# Industrial Automation and Robotics

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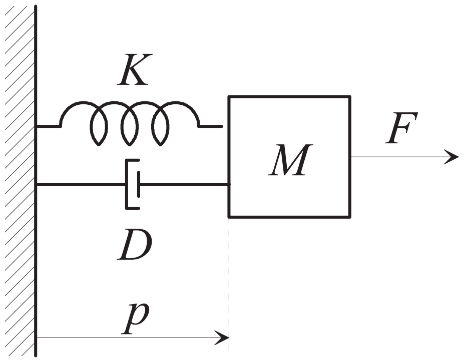
**Warnings**

- 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**

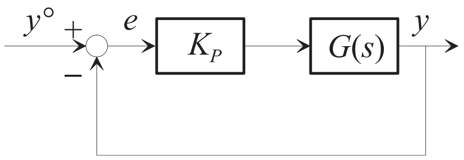
Consider the mechanical system depicted in the picture:




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:



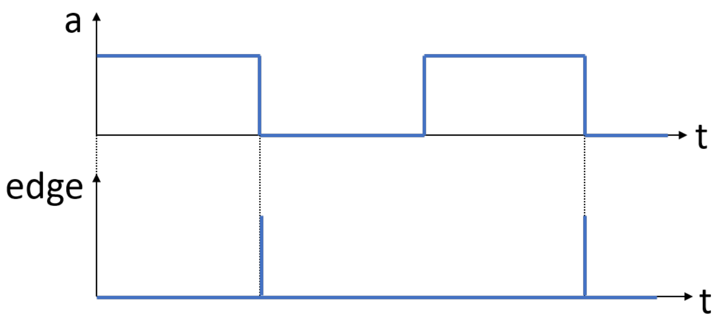

where $K_P = 10$, while $G(s)$ is the transfer function computed previously. Sketch the asymptotic Bode plot of the magnitude of the loop transfer function of the control system.

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

4. Discuss the stability of the closed-loop system, using any of the possible methods.

**EXERCISE 2**

1. Consider a PLC that has to detect a negative edge in a variable $a$, as in the following sketch:




   Write a program in Ladder Diagram that implements such edge recognition, without using the dedicated edge recognition contact. Assume that the variable $a$ is initialized to 1.

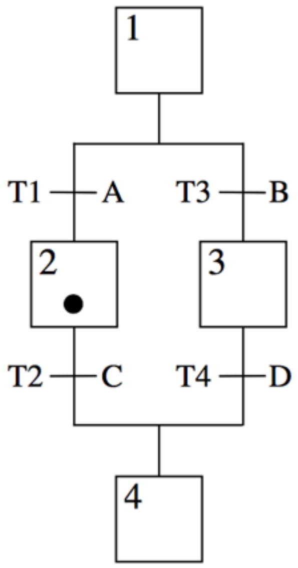
2. Consider now the following Ladder Diagram:

```
      A                   X
|---| |----------+-----( )---|
|                |           |
|     X      B   |           |
|---|/|----| |---+           |
|                            |
```

   Write the logical expression represented by the diagram.

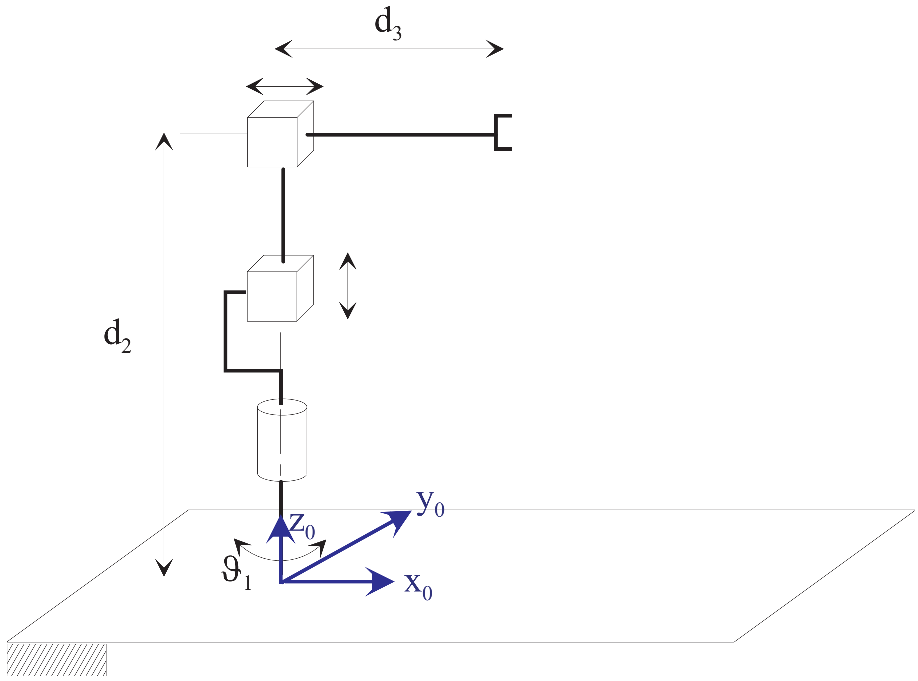
3. Making reference to a Sequential Function Chart, explain what is meant with the expression "a transition is superable".

4. Consider the Sequential Function Chart represented in the picture. Explain what programming structure it implements and whether there are constraints on the conditions associated to the transitions.



**EXERCISE 3**

Consider the following robot manipulator with 3 joints (rotational, prismatic and prismatic):




1. Find the expression of the direct kinematics of the robot, in terms of the position coordinates of the end effector with respect to the joint variables $\vartheta_1$, $d_2$, and $d_3$.

2. Explain what is a homogeneous transformation matrix.

3. Write the expression of the Jacobian of the manipulator of this exercise.

4. Characterize the singularities of the manipulator of this exercise.