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# **Narrowband Noise FxLMS Algorithm in VLSI Implementation for Active Noise Control**

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**ABSTRACT:** Active noise control (ANC) is a method used to reduce noise efficiently. The hardware executions of these ANC's are challenging in real time noise cancellation techniques. In this paper Filtered least mean square algorithm (FxLMS) is applied for narrow band noise with a variable step size to achieve noise control in acoustic environments like fans, blowers etc. Initially this paper deals with the implementation of variable step FxLMS (VSFxLMS) algorithm in Matlab to achieve noise control and also it discusses about convergence and noise reduction rates. These factors are used to demonstrate the efficiency of the algorithm used. Then it is implemented in VLSI platform through VHDL coding using Xilinx. This implementation is provided to obtain the low power via reducing the number of logic's and interior components like Lut, Mux and transistors.

**KEYWORDS:** Active noise control (ANC), Convergence rate, , FxLMS, Narrow band, Noise reduction, VLSI, VSFxLMS.

## **I. INTRODUCTION**

Acoustic noise reduction is a major real-life application for headphones, automobiles, mobile phones, and some diligences. ANC system using adaptive filters has smaller volume and it acts as best alternatives to those using passive methods, [1]. ANC can be used to remove interference by generating an anti-noise output that is used in the system to destructively cancel the primary intrusiveness, [2].The secondary sources in ANC are intersected through an electronic system using a specific signal processing algorithm for cancellation scheme. ANC has application to variety of problems in engineering, work processes, and consumer yields

The ANC system efficiently attenuates low-frequency noise where passive methods are ineffective and tend to be very expensive. ANC is mainly preferred because it provides improvements in noise control, with many benefits [3&4]. FxLMS algorithm can be beneficial in expressions of faster convergence process in the actual ANC because a pre-filtered output signal through the secondary path is used,[5].FXLMS algorithm is the most popular adaptive algorithm to update the controllers. This algorithm with a fixed step size provides better performance at the expense of a much heavier computational burden. To obtain an algorithm that takesreckless convergence in both stationary and non-stationary environments, the usage of a variable step size in the FXLMS algorithm tend to be active, [6].

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In FxLMS the reference signal (acoustic pressure picked up from the ambient) is filtered using an estimate model of the secondary path before being used by the algorithm. a general secondary path and stochastic noise field, these effects have been analyzed only when the secondary path model is assumed to be perfect,[7 & 8] The complexity due to the x-filtering blocks may become a real burden and pose a bottleneck in system implementation. This difficult has enthused us to pursue for new system structures where this problem may be avoided or alleviated,[9]Narrowband active noise control (ANC) is be used to reduce noise signals showing narrowband or discrete frequency characteristics. In the narrow band noise (range of small frequencies below 1 kHz) interferences are difficult to eliminate using submissive methods, but it can be efficiently removed using active noise control (ANC) techniques, i.e., by means of destructive noise,[10].

A fixed step size may not respond to time-variant channel parameters, resulting in poor performance. In order to overcome this limit variable step size methods are invented and many adaptive step functions are founded by appealing the drawbacks of existing structures. Usually the step size must be small in order to achieve a better convergence property,[11].In this paper active noise control system using filtered least mean square algorithm (FxLMS) in narrowband is analyzed with a variable step size in order to ensure the performance of the system. Using this approach better convergence rate and increased performance with less power and cost constraints are achieved.

Noise control technique has been widely studied and applied in thefield of wireless communication. It is an important technique used for compensating the distorted channel. With this technique either an alterable or an adjustable system thatimproves the performance of signal processing viacontacting with the outside can be designed.Nowadays, with the ability to operate athigh switching frequencies FPGAs (FieldProgrammable Gate Arrays) have provided an idealsolution for implementing large amounts of highspeed signal processing circuitry which is allowing thedesigner to reduce the size and cost of a product,[12]

The FPGA chips are reconfigurable and can process data and information simultaneously for different processing solicitations. LMS inhibitedprocedure which is implemented in FPGA using HDL coding consumes more number of logical specifications as described in [13]. These are considered while designing this VSFxLMS using HDL.In further section of this paper conventional section II contains the methodology of FxLMS algorithm, section III describesvariable step FxLMS algorithm, section IV describes the simulation results, section V explains the conclusion and section VI contains future work.

## II CONVENTIONAL FXLMS ALGORITHM

The most popular adaptation algorithm used for *ANC* applications is the *FxLMS* algorithm, which is a modified version of the *LMS* algorithm [5]-[7].The schematic diagram for a single-channel feed forward *ANC* system using the *FxLMS*algorithm is shown in figure.1. Here,  $P(z)$  is primary acoustic path between the reference noise source and the error microphone and  $S(z)$  is the secondary path following the ANC adaptive filter  $W(z)$ . The reference signal  $x(n)$  is filtered through  $S(z)$ , and appears as anti- noise signal  $y'(n)$  at the error microphone. This anti-noise signal combines with the primary noise signal  $d(n)$  to create a zone of silence in the vicinity of the error microphone.The error microphone measures the residual noise  $e(n)$ , which is used by  $W(z)$  for its adaptation to minimize the sound pressure at error microphone. Here  $\hat{S}(z)$  account for the model of the secondary path  $S(z)$  between the output of the controller and the output of the error microphone. The filtering of the given reference signals denoted to be  $x(n)$  through the secondary-path model  $\hat{S}(z)$  is demanded by the fact that the output  $y(n)$  of the adaptive controller  $W(z)$  is filtered through thesecondary path  $S(z)$ .

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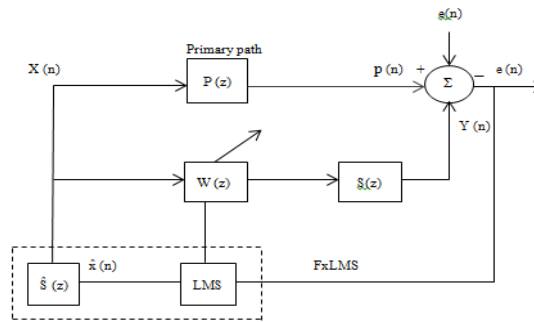


Fig-1 Conventional FxLMS algorithm

The expression for the residual error  $e(n)$  is computed using equation (1)

$$e(n) = d(n) - y'(n) \quad (1)$$

Where  $y'(n)$  is the controller output  $y(n)$  filtered through the secondary path  $S(z)$ . The  $y'(n)$  and  $y(n)$  are computed using equation (2) and (3)

$$y'(n) = s^T(n)y(n) \quad (2)$$

$$y(n) = w^T(n)x(n) \quad (3)$$

Where the weight vector is defined to be  $w(n) = [w_0(n)w_1(n)\dots\dots w_{L-1}(n)]^T$ , the reference signal is defined to be,  $x(n) = [x(n)x(n-1)\dots\dots x(n-L+1)]^T$  this reference signal is picked by the reference microphone and  $s(n)$  is impulse response of secondary path  $S(z)$ . It is assumed that there is no acoustic feedback from secondary loudspeaker to reference microphone. *FxLMS* update equation for the coefficients of  $w(z)$  is given in equation (4)

$$w_{n+1} = w_n + \mu e(n)x'(n) \quad (4)$$

Where  $x'(n)$  is reference signal of  $x(n)$  filtered through secondary path model  $\hat{S}(z)$  is given in equation (5)

$$x'(n) = \hat{s}^T(n)x(n) \quad (5)$$

### III. VSFxLMS ALGORITHM

In the previous work conventional FxLMS algorithm is applied for impulse noise, random noise and wide band noises with variable and fixed step sizes. In case of random noise control using FxLMS algorithm with fixed step size, control signal could match the magnitude of noise signal only at particular step size of 0.01 if the step is increased at little higher rate than noise signal could not be controlled by the anti-noise signal. Only for a particular step size the antinoise signal could cancel the primary noise. Hence variable step size is chosen to control the primary noise using varying step size.

In this VSFxLMS algorithm a narrowband noise is taken as source and it is controlled using FxLMS algorithm. This system controls harmonic sources by adaptively filtering a synthesized reference signal. This algorithm uses a variable step size function as shown in equation (6) which contains parameters  $\alpha$  and  $\beta$  in the step size function. The parameter  $\alpha(n)$  control the shape and speed of step-size of the algorithm, but parameter  $\beta(n)$  control the value range of the function. Algorithms step function is as follows,

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$$\mu(n) = \beta(n) (1 - \exp(\alpha(n) * |e(n)|^2)) \quad (6)$$

This step function is modeled at the desired values of parameters  $\alpha$  and  $\beta$  which are represented as,

$$\alpha(n) = \left| \frac{e(n)}{e(n-1)} \right|^k \quad (7)$$

Where the constant  $k$  is used to control  $\alpha(n)$  which is then regulates the convergence rate.

$$\beta(n) = (1 - b_0) \beta(n-1) + b_0 \left[ \frac{e(n)}{e(n-1)} \right]^2 - 1 \quad (8)$$

Where the constant  $b_0$  is used to ensure the convergence rate. This factor is limited as  $0 < b_0 < 1$ .

$$W(n+1) = W(n) + 2 \mu(n) \times e(n) \times x(n) \quad (9)$$

The update equation of the system without variable step FxLMS is shown in equation (4) and the change in update equation of the system with the presence of VSFxLMS is shown in equation (9).

Two parameters  $\alpha(n)$  and  $\beta(n)$  are the function of error ratio  $e(n)/e(n-1)$ . When the ratio in equation (7) is larger the error change is greater and VSFxLMS algorithm will be in the convergence stage. If the error ratio is smaller then, step size  $\mu(n)$  will be small which tends the algorithm to be in steady state. Similarly the parameter  $\beta(n)$  works.

Constant  $k$  is used to adjust the change speed of  $\alpha(n)$ . For higher convergence rate  $k$  tends to be smaller but to maintain accuracy  $k$  needs to be smaller. Constant  $b_0$  is used to ensure the convergence but different  $b_0$  values could affect the algorithm performance internally generated by the ANC system. When this step function is used the update equation for the coefficients of filter shown in equation (9) will be twice that of the conventional FxLMS. This VSFxLMS algorithm could adjust the coefficients of the filter in a faster way by means of updation equation (9) thereby increasing the convergence in a better way. Noise reduction is achieved using the equation shown in (10) where  $e(n)$  is the residual error which is described in equation (1) and  $d(n)$  is the primary noise.

$$R(dB) = -10 \log \left( \frac{\sum e^2(n)}{\sum d^2(n)} \right) \quad (10)$$

## IV. SIMULATION RESULTS

### a) MATLAB results

In this section the performance of the reviewed narrowband FxLMS algorithm is demonstrated with their characteristic curves. The computer simulation for variable step FxLMS algorithm performance is illustrated in the following figures. The simulation settings are as follows. The input signal is narrow band noise which is shown in figure (2). Reference input is a random noise; the sampling points are set to 1000. In the equation (6)  $\alpha$  value should be greater than 0.2 in condition to achieve desired step function and so it is considered as  $\alpha=0.4$ , and  $\beta$  should be greater than 0.099 in condition to achieve the control in step function and hence it is taken as  $\beta=1$  as constant values.

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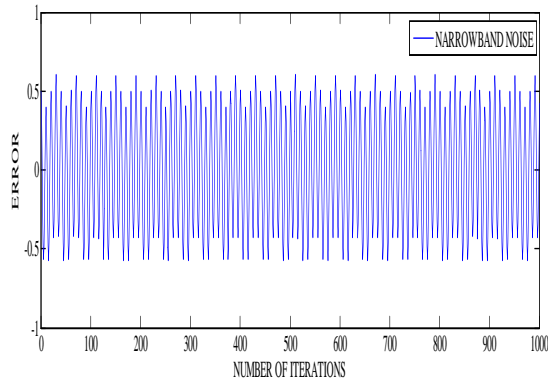


Figure 2 characteristics of narrowband noise

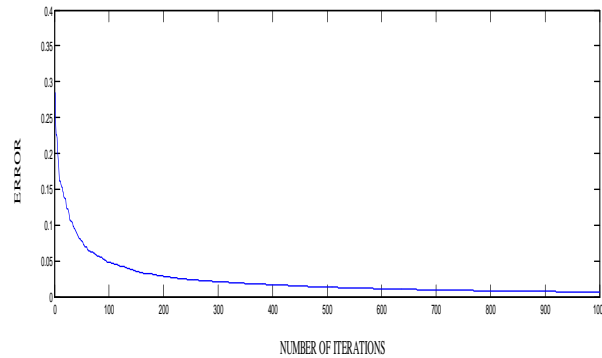


Figure 3 Convergence rate of VSFxLMS

Figure 3 shows the convergence rate of VSFxLMS algorithm. The convergence speed of VSFxLMS is achieved above 400 iterations. Using such an increased convergence speed stability of the system could be achieved. Figure 4 shows the noise reduction in dB of proposed variable step FxLMS algorithm. It can be noted that up to 30dB noise reduction level is achieved in the VSFxLMS algorithm.

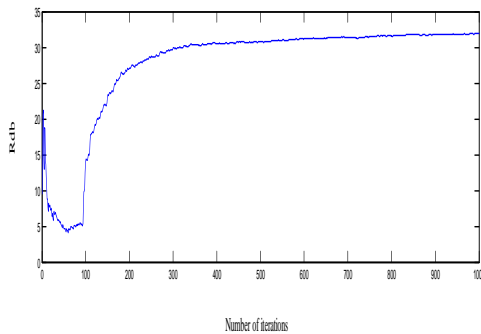


Figure 4 Noise reduction in dB

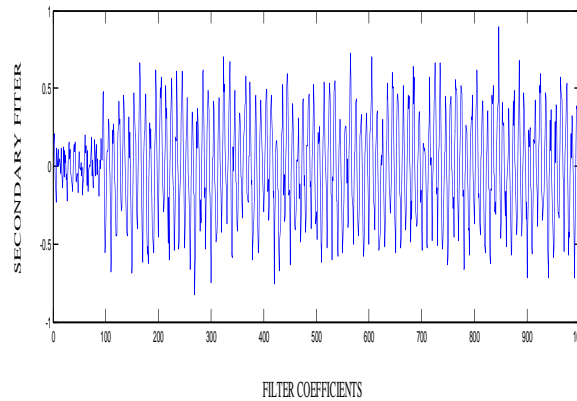


Figure 5 Correlations of filter coefficients

Figure 5 illustrates the correlation of filter coefficients with that of the step function. This correlation function is used to demonstrate improving convergence rate. The secondary filter in the simulation is created using FIR filters as defined in the MATLAB function.

## b) VHDL Results

In this paper the important part is the VHDL implementation of VSFxLMS algorithm for narrow band noise. Though these simulations couldn't depict the noise reduction levels this could give the number of logic's required to implement the algorithm. From the resultant logic utilization amount of power required and the design interiors like number of LUT's,

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gates etc could be known in order to implement in hardware. Behavioral simulation result of VSFxLMS algorithm is shown in figure 6. Here two cases of signals are depicted one with enabled clock and another with disabled clock. The clock enabled signal is containing the data input and step size as 001000000100 and 000000000100 its corresponding error output is 101000000010. Similarly for the clock disabled signals data in and step size are 11011111011 and 11101111100 where its error output is 1101010101.

Register transfer label of this particular algorithm is shown in figure 7. The sub circuits includes multiplexor, buffer, arithmetical units and the data units involved in the code. This is created with the behavioral model of HDL code. Only with the correctsimulation RTL logic could be achieved. Using this RTL logic the design summary report of the code could be obtained. It contains the interior logic connected between the flip flops, mux and the buffer created using Xilinx software.

Designsummary obtained using the RTL logic is shown in table and it is compared with the report of LMS algorithm as in, [14]. The no of slices is reduced rapidly from 292 to 60 using this VSFxLMS algorithm and also the no of 4 LUT's used is reduced to 83. Few other parameters like global clock, slices of flip flops are also compared with LMS as shown in table 1.



Figure 6 Behavioral simulations of VSFxLMS

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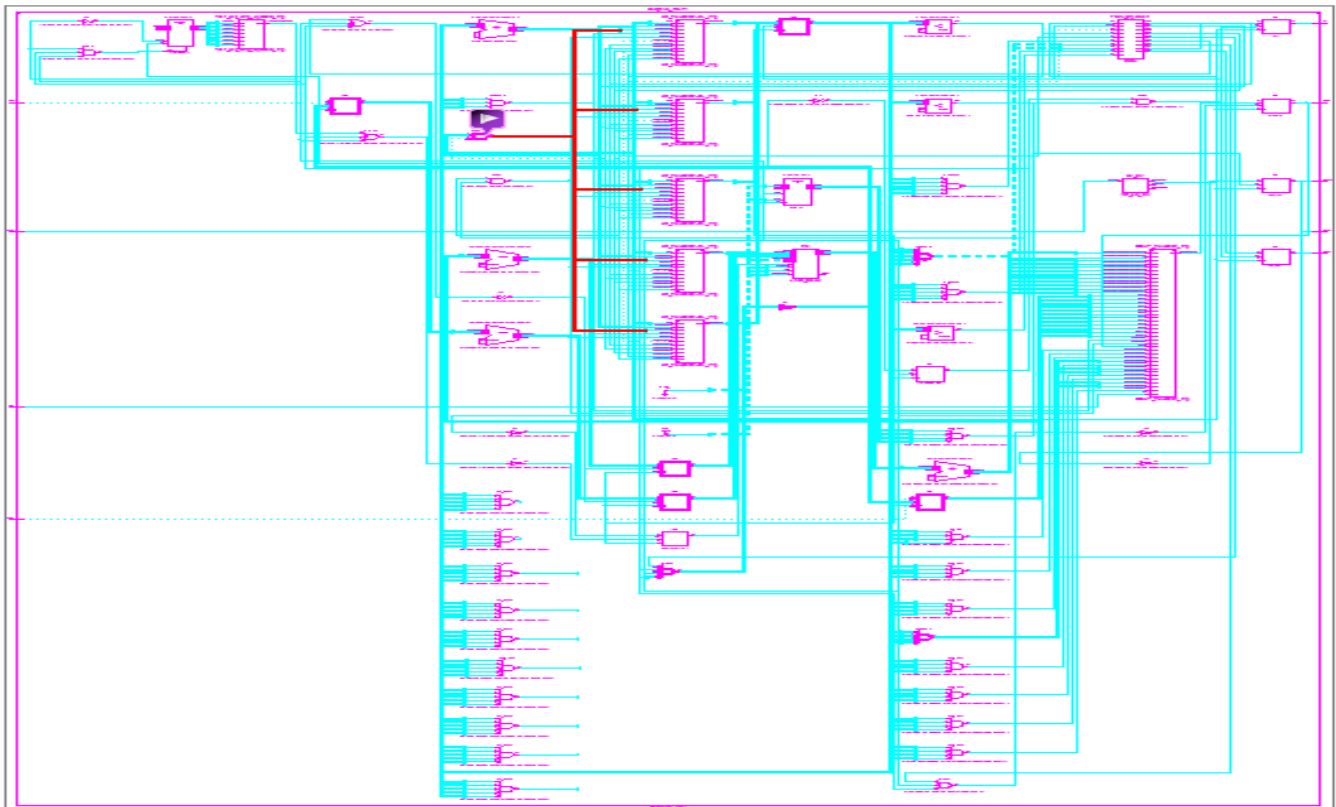


Figure 6 RTL technologies for VSFxLMS

TABLE 1  
Comparison of design summary

Parameters	VsFxLMS	LMS	utilization
No of slices	60	292	1
No of slice flip flops	72	591	0
No of 4 LUT's	83	630	0
No of bonded IOB's	9	34	13
No ofGCLK's	1	1	4

## V. CONCLUSION

ANC cancels the unwanted noise by generating antinoise of equal amplitude and opposite phase through the secondary sources In this paper FxLMS algorithm with narrow band noise reduction is investigated through MATLAB and VHDL simulations. The analysis is carried out by the means of convergence rate and noise reduction of 22dB has been achieved. And the logic utilization of VSFxLMS with LMS is compared. This technique could create an undesired acoustic

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feedback from the canceling loudspeaker back to the reference microphone is avoided, noise removes the causality constraint, an internally generated reference signal can control each harmonic independently. Also the power constraints for the hardware implementation is resolved using the logic summary.

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