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SKEE 3732
BASIC CONTROL LABORATORY
(Experiment 2)

ANGULAR POSITION CONTROL

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Date	: 1 September 2022	Date	: 1 September 2022

ANGULAR POSITION CONTROL

Equipment Required
ED-4400B DC Servo Trainer
Oscilloscope

Objectives

1. To investigate the angular position control performance and response of the servo motor under proportional control.
2. To investigate the position controller step response for various levels of proportional gain
3. To investigate the use of velocity feedback as a means of improving the transient response of an angular position control system.

Introduction

This experiment gives an introduction to control engineering principals by firstly considering the operating characteristics of the individual elements used in typical control engineering systems. In simple position control system, an error signal proportional to the difference between input of set position and actual position is generated. The error signals are then fed into the controller. The output from the controller drives the motor closer to the desired position. The analysis on the actually respond of the system to various steady state and transient operating criteria is observed. Some examples where accurate position control is required is the position control of the gun turret on a battle tank, which must be capable of rapid aiming, target tracking and rejection of external disturbances.

The full servomotor block connection for this experiment is shown in Figure 1.1. It is important that this block connection is maintained throughout this experiment. The ED-4400B DC Servo Trainer, which is used in this experiment is depicted in Figure 1.2.

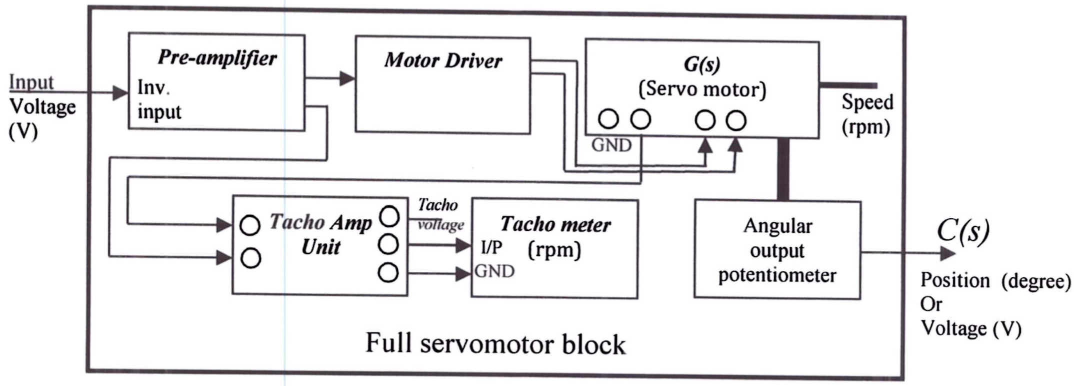

Figure 1.1 Servomotor block

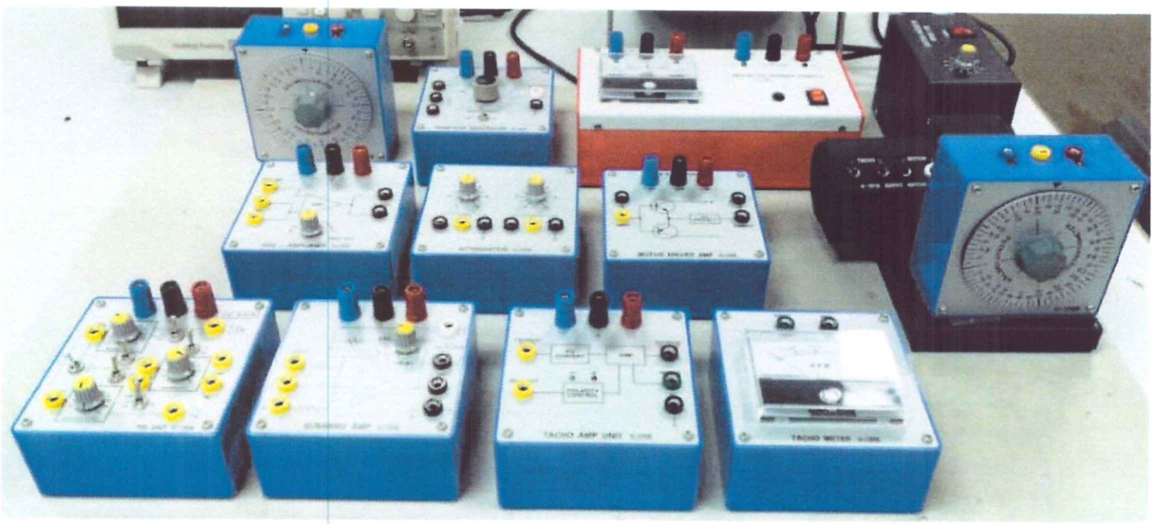

Figure 1.2 ED-4400B DC Servo Trainer

References:

1. Norman S. Nise, Control Systems Engineering (8th Edition), John Wiley and Sons, 2019.
2. Katsuhiko Ogata, Modern Control Engineering (5th Edition). Pearson Education International, Inc., 2010.

Procedure

In this laboratory, there are four experiments need to be performed.

A. Basic Tests and Dead Zones

1. Connect the equipment to give the equivalent block diagram as shown in Figure A.1. Use the P only in the PID module as the proportional controller, K_p
2. Switch on the power and set the initial setting for the reference position to 180 degree with $K_p = 0.2$
3. Slowly turn the reference position dial clockwise and verify that the angular position output gives the same clockwise direction.
4. Repeat step 3 in the anti-clockwise direction.
5. If the output shaft gives the opposite direction to the reference position, interchange the polarity connection at the motor driver output in Figure 1.1.
6. Slowly turn the reference position dial clockwise until the output shaft just begins to move. Read the angle (θ_1) on the reference position dial.
7. Turn the reference position dial anti-clockwise, and note the angle (θ_2) at which the output dial just begins to move.
8. The difference between these angles (θ_1 - θ_2) is the effective dead-zone width of the controller.
9. Record the difference in Table A.1.
10. Repeat the above procedure for $K_p = 0.4, 0.6, 0.8, 1.0$.

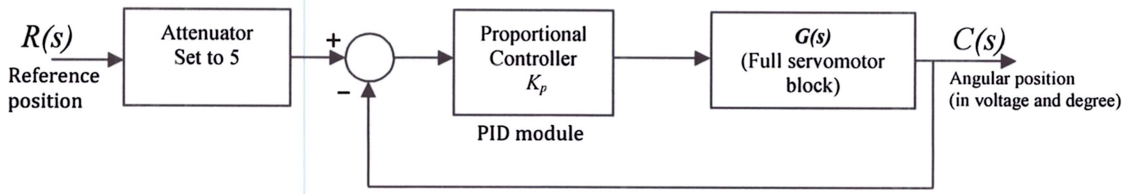

Figure A.1: Closed loop DC motor position control

ATTENTION: PLEASE SEPARATE THE POWER SUPPLY CONNECTIONS FOR THE MOTOR DRIVER FROM THE OTHER POWER SUPPLY CONNECTIONS.

ASK THE LAB SUPERVISOR/ASSISTANT ENGINEER TO VERIFY YOUR CIRCUIT CONNECTION BEFORE YOU PROCEED

Table A.1: Effective Dead-zone for Proportional Controller

Proportional Gain (K_p)	Width of input reference ($\theta_1 - \theta_2$)
0.2	
0.4	
0.6	
0.8	
1.0	

B. Angular Position Transducer Calibration

1. Use the same connection as in part A.
2. Switch on the power and set the initial setting for the output potentiometer position to 180 degree. Record the corresponding voltage.
3. Slowly turn the servomotor output shaft until the output potentiometer gives a specified angle.
4. Choose 5 positive and 5 negative angles for the output potentiometer, and record the corresponding position sensor output in Table B.1.

Table B.1: Output shaft angular position sensor calibration

	Indicated angle of Output shaft (degree)	**Position sensor output (V)**
Decreasing negative angle value		
	0	
Increasing positive angle value		

C. Servo Trainer position control: Step Response

1. Use the same connection as in Part A. In this part, a square wave input will be applied to the system as reference position and the output response will be measured using an oscilloscope.
2. Connect the square wave signal provided to the system at 0.1Hz.
3. Sketch the angular position output signal from oscilloscope for $K_p = 0.1$.
4. Measure the percent overshoot (*%OS*), peak time (T_p) and settling time (T_s) from the output responses.
5. Repeat steps 3 and 4 for $K_p = 0.2, 0.4, 0.6, 0.8$ and 1.0
6. Record the *%OS*, T_p, and T_s for different values of K_p in Table C.1.

Table C.1: Step response over various gain K_p

Propotional Gain K_p	**%OS**	T_p **(s)**	T_s **(s)**
0.1			
0.2			
0.4			
0.6			
0.8			
1.0			

D. Angular Position Control: Velocity Feedback

1. Connect the equipment corresponds to the block diagram shown in Figure D.1. The difference is just an additional minor feedback loop as compared to the connection in Part C.

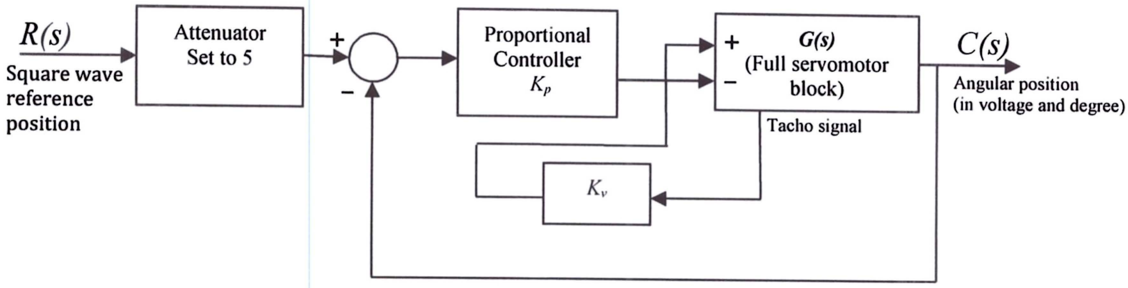

Figure D.1: Closed loop DC motor Position control with velocity feedback

2. Set the Proportional controller, $K_p = 0.2$ and the velocity feedback gain, $K_v = 1$.
3. Sketch the angular position output signal read from oscilloscope.
4. Measure $\%OS$, T_p, and T_s, from the output response.
5. Repeat for $K_p = 0.2, 0.4, 0.6, 0.8$ and 1.0
6. Record the $\%OS$, T_p, and T_s for different values of K_p in Table D.1.

Table D.1: Step response (using velocity feedback) over various gain K_p

Propotional Gain K_p	**%OS**	T_p **(s)**	T_s **(s)**
0.2			
0.4			
0.6			
0.8			
1.0			

Discussion and general conclusion

1) From Experiment B:
   a. Plot the graph using the data from Table B.1.
   b. Calculate the angle sensor constant, $K_\theta = \dfrac{\Delta\theta}{\Delta V}$
   c. Describe the relationship between the indicated angle and the position sensor output voltage.

2) From Experiment C:
   a. Discuss the relative performance of the controller with various gains K_p.
   b. Sketch the output waveform from the oscilloscope.

3) From Experiment D:
   a. Explain why the velocity feedback has a beneficial effect on the system transient response.
   b. Sketch the output waveform from the oscilloscope.

For long report.

1. In your own words, explain the relationship between the voltage and the position angle of the DC motor.
2. Draw in details, the output response of the system for different gains.
3. Carry out the time domain analysis on the system output response.
4. Discuss the effect of velocity feedback on the system transient response.
5. By using Matlab, compare your simulation results with experimental results.