Faculty :	FACULTY OF ELECTRICAL ENGINEERING		
Subject :	**Common Third Year Laboratory**	Review Released date Amendment	: **4** : **Sept 2016** : **Sept 2022**
Subject code :	**SKEE3732**	Procedure no.	: **PK-UTM-FKE-(O)-08**

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SKEE 3732
BASIC CONTROL LABORATORY
(Experiment 1)

ANGULAR SPEED CONTROL

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Date	: 1 September 2022	Date	: 1 September 2022

ANGULAR SPEED CONTROL

Equipment Required
ED-4400B DC Servo Trainer
Oscilloscope

Objectives

1. To calibrate the circuit of the Servomotor, namely the input actuator (the motor circuit).
2. To calibrate the circuit of the Servomotor, namely the output sensor (the speed sensors).
3. To determine the time constant, ***T*** of the servomotor transfer function with differing load.
4. To implement a proportional controller of the Servomotor speed and investigate the steady state errors.

Introduction

A servo control system is one of the most important and widely used forms of control system. Any machine or piece of equipment that has rotating parts will contain one or more servo control systems. The job of the control system may include:

- Maintaining the speed of a motor within certain limits, even when the load on the output of the motor might vary. This is called regulation.

- Varying the speed of a motor and load according to an externally set programmed of values. This is called set point (or reference) tracking.

The primary object of the servomotor training equipment is to provide a practical environment in which to study and understand the control of a servo-system. These systems are used widely throughout all branches of industry to such an extent that a ground in servo mechanism control forms a basic component of a control engineer's training. A simple but widespread industrial application of servo control is the regulation at a constant speed of an industrial manufacturing drive system. For example, in the production of strip plastic, a continuous strip of material is fed through a series of work stations. The speed at which the strip is fed through must be precisely controlled at each stage.

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.

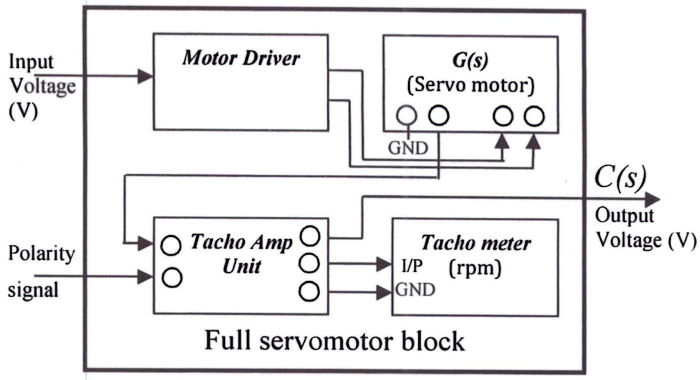

Figure 1.1 Servomotor block

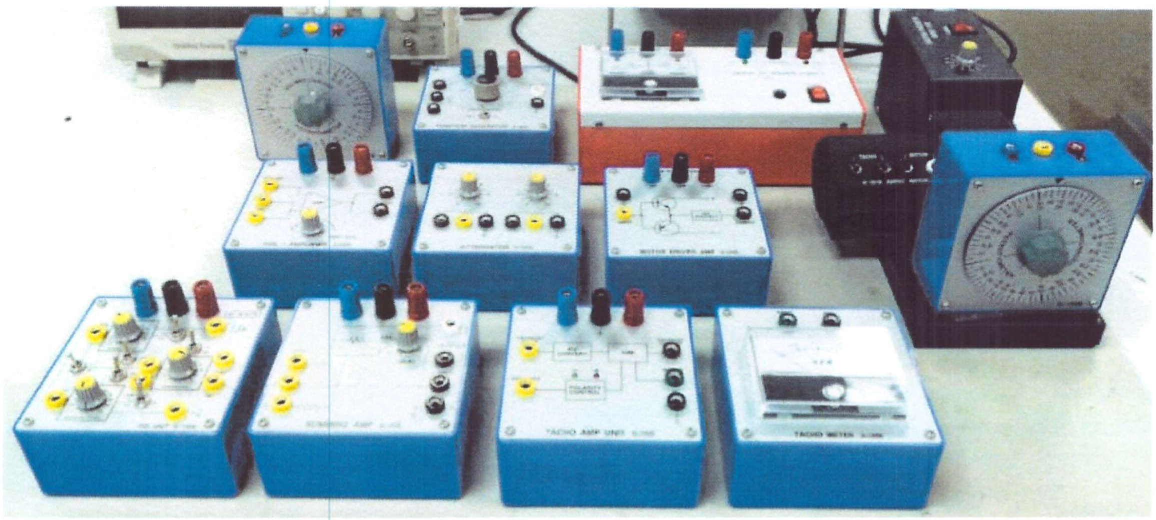

Figure 1.2 ED-4400B DC Servo Trainer

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. Motor Calibration Characteristics

Before starting, make sure all supplies are switched off.

1. Connect the equipment to give the equivalent block diagram as shown in Figure A.1. Refer Figure 1.1 for the full servomotor block connection and connect the polarity signal to the input voltage.
2. Set the input potentiometer so that the initial reading is 0 V. (The angle scale should be at the 180° mark)
3. Increase the input potentiometer until the motor starts to move and record the input voltage in Table A.1 together with the corresponding motor speed. (Note: Maximum motor drive voltage is 10 V)
4. Further increase input potentiometer voltage to all available scale and record the corresponding input voltage and motor speed in Table A.1.
5. Repeat the procedure with negative voltages.
6. Repeat the above procedure with a load attached to the servomotor and complete Table A.2. (Use the magnetic break as the load with scale 10).

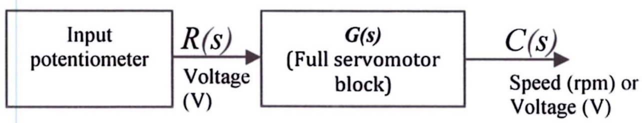

Figure A.1: Open loop DC motor speed control

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: Motor Drive Calibration (no load)

Motor Drive Voltage (V) (*Positive*)	Motor Speed (*rpm*)	Motor Drive Voltage (V) (*Negative*)	Motor Speed (*rpm*)
0	0	0	0

Table A.2: Motor Drive Calibration (with load)

Motor Drive Voltage (V) (*Positive*)	**Motor Speed (*rpm*)**	**Motor Drive Voltage (V) (*Negative*)**	**Motor Speed (*rpm*)**
0	0	0	0

B. Speed Sensor Calibration

1. Use the same connection as in Part A, which has the equivalent block diagram as shown in Figure A.1.
2. Set the input potentiometer so that the initial reading is 0 V. (The angle scale should be at the 180° mark)
3. Increase the input potentiometer to the next scale.
4. Record the corresponding tachometer voltage and the motor speed. Record the readings in Table B.1, accordingly.
5. Repeat the process for all input potentiometer scales for positive and negative speed sensor readings.

Table B.1: Speed Sensor Calibration (without load)

Motor Speed (*rpm*) (*Positive*)	**Speed Sensor Output (*V*)**	**Motor Speed (*rpm*) (*Negative*)**	**Speed Sensor Output (*V*)**

C. Measurement of Gain and Time Constant

1. Connect the equipment to give the equivalent block diagram as shown in Figure C.1.
2. Set the function generator to a square wave with a frequency of 0.1 Hz and the attenuator to scale 9.
3. Using an oscilloscope, observe and record that the square wave input signal to the servo motor (Use Channel 1 of the oscilloscope).
4. The output response of the tachometer will therefore be a series of step responses. Observe and record the output response using the other channel of the oscilloscope. Calculate the ratio between output voltage and the input voltage which is A.
5. Find the time constant T_c from the output responses without load and with load, respectively.
6. Record and draw the output responses for both conditions (with- and without load), respectively.
7. The servo motor transfer function is given by:

$$G(s) = \frac{A}{s + \frac{1}{T_c}}$$

where,
A = the ratio between output voltage and input voltage.

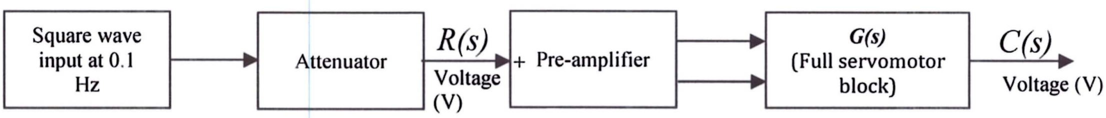

Figure C.1: Open loop DC motor Speed control with square wave input

D. Proportional Control of Servo Trainer Speed

1. Connect the equipment to give the equivalent block diagram as shown in Figure D.1, with no load attached.

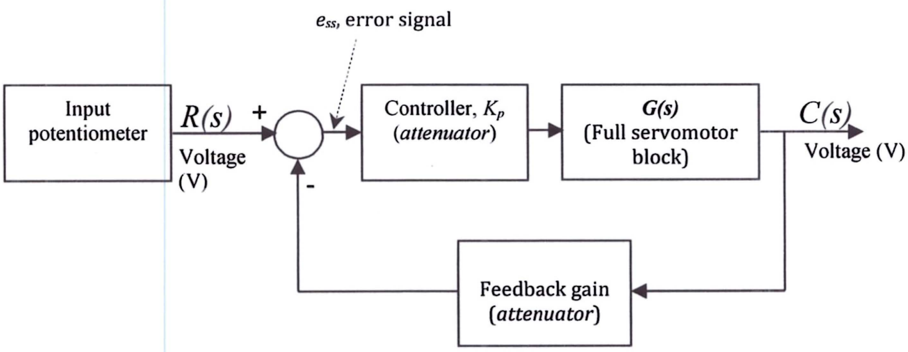

Figure D.1: Closed loop DC motor Speed control

2. Use the attenuator as the controller and set the gain, K_p = 1. (*To make use of the increasing scale of the attenuator correctly, reverse the ground connection at the attenuator*).
3. Set the attenuator for the feedback gain to scale 5.
4. Increase the reference speed voltage according to the scale on the potentiometer. Record the input potentiometer voltage y_r and the corresponding errors signals in Table D.1.

5. Use equation (1), the value of $K_p = 1$ and $G_1 = AT_c$ (where A and T_c are found in part C previously) to calculate the theoretical values of e_{ss} for various values of y_r and enter your results in Table D.1in the column provided.

$$e_{ss} = \frac{y_r}{1 + K_p G_1} \qquad (1)$$

Table D.1: Steady State Error for Various Reference Speeds

Potentiometer Setting (+*ve only*) (*Reference speed, y_r*)	**Measured Steady State Error Signal (*V*)**	**Theoretical Steady State Error Signal (*V*)**

5. Set the input potentiometer such that it gives a reading of 5 V.
6. Vary the controller gain K_p from 1 to 10 and record the corresponding error signal in Table D.2.
7. Use equation (1) to calculate the theoretical values of the error for each K_p value and enter the results in Table D.2.

Table D.2: Steady State Error for Various Controller Gains

Potentiometer Controller Gains (K_p)	**Measured Steady State Error Signal (*V*)**	**Theoretical Steady State Error Signal (*V*)**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Discussion and general conclusion

1) From Experiment A:
   a. Why does the different polarity of input voltage give different directions of motor movement?
   b. Plot the results obtained from Table A.1 and Table A.2. Identify the dead zones for both graphs,
   c. From the graphs, describe the relationship between the input motor drive voltage and the motor speed reading.
   d. Explain, why does motor drive calibration with and without load give different results.

2) From Experiment B:
   a. Explain the concept of angular speed measurement.
   b. Plot your results using the data from Table B.1.
   c. Obtain the speed sensor constant (ie, $\frac{\Delta rpm}{\Delta V}$).

3) From Experiment C:
   a. Comment on the output shape of the motor drive voltage to speed sensor output voltage characteristics.
   b. From the time constant obtained and assuming that the system can be approximated as a first order system, determine the servo motor transfer function.
   c. Discuss the differences (if any) between the time constants obtained from applying and not applying the load.

4) From Experiment D:
   a. Discuss the change in steady state error based on various values of y_r and K_p.

For long report.

1. In your own words, explain the relationships between the voltage and the speed of the DC motor.
2. What is the dead zone and how does the effect of load to the dead zone.
3. Draw the detail output response of the system and find the time constant.
4. Based on time domain analysis, find the transfer function of the system.
5. Discuss the effect of K_p on the system steady state error.
6. By using the Matlab software, compare your simulation results with the experimental results.