KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
Electrical Engineering Department

EE 380 - Control Engineering **Experiment # 3**

Identification of DC Motor and Tachometer Constants

OBJECTIVES:

To identify the constants in the mathematical models of a DC motor and a tachometer experimentally.

APPARATUS:

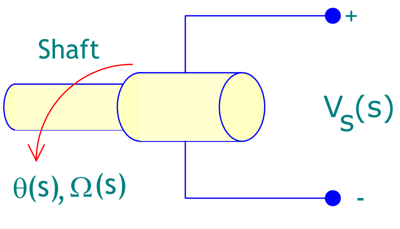
Servo Kit Components:

1. Servo Amplifier : SA150D
2. Servo Motor : MT150F
3. Power Supply : PS150E
4. Attenuator Unit : AU150B
5. Operational Amplifier : OU150A
6. Voltmeter – Osciloscope – x-y Plotter.
7. Stop-Watch

INTRODUCTION:

DC motors are used extensively in many control applications. Therefore, It is necessary to establish mathematical models for DC motors. The transfer function of a DC motor can be approximated by a first order model with unknown constants. These constants can be identified experimentally.

The tachometer works essentially as a voltage generator, with the output voltage proportional to the magnitude of the angular velocity of the input shaft. Tachometers are used in control systems in many ways; they can be used as a speed indicator to provide shaft-speed readout or to provide speed feedback signal in the case of speed control systems. A schematic diagram of the tachometer is given in Fig. 1.



$$V_s(s) = K_t \; \Omega(s) = K_t \; s\,\theta(s)$$

K_t tachometer constant

Fig. 1 Tachometer schematic diagram

SYSTEM COMPONENTS:

Servo amplifier [SA150D]:

This unit operates the motor from signals applied to the input sockets 1 or 2. These two inputs allow reversing the motor rotation. The unit may be connected for field control or armature control. For armature control, connect sockets (3,6), (4,5), and (7,8); these connections are indicated with the letter A. The servo amplifier is connected to the servo motor by an 8-pin plug and able. Terminals for ± 15 volts and ground (common) are available on this unit.

Servo motor [MT150F]:

This unit is a dc motor that produces a torque of the order of 8 oz-in (600 gm-cm) at 2A input current. The inertia is about $3x10^{-5} Kg-m^2$. The output shaft may be fitted with a brake disc and/or an inertia disc to load the motor. A second shaft on the side of the motor is coupled to the main shaft by 30:1 gears (the smaller shaft rotates slower than the main shaft). The tachometer with terminals +, - and common (ground) is attached to the motor. The transfer function of the motor is:

$$\frac{\Omega(s)}{E(s)} = \frac{K_M'}{b}\frac{1}{1+s\tau_m} = K_M \frac{1}{1+s\tau_m} \quad \text{where}$$

$\Omega(s)$	output speed Laplace transform
$E(s)$	input voltage Laplace transform
K_M'	motor torque constant (torque units/volt)
K_M	motor torque constant ([rad/sec] /volt)
b	motor shaft viscous friction coefficient (torque units / [rad/sec])
τ_m	motor time constant (sec)

If the input voltage is a unit-step, then the output speed (with zero initial condition) is:

$$\omega(t) = \frac{K_M'}{b}(1 - \epsilon^{-\frac{t}{\tau_m}}) = K_M\ (1 - \epsilon^{-\frac{t}{\tau_m}})$$

Power supply [PS150E]:

This unit provides the various supplied required for the servo components. There are terminals for ±15 volts, and common (ground). An ammeter is also included. The maximum current is 2 A. An 8-pin socket and cable connects this unit to the servo amplifier.

Attenuator unit [AU159B]:

This unit consists of two separate 10 $K\Omega$ potentiometers.

Operational amplifier unit [OU150A]:

This unit is an operational amplifier. A selector switch allows the use of the unit as a summer, integrator or with any external circuit in the feedback path. The unit is used as an error detector which determines the difference between the demand and response. Before using the unit, measure the output of the unit and adjust it to zero with the zero control, when the input voltages at sockets 1 and 2 are zero.

PROCEDURE:

The experiment consists of three parts: measurement of the tachometer coefficient, measurement of the motor constant , and measurement of the motor time constant.

I. Measurement of tachometer coefficient [K_t]

The tachometer output voltage v_t is proportional to the speed of its armature, i.e. $v_s = K_t\,\omega$, where tachometer constant. The following procedure can be used to identify the tachometer constant.

1. Connect the circuit shown in Fig. 2.
2. Mechanically attach the potentiometer with the scale to the motor slow speed shaft.
3. Set the input potentiometer (on the AU150B unit) to zero and turn on the power.
4. Vary the input potentiometer setting; the motor speed should change.
5. Measure the motor speed using a timer and the tachometer voltage using a voltmeter.
6. Calculate the value of K_t in mv/rpm. Compare with the nominal value.

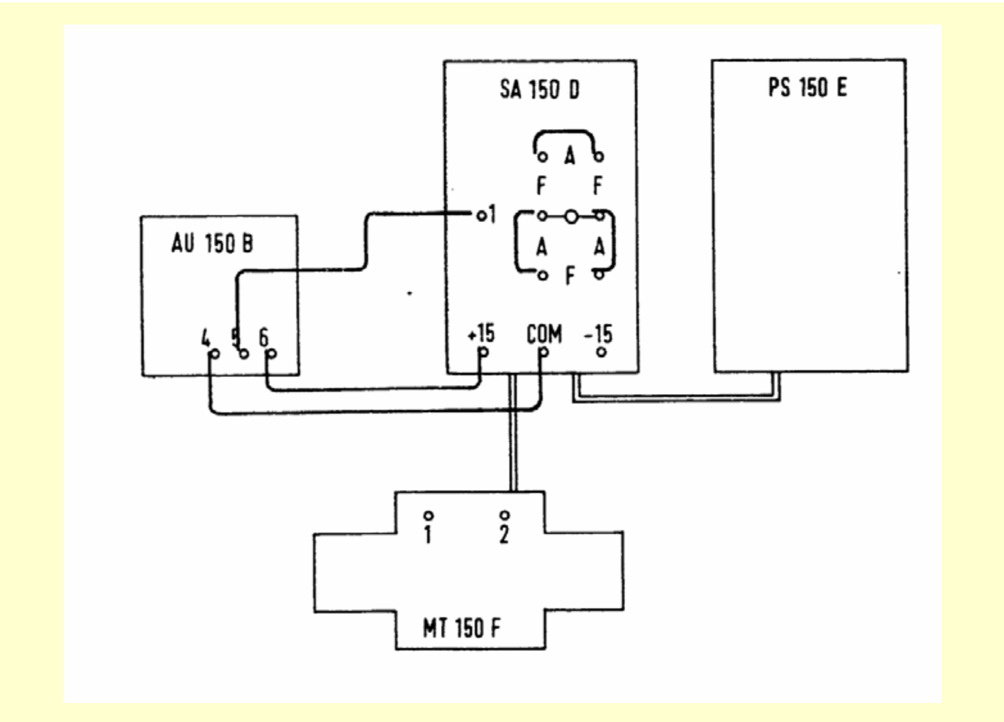


Fig. **1** Measurement of tachometer constant

II. Measurement of the servo motor-servo amplifier constant [$\frac{K'_M}{b}$]

1. Use the previous circuit shown in Figure 2, but remove the rotary potentiometer from the motor shaft.
2. Obtain a plot of tachometer voltage vs. servo amplifier input voltage. Do not exceed 2A from the power supply. Carefully note the input voltage when the motor just begins to turn.
3. Calculate the value of $\frac{K'_M}{b}$ for the servo motor /servo amplifier combination. Clearly show how you find this value.

III. Measurement of the motor time constant [τ_m]

1. Connect the circuit shown in Fig. 3.
2. Set the signal generator to provide a 0.1 Hz square wave. Adjust the amplitude to obtain a steady state tachometer voltage of 10 volts. Observe the tachometer voltage on the oscilloscope when the motor speed builds up and fall. You may use the **x-y plotter** to record this signal.

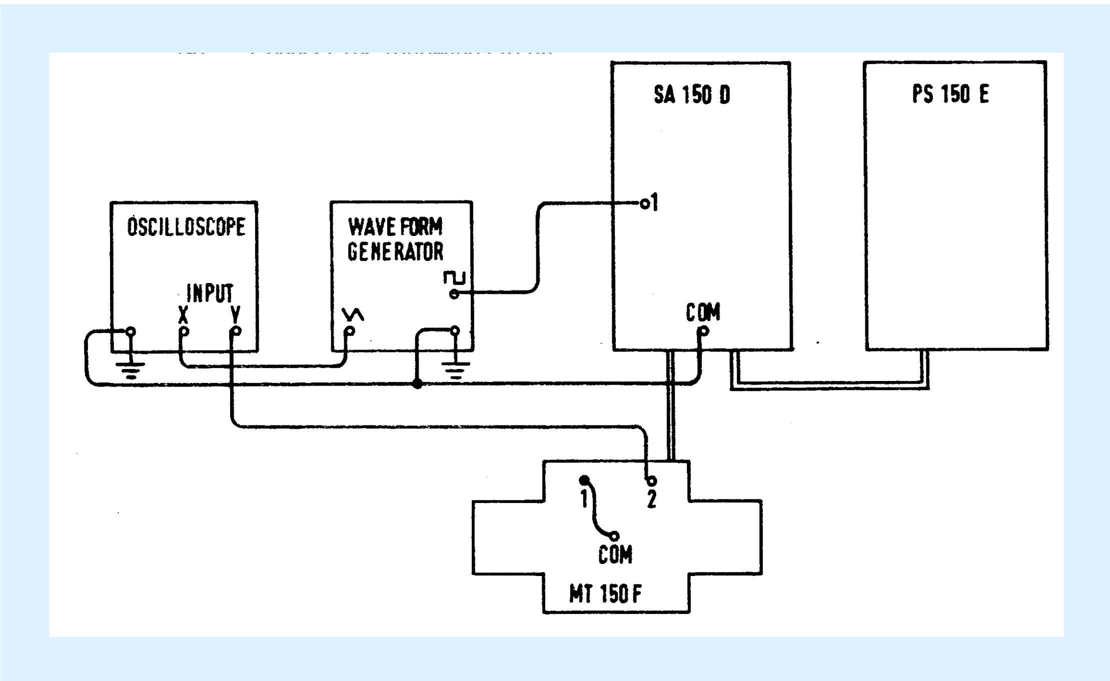


Fig. **2** Measurement of the motor time constant

DISCUSSION:

1. Explain the behavior of the motor speed when an input voltage is first switched. Assume the motor brushes produce a constant friction torque.
2. Give a brief idea about the open and closed loop performance of motor speed control.
3. Explain how the speed of the motor could be controlled using the field circuit. Compare this method of control with the armature control method.