Corso di Laurea Magistrale in Ingegneria Meccanica

Automatic Control A

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Name: ______________________________

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Signature: ______________________________

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 continuous time, linear and time-invariant dynamical system with input $u(t)$ and output $y(t)$

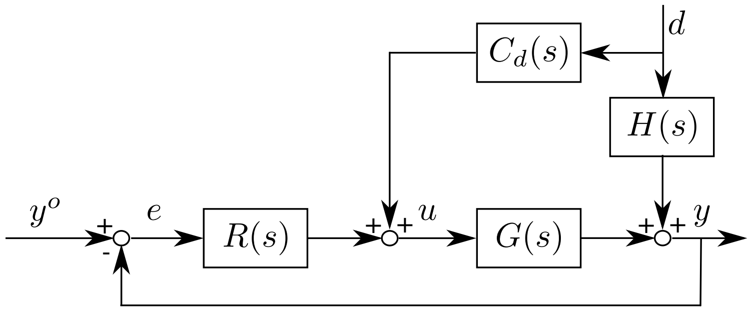
$$\begin{cases} \dot{x}_1(t) = -2x_1(t) + 3x_2(t) \\ \dot{x}_2(t) = -20x_2(t) + u(t) \\ \dot{x}_3(t) = 3x_3(t) \\ y(t) = 2x_1(t) \end{cases}$$

1. Does the state zero-input response of the system asymptotically tend to zero for any initial state?

2. Is the system completely controllable and completely observable?

Exercise 2

Consider the following control system



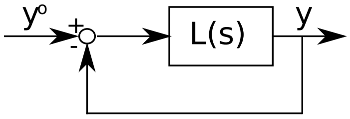
where $G(s) = \dfrac{10}{(1+10s)(1+s)^2}$ and $H(s) = \dfrac{5}{1+10s}$.

1. Design a PI controller in such a way that the crossover frequency is approximately $0.1\ rad/s$.

2. Write the relation required to design a disturbance compensator $C_d(s)$, so that the effect of a disturbance $d(t) = 5\sin(t)$ on the output y asymptotically tends to zero.

Exercise 3

Consider the following closed-loop system



where $L(s) = R(s)G(s)$ and $R(s) = \rho$, $G(s) = \dfrac{s-3}{(s^2+11s+30)(s-1)}$.

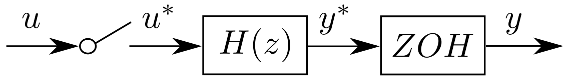
1. Sketch the direct and inverse root loci.

2. Using the previous root loci, find the values of $\rho > 0$ for which the closed-loop system is asymptotically stable.

3. Using the previous root loci, find the value of ρ for which the closed-loop system has one real pole in -1 and one in -9. For this value of ρ, is the closed-loop system asymptotically stable?

Exercise 4

Consider the following system



where $H(z) = 1$.

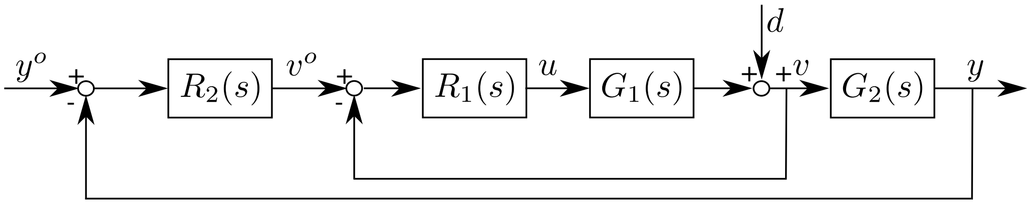
1. Compute the sampling time in such a way that a signal $u(t) = 5\sin(t) + 2\sin(10t)$ is converted without generating aliasing.

2. Compute the phase shift caused by the sample and hold system to each harmonic of the input signal $u(t)$.

3. Consider now a different input signal $u(t) = \sin(50t)$. Is the previous sampling time suitable even for this new input? If not, which is the frequency of the first aliasing harmonic? How can we design a filter in order to avoid the aliasing effect?

Exercise 5

Consider the following system



where $G(s) = \dfrac{10e^{-s}}{(1+10s)(1+0.01s)}$.

1. Explain how the system transfer function can be separated in two subsystems, $G_1(s)$ and $G_2(s)$, in order to set up a cascaded control architecture.

2. Design the two regulators, $R_1(s)$ and $R_2(s)$, satisfying the following requirements:
   - $R_1(s)$ is a PI controller, and $R_2(s)$ a P controller;
   - for the inner loop the crossover frequency, ω_{c_1}, satisfies the constraint $0.1\ rad/s \leq \omega_{c_1} \leq 1\ rad/s$, the phase margin φ_m is greater or equal to $70\ deg$;
   - for the outer loop the phase margin φ_m is greater or equal to $55\ deg$.

Exercise 6

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

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|--------------------------|
```

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 behaviour on a PLC.