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Electronic Module of Hydraulic Damper Test Bench using ARM Microcontroller Interfacing in LabVIEW

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ABSTRACT - The paper presents the universal electronic module based on System on Chip (SOC) architecture. It is related to the Industrial Control System(ICS) dealing with the software and hardware design of chip along with its implementation in hydraulic damper test benches .It mainly focuses on the use of a 32-bit RISC micro-controller to test the new or repaired pumps or valves with the help of virtual instrument technology software. The paper also contains the proposed results and observations made for test bench in LabVIEW with the help of PID algorithm. Thus, the paper basically emphasizes on the use of different hardware and software components used in chip making and interfacing with a number of required peripherals.

Index Terms— Hydraulic damper test bench, Industrial control system, LabVIEW, SOC, Microcontroller, PID algorithm, PWM

1 INTRODUCTION

An Industrial Control System consists of various control systems used in industrial production, including supervisory control and data acquition (SCADA) system, distributed control system (DCS) and programmable logic controllers (PLC). This system requires continuous monitoring and control of many parameters. An effective industrial control system can be made by use of digital control system from which we gain the advantages of implementation of complex functions, reliability in implementation, cost effective, accuracy [1]. It consists of digital controller, ADC and DAC. Digital control system with analog counterpart makes the system more flexible.

This paper basically deals with the two main aspects : mechanical and electronic. In mechanical system, hydraulic system is restored to functionality:

– Replace the system's oil and filter.
– Design blocking and flushing plates for the servo valve.
– Flush the system with the new oil to filter out old oil and debris.
– Eliminate any oil leaks in the system.

In electronics system, hydraulic system is restored to functionality: -Control cylinder position and motion.

– Read values from the rig's sensors

– Be expandable so that additional sensor readings can be added.

Hydraulic damper test bench is used to test the new or repaired pumps or valves .The testing of hydraulic damper and its components can be made on electronic module used for industrial control based on SoC (System on Chip) architecture. The hydraulic damper test bench using mechanical systems only has been obsolete. It is time taking, not very precise and cost inefficient. The electronic module for test bench using SoC architecture has already been proposed using 16-bit microcontroller [2].

However, this paper proposes for the implementation of a 32-bit RISC(Reduced Instruction Set Computer) microcontroller interfaced with hydraulic damper in virtual instrument software known as LabVIEW(Laboratory Virtual Instrument Engineering Workbench)[3].The use of digital control system on the chip microcontroller is the miniaturized form and also enhances the control system that integrate microcontroller processing, input sensor feeding, signal conditioning, peripherals like LCD, keyboards interfacing and outputs. Such control system requires hardware design and software development(C or assembly language). This paper basically presents the design of control system using LM3S8962, a 32 bit RISC microcontroller with the modification that can be easily adapted to the specific issue of industrial process.

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2 HARDWARE DESIGN

The hydraulic damper test bench was used to be based on mechanical systems only a few years ago. The main components of this system are servo amplifier, servo valve, hydraulic cylinder, load, position transducer.

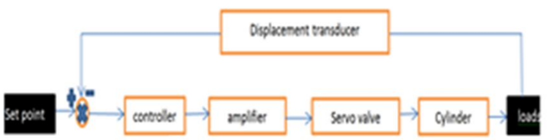

Fig 1. Block Diagram of Mechanical Damper System

According to the structure of position control system of hydraulic system efforts were done to create this mechatronic system of hydraulic damper test bench with the better performance that make use of digital control system on the chip microcontroller.

Digital controller of this system is LM3S8962, a 32 bit RISC microcontroller and the electronic module was developed with this. Module consists of 6 onboard relays, 8 analog inputs, 4 analog outputs,8 digital lines as input or output, keyboard interface, LCD interface, 4 open drain output, LVDT(Linear Variable Differential Transformer), PWM(Pulse Width Modulation) output for servo valve, RS485 interface[1],[5].

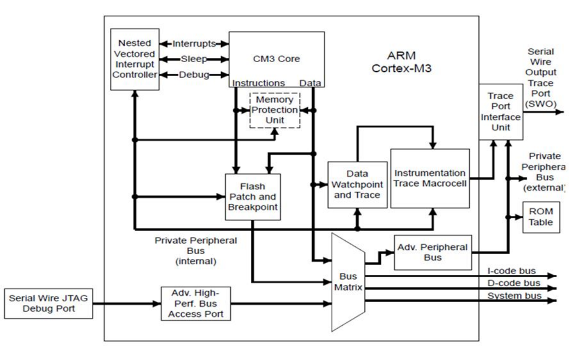

Fig 2.Block Diagram of ARM Cortex M-3 Processor Core

The Luminary Micro Stellaris® family of microcontrollers—the first ARM® Cortex™-M3 based controllers—brings high-performance 32-bit computing to cost-sensitive embedded microcontroller applications. These pioneering parts deliver customers 32-bit performance at a cost equivalent to legacy 8- and 16-bit devices, all in a package with a small footprint. Additionally, the microcontroller uses ARM's Thumb®-compatible Thumb-2 instruction set to reduce memory requirements and, thereby, cost. Finally, the LM3S8962 microcontroller is code-compatible to all members of the extensive Stellaris® family; providing flexibility to fit our customers' precise needs.

Features include compact core, Thumb-2 instruction set, delivering the high-performance expected of an ARM core in the memorysize usually associated with 8- and 16-bit devices, rapid application execution through Harvard architecture characterized by separate buses for instruction and data, exceptional interrupt handling, by implementing the register manipulations required for handling an interrupt in hardware, deterministic, memory protection unit (MPU) to provide a privileged mode of operation for complex applications, migration from the ARM7™ processor family for better performance and power efficiency.

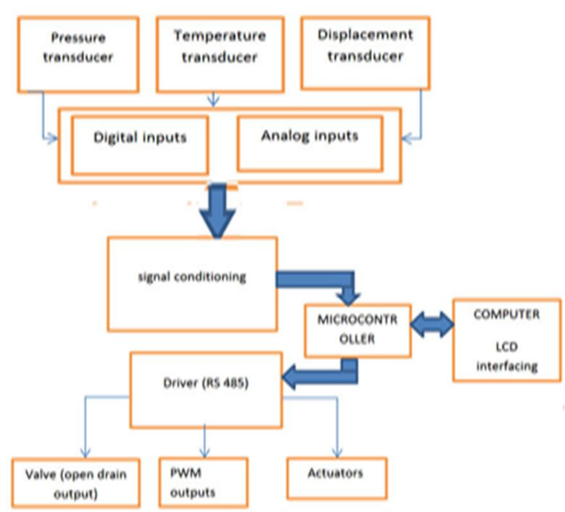

Fig 3. Electronic Module for Hydralic Damper Test Bench using SOC

Interface for inductive displacement transducer LVDT (Linear Variable Differential Transformer) sensor for measuring physical parameter such as pressure, force, displacement. LVDT signal conditioning requires pulse width modulation system, analog to digital converter (ADC), timer, processing power. Excitation frequency range 1-10KHz and the signal is read in digital inputs. RS485 is used for signal communication, twisted cable, differential signal, transmission speed of 35Mbit/s up to 10 m and 100 Kbit/s up to 1200 m between drivers and receivers. Low pin count drivers bring RS485 to active state. PWM output for servo valve, ARM have ADC but do not have DAC, thus PWM output is the closet solution. ARM produces PWM output with the use of various timer and comparator. Connection between actuators (servo valve, dc motor) and output pin is done with the electronic circuit called motor controller or H-bridge to prevent the blow off microcontroller. Driver circuitry uses MOSFETs; PWM frequency should never exceed the switching speed of MOSFET. Timer (also called as counter) as inbuilt microcontroller peripheral, used to generate accurately time pulse PWM signals. ARM have 8-bit and 16-bit timer. Timer to be used is governed by bit accuracy, mode of operation (fast PWM, phase correct PWM, phase and frequency correct PWM) that varies with actuator, output mode.

3 SOFTWARE DESIGN

The LabVIEW Embedded Module for ARM Microcontrollers is a comprehensive graphical development environment for embedded design [8]. This module builds on NI LabVIEW Embedded technology, which facilitates dataflow graphical programming for embedded systems and includes hundreds of analysis and signal processing functions, integrated I/O, and an interactive debugging interface.

The Embedded Module for ARM Microcontrollers has the following requirements:

- A computer with Windows Vista/XP/2000
- RealView Microcontroller Development Kit including Keil µVision3
- LabVIEW 8.6 with embedded support
- Keil ULINK2 USB-JTAG adaptor

To install LM3S8962 evaluation board with JTAG emulation, we need

- LM3S8962 evaluation board
- An IBM-compatible PC with two unused USB ports: one to supply power to the board and the other to perform ULINK2 USB-JTAG downloading and debugging
- ULINK2 USB-JTAG adaptor (included)
- Two USB serial cables, each no longer than 10 feet (included)

The main steps included in Build, Run and Debug of ARM application are:

1) Creating Front Panel

Fig 4. Selecting labels

2) Creating block diagram

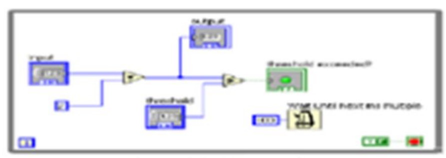

Fig 5.Creating Block Diagram

3) Building and running application: For faster development of embedded module, a JTAG connector was placed on board. This offers In Circuit Emulation and Programming, as well as advanced debugging techniques like step by step execution, register watch, multiple hardware and conditioned breakpoints.

4 PID CONTROL ALGORITHM

PID (proportional integrative derivative) algorithm is the most common algorithm used in industry.

PID controller determines the output value basically as valve position. It applies the controller output value to the system which in turn drives the process variable towards the set-point value [6],[9].

PID controller compares PV (process variable) to that of SV (set-point value) to get e (error).

$$e = SV - PV$$

Then PID controller calculates the controller action u(t), where Kc is controller gain.

$$u(t) = K_c\left\{ e + 1/T_i\left(\int_0^t e\cdot dt\right) + (T_d \cdot de/dt) \right\}$$

If the error and controller output have same range,-100% to 100%, controller gain is the reciprocal of proportional band. Ti is the integral time in minutes, called reset time and Td is the derivative time, called rate time.

For proportional action, the required formula is: $u_p(t) = K$

For integral action, the required formula is: $u_i(t) = K_c\left(\int_0^t e\cdot dt\right)/T_i$

For derivative action, the required formula is: $u_d(t) = K_c(de/dt)\cdot T_d$

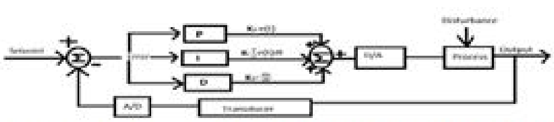

Fig 6.Electronic module of Digital Control Sytem using PID Algorithm

Test for integrated electronic module for mechatronic systems are performed on a hydraulic damper test bench that contains pump unit, linear actuator (hydraulic cylinder) with attached displacement and force transducer. This test is done with the help of PID algorithm in LabVIEW [4],[7].

5 SIMULATION AND RESULT

The DAQ (data acquisition system) with the closed loop makes PID algorithm productive. So, we can use the advanced-level DAQ VIs(Virtual Instrument) to configure the analog input and output only once instead of on each loop iteration.

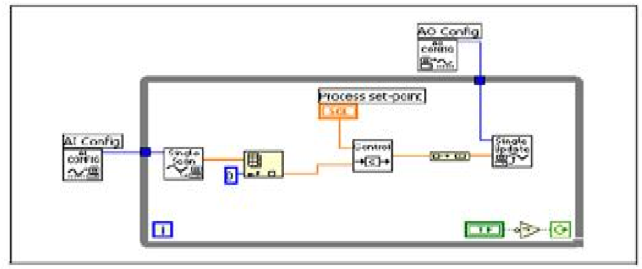

Fig 7.Process set-point

The simulation of damper test bench using ARM920T microcontroller is a proposed one [9].One of its basic testing known as water level testing is performed as below.

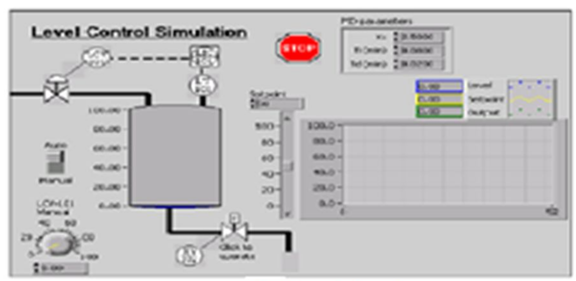

Fig 8.Front Panel of tank level

The Tank Level VI uses an integrating process with added noise, valve, dead band, lag, and dead time. The cycle time is fixed at 0.5 s.

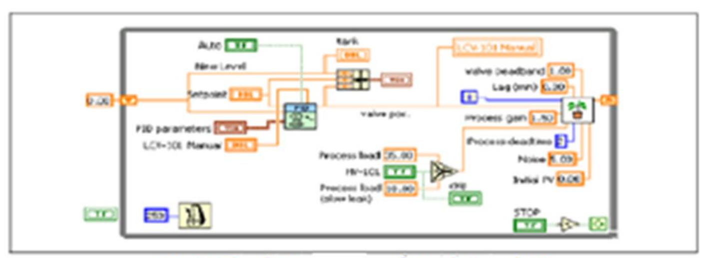

Fig 9.Block Diagram of Tank Level VI

6 CONCLUSION

The simulations and results shows that the LM3S8962 microcontroller based electronic module for the industrial control system is capable of performing in a more effective way with lower cost, high accuracy, saving in chip complexity and area, lower power consumption. The LM3S8962 microcontroller offers the advantages of ARM's widely available development tools, System-on-Chip (SoC)

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infrastructure IP applications, and a large user community. This module requires hardware design (electronic schematics) and software development. It is implemented with PID algorithm that provides auto tuning. The work of PID controllers varies from reading sensor to computing the desired output. Integration of all this make the module very flexible and suitable to be implemented in hydraulic application (hydraulic damper test bench).

7 REFERENCES

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