Industrial Automation and Robotics

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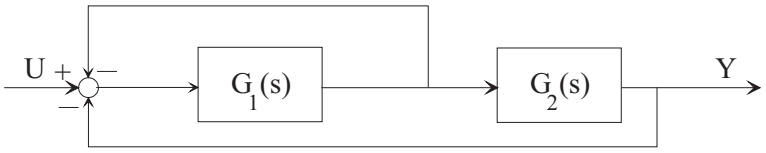
SIGNATURE: _____

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 dynamical 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 $G_1(s) = \dfrac{1}{s}$, $G_2(s) = k$, assign the parameter k such that the overall system has a pole in the point -10 of the complex plane.

4. Using the value of k found at the previous step, sketch the step response from input u to output y. What is the approximate duration of the transient?

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. Program the system with a Ladder Diagram code.

3. Explain the difference between a soft real time system and a hard real time system, citing one example for both.

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

Consider the planning of a trajectory $q(t)$ with initial and final times $t_i = 0$, $t_f = 2$, initial and final values of the position $q_i = 0$, $q_f = 20$, initial and final values of the speed $\dot{q}_i = 0$, $\dot{q}_f = 0$.

1. Using a cubic polynomial for the position, find the expressions of the position, the speed, and the acceleration, compatible with the data of the problem.

2. Find the maximum values of the speed $\dot{q}_{\max}$ and of the acceleration $\ddot{q}_{\max}$.

3. Consider now a trapezoidal velocity profile. Using as cruise speed the value $\dot{q}_{\max}$ found at the previous step, compute the acceleration time and the value of the initial acceleration for a trapezoidal velocity profile that brings q from q_i to q_f in the same time (t_f) as for the cubic profile. (*Hint:* the total displacement is the integral of the trapezoidal of the speed).

4. Using the COMAU PDL2 programming language, write a motion command that makes the robot end effector move along a straight line until a position `pos`, with a linear speed of $0.8m/s$.