# Lab 2: Time Domain System ID – First Order System

## Introduction

First order systems describe many physical phenomena. For example, the time history of a capacitor's voltage in a simple RC electrical circuit is a first order system. The temperature history of an oven that is losing heat from conduction or convection is also a first order system. In this laboratory experiment, the unit step response of the first order hydraulic motor system will be studied.

A major focus in engineering is to develop mathematical models of physical systems to be used to predict a system's response in different loading situations. These plant models are then used as the basis for the formulation of a controller. For example, once oven temperature as a function of heat input has been mathematically modeled, one can design a controller to keep the oven at a desired temperature.

An important step in developing these mathematical models is a process called "plant identification" or "identification analysis". In any given mathematical model, there are physical parameters, such as thermal conductivity, time constant, or elastic modulus, that must be determined. The plant identification step attempts to generate an experimental estimate for these parameters. Physicists may attempt to generate these values analytically.

In this lab exercise, numerical values for the time constant and the gain of a first order hydraulic motor will be estimated using its unit step response. In addition, non-ideal behavior will be studied and understood in terms of the actual physical system that is being investigated.

## Objectives

Proper completion of the laboratory exercise will have required you to:

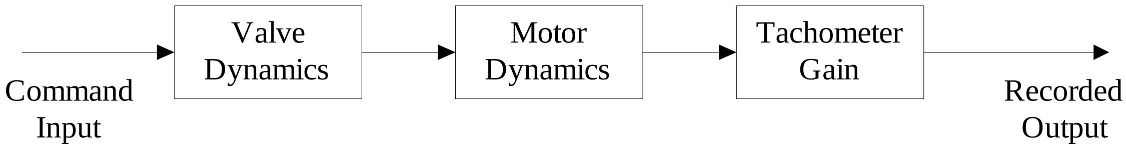
- Observe the characteristics of a first order response.
- Identify the time constant, $\tau$, and the gain, K, for the motor system.
- Deduce the source of unexpected dynamics and signal noise.

## Experimental Apparatus

The Parker Hannifin Hydraulic Trainer stand will be used in conjunction with portable valve/controller board subplates in this laboratory. Parker Hannifin's BD90 valve, in particular, will be used. The valve is a proportional directional control valve, which means that it has the ability to control the direction of the hydraulic fluid flow and the proportion of the flow that gets transmitted through the valve.

The valve will be used to control an actuator, in this case the hydraulic motor. The valve will receive open loop step inputs of varying magnitudes, and the speed response of the motor will be recorded. The Real-Time Windows Target program will be utilized for the data collection and open loop control.

The system block diagram looks like this:




Since the valve and tachometer dynamics are fast, it will be assumed that they do not play a part in the determination of the time constant $\tau$ and gain K. Such assumptions may not always hold, however, so one must be careful when examining the data.

The hydraulic motor's rotational speed is measured via the magnetic proximity sensor. These sensors are commonly used to measure the angular velocity of rotating machines. The engine speed of a car is typically measured with a proximity sensor. The gear induces current in the sensor and circuit. The signal from the proximity switch is available for measurement from the co-ax connection located on the side of the big gray box mounted on the trainer stand. It is labeled "tach".

The tachometer signal described above is a frequency signal. However, that is not as useful as a voltage signal that is directly proportional to the motor's speed. Analog input Channel 7 on the MW2000 converts frequency to a proportional DC voltage that is read by Real-Time Windows Target.

## Experimental Procedure

Construct a circuit to run the hydraulic motor using the Parker BD90 servo valve. The control signal will come from one of the analog output channels on the MW2000. Connect this to the co-ax plug labeled CMD (command). Connect the tachometer reading from the trainer stand to channel 7 on the MW2000.

Open the file 'N:\HydraulicsLab\ME460\first_order_sysid.mdl' and save it to C:\ME460 with a new name that for example contains your netid to make it unique from other students. Also change Matlab's current directory to C:\ME460. Set the step input to occur at 0.75 seconds. Included is a slider gain block in the Simulink program to enable quick changing of the magnitude of the step input. Set the maximum and minimum of the slider block respectively to zero and five. Set the time step to 0.002. Set the stop time to 5 seconds. Save the block diagram.

You will collect two sets of data. The first set will compare step inputs of various magnitudes at a given system pressure. In other words, at 400psi system pressure, you will give the valve step inputs of 1V, 2.5V and 5V.

The second set of data will compare a given step input size at three different system pressures. In other words, you will give the valve a 2.5V input at 300, 400 and 500 psi system pressures.

Have a TA check your connections before starting the system.

Power up the gray box on the valve subplate.

Set system pressure via the relief valve at 400psi.

To tell Simulink to generate C code and build your real-time controller, simply press the Run button. Be patient here as this could take 5 or 10 seconds as Simulink compiles the code. Double click the Scope blocks to see the recorded signals.

**Data Set 1:**

Set the gain in the Simulink block diagram to 1 Volt and start the controller.

After the Simulink controller has stopped the response data is stored in to the Matlab workspace. Show your TA the recorded response to make sure it looks correct.

Repeat the above data collection for step inputs of 2.5V and 5V.

**Data Set 2:**

Collect data for the 2.5V step at system pressures of 300psi and 500psi, and save the data using appropriate names. Use the procedure outlined in Data Set 1.

Shut down the hydraulic trainer stand system and power down the gray box on the subplate.

## Lab Report

1. By plotting the step input and the output voltage in the same plot, observe that there is a delay between the step input and the system response. What could cause the response not to begin at the exact same time as the command input? Think about what is happening in the physical system. What effect does this have on the response of the first order system? How will it (if at all) affect $\tau$ and K?
2. Determine the time constant $\tau$ (use 63% method) and steady state (DC) gain K for each trial in each data set (gain is defined as output divided by input). You are conducting a plant identification of the first order motor system.
3. In Data Set 1, do the gain and time constant change? From Lab 1 we know the system is nonlinear. Using your knowledge of the nonlinear model and physical system, explain why the gain and time constant do or do not change.
4. Compare Data Sets 1 and 2. Do the transfer functions change? What is the difference between the two Data Sets? Does this make physical intuitive sense?
5. Quite often, the response (motor speed) of the system to a step input overshoots the final steady state value. Overshoot is a characteristic of higher order systems. We assume our hydraulic motor is a first order system. Why do we see overshoot in the system response?
6. What physical parameters, such as pressure and inertia, affect the system’s response?
7. How did signal noise affect your system identification measurements?