Adaptive Control Technique for Vibrations in Aero Structures using FPGA

*Supriya Channigavi[1] , Siva Subba Rao Patange[2], Raja S[3], Aritri D[4]
[1] CMR Institute of Technology, Bangalore – 560037
[2] CSIR –National Aerospace Laboratories Bengaluru-560017

***Abstract*----In this project active vibration control (AVC) technique is carried out. The LMS algorithm is applied in controlling system. SPARTAN-3E FPGA kit is used for the implementation. Vibration generator generates vibrations. Shaker is placed such that it should touch surface of the specimen. And the amplified vibration signal is fed to FPGA board, and processed according to the required output.**

ADC and DAC blocks of FPGA board are utilized for conversion of signals. The PZT sensor is mounted on the specimen. Output signal from the sensor is given to conditioning amplifier where the signal reliability improves. Then obtained signal is converted in digital values with the help of ADC present in FPGA board. Digitized value of signal is input for the algorithm block. The output from the controlling block is equal and opposite value of that of input given. Again it is converted into analog signal using DAC present in SPARTAN-3E. Actuating amplifier's output drives the actuator. Actuator will minimize the vibrations of the specimen. Finally the system with minimized vibration is obtained.

Keywords----Field programmable gate array (FPGA), Least Mean Square Algorithm (LMS), Active Vibration Control (AVC), Piezoelectric Sensor (PZT).

I INTRODUCTION

The active vibration control (AVC) is a well defined research area, only few of real-world applications are predictable. Lack of suitable control systems is one of the main reason for it. So control systems with FPGA can provide best solution. This script describes implementation of AVC with LMS algorithm. Implementation is done with verilog coding. Adaptive algorithm is used because of presence of unknown parameters in vibrations of air structures. Comparing both conventional and adaptive systems, adaptive systems are having high efficiency. LMS algorithm is introduced in 1960 by Widrow and Hoff. LMS algorithm is simple compare to other adaptive algorithms. It is having many advantages which will help in implementing AVC system. There have been so many efforts in FPGA platform for the implementation of LMS algorithm. Mohammad Bahura has presented a architecture on FPGA. Virtex –II-

Pro board is used in his work. And architecture used is sequential.

Active vibration control system is having application of equal and opposite force to the vibration. So that air structures without any active vibrations or reduced active vibrations can be obtained. This AVC system yields light weight aero structures. And also gives improved comfort compare to passive control.
Algorithm used in this project is LMS adaptive algorithm. LMS (Least Mean Square) algorithm is one of the best adaptive filter algorithm which is used to obtain desired output by finding coefficients of filter. These filter coefficients are depends upon error signal of the filter. Adaptive algorithm describes how o adjust the parameters from present instant of time to next instant. The algorithm is used to update filter coefficients which intern minimizes an error of the filter.

II ALGORITHM

A Block Diagram

Filter output will be modified according to algorithm applied to the filter. The algorithm refines the error and gives desired output. Block diagram for LMS algorithm is as shown in Fig2.

Filter input - X

Filter output - Y

Desired output - D

Error - E

Weight - W

W = w(0), w(1)……w(n-1)

n = filter length

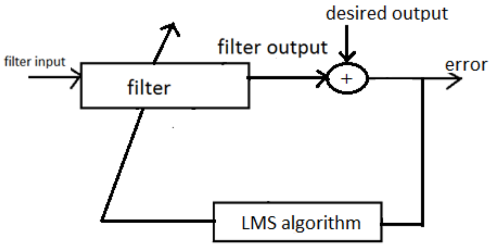

Fig1. Block diagram of adaptive filter with LMS algorithm

Error signal can be given as

E = D – Y

Where Y = X * W

W is weight of the filter, LMS algorithm modifies the values of filter to reduce the error.

$w(n+1) = w(n) + \{\mu . E(n) . X(n)\}$

μ is step size of signal.

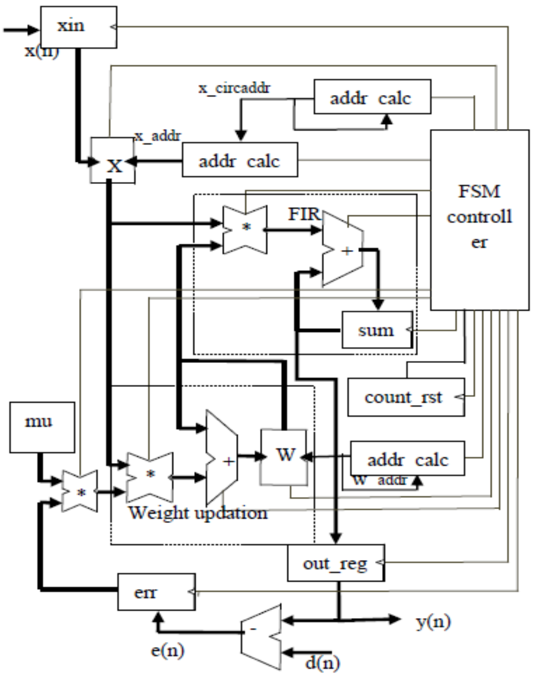

Fig2. Functional diagram of LMS algorithm

Fig 2 shows complete functionality of adaptive algorithm. Data transfer is included some registers. Data is fed to some operation blocks. Adaptive filter coefficient is represented by W. Input buffer is represented by X. Block arrows indicates flow of data. Connection made by line is the control signal. Addition and multiplication operation is shown by + and * respectively.

III IMPLIMENTATION

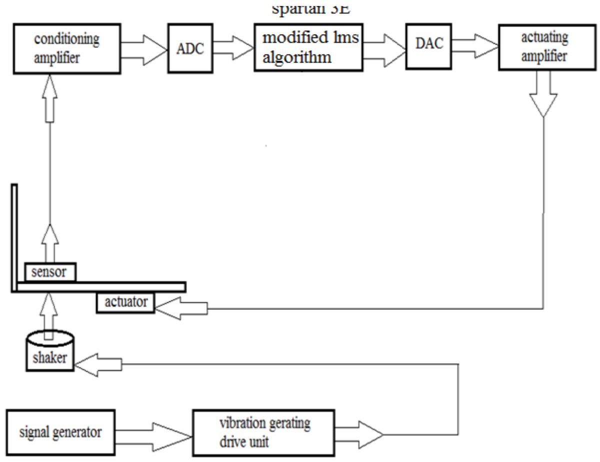

Fig3. Block diagram of AVC system

The designed LMS algorithm is implemented in SPARTAN-3E FPGA board. verilog coding is used for the implementation. The controlling system is shown in Fig3. The signal from FPGA is equal and opposite to that of vibration signal of the specimen. Actuators are used to generate equal and opposite signal. Efficiency of aero structure is improved. Signal generator generates the analog signal. This signal is passed to vibration generator. According to given input analog signal vibration generator generates vibrations. These vibrations drive the mechanism of shaker. Shaker makes specimen to vibrate and actuator controls vibrations. So that whole system works with no vibrations.

IV RESULTS

The output waveforms for ADC and DAC implemented in FPGA board are as shown below figure. While writing the code for ADC the input values of analog signal is specified. So that digital output is obtained. Digital value is expressing by making LEDs to glow. The state of LEDs after interfacing the FPGA board with ADC coding is shown in Fig 4.

DAC coding includes input values in the form of binary number. Given discrete values are converted in to their respective continuous values. So that analog signal is obtained at the DAC header present in spartan 3E board. It can be measured by oscilloscope and is shown in Fig 5.

Fig4. Output Wave Form of ADC

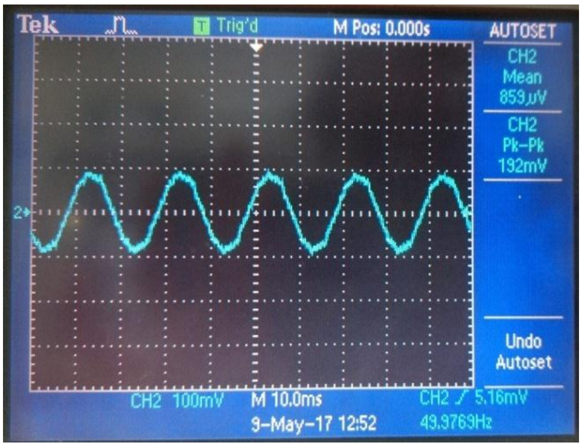

Fig5. Output Wave Form of DAC

V CONCLUSION

The implementation of ADC and DAC is done using verilog coding. The FPGA kit is working very well according to assigned flow of program. So this implementation can be include while designing controlling part for vibrations in aero-structure.

REFERENCES

[1] "Active Control of Aircraft Cabin Noise", D.G, ZIMCIK, Ottawa Institute for Aerospace Research, 2004.
[2] "Passive and Active Designs for Noise and Vibrations Reduction in Aircraft Cabins", MARANT, Paris. 2008.
[3] "Adaptive Filters-Theory and Applications", FARHANG-BOROUJENY, 1998, England Ltd, John Wiley and sons.
[4] "FPGA-Implementation of a Sequential Adaptive Noise Canceller using XILINX System Generator", H.Ezzaidi, M. Bahoura, 2009, Inter Conf on microelectronics – Icm, Marrakech.
[5] "An FPGA Implementation of the LMS Adaptive Filter for Audio Processing", S. Areibi, A. Elhossini, R. Dony,2006.
[6] "A FPGA-Based Adaptive Noise Cancelling System", Bernd Schwarz, 2009.
[7] "Adaptive Filter Theory", fourth edition, S. Haykin, Prentice hall, upper sadle river,2002.
[8] "Signal Processing for Active Control", San Diego, S. J. Elliott, 2001.
[9] "Active noise control systems algorithms and DSP implementations", D. R. Morgan, S. M. Kuo, New York, 1996.