



KTH Machine Design

Dynamics and Motion control

Exercises part 1. Modeling



1. Introduction

This document gives part 1 of the exercises that should be performed during the course. They should be done in groups of two or three students. There are two times three hours scheduled hours each week when assistance is available. It is however expected that you will work with the exercises on your own.

The two main laboratories where we will be working are the Mechatronics lab and the Electro-technical laboratory. You will have access to these labs on all hours but they are also used in other courses. See <https://www.md.kth.se/mrbs> for bookings of the labs, the electro lab is called “Wenström”. Due to collisions will some of the scheduled labs be in one of the computer halls in the main Machine house, see the online schedule for latest information. Please respect that others will work on the computer stations that you are using and always clean up when you leave it.

1.1 General guidelines for the exercises

The result of each exercise should be one or more Matlab scripts that can be run with a simple command. If it is necessary or simplifies the understanding of the results they can include an option as input.

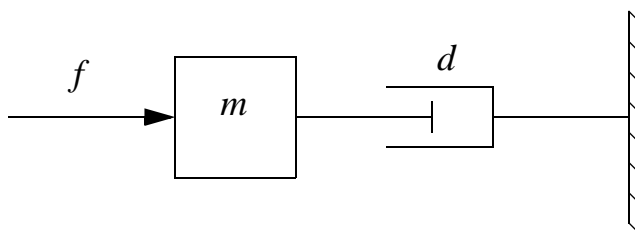
Observe that plots often have to be scaled in a proper way such that the interesting part of the plot is highlighted.

The *subplot* and *hold* commands are useful when plots are complex and build upon each other. Use titles and labels and colours to increase the understanding of the results.

2. Modelling, simulation and analysis of DC-motor with load

2.1

The mechanical system in the figure below consists of a load with mass $m = 0.1$ [kg], a damper $d = 0.5$ [Ns/m]. The damper is mounted between the load and a fixed point, $v = 0$. An external force f can be applied directly on the load.



How many energy storage are there? What is the order of the model.

Derive the model. Derive both a state space model and a transferfunction model. The state space is easiest to derive from Newton's laws of motion and the transferfunction model is easiest to derive using the impedance tools. But opposite is also possible!

In Matlab:

Plot the frequency response (bode), the step response and the pole zero plot. What are the dc-gain and time constant of the system? Both read them from the plot and calculate them numerically.

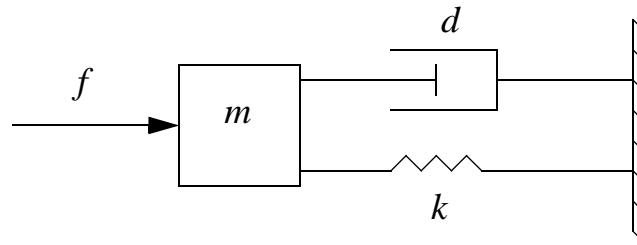
In Simulink:

In the same Simulink file you should model both the transferfunction (use a transferfunction block) and the block diagram of the state space model using $1/s$ blocks. Compare the results of both models to verify that they give the same results.

First simulate the model with the force as a step input, compare it with the Matlab step. Secondly, simulate the models with the applied force as a sine wave. Do two simulation one with sine wave frequency 1 rad/s and one with 10 rad/s. Plot both applied force and velocity in the same plot. Compare the results with the frequency plot and draw conclusions. Is it correct?

2.2

A spring $k = 8$ [N/m] is connected in parallel with the damper.



How many energy storage are there? What is the order of the model.

Derive the model. Derive both a state space model and a transferfunction model. The state space is easiest to derive from Newton's laws of motion and the transferfunction model is easiest to derive using the impedance tools. But opposite is also possible!

In Matlab:

Plot the frequency response (bode), the step response and the pole zero plot, what are the resonance frequency, relative damping and dc-gain?

Make a step response of the system from external force to position, what are the resonance frequency, relative damping and dc-gain now.

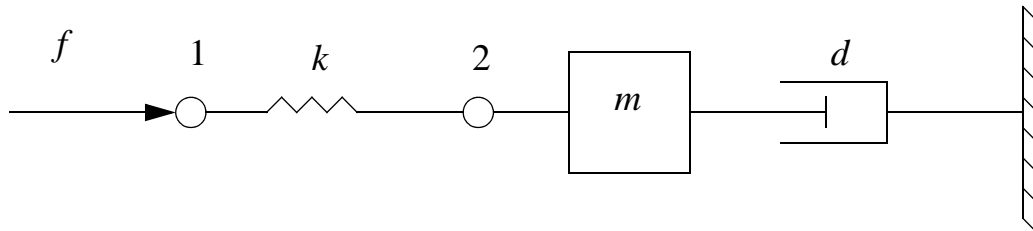
In Simulink:

In the same Simulink file you should model both the transferfunction (use a transferfunction block) and the block diagram of the state space model using $1/s$ blocks. Compare the results of both models to verify that they give the same results

First simulate the model with the force as a step input, compare it with the Matlab step. Secondly, simulate the model with the applied force as a sine wave. Do three simulation one with sine wave frequency below the resonance frequency, one with frequency at the resonance frequency and one at a frequency above the resonance frequency. Plot both applied force and velocity in the same plot. Compare the results with the frequency plot and draw conclusions. Is it correct?

2.3

The spring is now mounted between the applied force and the load.



How many energy storage are there? What is the order of the model.

Derive the following three models based on Newton's laws of motion, and based on the tools of impedance.

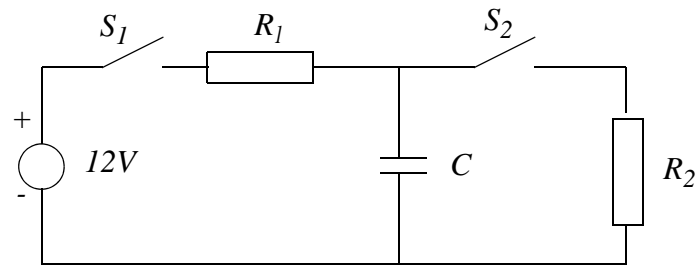
$$G_1(s) = \frac{v_2(s)}{v_1(s)} \text{ from velocity at node 1 to velocity at node 2.}$$

$$G_2(s) = \frac{v_2(s)}{f(s)} \text{ from applied force to velocity at node 2.}$$

$$G_3(s) = \frac{v_1(s)}{f(s)} \text{ from applied force to velocity at node 1.}$$

Do the same type of analysis in Matlab and Simulink as above. There is a problem with $G_3(s)$, why?

2.4 Nonlinear electric network



How many energy storage are there? What is the order of the model(s).

At (simulation) time zero the switch S_1 is closed and it is kept closed rest of the simulation time, so it does not have to be modelled, switch S_2 is open at time zero. Derive the model for the voltage over the capacitor. At time 0.2s the switch S_2 is closed, derive a second model for the voltage over the capacitor. Derive both transferfunction models using impedance tools and a state space models using Kirchhoff laws using both the current and voltage laws. (loop and node equations)

In Matlab:

Plot the frequency response (bode), the step response and the pole zero plot of both the model with S_2 open and when S_2 is closed. What are the dc-gain and time constant of the models? Both read them from the plot and calculate them numerically.

In Simulink:

In the same Simulink file build both a transferfunction model and a block diagram model using only **gain**, **sum** and **integrator** blocks and for S_2 use a **switch** block which is found in the Signal routing library of Simulink, feed it with a **clock** from the source library.

Observe, that for the transferfunction model you have to measure the voltage over the capacitor at two different places in the Simulink model whereas for the block diagram model it is possible to use the same signal line for the output voltage over the complete simulation, before and after closing S_2 .

Compare the results from the transferfunction model and the block diagram model to verify your design.

Simulate the model with a constant input voltage of 12V, $R_1 = 200\Omega$, $R_2 = 400\Omega$ and $C = 10\mu F$.