DESIGN AND IMPLEMENTATION OF DIGITAL CONTROLLER FOR THE SPEED CONTROL OF DC SERVOMOTOR

MSV'06

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Abstruct

This project deals with the speed control of a DC servo motor. The speed is controlled by a digital PI controller. The difference equation of the PI controller is obtained from the transfer function and the digital controller is implemented by the graphical Programming method. In speed control application of servomotor proportional controller can reduce the steady state error if the load is not applied. In the loaded condition, the steady state error increases which is eliminated by the use of the integral controller. So by using the PI controller we can attain the actual speed equal to the desired speed in spite of the load variations. During the development of the graphical control software, the PCI-1200 DAQ card is used for the real time control. Square and triangular reference wave signals are produced by the proposed software, which greatly simplified the hardware configuration.

I Introduction

The main focus of this project is to control the speed of the DC servo motor. The control system developed in this project renders the use of some hardware components. Using this software an implementation of a speed control of servomotor is made to investigate the properties of the software. This software monitors any variations in the motor speed so that it can quickly return the speed to its correct value. In this project a fully computer controlled system is designed in which we can produce the reference input signal by using the proposed software, and control the frequency and amplitude of the control signal, and we do not need external board for signal conditioning..

The use of a digital computer as a compensator (controller) device has grown during the past two decades as the reliability of digital computers has improved [1]. The digital computer in a system configuration receives the error in digital form and performs the calculations in order to provide an output in digital form. The computer may be programmed to provide an output, so that the performance of the process is near or equal to the desired performance.

A digital computer receives and operates on signals in digital (numerical) form, as contrasted to continuous signals [2].

In speed control application of servomotor proportional controller can reduce the steady state error if the load is not applied. In the loaded condition, integral controller is used together with the proportional controller, because in loaded case, the steady state error increases which is eliminated by the use of the integral controller. So by using the PI controller we can attain the actual speed equal to the desired speed in spite of the load variations.

The whole implementations work is done using the control software and the PCI 1200 DAQ card.

II System Familiarization and Modeling

A. System Characteristics

The servo system under consideration consists of the Power Supply Unit and Mechanical Unit. Tachogenerator, which provides a voltage proportional to the speed, and a magnetic brake, which loads the system are available in the Mechanical unit. For more detail about the different functions available with these units see [3].

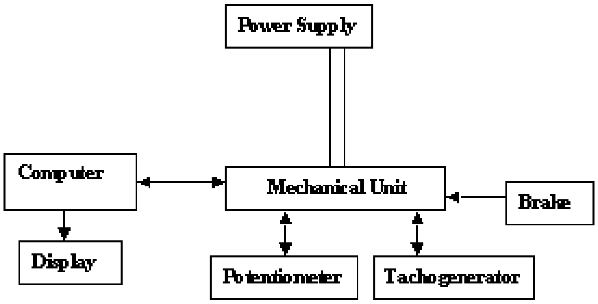

Fig. 1, Servo System

B. System Modeling:

The first step in analyzing a system is to establish a mathematical model of the system. In control engineering rather than dealing with hardware device whose components may be electromechanical, hydraulic, pneumatic or electronic we replace such devices or components by their mathematical models. In obtaining a mathematical model however, we must make a compromise between the simplicity of the model and the accuracy of the results of the analysis. Fig.2 shows the circuit diagram of the Dc servomotor, which is under consideration.

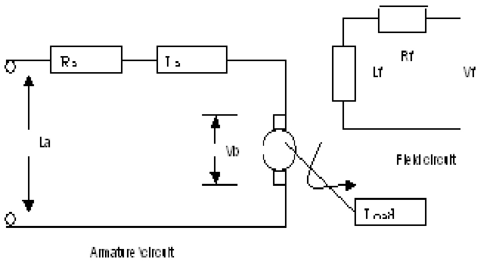

Fig. 2 Internal circuit diagram of the motor

The torque Γ generated by the motor [4] is

$$\Gamma(t) = K\, I_a(t)\, I_f(t) \tag{1}$$

The torque is used to drive a load through a shaft. The shaft is assumed to be rigid. Let J be the total amount of inertia of the load, shaft and the rotor of the motor, and θ be the angular displacement, and f the viscous friction coefficient of the bearing. Then the torque is

$$\Gamma(t) = J\,\frac{\mathrm{d}^2\,\theta(t)}{dt} + f\,\frac{d\theta(t)}{dt} \tag{2}$$

The above equation is the relationship between the motor torque and the load angular displacement. For armature controlled Dc motor, field current I_f is kept constant or the field circuit is replaced by the permanent magnetic field, and if the input voltage u(t) is applied to the motor then (2) can be rewritten as

$$\Gamma(t) = K_t\, I_a(t) \tag{3}$$

Where $K_t = KI_f(t)$ is a constant. When the motor is driving a load a back Electro-motive force (back emf) voltage V_b will be developed in the armature circuit to resist the applied voltage. The voltage $V_b(t)$ is linearly proportional to the angular velocity of the motor shaft.

$$V_b(t) = K_b\,\frac{d\theta(t)}{dt} \tag{4}$$

Thus the armature circuit in Fig.2 is

$$R_a I_a(t) + L_a\frac{dI_a(t)}{dt} + V_b(t) = V_a(t) = u(t) \tag{5}$$

$$or\ \ R_a I_a(t) + L_a\frac{dI_a(t)}{dt} + K_a\frac{d\theta(t)}{dt} = u(t) \tag{6}$$

$$K_t I_a(s) = Js^2\,\theta(s) + f\,\theta(s) \tag{7}$$

$$R_a I_a(s) + sL_a I_a(s) + sK_a\,\theta(s) = u(s) \tag{8}$$

Eliminating $I_a(s)$ from these equations yields

$$G(s) = \tag{9}$$

$$\frac{\theta(s)}{u(s)} = \frac{Kt}{[s(Js+f)(Ra+L_a s)+K_t K_b]}$$

Where L_a is very small and can be negligible

$$G(s) = \tag{10}$$

$$\frac{\theta(s)}{u(s)} = \frac{K_t}{[s(JR_a s + fR_a + K_t K_b)]} = \frac{K_m}{[s(\tau s+1)]}$$

$$\text{Where } K_m = \frac{K_t}{[K_t K_b + fR_a]}$$

$$and\ \ \tau = \frac{JR_a}{K_t K_b + fR_a}$$

The transfer function from v to θ

$$\frac{v(s)}{\theta(s)} = k_l s \tag{11}$$

and the combine transfer from v to u is

$$\frac{v(s)}{u(s)} = \frac{v(s)}{\theta(s)}.\frac{\theta(s)}{u(s)} \tag{12}$$

$$\frac{v(s)}{u(s)} = \frac{K_m}{[s(\tau s+1)]}.\,k_l s \tag{13}$$

$$\frac{v(s)}{u(s)} = \frac{k}{\tau s+1}. \tag{14}$$

where v is the tacho output, u is the input voltage, k is the motor dc gain constant, and τ is motor time constant. No matter how carefully the experiments have been performed in order to compute a system transfer function, there are always uncertainties in the system [4]. So from [5] we have set the transfer function as follow,

$$P(s)=\frac{k}{\tau s+1}. \tag{15}$$

Where $k\in[0.30,0.733]$, $\tau\in[0.1,0.325]$

III IMPLEMENTATION

The complete system which is used for implementation is shown in Fig.3

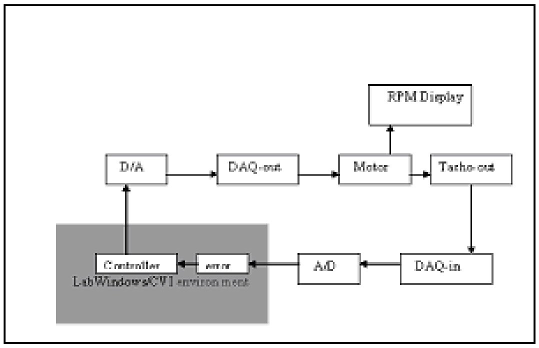

Fig. 3, complete servo- system block diagram

A. Digital PI Controller:

The transfer function of a PI controller is:

$$G_c(s)=\frac{U(s)}{E(s)}=K_p+\frac{K_i}{s} \tag{16}$$

$$=K_p\left(1+\frac{1}{Tis}\right) \tag{17}$$

$$\text{where}\quad T_i=\frac{K_p}{K_i}$$

$$=K_p\frac{T_i s+1}{T_i s} \tag{18}$$

In the implementation of our application, the proportional controller can be used to control the speed of the servomotor with zero external load, but when the external load is applied (on the disc break), the speed of the motor will decrease, and the error will increase. So by using the proportional-Integral controller we can eliminate the steady state error.

The transfer function of the PI controller in z-domain is [14],

$$D(z)=K_p+K_i\frac{T}{2}\left[\frac{z+1}{z-1}\right] \tag{19}$$

For the implementation purposes we need the difference equation of the PI controller, so the difference equation of the PI controller is,

u(kT)= (20)

$$\frac{1}{2}[2u[(k-1)T]+(2K_p+K_iT)e(kT)+$$
$$(K_iT-2K_p)e[(k-1)T]$$

where u(kT) is the controller output, K_p is the proportional gain, K_i is the integral gain, e(kT) is the error signal, and T is the sampling time.

B. Physical limitations

Consider the complete servo-system block diagram as shown in Fig. 3. During implementation a critical eye is kept on the following points:

1. PCI-1200 DAQ-output must be in the range of ± 4.99 volts. Since in our implementation we are dealing with the square wave as a reference input, so the DAQ should be configured as bi-directional. In this case the DAQ-output is limited to ± 4.99 volts.

2. Similarly DAQ-input must be in the range of ± 4.99 volts. Otherwise the inputs exceed the limit may damage the DAQ the PCI-1200 card. These are very important steps, which should be kept in mind while implementing our system; otherwise we can damage the PCI-1200 DAQ card.

3. The input to the motor must be in the range of ± 10 volts

IV Practical Results

Finally after designing the virtual instrument for speed control, we can control the servo system from the front panel of the user interface file. On this panel different controls are given, so by changing the control parameters we can see the effects of these changes on the system response. Changing the values of the controls we can see effects graphically on this panel, where the reference speed input, the controller output, the motor speed output response, and the speed error signal can be observed.

To observe the square wave response, the PCI-1200 is configured in the bipolar range [-3.5,3.5]. Motor speed response, when the reference input is switching from positive to negative is checked. When the positive input is applied the motor rotates in the clockwise direction, but for the negative input it moves in the anti-clock wise direction.

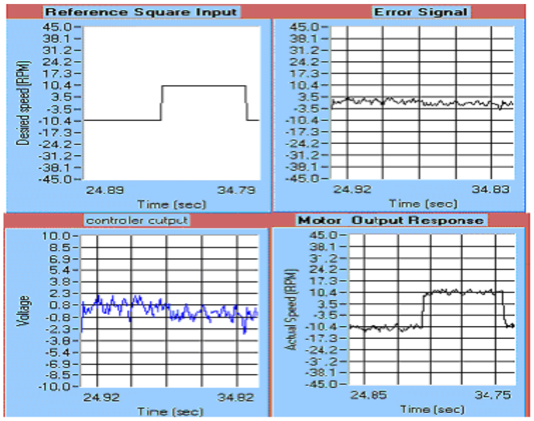

Fig. 4, Square wave response of the motor when the reference input signal is 10.4 rpm (no load)

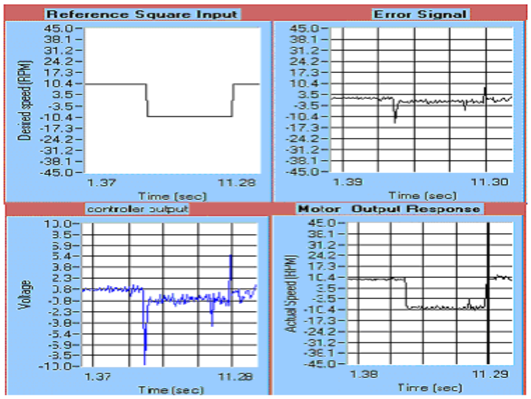

Fig. 5, Square wave response of the motor when the reference input signal is 10.4 rpm (with load)

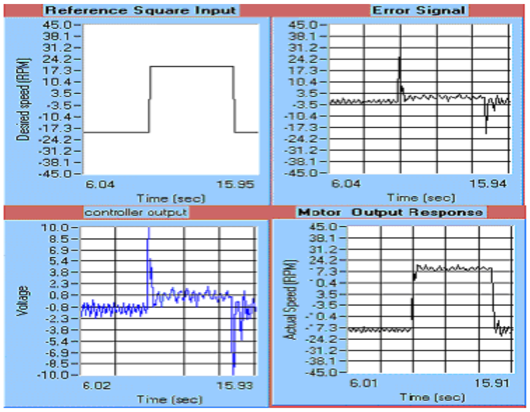

Fig.6 Square wave response of the motor when the reference input signal is 17.5 rpm (no load)

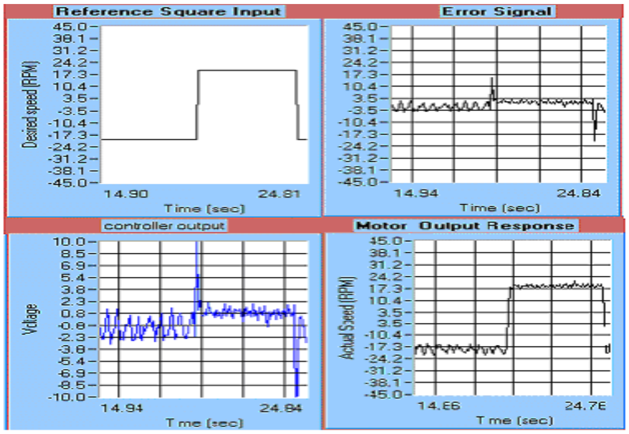

Fig.7, Square wave response of the motor when the reference input signal is 17.5 rpm (with load)

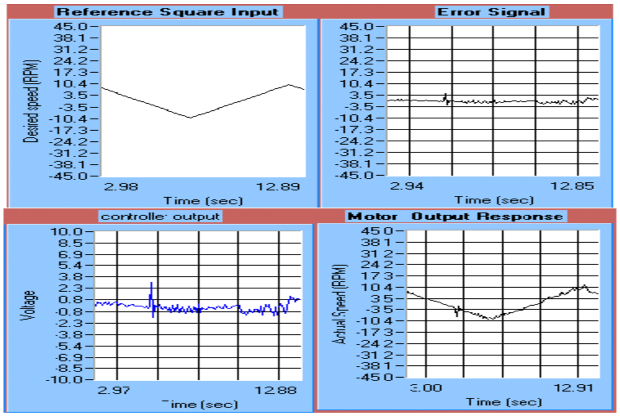

Fig.8, Triangular wave response of the motor when the reference input signal is 10.4 rpm (no load)

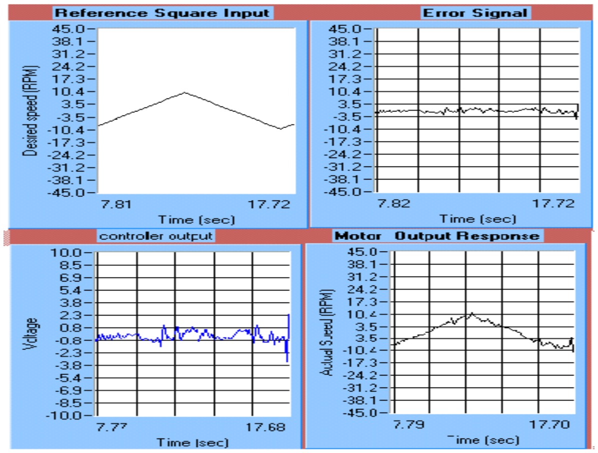

Fig.9, Triangular wave response of the motor when the reference input signal is 10.4 rpm (with load)

V Conclusion

This project focuses on the importance of computer-controlled systems. By using the proposed software implementation of speed control of servomotor is done. By using the proposed control technique, we can monitor how the system works in a sophisticated manner. On the computer screen we can see all operating values related to the control system.

This project concerns with the servo system, which includes a Mechanical unit (MU154C), so in order to get familiarized with the servo system, different experiments have been performed. Dead-zone, which is the nonlinear characteristic of the motor, is observed. Due to this characteristic, the system is insensitive to small input voltages in the range of [-0.7,0.7].

In the implementation of speed control of servomotor the proportional control reduces the steady state error, if the external load is not applied to the motor shaft. If the load is applied, the actual motor speed decreases, and the steady state error increases. To overcome this problem, we use integral controller together with the proportional controller, which eliminates the steady state error.

Using menu bars that are placed on the front panel of the graphical user interface, the whole system is controlled by pressing the relative command icon. Moreover it renders the use of some electronic boards by incorporating the functions of these boards in the software. This software can run standalone.

Using the proposed software square and triangular waves inputs are produced within the computer [7], which are used as reference input signals in speed control application.

VI References

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