Computation exercise 3(a): Control design

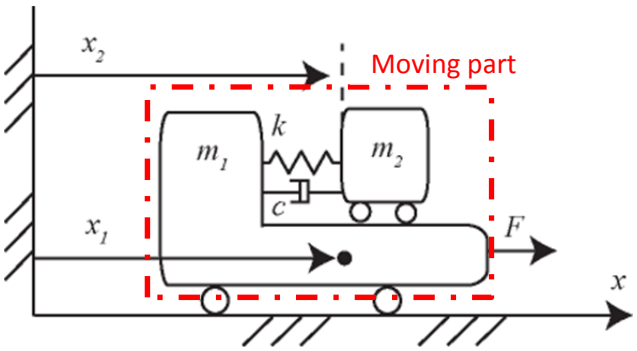
Mechatronic systems
376.050
2014W

Important: Answers must be a hard copy and submitted to the office in CA0421 by January 20, 2015 at 4pm. The work must be original.

Fig. 1 shows a lumped mass model of a positioning system using an electromagnetic actuator (e.g. Lorentz or reluctance actuator), which is introduced in the computation exercise 1(a). Fig. 2 shows a control block diagram to regulate the position x_2 by using the system input F, where $P(s)$ is the plant. The transfer function $C(s)$ is a controller and has the following structure:

$$C(s) = C_{PID}(s)C_{notch}(s),$$

where C_{PID} is a tamed PID controller with a low-pass filter and C_{notch} is a notch filter. Following the questions below, design and implement a feedback controller $C(s)$.



Parameter	Value	Unit
m_1	2	kg
m_2	5	kg
k	10^6	N/m
c	10	N/(m/s)

Fig. 1: A lumped mass model of a positioning system.

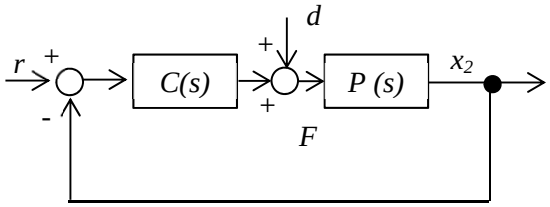


Fig. 2: Control block diagram.

i. Derive transfer function $P(s)$ and simulate a Bode plot. [5%]

ii. Design the notch filter, such that the peak in the magnitude of $P(s)$ is trimmed in the Bode plot of (i). For validation, add a simulated Bode plot of the transfer function $C_{notch}(s)P(s)$ on the figure of (i). [15%]

iii. Design $C_{PID}(s)$ to regulate the plant cascaded with the notch filter (i.e. $C_{notch}(s)P(s)$), fulfilling the following conditions. (See "rule of thumb" in the textbook.) Also simulate a Bode plot of the open-loop transfer function $C_{PID}(s)C_{notch}(s)P(s)$ for validation. [20%]

- Phase margin should be 40 deg or more.
- Gain margin should be 10 dB or more.
- The open-loop cross-over frequency should be as high as possible.

iv. Simulate step response of the closed-loop system with r as the input and x_2 as the output. Also draw step response with the disturbance d as the input and x_2 as the output. Using the results, discuss the influence of the notch filter on these inputs. [20%]

v. To implement *C(s)* designed in (iii) as a digital filter on a microcontroller running at a sampling frequency of 800Hz, discretize *C(s).* Special care should be taken not to change the notch frequency and the cross over frequency. For validation, show Bode plots of the continuous and the discrete controller (i.e. *C(s)* and *C(z)*) on one figure. [20 %]

vi. To implement *C(z)* with gains and memories (time delays), draw a block diagram showing an IIR filter structure and derive the coefficients of the gains. [20 %]