Laboratory 1: Plant Modeling and Block Diagrams

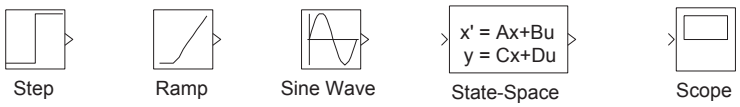
Problem 1:

We want to use Simulink for simulating the following state space models. We will try step input signals, ramp input signals and sinusoidal input signals. Document your simulation results!

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}-2 & -2\\ 2 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}1\\ -1\end{bmatrix} u \qquad \dot{x} = \begin{bmatrix}-3 & 1 & -1\\ 2 & -2 & 1\\ -3 & 4 & -5\end{bmatrix} x + \begin{bmatrix}0\\ 0\\ 1\end{bmatrix} u \qquad \dot{x} = 5\,x + 13\,u$$

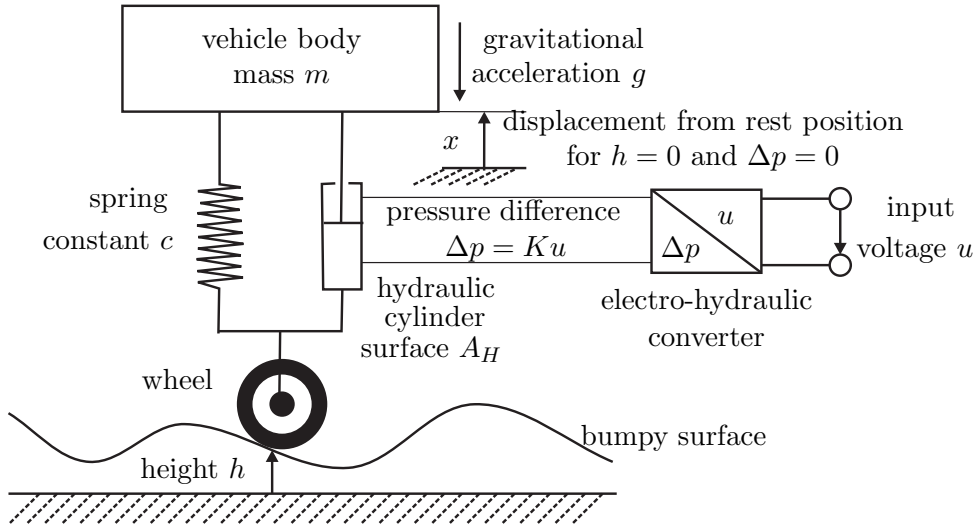
$$y = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} \qquad y = \begin{bmatrix}2 & -5 & 0\end{bmatrix} x \qquad y = x - 3\,u$$

Hint: Use the following blocks in the Simulink Library Browser.



Problem 2:

We examine the active suspension system shown in the following figure. It connects the vehicle body with mass m and the wheel of the car. It consists of a spring with the spring constant c and a hydraulic cylinder with surface A_H. The suspension system is actuated by the electro-hydraulic converter that generates the pressure difference Δp from given input voltage u. In general, the goal of the suspension system is to keep the displacement x from the rest position small (ideally 0) despite of a bumpy surface. This measure increases the ride comfort of the car. Our first task is to model the active suspension system.



a. Decide which of the shown physical variables represent the input signal, output signal and disturbance signal.

b. Determine a state space model that describes the dynamic behavior of the active suspension system. Assume that $h = 0$ for your model.

Hint: Use the following physical relations

- $m\ddot{x} = F_{\sum}$, whereby $F_{\sum}$ is the sum of all vertical forces that act on the car body
- $F_{\text{spring}} = mg + c(h - x)$ (spring force in upper direction)
- $F_{\text{cylinder}} = A_H \Delta p$ (hydraulic cylinder force in upper direction)
- $F_{\text{body}} = mg$ (vehicle body force in lower direction)

c. Simulate your model with the parameters $m = 1000\,\text{kg}$, $c = 10\,000\,\text{N/cm}$, $g = 10\,\text{N/kg}$, $A_H = 15\,\text{cm}^2$, $K = 100\,\text{N/cm}^2/\text{V}$. Use a step input of size 10 V.