Automatic Control A

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Name:...

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Warnings:

- This file consists of **8** pages (including cover). All the pages should be signed.
- 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.

Use this page ONLY in case of corrections or if the space reserved for some answers turned out to be insufficient

Exercise 1

Consider the following nonlinear dynamical system

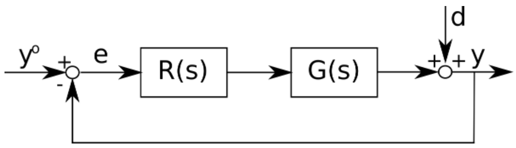
$$\begin{cases} \dot{x}_1 = -x_1 + \sqrt{x_2} \\ \dot{x}_2 = -x_2^2 + x_1 x_3 \\ \dot{x}_3 = -x_1^2 + u \\ y = \sqrt{x_3} \end{cases}$$

1.1 Find the values of the state and output equilibria corresponding to $u(t) = \bar{u} = 1$.

1.2 Compute the linearized system around the equilibrium point found in the previous step. Is this system stable, unstable or asymptotically stable?

Exercise 2

Consider the following control system



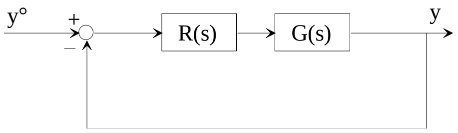
where $G(s) = \dfrac{100}{(1+s)^2(1+0.1s)}$.

Compute the transfer function $R(s)$ of a regulator in such a way that:

- $|e_\infty| = 0$ for $y°(t) = \text{sca}(t)$ and $d(t) = 0$;
- a disturbance $d(t) = D \sin(0.1t)$, where D is an arbitrary constant, is attenuated on the output y 10 times;
- the phase margin φ_m is greater or equal to 50°;
- the crossover frequency ω_c is greater or equal to 0.3 *rad/s*.

Exercise 3

Consider the following control system



where $G(s) = \frac{1}{s^2 - 1}$.

3.1 Using the root locus, find the transfer function $R(s)$ of the regulator in such a way that the closed-loop system has two complex poles with damping $\zeta = 1/\sqrt{2}$ and natural frequency $\omega_n = 5\sqrt{2}$.

3.2 Can the regulator $R(s)$ be designed using the Bode criterion?

Exercise 4

Consider the following discrete time system

$$G(z) = \frac{z-1}{9z^2 - 1}$$

4.1 Compute the initial value and, if possible, the final value of the unit step response.

4.2 Compute the analytic expression of the unit step response of the system, verifying the results of the previous step.

4.3 Write the difference equation, in the time domain, that represents the input-output relation given by $G(z)$.

Exercise 5

Consider a servomechanism with rigid transmission characterized by the following parameters:

- motor moment of inertia $J_m = 1.5 \cdot 10^{-4}\ Kg\ m^2$
- motor viscous friction $D_m = 0.0034\ Kg\ m^2/s$

5.1 Compute the parameters of a torque disturbance observer, justifying the selection of T_f, and show the block diagram of the system including the disturbance observer.

5.2 Explain, analyzing the transfer functions of the system including the torque disturbance observer, what happens when the servomechanism has a flexible transmission.

Exercise 6

6.1 List and describe the main steps executed by a PLC at every cycle.

6.2 Write the code implemented by the following ladder diagram.

```
     a                    then
|---| |---+-----------------(JMP)---|
|    d    |                         |
|---| |---+                         |
|    d                     x        |
|---| |---+-----------------(    )---|
|    c    |                         |
|---| |---+                         |
|    x                      y       |
|---|/|----------------------(    )---|
|                         endif     |
|---------------------------(JMP)---|
|    then                           |
|---|LBL|---------------------------|
|    b                     x        |
|---| |----------------------(    )---|
|    a                     y        |
|---| |----------------------(    )---|
|    endif                          |
|---|LBL|---------------------------|
```

6.3 Assume that a motor is started by an operator pushing a “start” button, and the motor moves until the operator pushes the “stop” button or a failure signal is received. Write the ladder diagram that allows to implement this behavior on a PLC.