

# Industrial Automation and Robotics

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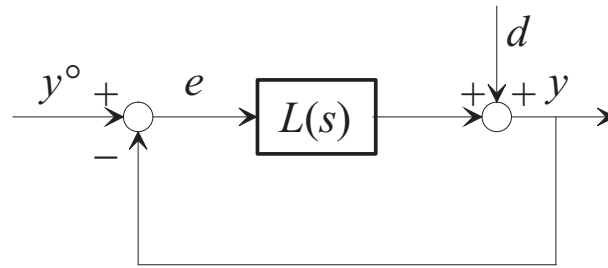
## Warnings

- 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.



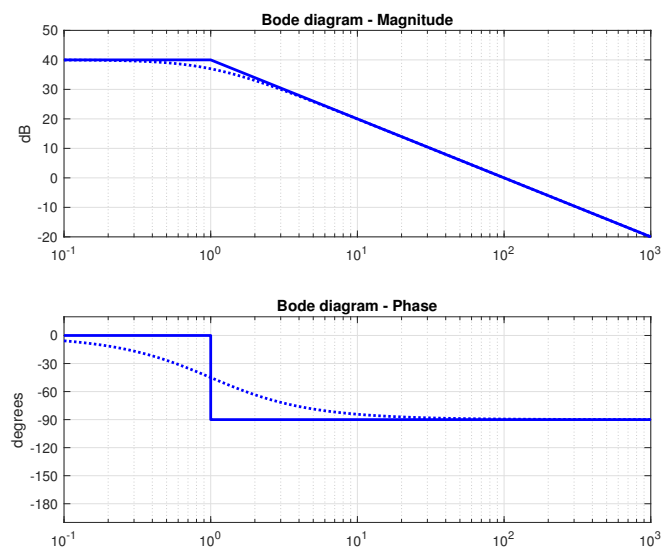
## EXERCISE 1

1. With reference to a generic control system



Give the definition of sensitivity function of the system, explaining its use.

2. Suppose that the loop transfer function  $L$  has the Bode plots of the magnitude and of the phase as shown in this picture:



Discuss the stability of the closed loop system.

3. Still making reference to the picture of this exercise, sketch the asymptotic Bode plot of the magnitude of the sensitivity function. Specify the bandwidth where a disturbance  $d(t)$  can be rejected.

4. Consider a disturbance  $d(t) = \sin(10t)$ . Compute the factor by which this disturbance is attenuated.

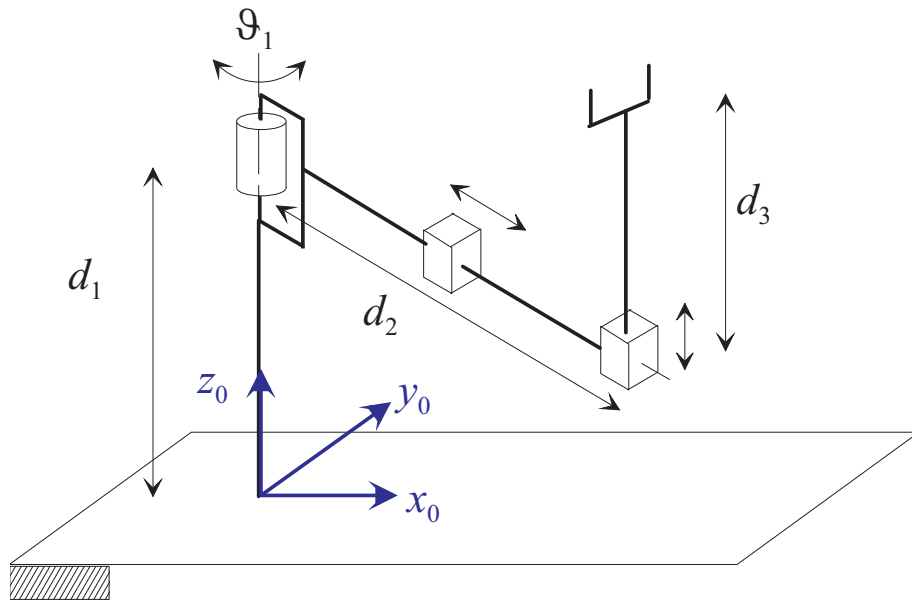


3. Briefly explain what is the ISO-OSI communication protocol in a distributed control system.

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 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. Define what is the (positional) Jacobian of a generic manipulator.

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

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