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Implementation of embedded shock and vibration monitoring system for underwater vehicles

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Abstract: Embedded Shock and Vibration monitoring system is considered to be the most effective method for analyzing the performance of the underwater vehicle and also for early fault detection. Shocks and vibrations of underwater vehicles cause the systems sometimes malfunction, faulty and sometimes fail. To avoid the failure of the systems the shocks and vibrations of the vehicle is to be evaluated and controlled. For monitoring these parameters a sophisticated monitoring system is required. The main aim of this work is Development and Testing of an embedded FPGA based 3-axis simultaneous shock and vibration system for monitoring of shocks and vibrations in the underwater vehicle. The shock and vibration monitoring system consists of piezoelectric accelerometers which perform well over the wide range of temperature and resists damage due to severe shocks and vibrations to acquire the vibration signals. This project proposes a data acquisition system to monitor and analyze the shock and vibration data along the three axes (horizontal, vertical, axial).During the real time mode the system can be used to monitor either shock or vibration signals from accelerometer representing the shock or vibration data along the three axes is recorded and stores in the NAND flash memories. During the offline mode, data will be retrieved to PC through USB. Retrieved data will be processed and plots will be created using MATLAB.

Keywords: NAND FLASH memory, FRAM memory.

I. INTRODUCTION

Vibration is the oscillating motion of a machine or machine component from its rest position [1-4]. When there is a change in direction with time, change in amplitude or intensity with time etc., forces are generated within the machine cause vibrations. Even machines in the best operating condition will have a level of vibration that may be regarded as normal or inherent. Whereas shock is a sudden acceleration or deceleration caused, for example, by impact, drop, kick, earthquake, or explosion. Shock is a transient physical excitation. When these shocks or vibrations increases beyond the maximum levels machinery faults occurs which are looseness, unbalance of rotating components, misalignments, resonance etc. Due to these faults the system becomes faulty and sometimes fails [5,6]. Early fault detection of machinery in the process industry is an important in order to avoid unexpected failures and to ensure high performance. Shock and vibration analysis is the most popular technique because almost 100% of the machinery failures are related to a change in the dynamics this is due to structural oscillations from the original behavior and show their presence as undesired harmonic components. To analyze the current condition of a machine the vibration signals along the three axes is to be acquired and stored for that an embedded shock and vibration monitoring system is developed using sensors and Nonvolatile memories. Shock and vibration monitoring system is the signal acquisition and processing unit of the vibration signals. Data acquisition is the process by which physical phenomenon from the real world are transformed into electrical signals that are measured and converted into a digital form for processing, analysis and storage by computer. Transducers and sensors provide the actual interface between the real world and data acquisition by converting physical phenomena into electrical signals that the signal conditioning or data acquisition hardware can accept.

Electrical signals generated by transducers often need to be converted to a form acceptable to the data acquisition hardware, particularly the A/D converter which converts an analog signal data to the required digital format. The various tasks performed by the signal conditioning are filtering, amplification, isolation. The signals acquired by the piezoelectric accelerometers which has got the frequency of 40 KHz and can perform well over the wide range of frequencies to resist the damage due to severe shocks and vibrations. Its output given to the analog to digital converter ADS 1606 which is high speed, high precision 16-bit delta sigma modulator. The micro blaze processor gives the control signals to perform all operations. FRAM acquires the ADC data and writes into the dual port block memory. The micro-blaze processor reads this data and send to NAND FLASH memory. FRAM also stores the counters like block numbers, page numbers. The stored vibration data can be downloaded from memories through USB 2.0 via GUI interface for further analysis in MATLAB. The shock and vibration monitoring systems are broadly utilized in any machine equipment to analyze the vibration levels for early fault detection. They can be used to collect the required data from any peripheral input devices, such as transducers, sensors and other sub systems. The measured data must be recorded in memory for further analysis of data. Currently

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FPGAs are emerged as one of the major technology which is being used for data acquisition and processing. FPGAs offer a very effective solution to microprocessor based data acquisition systems due to parallel execution, reconfigurable and no separate glue logic. Higher speeds can be achieved by FPGA.

II. LITERATURE SURVEY

L.M.Contreras-medina and RJ.Romero-troncoso [1,2] proposed an FPGA based multiple channel vibration analyzer embedded system for industrial applications. Several monitoring techniques for machinery failure detection have been developed, being vibration analysis one of the most important techniques. The typical equipment used for vibration analyses is a general purpose single channel spectrum analyzer that most of the cases is not well suited for the specific task and lacks from the capability of simultaneous multiple-channel analysis. In this paper the author presents the development of a special purpose vibration analyzer with multiple access capabilities, implemented into a single low cost FPGA, therefore, it can be used industrial applications as preventive maintenance that with the Soc approach results in an embedded system. The novelty of the development is also the consequent use of the reconfigurable capabilities of the FPGA for the implementation of special purpose processing algorithms in order to automatically detect failures in mechanical systems. The author presented two cases of study, broken bar and unbalance phenomena in induction motors where a special purpose post processing algorithm is implemented to diagnose the motor condition. Due to reconfigurability, the three-axes vibration analyzer can be modified in the post processing stage to be adapted to the detection of other vibration-related mechanical failures. The overall system can be viewed as a general purpose three axes spectrum analyzer with an open architecture for the design and implementation of post-processing units for automatic on-line parameter detection. Khurram shahzad, peng cheng [3,4] proposed different architectures in order to realize a high performance and low-power wireless vibration analyzer. The paper Architecture exploration for a high-performance and low power wireless vibration analyzer introduces four different architectures which are evaluated in terms of performance and energy consumption. Each architecture has two common modules, the sensing sub system and the radio transceiver.

The sensing subsystem is used to measure the actual vibration data and the radio transceiver is used to transmit the results of vibration data processing [6-8]. To select a processing unit for a high performance and low power vibration analyzer, the choice could either be a micro-controller, an FPGA, or a DSP. It is highly probable that a micro controller based architecture will result in a simple design, low power and low cost and thus should be included for evaluation. An FPGA based architecture is able to achieve a high performance due to hardware parallelism, and thus it is likely to result in low-energy consumption. Additionally an FPGA provides significant flexibility so as to optimize an algorithm for performance and power consumption. Therefore, for high sampling rate tri-axes vibration data processing, FPGA based architecture should be evaluated.

III. VIBRATION MONITORING SYSTEM

The description of the system study is given in this section Shock and vibration monitoring system is the signal acquisition and processing unit of the vibration signals. Shock and vibration detection and measurement plays an important role in the development and testing of new or prototype machines. Shock and vibration measurements provide overall performance data. All electrical machines generate noise and vibration, and the analysis of produced noise and vibration can be used to give information on the condition of the machine. Even very small amplitude of machine frame can produce high noise may lead to faults and failures. To detect those faults prior to failure shock and vibration monitoring system is developed.

The overall system of an embedded shock and vibration monitoring system is shown in figure 1.

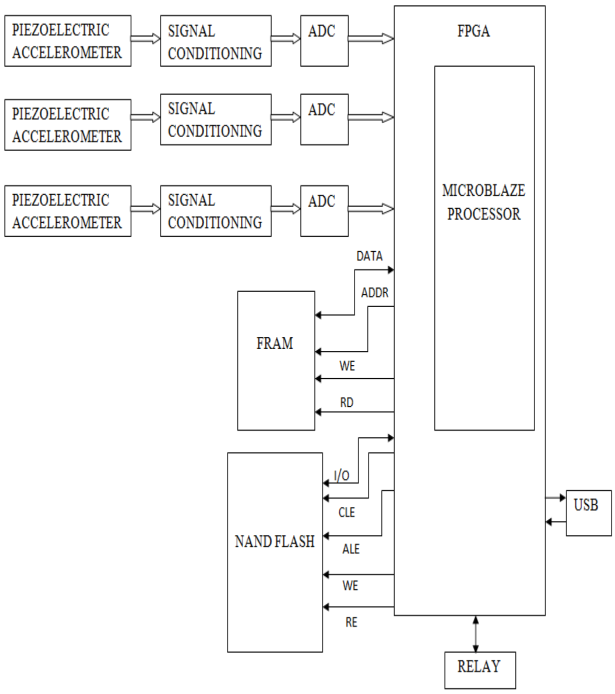

Fig.1: Block diagram of embedded vibration monitoring system

The embedded shock and vibration monitoring system is the signal acquisition and processing unit of the shock and vibration signals in three axis (X, Y, Z).It is a data acquisition & signal processing system with signal coming from a vibration sensors, processed by a software-hardware co-designed system based on Xilinx FPGA, ADCs and NAND Flash devices. The shock and vibration monitoring system consists of a dedicated sensing subsystem hardware module to acquire the shock or vibration data along the three axes. To use digital signal processing techniques the analog signal must be converted into digital representation for that the electrical signals coming from accelerometers is fed to the analog to digital converters. The digital data from ADCs is to be stored in the FRAM memory and again sends it to NAND flash

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Vol. 3, Issue 12, December 2014

memory in real time via GUI interface and also the F-RAM memory are used to store the counters like resets, block numbers and page numbers. FPGA implements the fixed modules while the Micro blaze (32-bit, 75MHz) processor implements the control logic in C.FPGA JTAG interface is used for In System Programmability and USB interface for GUI interfacing on the bench for programming To access the GUI the three way toggle switch is used to set the system into different modes. The shock and vibration monitoring system operates in three modes.

a) Application mode: During application mode the shock or vibration data is collected i.e., to be written into the NAND flash from the sensors and the counters in the FRAM are updated.

b) Monitoring mode: During monitoring mode the recorded data is downloaded from the NAND flash via GUI interface. By configuring the UART start block and end block are set there by the blocks of data can be downloaded from the NAND flash memory.

c) Pause mode: During pause mode there is a feasibility to pause the recording data and again we can start recording.

The communication interface between the UART of the microprocessor and the Host PC is performed by the USB RS232. The USB interface is used only for clearing memories before the trial and data uploading after trials. The downloaded data from the NAND flash which is in binary format is to be converted into readable form then the four channel data(count, X,Y,Z) is obtained for further analysis in MATLAB. By analyzing the spectrums of vibration X,Y,Z the current condition of a machine can be evaluated and can also detect the faults prior to the failure of the machine

IV. RESULTS

The results pertaining to shock and vibration testing are presented in this section. A signal of frequency 10 KHz and 2V peak-peak amplitude is generated and given as input to the system. This data is stored in the NAND flash. The downloaded data is in the form of

Count X	Y Z		
0.098304	0.000000	-0.011536	-4.05125
0.098312	-0.008331	-0.008011	-4.589905
0.098320	-0.007050	-0.004807	-4.053177
0.098328	-0.006409	-0.006409	-2.575333
0.098336	-0.006409	-0.008331	-0.508850
0.098344	-0.010254	-0.009613	1.628128
0.098352	-0.007370	-0.006409	3.305923
0.098360	-0.008652	-0.004486	4.108612
0.098368	-0.008652	-0.007370	3.840088
0.098376	-0.007050	-0.015381	2.567322
0.098384	-0.008652	-0.008972	0.601456
0.098392	-0.009293	-0.005127	-1.570129
0.098400	-0.006729	-0.003845	-3.407501
0.098408	-0.005768	-0.010574	-4.452438
0.098416	-0.009933	-0.013779	-4.457245
0.098424	-0.008972	-0.005768	-3.412949
0.098432	-0.008011	0.000000	-1.584869
0.098440	-0.007050	-0.007370	0.586716
0.098448	-0.008011	-0.013779	2.555145
0.098456	-0.006088	-0.008331	3.835281
0.098464	-0.007370	-0.001282	4.108292
0.098472	-0.009613	-0.006088	3.312973
0.098480	-0.008652	-0.010574	1.645752
0.098488	-0.006088	-0.009293	-0.489944
0.098496	-0.009293	-0.007690	-2.562836
0.098504	-0.010895	-0.006409	-4.052856
0.098512	-0.006409	-0.007370	-4.588623
0.098520	-0.007050	-0.007370	-4.050613
0.098528	-0.008972	-0.006409	-2.574692
0.098536	-0.011215	-0.006088	-0.510452
0.098544	-0.007050	-0.009933	1.631012
0.098552	-0.005768	-0.009933	3.306244
0.098560	-0.010574	-0.007050	4.103806
0.098568	-0.007370	-0.007370	3.838486
0.098576	-0.005447	-0.012497	2.568283

Fig 2: Downloaded data

The vibration spectrums for test input signal are given in the Fig.3 through Fig.5.

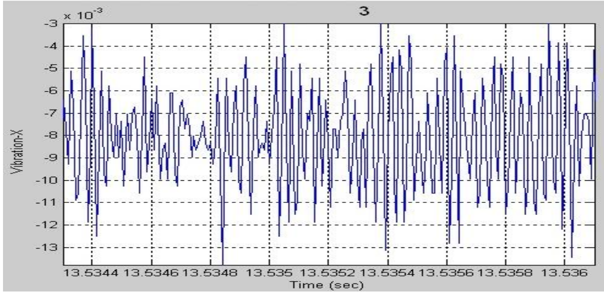

Fig 3: Vibration spectrum along X-axis

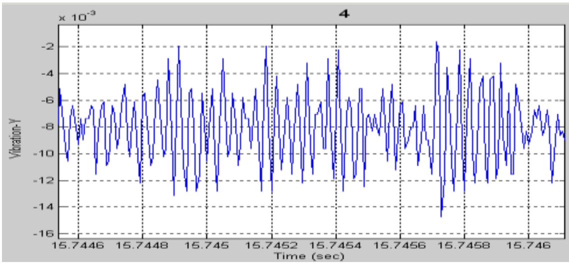

Fig 4: Vibration spectrum along Y-axis

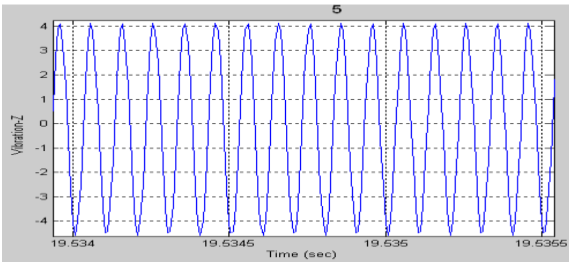

Fig 5: Vibration spectrum along Z-axis.

The results pertaining to vibration spectrums for controller signal are given here. From the controller a signal is generated. Based on this signal vibrations are produced and stored in the system. The Results for downloaded data along different axis are given in Fig.6 through Fig. 9.

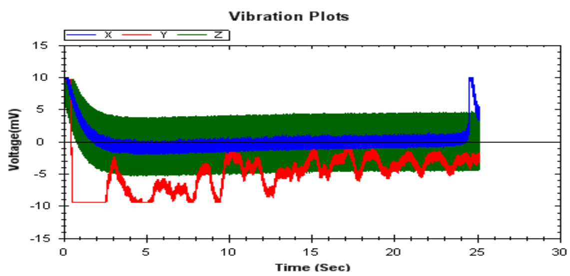

Fig 5: Vibration spectrum along three axes (X-axis, Y-axis, Z-axis)

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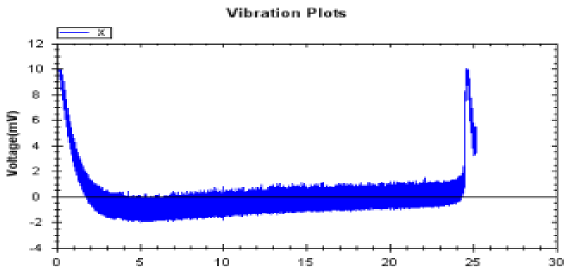

Fig 6 : Vibration spectrum along X-axis

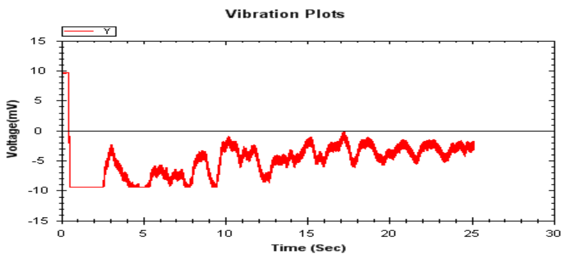

Fig 7: Vibration spectrum along Y-axis

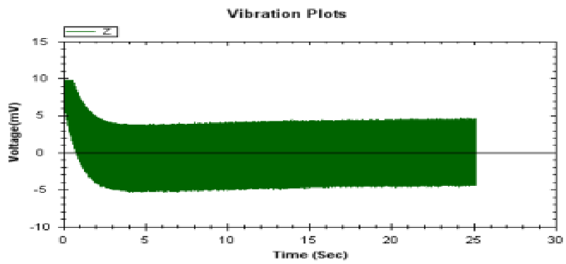

Fig 8: Vibration spectrum along Z-axis

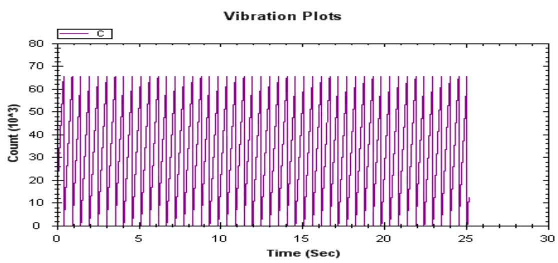

Fig 9 : Spectrum of count

Results pertaining to shock spectrum for test input signal are as given in Fig.10.

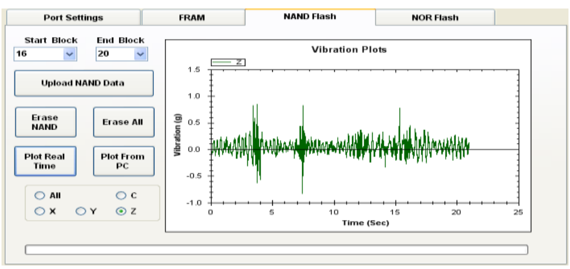

Fig 10 : Shock spectrum along Z-axis

V. Conclusion

An Embedded Vibration Monitoring system can be used in any machine equipments to evaluate the condition of the machine. In order to acquire the vibration data along the three axes for evaluating current condition of the machine an Embedded Vibration Monitoring System is developed and tested using Piezoelectric sensor Module based on Microblaze processor that communicate via USB. The host PC collects the data and performs signal analysis under MATLAB environment.

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