

# ME 4232: Fluid Power Control Lab

University of Minnesota

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## Lab. 15: Introduction to the Electro-hydraulic control setups

### Objective

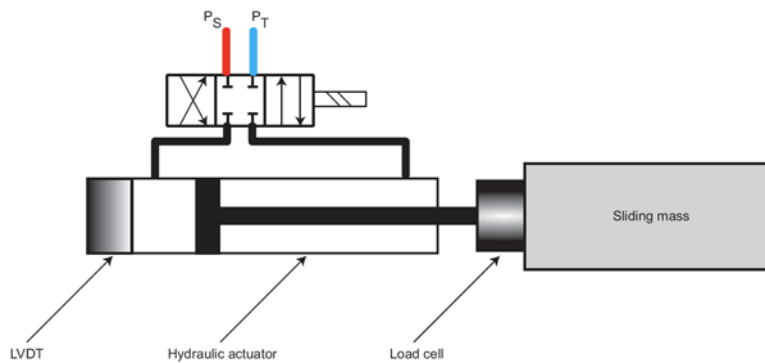
During the second half of the course, we will perform experiments on two electro-hydraulic setups. First, you will identify models for the systems. Then, you will design, analyze, and simulate (in Simulink) the performance of controllers for position regulation and trajectory tracking. Only then will you implement and test the controllers on the experimental hardware.

The purpose of this lab is to introduce you to the various aspects of the setup i.e., hardware components, hydraulic systems, electrical systems and control software.

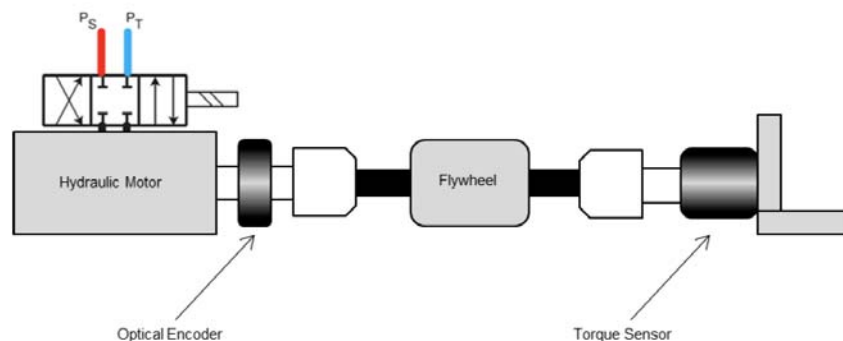
### Hardware Components

The schematics of the two setups are given to you.

#### Setup 1



#### Setup 2

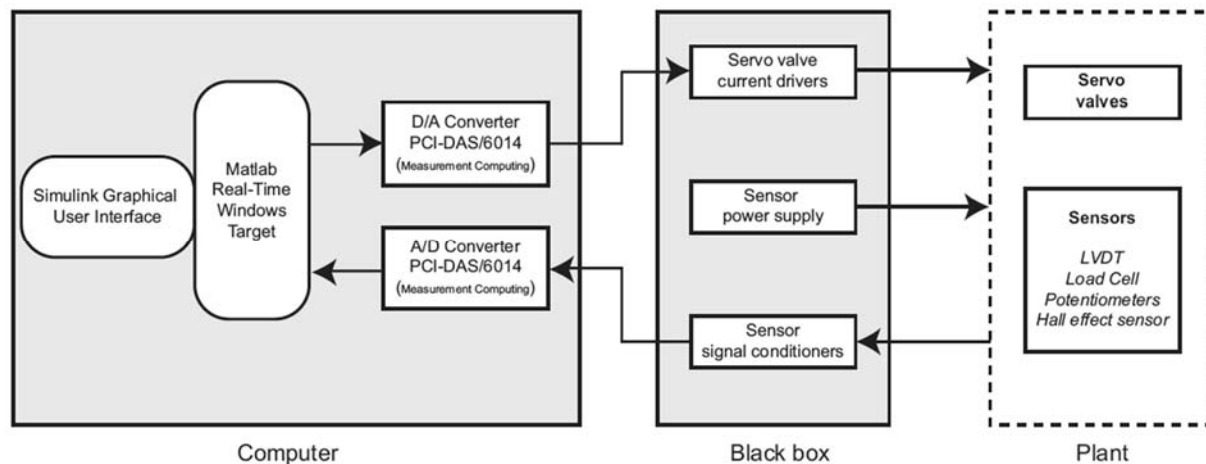


### Hydraulic setup

For servo-valve control applications, hydraulic systems are typically run under a constant pressure condition (as opposed to constant flow rate which was the case on the hydraulic test bench) to ensure precise control of the fluid flow rate to the application. This is achieved by the use of a pump, relief valve, accumulator, and closed center flow control valves. This is a more reliable method to maintain a constant line pressure than using a relief valve alone.

## Electrical setup

The general schematic of the electrical setup is shown in the figure below.



It consists of:

1. **A computer** with a data acquisition card (*Measurement Computing PCI-6014*) for sending (D/A) and receiving(A/D) the control signals to and from the real-world.
2. **A signal conditioner** i.e., the “black-box” which is used to provide the following:
  - a. Current amplification to drive the torque motor in the servo valves
  - b. Appropriate DC power supply for the various sensors (optical encoder, load cell, torque cell, etc)
  - c. The excitation AC supply for the LVDT (Linear Variable Differential Transducer)
  - d. Amplification of the sensor signal from the load/torque transducer
  - e. Conditioning of the LVDT signal to extract the amplitude of the AC signal and convert it to a DC voltage

## Control software

The MATLAB/Simulink along with the Real-time Windows Target toolbox allows us to communicate with the Measurement Computing PCI-6014 computer board. We can collect the signals from the various sensors and after some analysis and manipulation, generate a control command signal to make the physical hardware perform the desired tasks.

## Procedure

### Simulink model

1. Set the sampling rate to be 0.001s
2. Add additional blocks to the simulink model given to you to output a control command to the servo valve(s) and read the signals from the various sensors

3. Make sure you can save the all the data into the workspace (an array) to be accessed later in Matlab

## Calibration of the system

1. Calibrate the servo valve signal to remove any bias i.e., for a control signal of “0”, the actuator should remain stationary
2. For each of the sensors, identify the coefficients in the linear transformation from the sensor signal’s voltage to an appropriate physical quantity i.e.,  $[V_{\min}, V_{\max}] \rightarrow [-X, X]$ . Ensure that the null position i.e., “0” for each of the sensor occurs in the middle of its range

## Open loop identification (Time-domain)

In this part, you will perform experiments on the system to identify “open-loop” models for your current electro-hydraulic actuator setup.

- Send various constant command signals (e.g. 0,  $\pm 1$ ,  $\pm 2$ ,  $\pm 3$ ,  $\pm 4$ ,  $\pm 5$ ... etc.) to the servo valves and observe the velocities of the actuators
  - Write a Matlab script to determine the velocity
- Determine the resolution of the output voltage. Can any change be observed in the system response at the level of the resolution?
- At what input (positive and negative) does the system response stop changing? Why does this occur?
- Derive a linear transfer function model of the system from your experiments (please be sure to justify the form of the model before determining the parameter[s])

## Report

- A schematic of hydraulic circuit.
- Document all your calibration coefficients i.e., various biases and gains for the servo valves and the sensors.
- Explain the model identification procedure in detail. Make sure to include the following figures,
  - Show the plot of the actuator movement from one end to another for a certain input. One the same plot, highlight the linear region used for calculating the velocity.
  - On another plot, show the extracted linear region of the actuator movement plot and the results of the least square fit.
  - Show one plot of ‘**v**’ vs ‘**u**’ i.e., the velocity of the actuator as a function of the servo valve command. Highlight the data points corresponding to the linear region and show the corresponding line fit.
- Does the system performance change when the input is positive or negative? Why?