Development of Adaptive Filter using FPGA for Structural Application

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***Abstract*-Active Vibration Control method is using to control vibration in structures upto 500Hz frequency .Vibration can be sensed by PZT sensor .It will send the vibration reading to controlling block.PZT sensor or Piezoelectric sensors measure the electrical potential caused by applying mechanical force to piezoelectric material .A Piezoelectric sensor works on the principle of conversion of energy in mechanical and electrical energy forms .If a Piezoelectric elements rigidly mounted to a flexible structure ,vibration and deformations in the structure are coupled to the attached Piezoelectric transducer .Using the voltage induced in the sensor as an input signal the stress monitored by FPGA(XILINX 3E) controlled using external feedback circuit.M-8528-P1 consist of width 40mm,length 112mm,capacitance 5.70nf .,is an innovative actuators that offers high performance and flexibilities in a cost comparative device .Experiments were conducted on SISO .In this experiment RLS algorithm will suppress vibration upto 500hz frequency by dumping RLS algorithm in FPGA board ,using FPGA controller.**

I. INTRODUCTION

The Active techniques are best suited for vibration control in Aircraft/Aerospace structures where the size, weight, volume and cost are very crucial. Active vibration control can be achieved on typical structures on the basis of principle of super position theorem in which an opposite phase signal is generated using the control software and is superimposed on the structure in order to cancel out or suppress the effect of primary vibrations. But the system characteristics are more dynamic in nature, so adaptive systems are more appropriate and efficient in performance compared to conventional systems with fixed structure. Adaptive systems have the ability to track changes in system parameters with respect to time and provide optimal control over much broader range of conditions .A reference input received / monitored using either accelerometer or smart PZT (lead zirconate titanate) sensor is suitably manipulated in the control filter, and the filter response (which is a spectrum of cancellation force) is applied in an equal and opposite direction using PZT/MFC (Macro Fiber Composite) actuators. The Adaptive control algorithm dynamically updates the filter coefficients based on signal obtained from another set of error sensors. LMS algorithm is best suited for Vibration control because of its simplicity and also various advantages it has over other adaptive algorithms.LMS algorithm is implemented using tapped delay line FIR (finite impulse response) filter structure, and is preferred as it does not require matrix inversion, off-line gradient estimations of data and also for the ease of implementation on finite hardware The implementation of adaptive filter could be done using an ASIC (Application-Specific Integrated Circuit) custom chip, general purpose processor (GPP) or DSP processors. Though ASIC meets all the hard constraints, it lacks the flexibility that exists in the other two, and its design cycle is much longer involving huge expenditure. Reconfigurable systems for prototyping of digital system are very advantageous. Using reconfigurable devices like FPGAs for Digital Signal Processor (DSP) applications provides the flexibility of GPP, DSP processors, and the high performance of dedicated hardware using ASIC technology. Modern FPGAs contain many resources that support DSP applications such as embedded multipliers, multiply accumulate units (MAC), and processor cores. These resources are implemented on the FPGA fabric and optimized for high performance and low power consumption. Also many soft IP cores are available from different vendors that provide a support for the basic blocks in many DSP applications .The FPGAs can embed more and more functionality into a small silicon area without compromising any of the performance parameters like speed and accuracy. FPGAs can be viewed as a structural decomposition of an array of

configurable logic blocks integrated together to form any complex digital systems. The programming procedure and usage is much similar to its predecessors like microprocessor/DSP families but the dynamic-reusability and reconfigurebliity of its own individual hardware elements makes
it most suited for the embedded systems applications. In the recent years FPGA systems are preferred due to their greater flexibility and higher bandwidth, resulting from the parallel architecture. In several application of interference cancellation, with the help of adaptive algorithms the changes in signal characteristics could be rather fast. Because of simplicity in computation and implementation, LMS and NLMS adaptive filters are widely used in signal processing application. The RLS algorithm is the "ultimate" adaptive filtering algorithm since it is exhibiting the best convergence behavior

RLS ALGORITHM

The RLS algorithm is the "ultimate" adaptive filtering algorithm since it is exhibiting the best convergence behavior . A new RLS algorithm is developed by Chansarkar , M.M.Desai & U.B. in 1997; due to persistent and bounded data disruptions to be bounded t his algorithm ensures the annealed bias in the weight vector. An approximate recursive implementation is called as the Robust Recursive Least Squares algorithm. The RLS algorithm is racy with respect to persistent bounded data disruptions. The difference of the adaptive filter and general filter is that the parameters of the adaptive filter could adjust with the characteristics of the input signal to maintain optimal filtering. While how to adjust the parameters is determined by the adaptive algorithm, the behavior of the adaptive algorithm is critical for the filtering performance. As is shown in Figure 1, the adaptive filter is consisted of the filter structure and the weight adjusting algorithm.

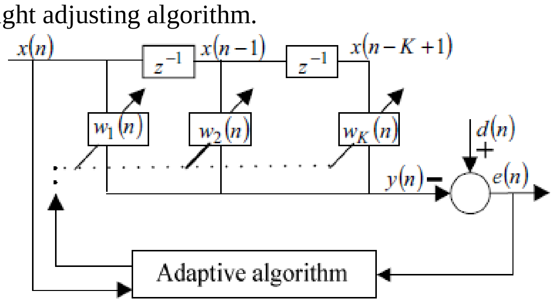

Figure 1. The schematic diagram of adaptive filter

RLS Adaptive Filter Algorithm

Aiming to minimize the sum of the squares of the difference between the desired signal and the filter output, least square (LS) algorithm could use recursive form to solve

least-squares at the moment the latest sampling value is acquired . The filter output and the error function of RLS algorithm is

$y(n) = w^T(n)x(n)$

$e(n) = d(n) - y(n)$ (1)

The weighting update equation is

$w(n) = w(n-1) + \xi(n)[d(n) - w^T(n)x(n)]$ (2)

Here $\xi(n)$ is the gain coefficient.
According to equation 1and 2, we can get
$w(n) = w(n-1) + \xi(n)e(n)$

Control Algorithm for Structural Application

To verify the performance of RLS algorithm in smart structure, an cantilever epoxy beam with surface bonded PZT sensors and actuators is taken as the controlled experimental object. The bonded sensors are used to detect the vibration response of the flexible beam, while the sensor signals is transmitted to the controller, the output of the controller is imposed on the PZT actuators, as is shown in Figure 2.

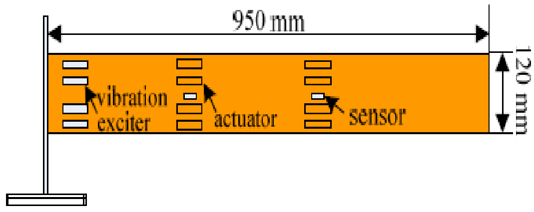

Figure 2. Schematic diagram of experiment object

The adaptive filter algorithm for active vibration control aims to cancel the vibration response of the controlled object caused by external disturbance. According to the vibration signal picked by the error sensors, the adaptive controller outputs certain control signal to the actuators to cancel the vibration response of the controlled structure.

Block Daigram Of Experiment

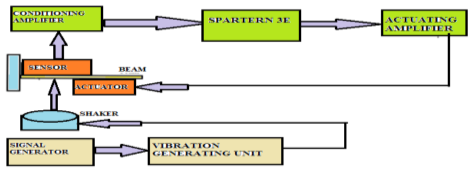

Fig 3:block diagram of single channel AVC

The above fig 3 shows that daigram for experimental set up for single channel AVC. Vibration control is essential for high accuaracy visual inspection, comfort, acoustics. Active

vibration control makes it possible to achive better performances in areas where passive methods haveexhiited some limits.In fig 3 the beam is excited by using a shaker driven/excited with band limited random signal.

MAJOR COMPONENTS OF SETUP

1.SENSOR:It is bonded to to the host strcture(beam).It is generally made up of piezoelectric crystals.It senses the disturbance of beam and generates a charge which is directly propotional to the strain.Direct piezoelectric is used .

2.CONTROLLER:The error signal produced by the sensor is fed to the controller.By using an adaptive algorithm,the controller produces the control signal .This control signal is fed to the actuators,which helps to reduce the vibrations

3.ACTUATOR :The lined up charge from the controller causes pinching action along the surface of the host which act as a damping force and helps in the alternating vibration motion of the beam.Converse piezoelectric is used.

Active vibration control finds its aplication in all the modern day machines, Engineering structures, auyo mobiles, gadgets, sports equipments, ceracics, electronics etc.As the electronics is also developing at a very fast rate size of a processor is alsso reducing,which is very fast rate the size ofprocessor is also reducing ,which is very useful in the design of the control system.

Control Design Objective:

The control design objective is to design controller to suppress the induced vibration of the flexible beam in the presence of distrurbance,such as sensor noise and uncertenity,such as changing mass or stiffness,by using the PZT actuator and the PZT sensor.The PZT sensor will sense the vibration of the beam, and PZT actuator will generate control action to countreact the beam vibration .The active vibration control achived by introducing secondary forces to cancel the effects of undesired primary vibration sources.The secondary forces driven such that the superposition of primary vibration sources.The secondary forces and driven such that superposition of primary and secondary fields distructively interface with each other .Thus in AVC ,vibration in the structures are suppressed or cancelled by using the principle of linear superposition theory.i,e.the secondary actuation signal is sent in an equal and opposite phases to primary ,so as to nullify or suppress the error.The secondary actuation signal will be generate through RLS Adaptive algorithm ,which act as main ontroller in the set up,RLS algorithm is dumped in xilinx controller or spartern 3e.Hence the implementation of RLS Adaptive algorithm playes an important role in this dissertion.

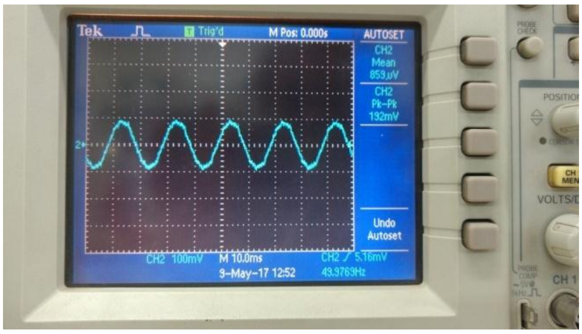

Fig 3:output of DAC and ADC in CRO

Fig4:output ADC and DAC code in SPARTAN 3E

CONCLUSION

The algorithm doveloped for ADC and DAC are succesfully implemented on spartan 3E.This DAC and ADC algorithm can be easily used adapted for AVC on structural aplications.

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