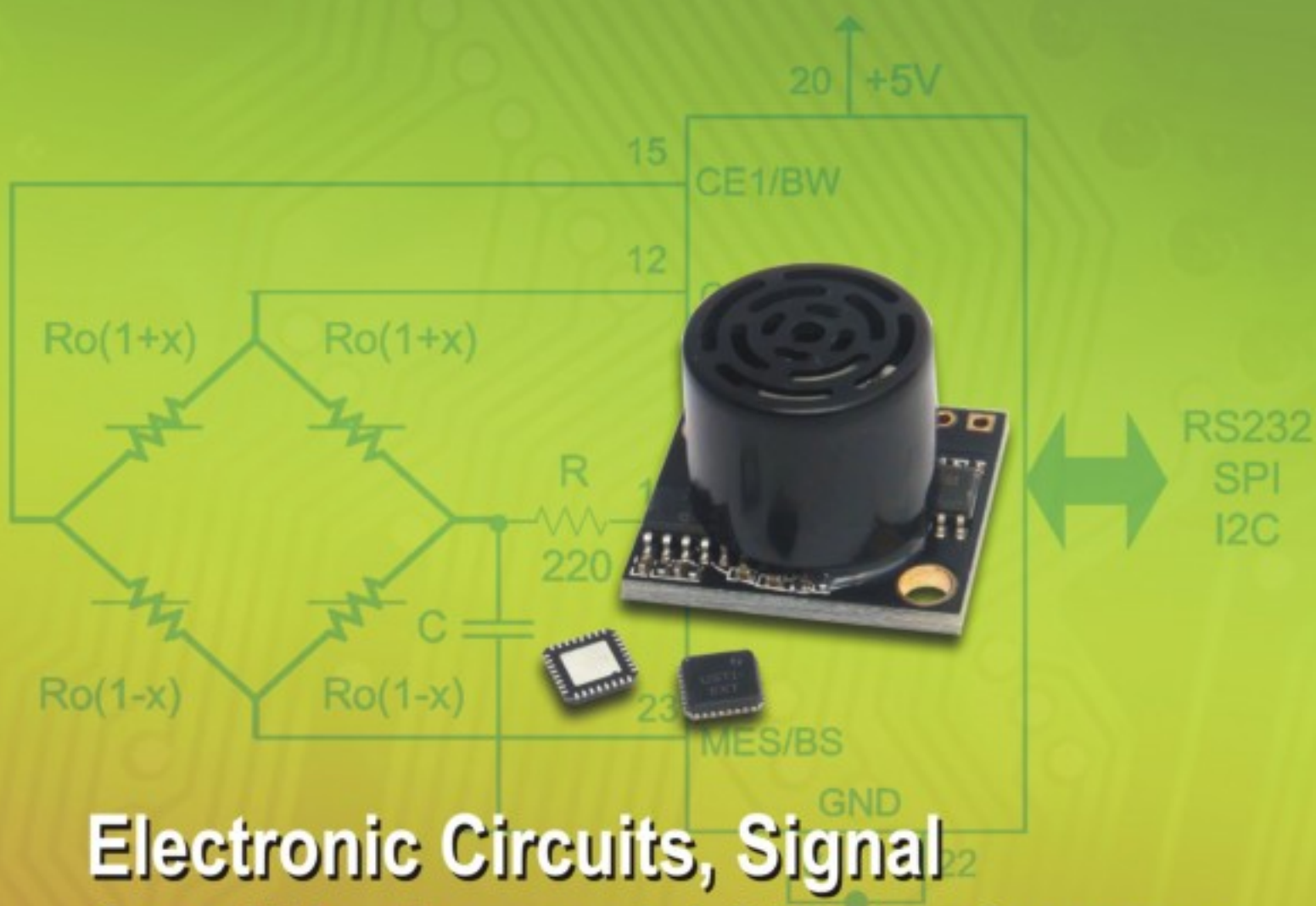


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ARM Cortex Processor Based Closed Loop Servo Motor Position Control System

¹ Madhusudhana Reddy NARAYANAREDDYGARI, ² Nagabhushan Raju. K,
² Chandra Mouli. C., ³ Chandrasekhar Reddy DEVANNA

¹ Department of Electronics, Sri Krishnadevaraya University, Anantapur, AP, India

² Department of Instrumentation, Sri Krishnadevaraya University, Anantapur, AP, India

³ Megabyte Technologies, Bangalore, Karnataka, India

E-mail: madhu_sd24@yahoo.com, ravichandru@mail.com.

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Abstract: Design and implementation of embedded web server based remote online supervisory control system is a new technique in embedded control system applications. The web server is a universal networking communication standard for interfacing multiple devices in various locations, that use the TCP/IP Protocol Suite to serve multiple users simultaneously and allows the user to interact with real time monitoring and controlling. This paper presents the design and development of Ethernet based embedded web server for controlling the position of a servo motor, using ARM based LM3S9B96 microcontroller. This is a Single chip IDMCS (integral device monitoring and control system) method which improves the processing capability of a system and overcomes the problem of poor real time and reliability. *Copyright © 2012 IFSA.*

Keywords: ARM-cortex, Servo motor, Ethernet, PID controller, PWM.

1. Introduction

Microcontrollers provide low-cost computing and automated decision-making capabilities to control various devices, products, and processes. Commonly, microcontrollers are integrated into automated machines/products which facilitates user to interact via LED/LCD displays, buttons/knobs and keypads [1]. Although typically this is not a problem, in some applications a user may need to acquire sensory data from the microcontroller and/or to provide actuator control commands to the microcontroller

remotely [2-4]. It enables development of interactive GUIs for process monitoring and control [5]. In recent years; several vendors have developed Ethernet-enabling devices that can be interfaced to microcontrollers [6, 7]. Unfortunately, integration of microcontrollers with Ethernet-enabling devices requires application developers to commit significant amounts of hardware and software resources, such scenarios can be overcome by the web server integrated with graphical user interface (GUI) and is unified for the ease of operations by the remote users. System also allows transmission of process commands, including on/off signals via Ethernet client server, will provide a versatile and flexible solution to the above problem. A PC based GUI for microcontroller applications necessitates data communication between the microcontroller and the PC that can be performed, using serial communication [8]. Unfortunately, data transfer using RS232, RS422 serial communication allows small distance and only one user interaction, in close proximity of the microcontroller, to interact with the microcontroller at a given time. This motivates the exploration of alternative methods of efficient data transfer with remote, multi-user connectivity capabilities between a microcontroller and a PC. Ethernet is the widely used efficient and reliable networking technique. Thus, it is a better choice for data communication tasks arising in remote monitoring and controlling of embedded applications.

2. Experimental Setup

2.1. Hardware Design

The experimental set up for servo motor position measurement and control system hardware consists of ARM Cortex M3 based controller; relay circuit, PWM, JTAG and frequency to voltage converter are integrated in to a single unit with the interface of servo arm. The principle and block diagram of the Design and Implementation of Arm Cortex Based Position Control of Servo Motor is defined in Fig. 1.

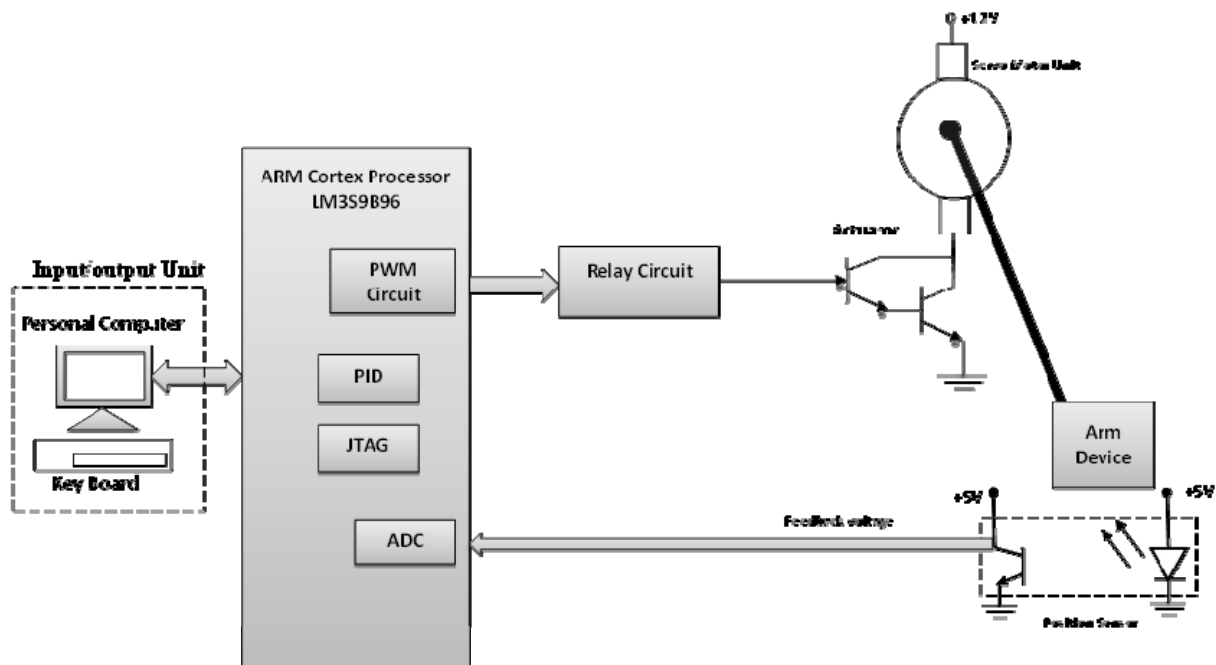


Fig. 1. Architecture of Design and Implementation of Arm Cortex Based Position Control of Servo Motor Using PID Technique.

The main process of generating PWM signal and reading feedback signal and performing PID algorithm is done by the ARM Cortex based LM3S9B96 controller, which is a 100 pin QFP package

from Texas instruments. It includes PWM generator, ADC, Ethernet and etc. This microcontroller consists of real time emulation and embedded trace support.

Ethernet feature is enabled in the microcontroller for establishing communication with external world to receive command signals and to send the resulting positional values of the motor.

A 2-channel TTL relay board with 5 V with solid state relays switches (Fig. 2) has been connected between the controller and the motor to avoid the back EMF of the motor on controller. The relay needs the input control signals and has no effect on the output voltage with the relay contacts; the controller PWM output is fed as an input control signal for the relay board. The active driver circuits allow lower current input signals such as 5 V TTL to be used. The relay contacts are electrically isolated from the rest of the board, with status of each relay is indicated visually by LED's.



Fig. 2. Two channel relay control board.

2.2. Servo Motor and Sensor Unit

The motor module is a combination of servo motor and position feedback sensing circuit.

Position sensing unit will give train of pulses with some frequency depending upon the position of the motor. The Servo motor is less weight, low power consumption etc. The lifetime of the motor may vary from a few hundred hours. The specifications of Servo motor used in the present study are shown in Table 1.

Table 1. The specifications of Servo motor.

| | |
|--------------------|--|
| PWM input range | Pulse Cycle 20 ± 2 ms, Positive Pulse 1~2 ms |
| Operating Voltage: | 4.8 V ~ 6.0 V (DC) |
| STD Direction: | Counter Clockwise / Pulse Traveling 1500 to 1900 μ s |
| Test Voltage: | 4.8 V |
| Operating Speed: | 0.33 s/ 60° at 4.8 V, 0.3 s/ 60° at 6 V at no load |
| Output Angle: | $\geq 170^\circ$ |
| Size : | 43×23×38.2 mm |
| Weight: | 43 g |

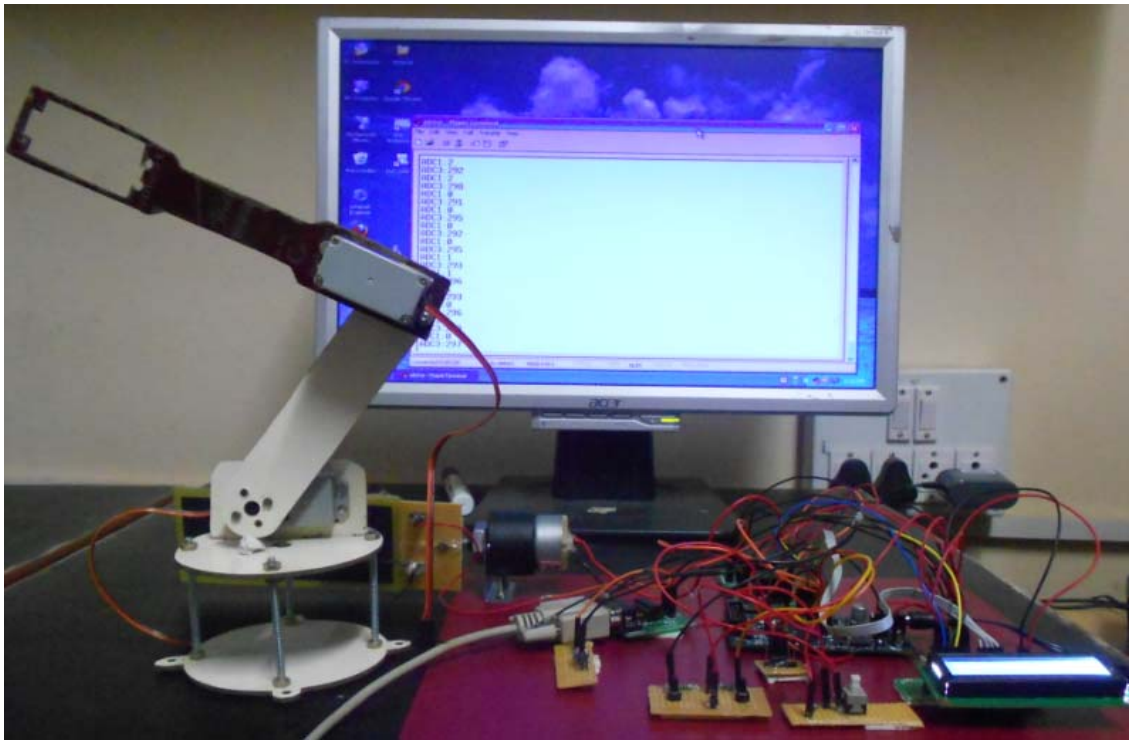


Fig. 3. Photograph of the experimental setup with functional units.

3. System Functionality

Web server based remote controlling and monitoring system is interfaced with the servo motor mechanical unit through the driver/relay circuit. The position values are fed from the PC through Ethernet channel, the controller will receive the control signal and generates the PWM signal corresponds to the control signal input, which will make the motor to drive to the appropriate position, the position of the motor will be read as a feedback and perform the computation with the referenced positional values if not matches then the controller will perform the PID algorithm and generates the appropriate PWM signal to control the motors position.

3.1. Proportional Plus Integral Plus Derivative Control (PID)

As the PID controller is composed of three components, it produces an output signal consisting of three terms-one is proportional to the error signal $e(t)$, another one is proportional to integral of error signal $e(t)$ and the third one is proportional to derivative of the error signal $e(t)$ [6-10]. The equation of the PID controller is given as

$$u(t) \propto [e(t) + \int e(t) dt + de(t)/dt]$$

$$u(t) = K_p e(t) + K_p / T_i \int e(t) dt + K_p T_d de(t)/dt,$$

where

K_p is the proportional gain;

T_i is the integral time;

T_d is the derivative time.

The transfer function can be written as

$$U(s)/E(s) = K_p(1 + 1/T_i s + T_d s)$$

The block diagram representation of the PID controller is shown in Fig. 4.

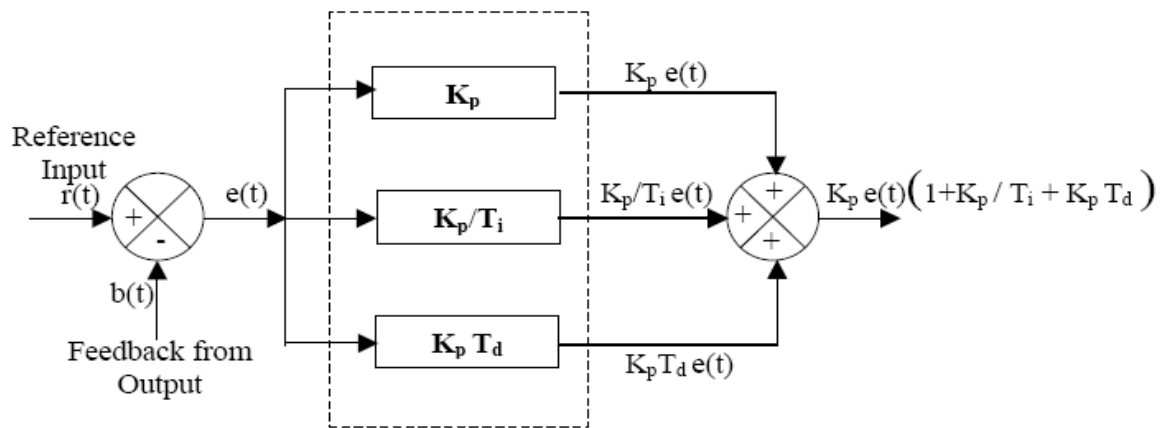


Fig. 4. Block diagram of the PID controller.

3.2. Software

The algorithm followed for designing the software is given in the form of Flow chart in Fig. 5.

The application software has been implemented in Keil-4 IDE (Integrated Development Environment) using embedded C programming. Peripheral drivers have been written to perform the respective jobs. The software is implemented as reusable modular programs which make the application more users friendly to interact. The compiled program is tested through the JTAG (Joint Test Application Group) debugger and ported the exe file into the controller ROM.

User interface software is developed using C# programming with ASP.NET framework on Personal Computer. GUI window is designed to provide graphical view for the user to interact with application during runtime, TCP/IP socket programming has been written to establish communication with controller through Ethernet remotely (Fig. 6).

4. Results and Discussion

The designed web server provides facilities for the user to monitor and control the motor remotely using Ethernet communication. User can pass the command signals to the controlling unit, the controller generates continuous pulse width modulation (PWM) according to the user inputs for the servo motor at 20 ms (20 kHz). The duration of the ON pulse (logic high) determines the position of the servo shaft, the range of duration between 1 ms (0°) and 2 ms (180°). A short ON pulse (1 ms) moves the servo to the far left, while a long ON pulse (2 ms) moves the servo to the far right. Intermediate length pulses (1.5 ms) correspond to neutral positions. Fig. 7 illustrates the timing constraints of the control signal. Since the rotation limits to 180° and the duration range is 2 ms (2 ms–1 ms = 2 ms), so the amount of movement for each one degree equal 0.01111 ms (11.1111 μs).

Movement (1°) = 2 ms/180° = 0.01111 ms (11.1111 μs).

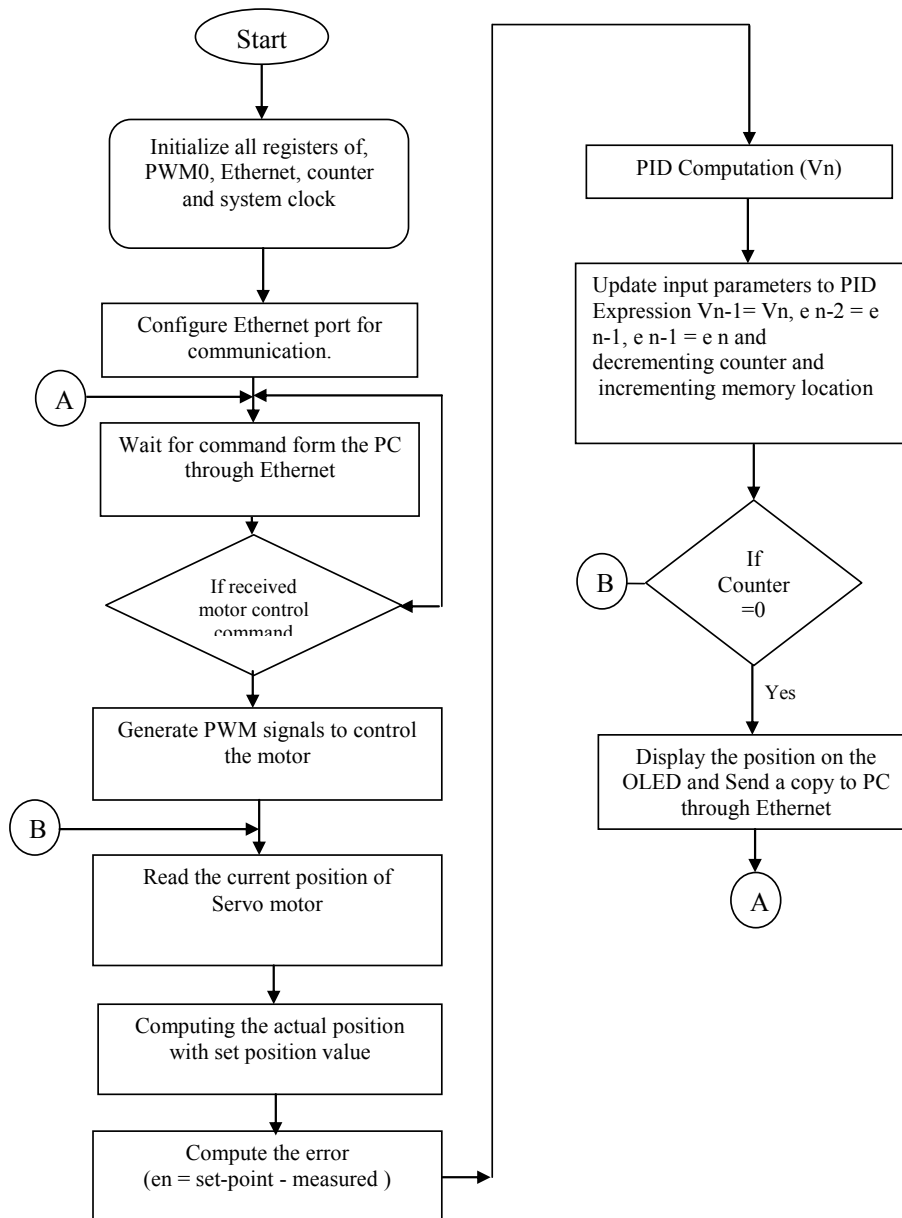


Fig. 5. Software flow diagram for microcontroller.

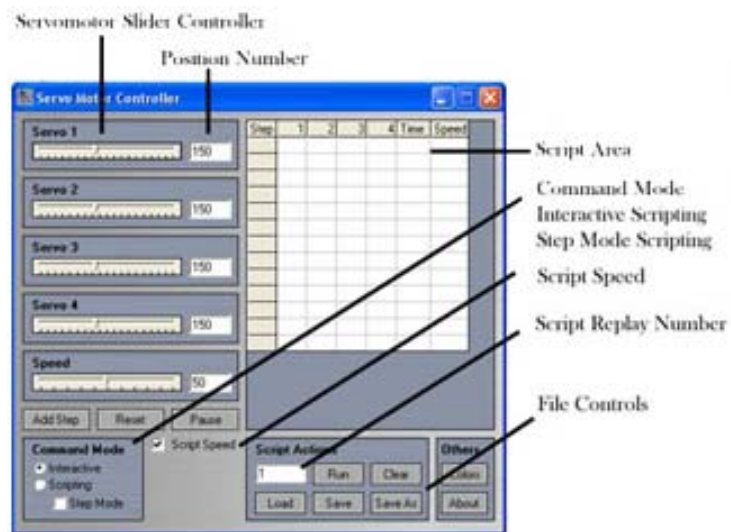


Fig. 6. GUI window to control and monitor the servo from PC.

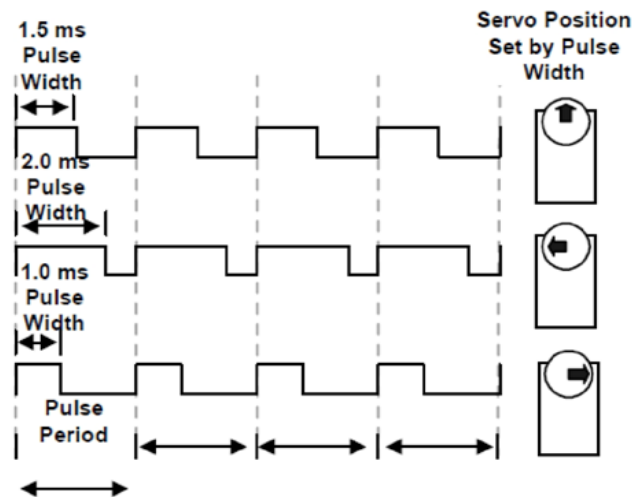


Fig. 7. Analysis graph.

5. Conclusion

Embedded web server for servo motor position control is developed using LM3S9B96 ARM microcontroller. A PID controller was successfully implemented using the above microcontroller and tested on a servo motor position control system. With the added PID controller, desired output speed was obtained. The system outputs also agreed with theoretical results, indicating better accuracy of the system. The system designed in this paper, can deal with many middle and small power motor control systems. LM3S9B96 microcontroller control system has a complete set of common peripherals compared with others, thereby giving the system strong task management and real time response. When external attachments are added, it really minimizes overall system costs and eliminates the need to configure additional components.

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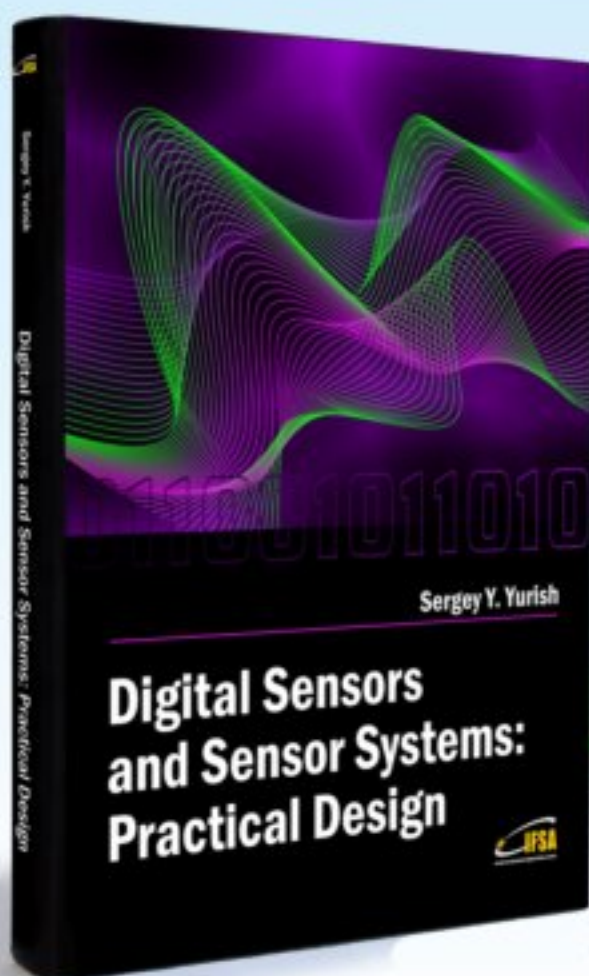
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