 DSP Kit

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Abstract*:* This paper deals with the study and analysis of comparative performance of LMS and NLMS filters for removing the noise in ECG signal by means of MATLAB software and then it is implemented in TMS320C5505 DSK kit. The LMS and NLMS are the types of adaptive filters that are mainly used in the field of digital signal processing and finds numerous application in the areas of science and technology viz. echo cancellation, channel equalization, adaptive noise cancellation, adaptive beam-forming, biomedical signal processing etc . A Simulink model for both LMS and NLMS filters are designed by using the MATLAB tool and the output results are analyzed by using the digital storage oscilloscope. The results shows that the comparative performance of parameters such as SNR, power line interference, delay, MSE in NLMS filter is more superior when compared to that of LMS filter.

Keyword: Adaptive filters, Least Mean Square (LMS), Normalized Least Mean Square (NLMS), Electrocardiogram (ECG), Digital Storage Oscilloscope (DSO), TMS320C5505 DSK kit.

I. INTRODUCTION

Electrocardiogram is a diagnostic tool that measures and records the electrical activity of the heart. A typical ECG tracing of a normal heartbeat (or cardiac cycle) consists of a P wave, QRS complex, T wave and a U-wave. The base line voltage of the electrocardiogram is known as the isoelectric line. The electrical activity of the heart can be recorded at the surface of the body using an electrocardiogram.

Therefore the ECG is simply a voltmeter that uses up to 12 different leads placed on designated areas of the body. The electrical activity of the heart is generally sensed by monitoring electrodes placed on the skin surface. The electrical signal is very small (normally 0.0001 to 0.003 volt). These signals are within the frequency range of 0.05 to 100 Hertz (Hz) or cycles per second. Since ECG signals are very noisy, usually 50Hz noise, MATLAB was used to test and adjust a digital filter (types of adaptive filters) in order to obtain a good QRS complex, which represents a ventricular depolarization in the ECG, i.e. it shows the electrical impulse of heart as it passes through the ventricles.

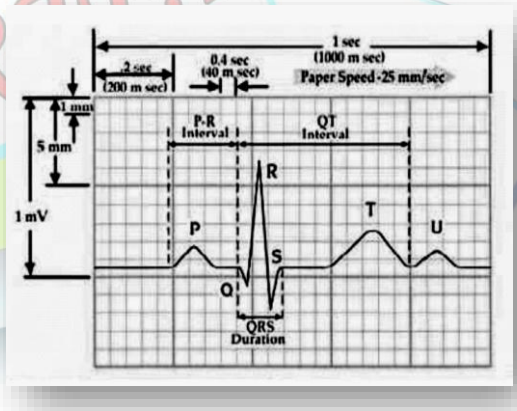

Figure1.Typical one-cycle ECG signal tracking

II. ADAPTIVE FILTERS

The purpose of an adaptive filter is to remove noise from a signal adaptively to improve the signal to noise ratio. The discrete adaptive filter process the reference signal n1(n) to produce the output signal y(n) by a convolution with filter's weight, w(n). Then, a desired signal reference signal d(n) is compared with the output y(n) to obtain an

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estimation error e(n).The objective here is to minimize the error signal e(n) which is equivalent to minimize d(n) – y(n).This error signal is used to incrementally adjust the filter's weights for next time instant.

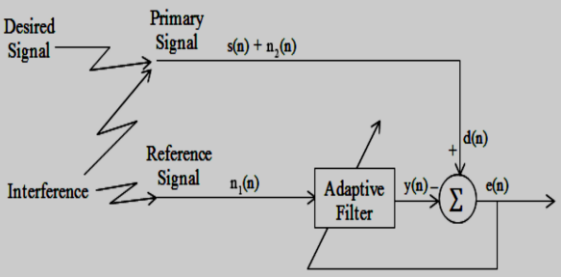

Figure 2. Adaptive filter for Noise Cancellation

The types of adaptive filter algorithm used here is Least Mean Square algorithm and Normalized Least Mean Square algorithm. Let us discuss about these algorithms as follows.

III. ADAPTIVE FILTER ALGORITHMS

A. Least Mean Square Algorithm

Least mean squares (LMS) algorithms are a class of adaptive filter used to mimic a desired filter by finding the filter coefficients that relate to producing the least mean squares of the error signal (difference between the desired and the actual signal). It is a stochastic gradient descent method in that the filter is only adapted based on the error at the current time. The LMS Algorithm consists of two basic processes 1. Filtering process:

Calculate the output of FIR filter by convolving input and taps.

Calculate estimation error by comparing the output to desired signal.

2. Adaptation process:

Adjust tap weights based on the estimation error.

B. Implementation of Least Mean Square Algorithm:

For the Implementation of each iteration of the LMS algorithm requires three distinct steps in the following order:

1. The output of the FIR filter,

$y(n) = wT(n)\, x(n)$

2. The value of the error estimation is calculated using,

$e(n) = d(n) - y(n)$

3. The tap weights of the FIR vector are updated in preparation for the next iteration,

$w(n+1) = w(n) + 2\,\mu e(n)\, x(n)$

For each iteration, the LMS algorithm requires 2N additions and 2N+1 multiplication.

C. Normalized Least Mean Square Algorithm

When the convergence factor μ is large, the algorithm experiences a gradient noise amplification problem. In order to solve this difficulty we can use the NLMS algorithm. The correction applied to the weight vector w(n) at iteration n+1 is "normalized" with respect to the squared Euclidian norm of the input vector x(n) at iteration n. Convergence factor μ-

$\mu(n) = \alpha / (c + \|x(n)\|^2)$;

where c is constant less than 1, and α is NLMS adaption constant and should satisfy $0<\alpha<2$. It obeys principle of minimum disturbance.

D. Implementation of Normalized Least Mean Square Algorithm Steps

It is essentially an improvement over LMS algorithm with the added calculation of step size parameter for each iteration.

1. The output of the adaptive filter is calculated as:

$y(n) = wT(n)\, x(n)$

2. The error signal is calculated as the difference between the desired output and the filter output given by:

$e(n) = d(n) - y(n)$

3. The step size and filter tap weight vectors are updated using the following equations in preparation for the next iteration:

For i=0,1,2,…….N-1;

$\mu i(n) = \alpha / (c + \|xi(n)\|^2)$

With $\alpha = 0.02$ and $c=0.001$, each iteration of the NLMS algorithm requires 3N+1 multiplication operations.

IV. SIMULINK MODEL FOR LMS AND NLMS ALGORITHMS

For hardware implementation we require a recorded ECG signal, reference noise signal, TMS320C5505 DSK kit, and a digital storage oscilloscope. The input signals are processed by DSK that is controlled by simulink model running in the computer system. The Adaptive Noise Cancellation (ANC) Simulink model is designed using LMS and NLMS algorithms for generating C code and to download this code on DSP target processor. The ANC model is designed with help of inbuilt library of Simulink and the blocks are reconfigured as per the requirements of TMS320C5505 DSP processor.

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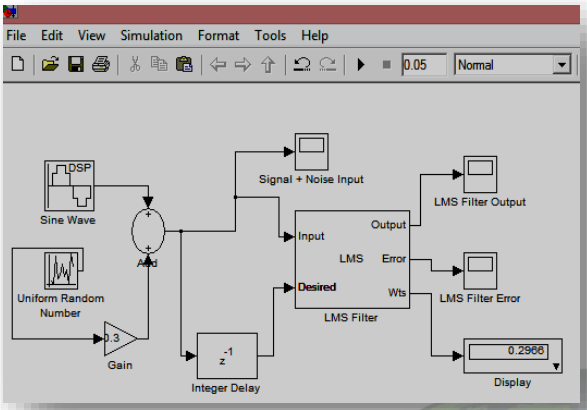

Figure 3.Simulink Model for LMS algorithm

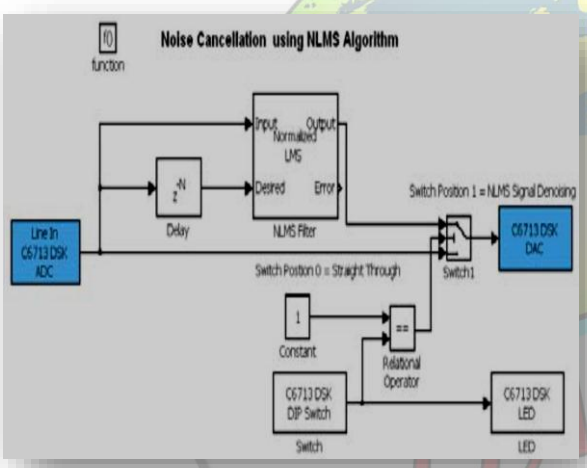

Figure 4.Simulink Model for NLMS algorithm

V. RESULTS

The real-time implementation is also done to remove the noise of an ECG signal which is corrupted by various types of interferences & distortions.

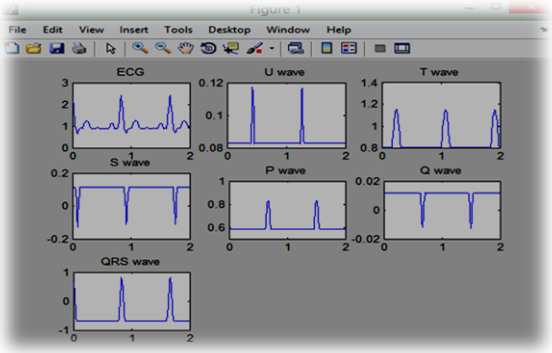

Figure 5.Normal ECG signal waveform

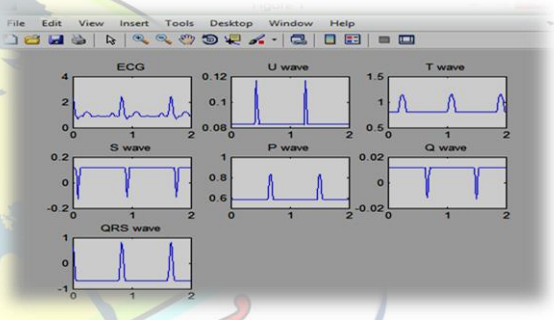

Figure 6.Abnormal ECG signal waveform

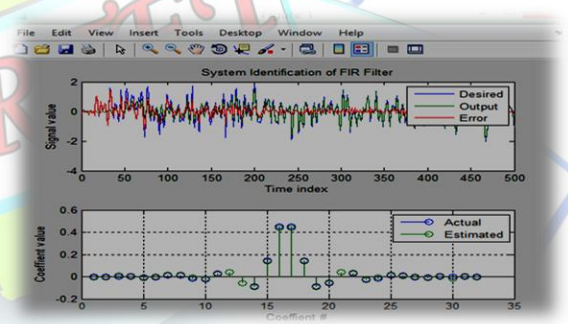

Figure 7.LMS algorithm output

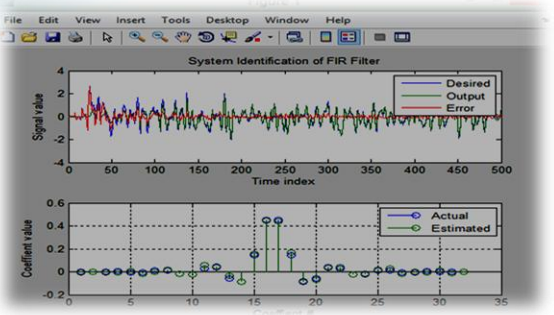

Figure 8.NLMS algorithm output

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VI. CONCLUSION

The implementation of LMS and NLMS filters have been done and hence the results are compared. The results shows that the performance of NLMS is better when compared to that of LMS filter. By using NLMS algorithm which highly preserves the peak of QRS complex of ECG signal compared to LMS algorithm. Hence we conclude that NLMS algorithm is better than that of LMS algorithm.

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