Corso di Laurea Magistrale in Ingegneria Meccanica

Automatic Control A

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Name: ______________________________

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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 following linear and time invariant dynamical system (where $\alpha \in \mathbb{R}$)

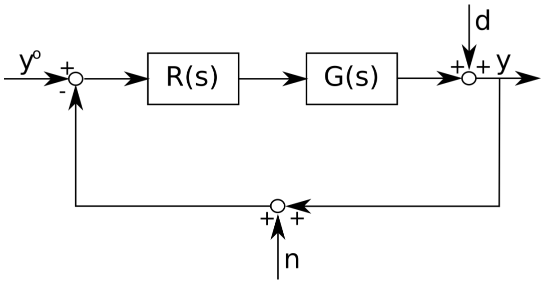
$$\begin{cases} \dot{x}_1 = -x_1 + \alpha x_3 \\ \dot{x}_2 = -x_3 + u \\ \dot{x}_3 = \alpha x_1 + x_2 \\ y = x_3 \end{cases}$$

1. Find the values of parameter α for which the system is asymptotically stable.

2. Find the values of parameter α for which the system is completely controllable and completely observable.

Exercise 2

Consider the following control loop



where $G(s) = \dfrac{1}{(1+s/3)(1+10s/3)}$.

1. Compute the transfer function $R(s)$ of the controller in such a way that:
   - $|e_\infty| = 0$ for $y^\circ(t) = A\text{sca}(t)$, where A is an arbitrary real constant, and $d(t) = n(t) = 0$;
   - a disturbance $d(t) = Dsin(\omega_D t)$, where D is an arbitrary constant and $\omega_D \leq 0.1\ rad/s$, is attenuated on the output of 10 times;
   - a disturbance $n(t) = Nsin(\omega_N t)$, where N is an arbitrary constant and $\omega_N \geq 10\ rad/s$, is attenuated on the output of more than 10 times;
   - $\varphi_m \geq 65^\circ$ and $\omega_c \geq\ 1 rad/s$.

Exercise 3

Given the following linear and time invariant dynamical system

$$G(s) = \frac{s+2}{s^2+0.4s+1}$$

1. Compute a realization of the transfer function $G(s)$.

2. Design a pole placement controller that increases the damping of the poles so that the closed-loop poles have a damping of 0.7, keeping the same natural frequency.

3. Design a state estimator whose error dynamics are 10 times faster than the system dynamics.

Exercise 4

Consider the following discrete time dynamic system

$$G(z) = \frac{z}{z^2 - z - 6}$$

1. Compute the gain and type of the transfer function.

2. Compute the analytic expression ($y(k) = \dots$) of the unit step response.

3. Write the expression of the frequency response associated to the transfer function $G(z)$ for $\theta = \pi/2$.

Exercise 5

1. Consider the design of a 3rd order and a 5th order polynomial trajectory, from $q_i = 5°$ to $q_f = 25°$, with $\dot{q}_{max} = 15°/s$ and $\ddot{q}_{max} = 50°/s^2$. Find the minimum positioning time for each type of trajectory.

2. The parametric form of a harmonic trajectory is given by $\sigma(\tau) = 0.5\,(1 - \cos(\pi\tau))$. Find the expressions of the maximum velocity and maximum acceleration for such trajectory in terms of the positioning time T and the total displacement h.

3. Consider the design of a harmonic trajectory, from $q_i = 5°$ to $q_f = 25°$, with $\dot{q}_{max} = 15°/s$ and $\ddot{q}_{max} = 50°/s^2$. Find the minimum positioning time.

Exercise 6

1. Consider a temperature sensor, measuring a temperature in the range $0 - 100\ °C$ and having an output in the range $0 - 24\ V$, and an ADC converter operating in the range $0 - 10\ V$. Design the conditioning circuit and select the minimum number of bits required to guarantee a resolution of $0.1\ °C$.

2. Draw a schematic diagram of the conditioning circuit designed in 6.1, assuming a single-ended for the sensor signal.

3. Design a passive anti-aliasing filter for the previous sensor, characterised by a cut-off frequency of $10\ Hz$.