Industrial Automation and Robotics

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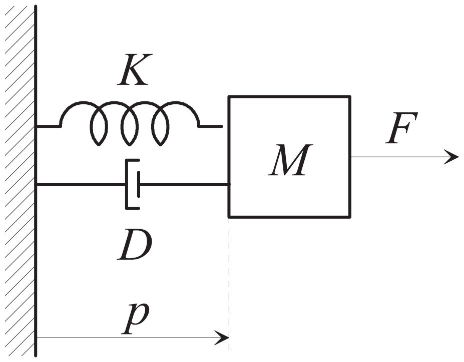
Warnings

- This file consists of **8** pages (including cover).
- During the exam you are not allowed to exit the room for any other reason than handing your work or withdrawing from the exam.
- You are not allowed to withdraw from the exam during the first 30 minutes.
- During the exam you are not allowed to consult books or any kind of notes.
- You are not allowed to use calculators with graphic display.
- Solutions and answers can be given **either in English or in Italian**.
- Solutions and answers must be given **exclusively in the reserved space**. Only in the case of corrections, or if the space is not sufficient, use the back of the front cover.
- The clarity and the order of the answers will be considered in the evaluation.
- At the end of the test you have to **hand this file only**. Every other sheet you may hand will not be taken into consideration.

EXERCISE 1

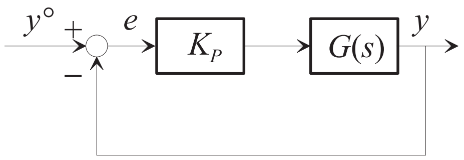
Consider the mechanical system depicted in the picture:



The system is composed by a body of mass M subjected to a viscous friction force, proportional to speed through the coefficient D, and an elastic force, proportional to position through the coefficient K.

1. Setting $M = 1$, $K = 1$, $D = 2$, find the transfer function $G(s)$ from the force F to the position p.

2. Consider now the block diagram sketched in the picture:



where $K_P = 100$, while $G(s)$ is the transfer function computed previously. Sketch the asymptotic Bode plot of the magnitude of the loop transfer function of the control system.

3. Compute the crossover frequency and the phase margin of the control system.

4. Discuss the stability of the closed-loop system using the Bode criterion, then verify the result with the analysis of the closed loop polynimial.

EXERCISE 2

1. Consider the Ladder Diagram programming language for PLCs. Explain what is a normal timer and how it works.

2. Consider now the following process: when an operator on a production line presses a button **START**, pieces travelling on a conveyor belt are deviated for two minutes to undergo some inspection process. After such time interval, pieces resume their normal path in the conveyor and for 60 minutes pressing the button **START** cannot deviate the pieces anymore. Program the system with a Ladder Diagram code.

3. Briefly explain what is the ISO-OSI communication protocol in a distributed control system.

4. Considering the MAC (Medium Access Control) level of the protocol, briefly describe what this level is in charge of and what is the token bus (or token ring) method.

EXERCISE 3

Consider the planning of a cubic polynomial trajectory $q(t)$, starting at $t = 0$ from $q = 0$, and with initial and final zero values of the speed.

1. Find the expressions of the position, the speed and the acceleration as a function of the total displacement h and the total positioning time T.

2. Find the expressions of the maximum values of the speed $\dot{q}_{\max}$ and of the acceleration $\ddot{q}_{\max}$ as a function of h and T.

3. Assume that the displacement is $h = 20$ and the maximum value of the speed $\dot{q}_{\max}$ is 10. Find the corresponding minimum positioning time T and the corresponding maximum value of the acceleration $\ddot{q}_{\max}$.

4. Write the expression of a segment in space parameterized by the natural coordinate s.