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VLSI Implementation of Separating Fetal ECG Using Adaptive Line Enhancer

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Abstract: fetal electrocardiogram (fecg) signal recording is the popular technique for heart signal monitoring of fetus. It is also used to monitor health condition of fetus in pregnancy period continuously. Fetal electrocardiogram monitors the electrical activity of fetus's heart. Fecg is extracted from a signal recorded on the mother's abdomen, which is an indirect method (non-invasive method). The mother's heartbeat, which has an amplitude 2 to 10 times greater than that of the fetal heartbeat, and often interferes in recording. Nowadays the introduction of adaptive filter used to separate one signal from more than one signals. In this technique employed to separate the signal very effective manner compare to the earlier techniques. The adaptive filter such as finite impulse response (fir) used to compute the input signal in different filter orders such as n = 4, 8, 16 and 32 to obtain the snr, mse and the computation time. Least mean square algorithm (lms) used to update the filter coefficient during the run time so the output signal are obtain the excepted output signal. The proposed system was implemented in verilog hdl language to obtain the unique design using tmsc 90nm cadence environment.

Key words – fecg, eeg, adaptive filter, lms, signal separation.

I. INTRODUCTION

During pregnancy period health condition of fetus must be continuously monitored, to keep the fetus healthy. For this one of the best techniques is heart signal monitoring which gives us important information about fetal health condition. Electrical potentials produced by heart are graphically recorded as ECG. The electrical potentials are generated by simultaneous repolarization and depolarization of cells due to Na+ and K+ ions momentum in the blood. The range of ECG signal is typically 2mv and requires 0.1 to 400 Hz recording bandwidth [1, 2].FECG, which is nothing but biomedical signal that gives electrical representation of Fetus heart beat from the recordings on the mother's abdomen. The fetus pulse rate is around 132 beats per minute and the pulse rate of mother is around 85 beats per minute. The FECG signal is a comparatively weak signal (less than 20% of the mother ECG) and often embedded in AECG and noise. The FECG lies in the range from 1.3 to 3.5 Hz and sometimes it is possible for the mother and some of the FECG signals to be closely overlapping [3]. The FECG monitoring enables accurate measurement of fetal cardiac performance including transient or permanent abnormalities of rhythm. The FECG is very much related to the mother ECG i.e., MECG, containing the same basic waveforms including the P wave, the QRS complex, and the T wave as shown in Figure 1.

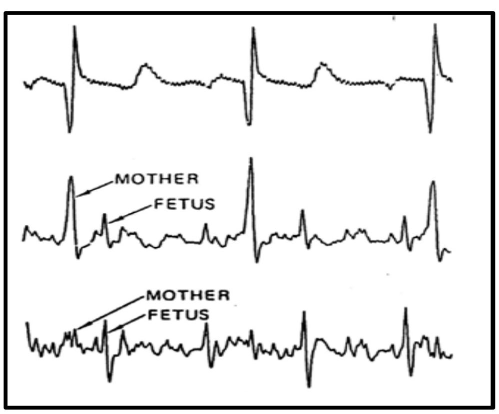

Figure 1: Example of MECG and FECG

Adaptive filtering technique has been shown to be useful in many biomedical applications. The basic idea behind adaptive filtering has been summarized by Widrow et al. [4]. It reduces the mean-squared error between a primary input, which is the noisy ECG, and a reference input, which is either noise that is primary input. Adaptive filters permit to detect time-varying potentials and to track the dynamic variations of the signal. These types of filters learn the deterministic signal and remove the noise. Besides, they modify their behavior according to the input signal. Therefore, they can detect shape variations in the ensemble and thus can obtain a better signal estimation. The first aim of this paper is to observe the original ECG signal of the fetus which is observed at the abdomen of the mother by eliminating the mother's ECG using adaptive line enhancer. The adaptive filter weights are updated by using the least mean square algorithm.

II. FETAL ECG EXTRACTION USING ALE

There are several techniques used to process biomedical signals but these systems analyse the input signal, the noise signal and the output signals. Adaptive line enhancer is similar to ANC architecture but ANC uses two input signals whereas ALE uses the input signal as the reference signal so the signal is nearly error-free [5, 6]. The proposed ALE architecture was implemented to process and separate the signal at the same time in order to analyse the real time signals as shown in Figure 2. In this architecture, the input signal is taken to be the reference signal to obtain the minimum error rate of the output signal. It reduces error with the help of adaptive FIR filters and Adaptive Algorithms. The adaptive algorithms provide feedback to the system to update the FIR filter coefficient. Here, Adaptive LMS algorithm is employed. One major advantage of the ALE is that during the run time, the adaptive FIR filter coefficients update each iteration so the coefficient valves change in each tap from a feedback of adaptive filter tap output in each iteration, thus reducing the errors and increases the SNR. Here, the noise signal is removed from the measured signal to obtain the signal of interest.

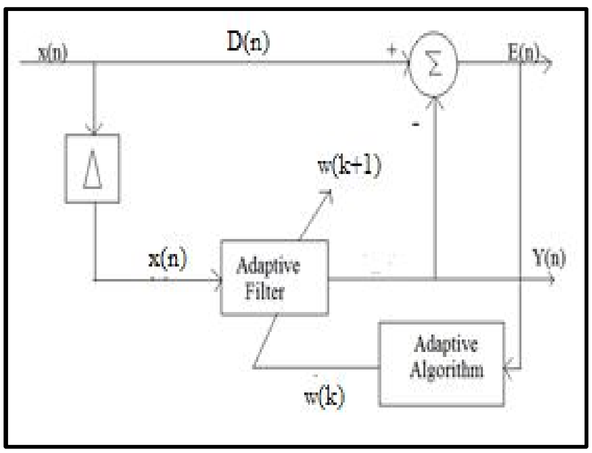

Figure: 2 Adaptive Line Enhancer for MECG Cancellation

III. ADAPTIVE FILTERS

By using adaptive filters, the optimization problem on which all adaptive signal processing functions are designed can be resolved. The adaptive filter consists of two parts namely adaptive FIR filter and adaptive algorithm. The filter part can be based on any of the filter structures [7].The filter is used to compute and calculate the output signal y(n).The set of FIR filter coefficients are continuously updating or adjusted by the adaptive algorithm. Adaptive algorithm is responsible for adjusting the filter coefficients or weights so that the filter output becomes as very close as possible to a desires signal d(n).In many cases, the adaptive algorithm adjusts the filter coefficients a little bit to minimize error signal E(n).The error signal is defined as the variation among the desired signal and the filter output [8-9].

$$E(n) = D(n) - y(n) \qquad \text{.... (1)}$$

The adaptive filter function is used to minimize the error value as well as improve the overall system performance.

IV. ADAPTIVE LINE ENHANCEMENT USING LMS

Adaptive algorithms such as LMS and RLS are used to adjust the co-efficient of digital filter such that the noise is minimized [10, 11]. This paper briefs the implementation of LMS algorithm to separate the maternal ECG and the fetal ECG. The main reason for the LMS algorithms popularity in adaptive filtering is its computational simplicity, making it easier to implement than all other commonly used adaptive algorithms. For each iteration the LMS algorithm requires 2N additions and 2N+1 multiplications. Each iteration of LMS involves three steps:

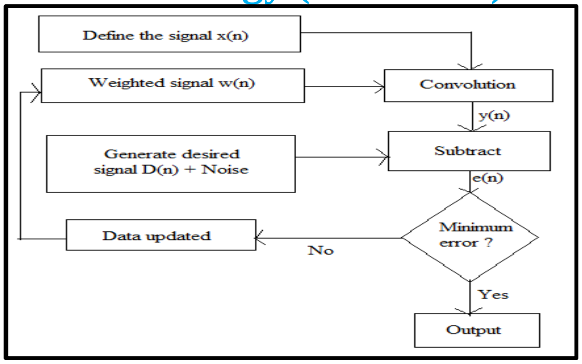

Figure: 3 Design Flow of the ALE-LMS

Here, we assume input signal x(n), desired signal D(n), output signal y(n) and error signal E(n). Internally, the filter coefficients w(k) are updated on a sample-by-sample basis.

Where, x(n) consist of the desired signal and some additional information called noise. D(n) is the desired signal which is obtained after eliminating the unwanted signal from the input signal x(n).

The output signal y(n) is computed by a standard FIR filter as follows.

$$y(n) = w(0) * x(n) + w(1) * x(n+1) + w(2) * x(n-2) + \ldots + w(N-1) * x(n-N+1) \quad \ldots. (2)$$

The error signal can be computed by the equation 1. After each sample of the error signal is computed, the filter coefficients w(k) are updated on a sample by sample basis as in equation 3.

$$W(k+1) = w(k) + E(n) * \mu * x(n-k), \text{ for } k=0, 1,\ldots\ldots\ldots,N-1 \quad \ldots. (3)$$

Where, µ is the step size which controls the rate of coefficient convergence. Figure 3 describes the design flow of adaptive line enhancer implemented using LMS algorithm.

V. SIMULATION AND HARDWARE IMPLEMENTATION USING CADENCE

Cadence software simulate the original FECG signal and produces the desired response which is used in real time applications. Although, the Maternal ECG is uncorrelated with the Fetal ECG, the adaptive technique proved worthy. The Maternal ECG Signal (i.e.), interference is cancelled from the Heart ECG Signal. ECG Signal was given as an input and was simulated using Cadence. The proposed design is implemented using Cadence which is shown in Figure 4.

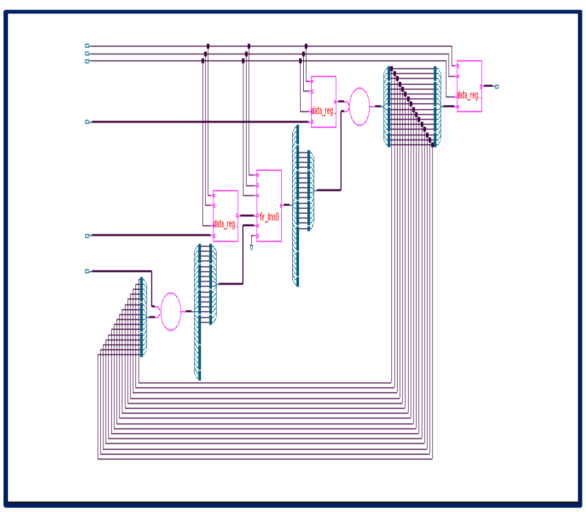

Figure: 4 RTL View of the Proposed System

VI. RESULT AND ANALYSIS

Table 1 shows the system performance level for ALE-LMS 4th order, 8th order, 16th order and 32nd order respectively and mean square error, signal to noise ratio and computational time is represented in Figure 5.

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Table: 1 Parameter Utilization of ALE-LMS

Filter Order	N=4	N-8	N=16	N=32
SNR	9.0334	9.8903	8.0921	7.2955
RMSE	1.8688	1.3214	1.3214	0.6607
Time	0.229	0.223	0.203	0.2247

UTILIZATION OF TIME		
RISE TIME (ps)	FALL TIME (ps)	TOTAL TIME (ps)
583512	239840	823352

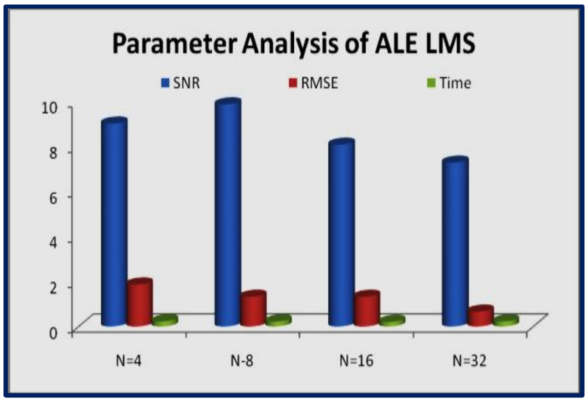

Figure: 5 Analysis using MATLAB

Figure 5 shows the pictorial representation of performance analysis of ALE-LMS with filters of order 4, 8, 16 and 32.The proposed system was simulated and synthesized to obtain the major design parameters considered in VLSI technology such as area, gates, power and timing analysis obtained in Cadence RC synthesizer. The obtained values of ALE-LMS architecture represented in a graphical form shown in Figure 6, 7, 8 and the parameter values of cells and area shown in Table 2, the utilization of power is represented in Table 3 and the total time to complete the process is shown in Table 4.

Table: 2 Cells and Area Utilization

UTILIZATION OF CELLS AND AREA	
CELLS	AREA
9285	83622

Table: 3 Power Utilization

UTILIZATION OF POWER		
LEAKAGE POWER (nW)	DYNAMIC POWER (nW)	TOTAL POWER (nW)
351361	4698831	5050192

Table: 4 Time Utilization

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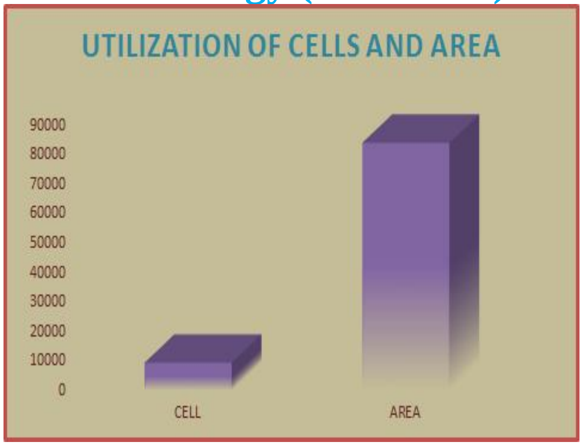

Figure: 6 Cells and Area Utilization Summary Using Cadence

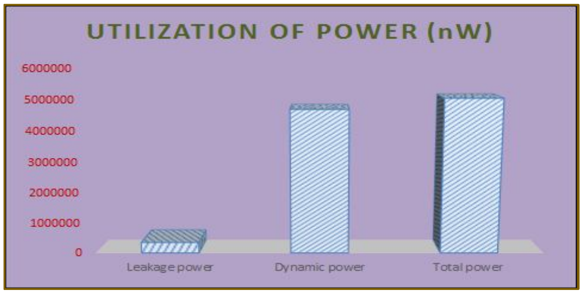

Figure: 7 Power Utilization Summary Using Cadence

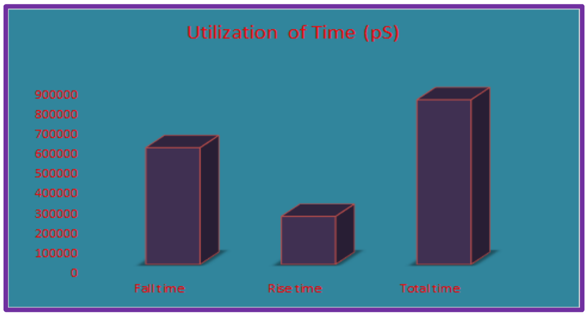

Figure: 8 Time Utilization Summary Using Cadence

The above Figures 6, 7, 8 shows the utilization of gates, area, power and time respectively using Cadence tool. From this analysis we can see that the proposed architecture minimizes the area, power and time. Also, it yields better SNR and recursive mean square error values.

VII. CONCLUSION

The cancellation of Maternal ECG from the Fetal ECG is more important in case of ascertaining the proper growth of fetal because the distorted Fetal ECG will lead to abnormal conclusions. This implementation gives us the way for extracting the Fetal ECG in order for the checking of the working of the fetal heart. This implementation in VLSI carves a new path in technology for averting the usage of the harmful Echocardiogram that can be put into real time evaluation. It is known from the above analysis filters of order 8 and 16 gives the better resource utilization. The filter order chosen to the proposed system is 8 and the SNR, MSE and time utilization is about 9.8903dB, 1.3214dB and 0.223s respectively. From the above analysis it can be concluded that this work minimizes the overall resource utilization and obtain better SNR and mean square error values when compared to the previous works. Further enhancement of BSS using VLSI implementation is under work.

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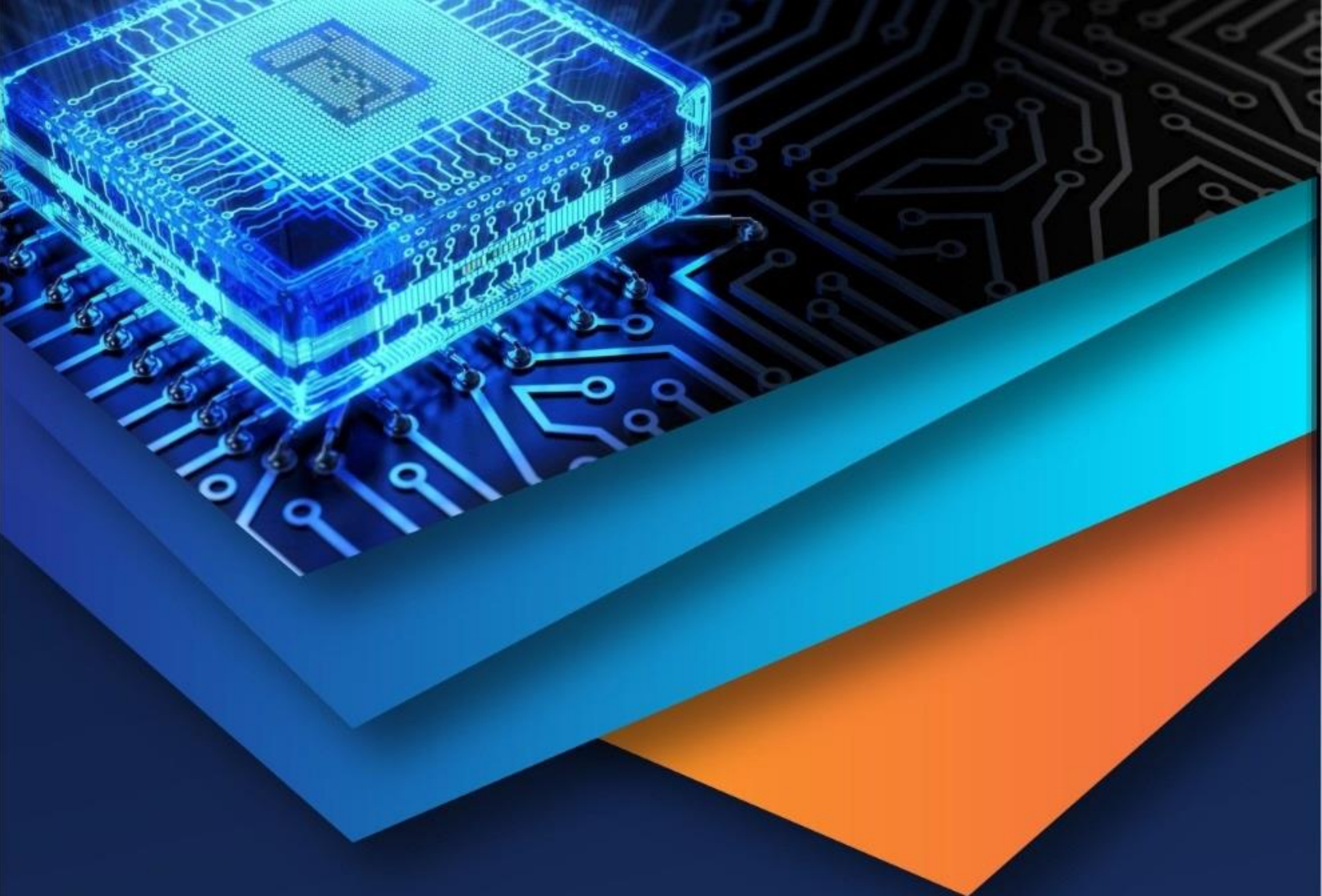

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