

Fakulti:	<b>FAKULTI KEJURUTERAAN ELEKTRIK</b>		
Nama Matapelajaran : MAKMAL TAHUN TIGA UMUM	Semakan	: <b>3</b>	
Kod Matapelajaran : <b>SKEE 3732</b>	Tarikh Keluaran	: <b>Sept 2016</b>	
	Pindaan Terakhir	: <b>Sept 2017</b>	
	No. Prosedur	: <b>PK-UTM-FKE-(O)-08</b>	



**FAKULTI KEJURUTERAAN ELEKTRIK  
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## **SKEE 3732 BASIC CONTROL LABORATORY (Experiment 1) ANGULAR SPEED CONTROL**

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**Recommended References:**

1. Norman S. Nise, Control Systems Engineering (6th Edition), John Wiley and Sons, 2008
  2. Katsuhiko Ogata, Modern Control Engineering (4th Edition). Pearson Education International, Inc., 2002.
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## ANGULAR SPEED CONTROL

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### **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.

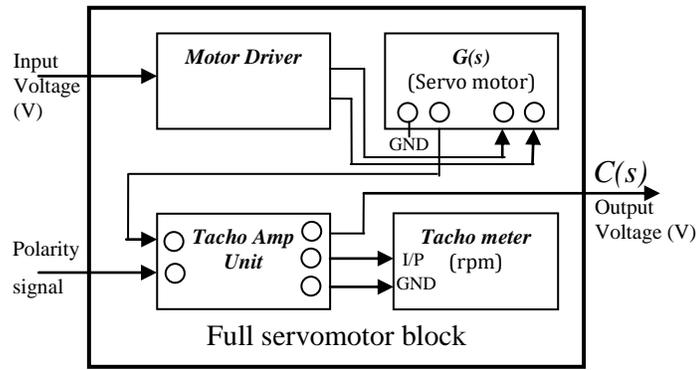


Figure 1.1 Servomotor block

References:

1. Norman S. Nise, Control Systems Engineering (6th Edition), John Wiley and Sons, 2008.
2. Katsuhiko Ogata, Modern Control Engineering (4th Edition). Pearson Education International, Inc., 2002.





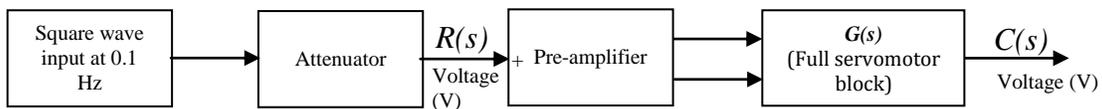
### C. Measurement of Gain and Time Constant

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,

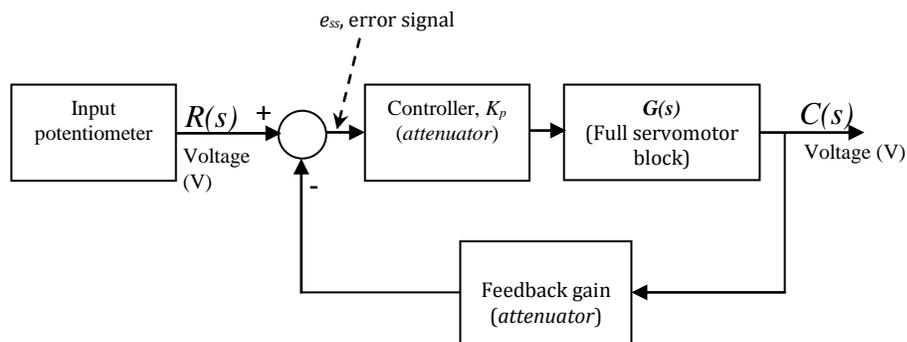
$A$  = the ratio between output voltage and input voltage.



**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.

- 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.1 in the column provided.

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

**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)

- Set the input potentiometer such that it gives a reading of 5 V.
- Vary the controller gain  $K_p$  from 1 to 10 and record the corresponding error signal in Table D.2.
- 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, the servo motor transfer function.
  - c. Discuss the differences (if any) between the time constants obtained from engaging and disengaging the clutch.
- 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.