Industrial Automation and Robotics

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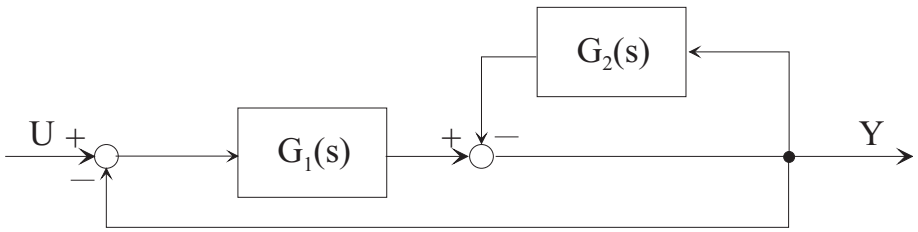
Warnings

- 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. Consider the dynamic system described by the following block diagram:



   Solve the block diagram by determining the transfer function from u to y.

2. Discuss whether it is necessary and/or sufficient that one or more of the transfer functions be asymptotically stable in order for the overall system to be asymptotically stable

3. Setting $G_1(s) = \dfrac{1}{1+s}$, $G_2(s) = k$, assign the parameter k such that the dc gain of the overall transfer function is $\mu = 0.25$.

4. Using the value of k found at the previous step, sketch the step response of the transfer function from U to Y. What is the approximate time for the output to practically reach the steady state value?

EXERCISE 2

1. Consider the Ladder Diagram programming language for PLCs. List the types of timers that can be included in a Ladder Diagram, briefly explaining how they work.

2. Consider now the following process: pressing a button **START** a light turns on for one minute. After such time interval, the light turns off and for 10 minutes pressing the button **START** cannot turn on the light, unless a second button **RESTART** is first pressed (pressing the button when the light is on has no effect). Program the system with a Ladder Diagram code.

3. Explain what is the ISO-OSI communication protocol and mention the names of the levels 1 and 2.

4. Consider now the Ethernet protocol for the digital communication on a bus: briefly describe how the access to the bus among the various agents is handled.

EXERCISE 3

1. In the framework of the motion planning for a robot, explain what is the meaning of an instruction in the PDL2 programming language `MOVE LINEAR TO POS WITH $LIN_SPD=0.6`

2. Consider now the design of a trajectory for a variable q with a cubic time law. The total displacement is $h = 2$, the total positioning time is $T = 2s$ and the velocity at the beginning and at the and are zero. Compute the expression of variable q and of its first time derivative $\dot{q}$.

3. Consider the generation of the trajectory in the operational space. Write the expression of a segment (linear Cartesian path) for the position of the end effector.

4. Assume now that the initial point for the end effector is $\mathbf{p}_1 = \begin{bmatrix} 0 \\ 1 \\ 2 \end{bmatrix}$ and the final point is $\mathbf{p}_2 = \begin{bmatrix} \sqrt{2} \\ 0 \\ 3 \end{bmatrix}$. Suppose that you want to use the cubic profile previously computed for the generation of the operational space trajectory (the segment as previously discussed). Explain if and how this can be done. What would be the maximum linear velocity of the end-effector in this case?