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Software interfacing of servo motor with microcontroller

Ahmed M. Haidar University of Wollongong, ahaidar@uow.edu.au

Chellali Benachaiba University of Bechar

Mohamad Zahir University Malaysia Pahang

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Abstract

Automatic control of DC servo motor in terms of rotation angle has played a vital role in the advance Electromechanical Engineering. Nowadays, the automatic process of motor control using a Personal Computer (PC) is commonly used. The controllers are designed to interface between a Computer and Motor. This paper presents the implementation of PIC Microcontroller with Graphical User Interface (GUI) in Matlab to track the rotational angle of DC servo motor. The movement of slider on GUI will act as an input signal into the Microcontroller to change the rotation angle. A simulation on the performance of the system has been carried out using Proteus software interfaced with Matlab and the controller was tested on real-time application. Results show that the use of PIC Microcontroller and GUI in Matlab is an advantage solution to control the rotational angle.

Keywords

interfacing, microcontroller, software, motor, servo

Disciplines

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Ahmed M. A. Haidar¹, Chellali Benachaiba, Mohamad Zahir³

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Regular paper



Software Interfacing of Servo Motor with Microcontroller

Automatic control of DC servo motor in tegines hoafs rptayieoch anvital advance Electromechanical Engineering. Nowadays, the automausing a Personal Computer (PC) is commonly used. The control between a Computer and Motor. The issent psape thre pimplementation Microcontroller with Graphical User Interface (GUI) in Matlab to DC servo motor. The movement of slider on a Gound putils ignimaticast Microcontrolder hangtenerotatic and gleA simulation on the performance has been carried out using Proteus software interface to owline how as the on re-tailment application. Results show that the use of PIC Microco is an advantaugteios noto control the rotational angle.

Keywords:Automatic control; Matlab GUI; DC servo motor; PIC Microcontroller; Proteus softw

1. Introduction

DC Servo Motors become an important device in a wide range of industrial applications that require high dynamics on position controlled as numerically controlled machinery, robotics, a unanotable more chanism where the starting and stopping functions equickly and accuratel [1,2]. These applications require a high peed control accuracy and good dynamic respond. In robotic applications, servo motors are used to move the robotic arm to a relevant position by means of controllers in the automated manufacturing lines of industries [3, 4]. The rotor construction of servo motors made of special mature high less weight to decrease the inertia of armature but capable to produce the necessary magnetic flux. Low rotor inertia increases the capability of immediately starting and stopping during the onoff conditions. The high cost of servo motor becomesajor issue. Therefore, the small-scale manufacturers or users cannot afford to use this type of DC Motor.

DC Servo Motors have a large market share in the Industry Automation & Drive Technologies. The common problems in controlling the servo motor withif is speed and position is the tuning of the parameters. Many different techniques have been proposed in order to cope with the tuning problems. Fuzzy Logic is one of the implemented techniques that have been used out with these problem [4, 5]. The nonlinearity of the servo motor is one of the difficulties in controlling the servo motor. Since the load pressure varies over a wide range under internal parameter variations and external disturbances (load torque ariations), these two factors tento induce a higher degree of nonlinearity [6, 7].

Along with the rapid development of digital and computer control technology, embedded hardware interfacing with the technology infulink software is undergoing tremendous change. Currently here are searal commercially available embedded hardware interfacing, including advanced RISC machine (ARM), digital signal processing

¹ Ahmed M. A. HaidarUniversity of WollongongNSW, Australia E-mail: ahaidar@uow.edu.au

² Chellali Benachaiba Iniversity of Bechar Algeria

³Mohamad ZahirUniversity Malaysia Pahang, Malaysia

(DSP), applicationspecific integrated circitu (ASIC), and field programmable gate array (FPGA). Among them, FPGA have a number reformamble logic resources that make it possible to integrate with microprocessors to form a complete embedded system and perform complex computations in hardward. Many researchers have investigated servo system simulation focusing control teaching and maintain trainings, 9, 10, 11, 12]. In [10], an integrated Matlab/Simulink with neural networkand LabVIEW was designed develop a SCADA reatime AC servo motor monitoring control system. Another ulink testing system is introduced [6] for intelligent robot control using Matlab environment and Turbo C software. Both systems are an effective solution to simplify the data processing with a high performance servo motor tracking scheme.

The traditional test system can no longer meet the respired lopment of modern servo system. Therefore new kind of automatic tests systems incorporating monitoring software are needed. Ref[.13] discusses the development of simulation software models for two axis servo platform based on the National Instants LabVIEW. The system is used to evaluate and test an advanced servo control algorithms before being implemented into the actual system. An overall network structure offeweloped system in layers was designed in[14]. The system consists of advance dest instruments, use friendly virtual interface, database server, LAN clients and web server. The connection between LabVIEW and database is realized by using the Database Connectivity Total kistimplify the program, Virtual Instruments Software Architeure was applied with written commands to the buffer, instead of considering any specific communication protocols.

This paper presents the implementation of computer interfacing control for servo motor based on Matlab coding imbedded in **roi**controller. Proteus software wassed to simulate the hardware and verify thealthab coding for real time application. In this work, some of the components can be changed easily to upgrade the performance of the system. The work is organizeds such that section 1 gives a brief introduction of DC servo motor with the existing software A literature review on DC motors and ontrol methods are presented in action 2. Section 3 presents the rinciple operation of DC servo motor control. The methodology, software simulation and hardware implementation outlined in Sections 4 and 5 respectively. The results are discussed Section 6, while Section 7 drafts the conclusion.

2. A review on dc servo motor control

According to the variety of DC motor, different techniques designed to control the DC motor and overcome the volatility characteristics of the physical DC motor system itself. The types of DC motor are permanent magnet, winding, stepper and servo, etc. Permanentmagnet DC motor has a small size and comparctpease to other types of DC motor but the magnetic field strengthannot be varied. Winding DC motors which are shuntwound, series wound and compound provide try high range speed antidrque However, the stepper motor has a higher precise speed cantidarge torque at low speed but in terms of cost, this type is expensive. Alternatively, servo motor is an important for the application at the industries due to its ability of quick response and precise positioning but motor is expensive.

A servo motor is an electromechanical device in which the electrical input determines the position of motor armature. It is actually an assembly of four things: a normal DC motor, a gear reduction unit, a positisensing device and a control circuit. Servo motors are used exensively in robotics industry and radiontrolled cars. The implemented types in modern servo systems are AC servo motors based on induction motor designs, DC servo motors based on DC motor designs, DC brushless motors and AC brushless sterso mo based on synchronous motor designs. These motors are working in a closed loop control systems where the programmed position of motion and velocity feedback controllers are required [4]. Different studies and researches have been conducted on themsetoro control. Currently, the conventional method of servo motor control is based on proportional integral derivative. Other suggested methods such as artificial intelligence and fuzzy logic were mentioned in Ref [15]. Usually the control method of fuzzy in a fixed set of quantizing factor and scaling factor is often used in the fuzzy control However, the variations of quantizing factor, scaling factor and control rule in the fuzzy look up table may significantly affect the speed of DC Motor. Indiation, with the same set of fuzzy control rule, quantizing factor and scaling factor, the variation of membership function will also affect the control performance of fuzzy control, 18].

So far, several approaches for robust control have been proposted onsiderable progress was made in this area. The popular techniques primarily intended for linear systems such as linear Quadratic Gaussian control design with loop transfer recovery (LQG/LTR) technique and adaptive or stalfning control. Among theethniques used mainly for nonlinear systems, the sliding control. Recently, Time Delay Control (TDC) has also attracted attention as an excellent robust nonlinear control algorithm. The main purpose of using TDC methods is to assure control performation as accuracy, stability, speed, etc) Generally, TDC uses the tidelayed values of control inputs and derivatives of state variables at the previous time step to cancel the nominal nonlinear dynamics and the aforementioned uncertainties. Thus, does not require any retaine computation of nonlinear dynamics, nor does it use the parameter estimations as in adaptive control [19].

Proportional integration (PI) controller is unquestionable as the most common controller in the process control indust The main reason for using this controller is its relatively simple structure, which can be easily understood and implemented in practice. It also implemented in the sophisticated control strategies, sas model predictive control. PI control ismath total of integration error and multiplying of error with total of integration error and multiplying of error with netal [21]. A simplest method to control the rotation speed of a DC motor is to control its driving voltage. The higher the voltage is the higher speed the motor tries to reach. In many applications, a simple voltage regulation would cause lots of power loss on control circuit, thus, apulse width modulation method (PWM) is used in many DC motor controlling applications[4, 22]. In the basic PWM method, the operating power to the motors is etdr ON and OFF to modulate the current to the motor. The PWM control method uses the widths of pulses in a pulse train to control the speed of the nhash The pulses are arranged such that, only one pulse occurs for every period of the system cleatut vh cycle of the pulses determines the speed of the motor. Therefore, the higher the duty cycles the higher the spedd]. This would give the motor the ability to safely vary the speed from stand still to its maximum speed. For this reason, the PMM od was chosen to be implemented in the motor control design. Sometimes, the rotation direction needs to be changed. In the normal permanent magnet motors, this rotation is changed by changing the polarity of operating power (for example by switching from gative power supply to positive orby interchanging the power terminals going to power supply). This direction changing is typically implemented using relay or a circuit called an H b [3] ge

The main purpose of interfacing motor control is to implementation control of servo motor position utilizing a local interconnect network (LIN) to allow a series of similar motors connected together and controlled by master controller. Since the motor is used for steering and driving systems, a singlerothet can be used for both functions. A microcontroller is applied to produce the PWM signal. The control programming based on computer interfacing to produce the PWM output would eliminate the need for additional hardware, saving on the overall cost octs a motor drive circuit [24, 25]. The Complex high-performance controllers such as PID have to be programmed and loaded into the microcontroller by converting it into hex file. Interfacing the motor with computer programming is achieved by the generate of LIN application [26, 27, 28].

3. Principle operation of dc servo motor control

Servos are controlled by a pulse of variableth. The sent signal of this input pulse is characterized by a minimum pulse aximum, and a repetition rate as seen in Figure Given the rotation constraints the servo, neutral is defined to be the position where the servo has exactly the same ambourhotential rotation in a clockwise direction as it is in a counter clockwise directio [29]. The angle is determined by the duration of applied pulse to the signal wire which is called PWM or Pulse Coded Modulation. The servo should detect a pulse eve 20 ms. The length of the pulse will determine how far the motor turns For example a 1.5 ms pulse will make the motor turn to 90 degree position (neutral position). The position pulse must be repeated to instructs throw to stay in position 28].

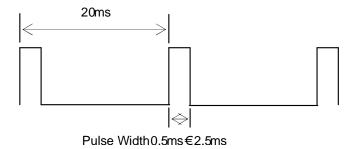


Fig. 1: Input pulse of servo motor

When a pulse is sent to a servo that is less 1th farms, the servo rotates to a position and holds its output shaft some number of degreessnterclockwise from the neutral point. When the pulse is wider than 1.5 ms, the opposite operation is occurred he minimal width and the maximum width of pulse that will command the servo to turn to a valid position are functions of each servo enerally the minimum pulse will be about wide (some servo is 0.5 ms) and the maximum pulse will be ms wide (some servo is 2.5 ms). The servo motor operates in the range 50 f% to 10 % of duty cycles Figure 2 shows relationship between pulse and direction of servo motor.

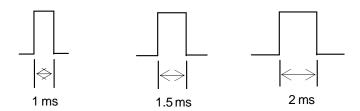


Fig. 2: Relationship between pulse and direction of servo motor

The PWM is a commonly used technique for controlling pointer electrical device. The average value ofoltage (and current) fed to the load is controlled by turning the switch betwee supply and load, ON and OFF at a fast pace. The longer the switch is ON compared to the OFF periods, the higher the power supplied to the load is. AC drives required the sinusoidal signal and modulation generator. The triangular signal is the carrier or switching frequency of the inverter. The modulation generator produces a sine wave signal that determines the width of the pulses, and therefore the RMS voltage output of the inverter. For DC drives, the PWM signal is generated by comparing a triangulær wa signal with a DC signal as shown in FigureThe DC signal can be ranged between the minimum and maximum voltages of the triangle wave. The PWM signal is measured using the percentage of duty cycle where the pulse atitum over the pulse perio [26].

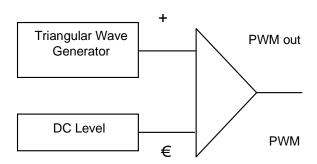


Fig. 3: The generation of PWM for DC drives

The mathematical model of DC servo motor can be simplified by mean of the circuit as shown in Figure The electrical part represented by armature and the mechanical part and J. As the field excitation is constant, the armature controller only dependent voltage [30, 31]. The mechanical equations describing this system can be written with the

assumptions that the loss is included in load torque and neglection constant [30] as given below,

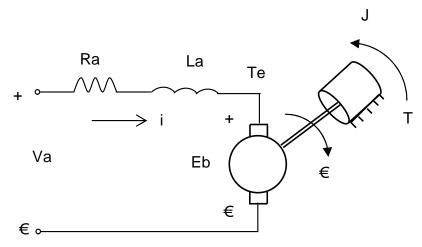


Fig. 4: DC servo motor quivalent circuit

$$V_a \delta = R_a i \delta = L_a \frac{di}{dt} \delta = L_b$$
 (1)

$$J\frac{d\delta W}{dt} \delta = I_{e} \delta - T$$
 (2)

With,

$$\mathsf{E}_\mathsf{b} \ \check{\mathsf{0}} + \mathsf{W}$$

$$T_{p} \delta = K i$$
 (4)

where, i : armature current, V_a : armature voltage, R_a : armature resistance; K: torque and back electromagnetic constant V_a : w; rotor angular speed; T_e : electromagnetic torque, V_a : total load torque; V_a : rotor inertia.

The control input is the armature volta $\mathbf{v}_{\mathbf{q}}$ and the total load torque is the disturbing input. The two state variables are armature curiented angular spector. Then the previous equations lead to the state space model of DC motor:

The two state variables excited the angular speed in order to perform a speed regulator related with the angular speed. Therefore, is considered as the output of the system and V_a is the input. Taking into account only these two system variables, the transfer function of the DC motor is:

$$H(s) \stackrel{\bullet}{\delta} = \frac{W(s)}{V_a(s)} \stackrel{\bullet}{\delta} = \frac{1}{K} \frac{1}{\stackrel{\bullet}{\delta} \underset{\bullet}{e} \stackrel{R_a J}{K^2}} s \stackrel{\bullet}{\delta} + \frac{L_a J}{K^2} s^2 \stackrel{\bullet}{\delta}$$
(6)

The two time constants are defined as: Electrical time constat.

$$t_{e} \stackrel{\mathsf{D}=\frac{\mathsf{L}_{a}}{\mathsf{R}_{a}}}{\mathsf{R}_{a}} \tag{7}$$

And electro mechanical time constant,

$$t_{em} \tilde{O} = \frac{R_a J}{K^2}$$
 (8)

Therefore,

$$H(s) \tilde{\partial} = \frac{\tilde{\partial} V(s)}{U(s)} \tilde{\partial} = \frac{1}{K} \frac{1}{\tilde{\partial}(\tilde{\partial} +_{em} s \tilde{\partial} +_{em} t_{e} s^{2} \tilde{\partial})}$$
(9)

4. Software implementation of servo motor control

This section presents imulation procedures of servo motor control using the Proteus and Matlab software interfaced with Virtual Serial Port. The Process design suite is wholly unique in offering the ability to esimulate both high and lowevel microcontroller code in the context of a mixed node SPICE circuit simulation. There are ove 8000 digital and analog devices model that can be simulated by ipt and wired it up. The most exciting and important feature of Proteus is its ability to simulate the interaction between software running on amicrocontrollerand any analog or digital electronics connected to it. Proteus can work with popular compilerand assembler to simulate the execution of the object code (machine code), just like a real chip. If the program code is written to a port, the logic levels in the circuit will be changed accordingly, and if the circuit changes the state of the processos pins, this can be seen by the program code, just as in a real [182, 33].

The application of GUI for system control is widely used in the industries and robotic. In this work, the slider in Matlab GUI contributes to control the servo motor rotatigue as seen in Figure5. The signal data obtained from tladeljusted slidewill be sent to the microcontroller and thissignal will rotate the servo motor based on the desired angle adjusted by slider. The schematic diagram of servo motor control is showingure6. The system was built and developed using Proteus software incorporating with Matlab coding. The microcontroller coding are compiled using the Micro Code Studio. Hex file of coding program can be uploaded into the microcontrollermake it ready for real application during hardware implementatioAs seen from Figure, the output from microcontroller is measured using the digital oscilloscope provided within Proteus. This measurement is an important to determine the correct output from theration troller into a servo motor. The Virtual Serial Port Kit creates virtual serial ports and connects each pair of them via a virtual null-modem cable. Consequently, all the data written to one virtual serial port can be immediately read by thether one and vice versa. Moreover, this functionality is easily integrated into the softwar Figure 8 shows how virtual nulmodem cables are connected between two serial port [32, 33]. The ports have to be defined correctly in virtual serial port to make surthat the signal has been sent into the nighth.

Fig. 5: Servo motor control graphical user interface

Fig. 6: The schematic diagm of servo motor control

Fig. 7: Digital oscilloscope within Poteus

Fig. 8: Virtual Null-modem cables connection

In order to control the servo motohet Matlabinterfacing with Proteussoftware is achieved by the combination of GUI, microcontroller and virtual port communication between Matalb and Proteus as shown in Figuriene pair of serial ports is fixed at CO2M for GUI and COM4 for microcontroller as seen in Figuriene. The procedures of interfacing simulationare summarized below:

- Construct the schematic diagram using Proteus software.
- Write the PIC coding in Micr@ode Studio compiler and compile them. This can be
 done using compiler such as MPLAB. Tbetcomeof compiling is the generation
 the HEX file.
- Upload the HEX file to the microcontroller in the Proteus software.
- Run the Virtual SeriaPort and define both port©OM2 for Matlab and COM for serial port (COMPIN) at the Proteus.
- Define the serial port (COAPIN) at the Proteus as COAM
- Define the port at the rfile (the written program of servo mortoontrol) of Matlab GUI as COM2.
- Run both software and start controlling the servo motor using sliders

Fig. 9: Virtual port communication

Fig. 10: The virtual interface between Matlab and Proteus

Referring to the whole controlling system, the servo controller receives position commands through a serial connection which be provided by using one inpottiput (I/O) pin of another microcontroller, or a PCs serial port. This pulse signal will cause the shaft to locate itself at the midway position 90 degrees The shaft rotation on a servo motor is limited to approximatelly 80 degrees +/-90 degrees from center position) A 1-ms pulse will rotate the shaft all the way to the left a 2-ms pulse will turn the shaft all the way to the right by varying the pulse width between and 2 ms, the servo motor shaft can be rotated to any degree position within its range.

5. Hardware implementation of servo motor control

Figure 11 shows the schematic diagram of the controlling system the hardware of this system is depicted in Figure. The application of MAX232 is used to regulate the signal from PC to microcontroller dug the interfacing process. Thechip receives signals -10V to +10V from PC for logic 0,and ,1f and converts them into and 5V in logic ,0f and ,1f for microcontroller in order to process the sending. Americal port acts as a medium for sending the that from PC to servo motor control circuit. This controlling system is using the Integrated Circ(InfC) LM 7805 to regulate the 5V voltage supply to entire circuit. A light-emitting diode (LED) is used as an indicator to determine the PWM output generated microcontroller and sent to the servo motor. The DC servo motor utilized in this hardware is a Cytron RC Servo mc(InfC+0R). The specification of the speed of DC servo 25.

RS-232 is a standard for serial binary data signals connected between data terminal equipment and datarcuit terminating equipment [82]. According to this standard a logical "0" has a voltage level between 5V and 5V and a logical 1" has a level between 5V and +15V. The microcontrollers use 5V TTL-level (transistor logic) to transmit signals Therefore the signals should be converted by using M29X that only needs 5V power supply to convert the signal from T-Telvel to RS232 level and reverse RS232 is a serial interface that transfells data bit by bit and requires only two single wires, one, to send and another, to receive the data. Most of digital logic circuits and processors operate with a "+5... voltUsually the input circuit is unregulated power supply ranging formolts to 24 volts (DC). For this reasonLM 7805 is placed in the hardware and reacts as a regulator to supply 5 volt [33].

Fig. 11: schematic diagram of the controlling system

Fig. 12: Hardware of servo motor control

Table1: Specification of the RGervo motor

Speed(s/60°)	0.19		
Torque (Kg.cm)	6.00		
Pulse Width Range (ms)	0.546ms to 2.4ms		
Weight (g)	38		
Gear material	Plastic		
Servo type	Standard		
Input voltage (V)	5		

The rotational angle of DC servo motor is measured manually using the protractor. One of the blades will be marked as a reference point. The DC motor is placed at the centre of the protractor and each mement of the slider in GUI Matalb will rotate the servo motor and the angle can be recorded gure 13 illustrates the measurement of anythe maximum and minimum values of angle in the slider are in the range to 180°. The angle must be limited to 80°. For example if the slider has a range of to -60°, it means that the measured value by the instrument in the range of maximum and minimum is

Fig. 13: Angle measurement

6. Result and discussion

The simulation is used to validate the results obtained from Proteus interfacing with Matlab GUI and with those found by the hardware interfacing atlab GUI. The GUI is manually controlling the desired rotation angle of servo motor by the .stricteure 14

shows the 90° rotation of servo motor indicated by slider and the input signal from the PC into the microcontroller Table 2 illustrates the measurement values of five motors taken during the simulation.

Fig. 14: Servo motor1 at 90° and the input signal from PC

Table2: The measurement values of five motors taken during the simulation

Servo Motor	Slider Positior(°)	Servo angle (°)	PWM output (ms)	Voltage Magnitude PWM output (V)	Sending signal from PC(mV)
1	90 -30	90 -30	2.35 1.10	2.54 2.55	214.52 267.91
1	-60	-60	0.80	2.58	290.07
2	80	80	1.95	2.52	300.09
2	-40	-40	0.75	2.52	115.24
3	95	95	2.55	2.53	290.21
3	-95	-95	550u	2.56	144.71
4	170	170	1.70	2.59	115.34
7	240	240	2.80	2.48	154.95
5	240	240	2.80	2.56	177.64
	170	170	1.65	2.57	302.42

For real time implementation, the measurements of input signals and PWM output from the microcontroller were recorded in order to be compared with the signals obtained by the simulation Figure 15 shows the real time implementation of the hardware. The initial measurement of the inp(x.20 mV) and output signa(161 mV) are shown in Figure 6. Table 3 illustrates the measurement values of five motors taken during the hardware testing

Fig. 15: Real time hardware testing

Fig. 16: Sending signal from PC and output from the microcontroller

As seen from the software and hardware results, the system is not operating as desired for somesent signals from the PC into the control circuit. The measurement of signals from the PC is too small and these signals cannot be operated by the microcontroller. But, the circuit and GUI are functioning well in terms of rotating angle. The hardwards estudy that the output signals from microcontroller with a shape approaching the sine wave form. On the other hand, the outputs of microcontroller supposed to be as square wave and exceeding the PWM shape for DC drive. Finally, a comparison results bretthree simulation and realtime implementation are given in TableAs noted from the table, the values ofthe simulated and real time signals are not similare functions of the virtual

interface and the database system may need to be expended the middle rent types of PC configurations to perform an accurate sending of significal the hardware without loss of information. The compatibility of Matlab ar Pototeus however, has an influence under the present condition.

Table3: The measurement values five motors

Servo Motor	Slider Positior(°)	PWM output (ns)	Voltage Magnitude PWM output (mV)	Sending signal from PC (mV)	
1	90 -30	88.32 90.34	161.0 249.0	74.4 72.8	
	-60	49.53	258.0	73.6	
2	80	83.54	517.0	75.2	
_	-40	103.30	160.0	46.4	
3	95	63.90	515.0	74.4	
	-95	74.75	48.0	23.2	
4	170	392.80	76.8	32.0	
	240	-	75.2	44.8	
5	240	-	71.2	44.8	
	170	65.96	518.0	46.4	

Table4: Comparison result of simulation and retaile testing

Servo Motor	Slider position(°)	Rotation angle (°)	Signal sending (mV)		Output from Microcontroller (mV)		PWM	
Ser	Slider	Rotati	Simulation	Real time	Simulation	Real time	Simulation (ms)	Real Time (ns)
1	90 -30	90 -30	214.52 267.91	74.4 72.8	2540 2550	161 249	2.35 1.10	88.32 90.34
	-60	-60	290.09	73.6	2580	258	800	49.53
2	80	80	300.09	75.2	2520	517	1.95	83.54
	-40	-40	115.24	46.4	2520	160	750	103.30
3	95	95	290.21	74.4	2530	515	2.55	63.90
	-95	-95	144.71	23.2	2560	48.0	550	74.74
4	170	17	115.37	32.0	2590	76.8	1.70	392.80
	240	24	154.95	44.8	2480	75.2	2.80	-
5	240	24	177.64	44.8	2560	71.2	2.80	-
	170	17	302.42	46.4	2570	518	1.65	65.96n

7. Conclusion

In this paper, microcontrollen Matlab GUI is proposed to control the desired position of rotation angle using the GUI sliders. Based on the regulated vasue he sliders control the rotation of the servo motor. In retain application, the sent data from PC is too small and the microcontrollers are not passing enough signals to produce the actual desired rotations. In order to improve the accuracy for retain application, there is needed amplifier for increasing the signals from PC to the microcontroller. The major contribution of this paper is the incorporation of two different softwareding for real time control of a servo motor rotation angle using GldIMatlab.

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