Industrial Automation and Robotics

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FEBRUARY 13, 2025

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UNIVERSITY ID NUMBER:

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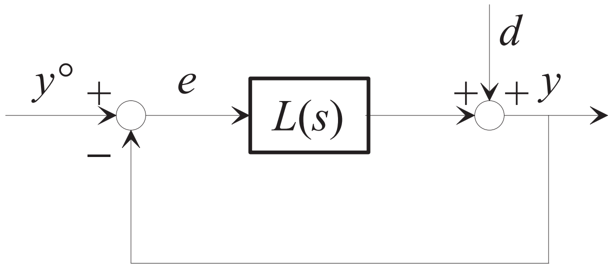
Warnings

- 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.

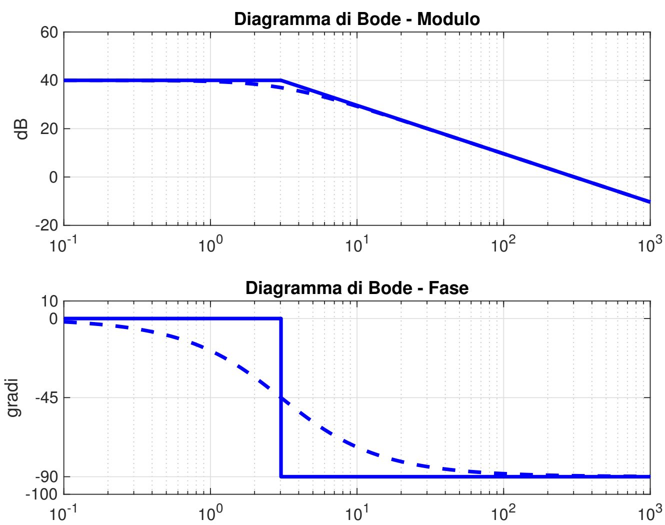
EXERCISE 1

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:



   Find the value of the crossover frequency of the control system and 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 two disturbances $d_1(t) = sin(30t)$ and $d_2(t) = sin(1000t)$. Assess whether such disturbances can be dampened by the control system and, in case, by which factor.

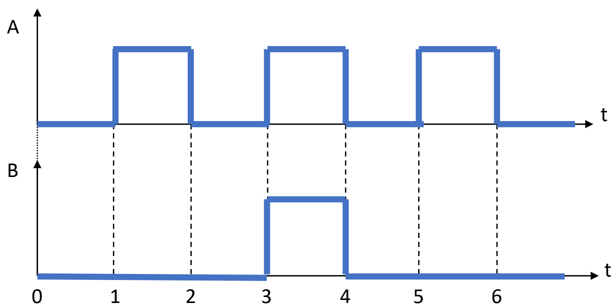
EXERCISE 2

1. Explain what is a “discrete event system” and what are its peculiarities. Identify an example of discrete event system, specifying what is the state and what are the events for such system.

2. Making reference to the following Ladder Diagram code:

```
|                                       |
|     A          +------------+         |
|-+--|/|--+------|    T       |--------|
| |       |      |    2s      |        |
| |   B   |      +------------+        |
| +--| |--+                            |
|                                       |
```

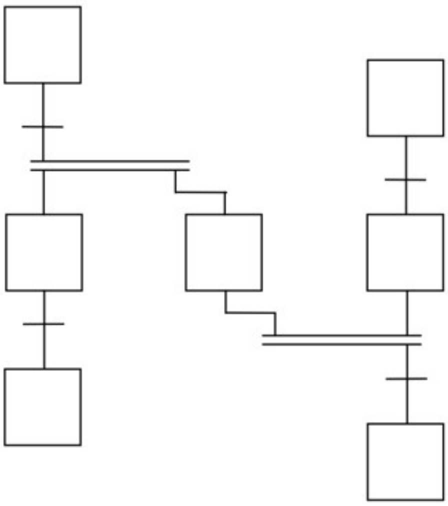
   assume that the Boolean inputs A and B have the time histories depicted in the following plots:



   Sketch the plot of the Boolean variable T associated to the timer, commenting the answer.

3. Consider now a Sequential Function Chart (SFC). Explain what is a step in a SFC. What is a "time limited" action associated to a step and what does it mean that an action is "stored"?

4. Consider the following piece of code in SFC:



Explain what flow control structures are used.

EXERCISE 3

1. Explain what is meant with trajectory generation in the operational space for a robot, commenting about advantages and disadvantages of such approach.

2. Consider now the generation of a position trajectory in the Cartesian space. Select as an initial point $\mathbf{p}_i = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$ and as a final point $\mathbf{p}_f = \begin{bmatrix} \sqrt{3} \\ 3 \\ 4 \end{bmatrix}$. Write the expression of a segment connecting the initial and the final points, parameterized with the natural coordinate.

3. Assume a travel time $T = 2s$. Design a time law, which covers the path determined in the previous step, using a cubic dependence on time.

4. Compute the maximum linear velocity of the end effector along the trajectory designed in the previous step.