PNEUMATIC POSITIONING IN PRACTICE

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ABSTRACT

In recent years considerable investigation has been devoted to the pneumatic positioning. Several methods are applied to control these positioning systems. Due to the fact that DSP owns the advantage of low cost, high speed and calculation performance, it has been widely applied. The main contribution of this paper is a design of a robust sliding mode controller implemented on DSP system. The effectiveness of the proposed control schemes is demonstrated by some simulated and experimental results.
Keywords: Sliding mode control, DSP, chattering, pneumatic system.

1. INTRODUCTION

Increased industrial demands on quality and performance over a wide range of operating regions have led to a significant interest in the area of pneumatic linear actuators and motion control systems that combine high speed with high accuracy, repeatability, and reliability. The goal of this project is to create a flexible laboratory test stand capable to perform in various hardware configurations all necessary tests and measurements included our research program.

The following requirements for the system have been met:

- the system should be built basing on industry equipment,
- the system should fulfil all requirements imposed by the research program,
- the system should be universal and easy to use,
- except testing of the pneumatic positioning system, the system should be used as a laboratory subject for students.

Changing loads, contaminated air supplies, cylinder orientation, long strokes, bore sizes, and cylinder sticktion are just a few of the challenges that have contributed to the negativity associated with servopneumatics.

Because on control difficulties, caused by the high nonlinearity of pneumatic systems, a robust control method must be applied. There are two main classical directions in the field of robust control. One is the H infinite control for linear systems, and the other is the sliding mode control for nonlinear systems. Another solution is to employ the advanced nonlinear control strategies developed in recent years (soft computing) [10][11].

The variable structure control with sliding mode strategy was first proposed by a group of Soviet scientists [1][2] in 1950's. It has been proven as an effective and robust control methodology and applied in many practical applications [3]. Sliding mode control (SMC) has been traditionally recognized as a high gain control technique with outstanding robustness features for both stabilization and tracking problems. Some of the experimental work indicated that sliding mode has limitations in practice, due to the need for a high sampling frequency to reduce the high-frequency oscillation phenomenon about the sliding mode manifold - collectively referred to as „chattering". A great deal of energy was invested in empirical techniques to reduce chattering.

2. DESCRIPTION OF THE TEST SYSTEM

The test equipment

The system is shown in Fig.1. (details can be found in [9]). It consists of a double-acting pneumatic rodless cylinder (MECMAN 170 type) with bore of 32 mm, and a stroke of 500 mm, controlled by a five-way servo- distributor (FESTO MPYE-5-1/8 HF-010B tip.). A linear encoder (LINIMIK MSA 320 tip.) gives the position. Velocity and acceleration are obtained by numerical derivation. Pressure sensors (Motorola MPX5999D) are set in each chamber. Because on control difficulties caused by the high nonlinearity of pneumatic systems a nonlinear control method must be applied. So we will deal with robust control and a DSP based sliding mode control was designed. The block diagram of the system is shown in Fig. 2.

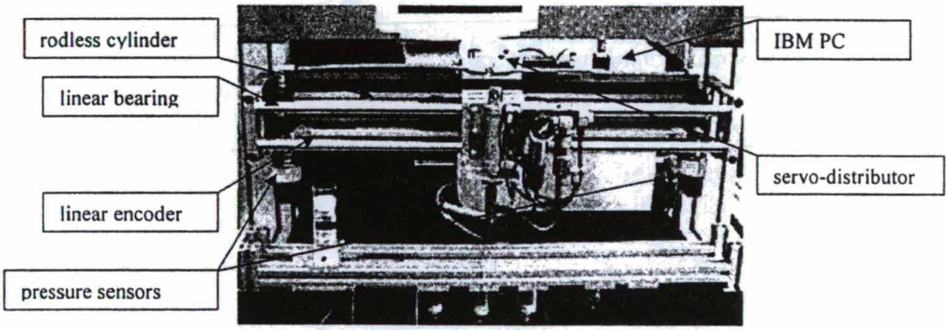

Fig. 1. The test equipment

The control system

DSPs are designed for signal processing and have hardware optimizations which are directly applicable to digital control. Some of these desirable features are short instruction cycle duration, pipelining to achieve one instruction per cycle, and one cycle hardware multipliers. With integration increasing and die sizes dropping, peripherals such as encoder interfaces, PWM generators, multiple synchronous A/Ds, and more are available on the same chip with the DSP. Other functions associated with high-end applications (and expense), such as real-time interpolated sinusoidal encoders, resolvers, and other transducers, can be done in software. This can mean that low-cost encoders/transducers may be used to produce very high resolutions.

Several DSP based controllers have been proposed within the last several years [1][2][5].

In our investigation we have used the „eZdspTM for TMS320LF2407" DSP target board from Spectrum Digital. The control goal is to move the piston from any initial position to the target position. Using the sliding approach it is possible to minimize the positioning errors. A simplified functional block diagram of the control module is shown in Fig. 3.

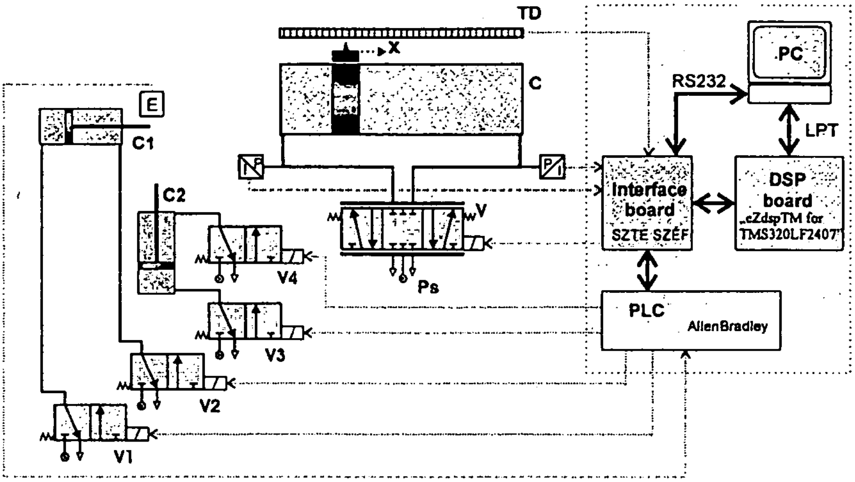

Fig. 2. The block diagram of the system

The TMS320LF2407 devices use an advanced Harvard architecture that maximizes processing power by maintaining two separate memory bus structures — program and data — for full-speed execution. This multiple bus structure allows data and instructions to be read simultaneously. Instructions support data transfers between program memory and data memory. This architecture permits coefficients that are stored in program memory to be read in RAM, thereby eliminating the need for a separate coefficient ROM. This coupled with a four-deep pipeline, allows the LF2407 devices to execute most instructions in a single cycle. See the functional block diagram of the 2407 DSP CPU for more information in Fig. 3.

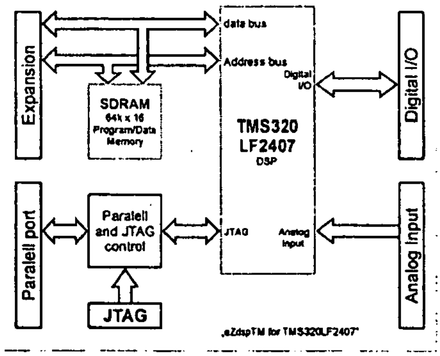

Fig. 3. Functional block diagram of the 2407 DSP CPU

Hardware Features

- TMS320LF2407 Digital Signal Processor operating at 40 Mhz from Texas Instruments
- Communications to host PC via parallel port for debug and communications
- 64K words of zero wait state memory (32K program, 32K data)
- Embedded IEEE 1149.1 JTAG scan controller
- Expansion connectors for custom user logic (data, address, I/O)
- Compatible with eZdsp wire wrap prototype card
- Compatible with DMC Motor Controllers

Software Features

- Compatible with "C2000 Code Composer" from Texas Instruments
- Compatible with SDFlash programming utility from Spectrum Digital

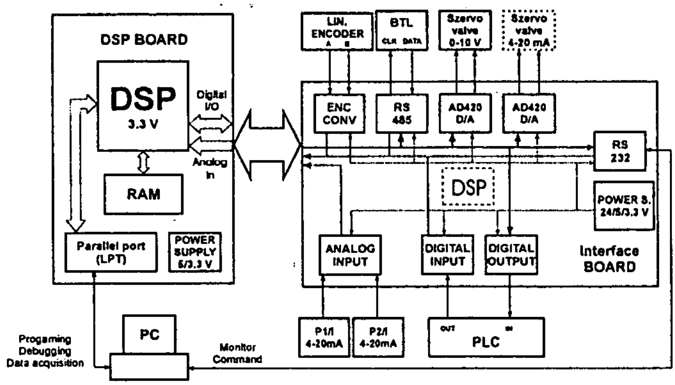

Fig. 4. „eZdspTM for TMS320LF2407" DSP target board and Interface board

In order to analyze the positioning methods a real-time data acquisition program was designed for a PC to capture the system output data through the communication interface between the PC and the DSP controller. The control program is in the DSP program memory. So the DSP controller can operate independently. In our experiments, we use D/A channel for control and incremental encoder channel for position measurements.

For flexibility, the design includes an extra interface board to fit I/O ports, to support both of the two main types of position encoder and providing two analog outputs for the servo-valves and serial communications link to a host computer (Fig. 4.). In this application, the second board can be plugged. The two boards contain a DSP controller TMS320LF240 and its oscillator, a JTAG and an RS232 link and the necessary inputs and outputs.

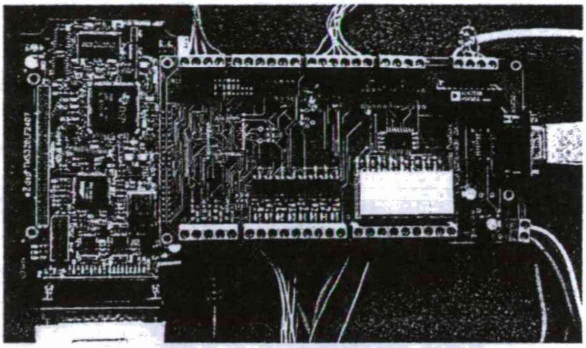

Fig. 5. Top View of „eZdspTM for TMS320LF2407"
DSP target board and Interface board

Fig. 6. The controller operating window

and it is robust to variations of system parameters and external disturbances, and they do not require accurate modeling. Further works we have done with applying the BTL5-S101 type Micropulse Linear Transducer with 1 μm resolution from Balluff.

3. EXPERIMENTAL RESULT

Based on the laboratory measurements we can conclude that the DSP based sliding mode controllers suitable and effective for the position control. The steady-state position error is within ±0.01 mm (Fig.4.). The robustness of the proposed SMC is also tested on the vertical position cylinder with mass load disturbances.

The experimental results indicate that the proposed sliding mode controller gives also fast response, good transient performance and it is robust to variations of system parameters and external disturbances, and they do not require accurate modeling.

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