Design and Development of a Servo-Actuated Robotic Arm

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Abstract— Robotics is one of the fields which is exploring applications in many fields like surgery, battlefield weapons and industrial automation. The present work aims at developing a servo actuated robotic arm, which can be operated through potentiometers. The movement of the 5 DOF mechanical structure is limited by the rotation of the sliders.

Key words: Robotics, microcontroller, potentiometers, Robotic arm

I. Introduction

In the past decade, many gesture-controlled and anthropomorphic robotic arm designs have been developed [1-6]. These designs suffice for applications such as assisting a disabled person [1], working in radioactive environment or during bomb disposal [2], carrying out tedious, undesirable or repetitive tasks [3], industrial automation [4,5] and for performing surgery [6]. The concept presented in this paper is to extend the capabilities of these robots by adding the tele-operation feature. Many of the previous works also demonstrate the use of a variety of sensors for controlling robots, which include EMG (Electromyograph) signals[6], accelerometer[2], potentiometers[3,4], flex sensors[7], switches [5] or any combination of these. J. Gonzalez proposed a system based on wireless communication for controlling a 2 DOF robotic arm by acquiring surface EMG signals [6]. Design of a web-enabled anthropomorphic robotic arm was presented by G. Sen Gupta in the year 2008[7], using WiFi. Experiments for tele-surgery were carried out in [8-11]. Although reliable, TCP/IP (Transmission control protocol) showed to impose latency constraints. M. Mitsuishi et al. have developed a tele-endoscopic surgical system with force feedback capability. The authors successfully demonstrated a laparoscopic surgery at a long distance through the internet [8]. The feasibility of robotic tele-surgery was proved experimentally by conducting a series of tests [9,10]. P. Berkelman and J. Ma proposed a compact, modular, sterilizable and portable tele- surgical system [11].

II. System overview

The block diagram of proposed system is presented in Fig. 1. The sensing unit consists of five potentiometers. The amount of change of resistance across potentiometer will result into voltage change. These analog voltage values will be fed into the inbuilt analog to digital converter (ADC) of the micro-controller and appropriate digital values will be generated corresponding to the position of the slider on the sensor. The controller will generate pulse width modulated signals based on these digital values for each corresponding actuator.

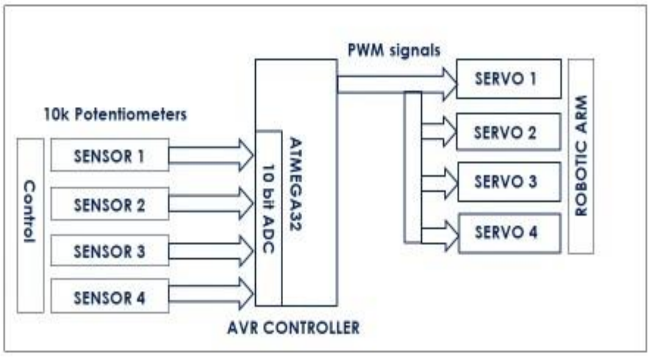

Fig. 1: Proposed Block Diagram of the System

III. Developed prototype

A. Mechanical Construction of Robotic Arm

A three dimensional view of the prototype is displayed in Fig. 2. The robot consists of five servo motors. The proposed design is for five degrees of freedom consisting of base, shoulder, elbow, wrist and grip movement. The electromechanical specifications of the servo motors are mentioned in the Table I. Radio controlled (RC) servo motors are most popularly used actuators for remotely controlling a robot. Some of the reasons for its popularity includes high holding torque, closed loop operation, precision, ability to maintain a specified position or angle over a single signal wire, smaller size and less-noisy operation.

RC Servo specifications		
Torque	8.5 kgf·cm (4.8 V)	10 kgf·cm (6 V)
Operating speed	0.2 s/60º (4.8 V)	0.16 s/60º (6 V)
Range	180 degrees	
Weight	55g	
Dimension	40.7 x 19.7 x 42.9 mm	

Table 1: Servo Specifications

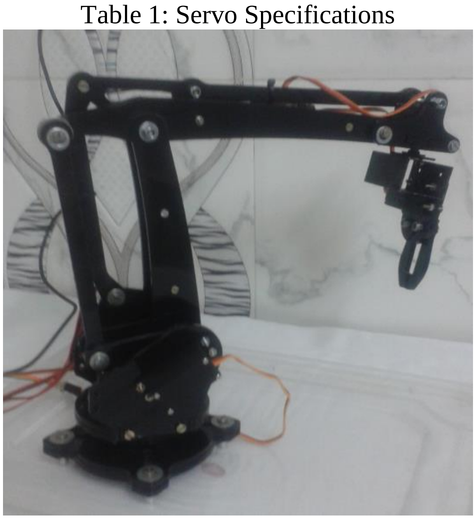

Fig. 2: Robotic Arm

The supply to the motors and controller are given separately since the motors require more power to run while the controller cannot bear such high power. The servo motors in the robotic arm are supplied with a 12V 10A power supply. A voltage regulator is used for each servo motor. The internal construction and working of a typical servo is demonstrated in Fig. 3. A position feedback sensor is used internally, which determine the initial position of the motor. The sensed position is fed to a differential amplifier, which calculates the error in the input pwm signal and the sensed position. The error value is transmitted to the motor and gear assembly. Hence the motor rotation is entirely controlled by the input control pulse.

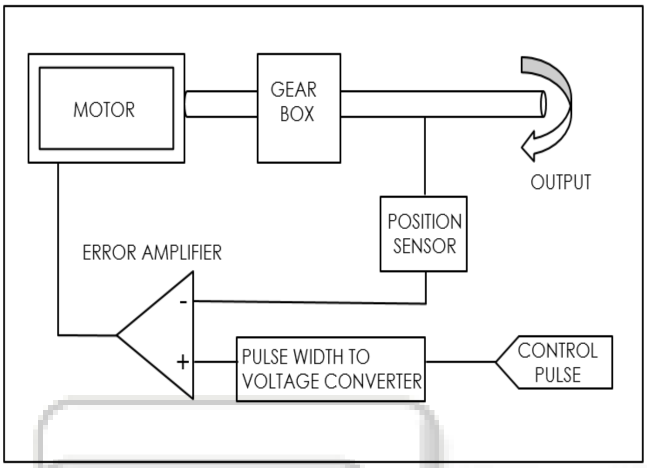

Fig. 3: Internal Construction of Servo

B. *Circuit Diagram and Description*

The controller used in the circuit is AVR ATmega32 which consists of 8 ADC channels with 10 bit accuracy. Servo motors were chosen over stepper motors because of the inherent closed loop mechanism. The circuit in Fig. 4 is designed in Proteus professional v7.8. Programming for the controller was done in AVR studio. The servo movement which depends on on-time duty cycle of the control pulse, was carried out by generating PWM pulses. The flowchart of the programming is shown in Fig. 5.

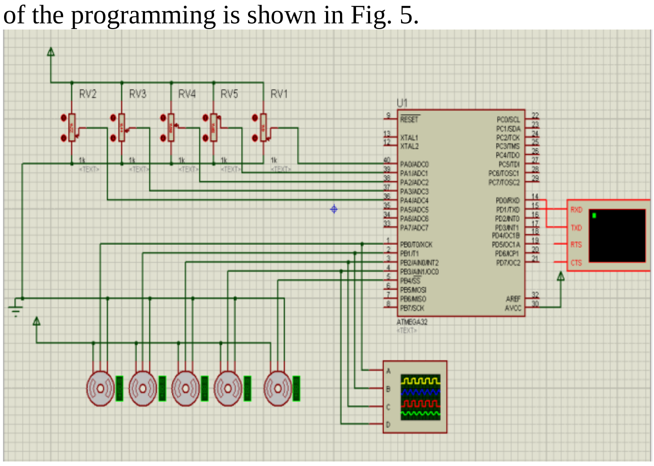

Fig. 4: Simulation Circuit of Servomotor Control using ATmega32

C. *Working*

The single turn potentiometers can be rotated upto 300 degrees and they produce a voltage change with the change in slider position. The supply voltage is 5V. The position of the slider is determined in analog form and fed to the 10 bit ADC. Thus, the 2^{10} digital levels (from 0 to 1023), thus obtained give a representation of the angular position. Hence, the value 512 refers to 2.5 V. The controller reads this digital data and based on a particular angular position obtained for each potentiometer, the ON time pulse is set. The duration of each pulse is of 20ms. The ON time is usually kept between 1ms to 2ms duration. Thus, 1.5 ms on time pulse will position the motor at the center, 1 ms pulse width will cause the motor to rotate clockwise and 2 ms pulse duration will cause the motor to turn counter-clockwise. Thus, the pulse duration or the length of the pulse essentially determines the voltage. Each 0.5 ms pulse is capable of controlling 90 degrees of rotation in either direction.

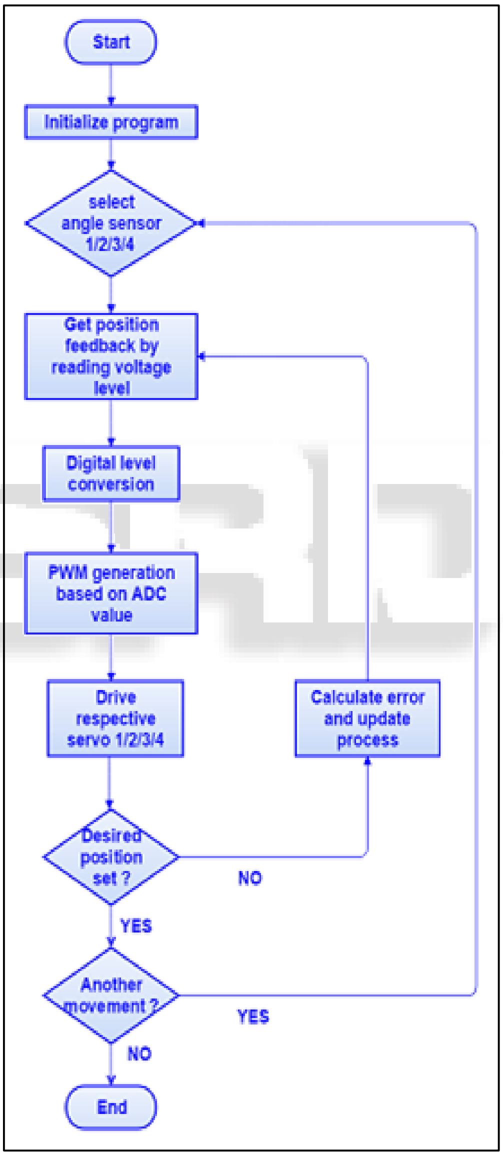

Fig. 5: Flowchart of Programming

IV. RESULTS AND CONCLUSION

In this paper, design of a 5 DOF robotic arm has been presented with ADC conversion and PWM generation. Fig. 6 shows the PWM waveform generated on an oscilloscope. A smooth movement of the servo motors was obtained relative to the slider position. Simulation results obtained in proteus also gave similar results.

Fig. 6: PWM signals generated on oscilloscope

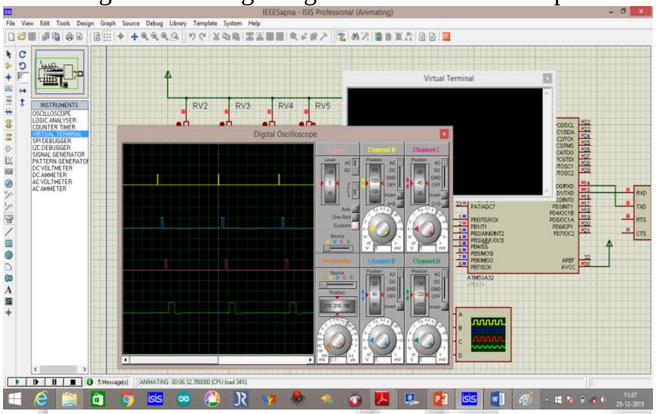

Fig. 7: Simulation results in Proteus

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