ELEC-E8101 Digital and Optimal Control

Homework 2

Homework 2 given on Tuesday 22.10.2019. To be returned electronically by Monday, 04.11.2019 at 23:55 in MyCourses portal ("Assignments").

The homeworks are not mandatory (compulsory), but they give 4 points per homework. For more information, see Course PM. It is highly recommended to do them. Solutions must be delivered in pdf-form (not Word, no Latex files, etc.). The whole solution must be written in one document and set in one file, including calculations, program codes, figures, etc. The solution file must have enough information, so that it becomes clear, how you have solved the problem. For example, the Matlab program codes and Simulink diagrams must be included in the solution document. If you want to use handwriting (and then change the document to pdf) you can do it, provided that the document can be read without difficulty. It is allowed to discuss and do the problems in groups. However, everybody must prepare and deliver his/her solutions individually. Copying directly somebody else's solution is not considered group work and is prohibited.

The above information concerns all 4 homework assignments to be given during the course.

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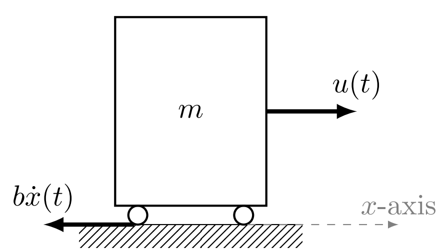
1. A cruise control system of a car is often modeled (for simplicity) as a cart experiencing friction (with the average friction coefficient being b) and controller's action (denoted by u), as shown below:



   a) Prove that the 2[nd] order ordinary differential equation (ODE) with respect to displacement x describing the evolution of the simplified cruise control system is given by

   $$\dot{v}(t) + \frac{b}{m}v(t) = \frac{u(t)}{m},$$

   where $v(t) = \dot{x}(t)$. [0.5p]

   b) Consider a car, which has a weight $m = 1000$ kg. Assuming the average friction coefficient $b = 100$, design a cruise control system such that the car can reach 100 km/h from 0 km/h in 8 s with an overshoot less 20%.

      i) Find a PI controller that achieves the design specifications. [0.5p]

      ii) Verify the controller design via Simulink. [0.5p]

c) Design a discrete-time controller by discretizing the continuous-time controller with a sampling rate 30 times the bandwidth using the Tustin transformation and verify via Simulink that the specifications are met. [0.75p]

d) Design a discrete-time controller by

   i) discretizing the continuous-time controller with a sampling rate 6 times the bandwidth using the Tustin transformation. Does the controller meet the specifications set? [0.75p]

   ii) discretizing the plant with a sampling rate 6 times the bandwidth and designing a discrete-time PI controller. Does the controller meet the specifications set in this case? [1p]