Corso di Laurea Magistrale in Ingegneria Meccanica

# Automatic Control A

Prof. Luca Bascetta

## A.A. 2016/2017 – July 24, 2017

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Name: ____________________

Surname: ____________________

University ID number: ____________________

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

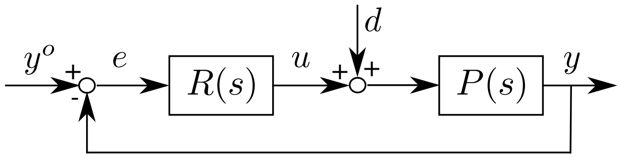
$$\begin{cases} \dot{x}_1(t) = x_2(t) \\ \dot{x}_2(t) = x_3(t) \\ \dot{x}_3(t) = -\alpha x_1(t) - 3x_2(t) - 2x_3(t) + u(t) \\ y(t) = x_1(t) \end{cases}$$

1. Find the values of parameter $\alpha \in \mathbb{R}$ for which the system is asymptotically stable.

2. Find the values of parameter $\alpha \in \mathbb{R}$ for which the system is completely controllable and completely observable.

## Exercise 2

Consider the following control loop




where $P(s) = 5\dfrac{1+0.01s}{1+s}$

1. Determine a reasonable value for the crossover frequency, clearly explaining the method you have used.

2. Assuming that the plant is controlled using a PI controller characterized by the following transfer function

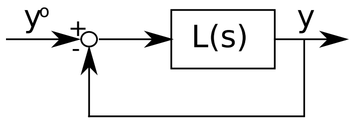
$$R(s) = 0.4\frac{1+s}{s}$$

   Compute the crossover frequency, the phase margin, and the maximum delay that can be added to the feedback loop keeping it asymptotically stable.

3. Considering the same PI controller, compute the settling time of the response of the controlled variable to a unitary step on the reference signal and to a unitary step on the load disturbance $d$.

## Exercise 3

Consider the following closed-loop system




where $L(s) = \rho \dfrac{(s-2)(s+1)}{(s+2)^2(s-1)^2}$.

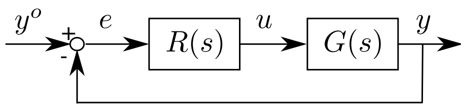
1. Sketch the direct and inverse root loci.

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

3. Assuming $\rho = 1$, sketch the Nyquist diagram. According to the Nyquist stability criterion, is the closed loop system asymptotically stable?

## Exercise 4

Consider the following control loop




where $R(s) = 10\dfrac{(1+10s)^2}{(1+100s)(1+s)^2}$ and $G(s) = \dfrac{1-s}{(1+10s)^2}$.

1. Determine a sampling time for the digital implementation of $R(s)$, in such a way that the decrement of phase margin introduced by the sample-and-hold is less or equal to $5$ deg.

2. Does a disturbance $n(t) = \sin(2.7t)$ in the feedback path generate aliasing? And, if so, which is the frequency of the aliasing harmonic?

3. Write the relation required to compute the transfer function $R(z)$ of the digital regulator using the Tustin transformation.

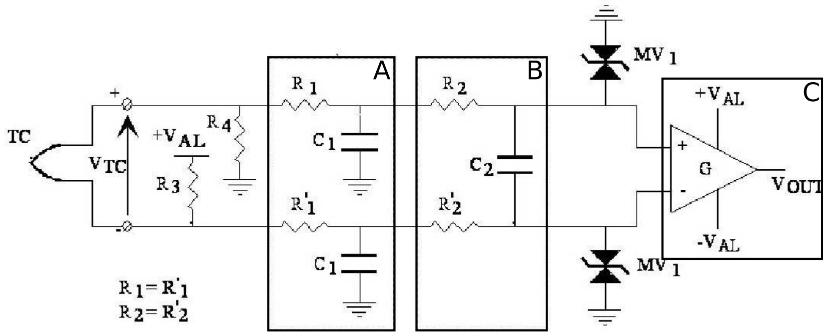
## Exercise 5

1. Write the PID standard ISA form of the transfer function of a PID regulator, and show how it can be interpreted as a 2-d.o.f. regulator (i.e., separating the feedforward and feedback blocks).

2. Clearly explain the integral wind-up effect, and describe (showing the block diagram as well) two anti-windup configurations of a PID regulator.

## Exercise 6

Consider the following circuit, that is used for conditioning and filtering a thermocouple sensor




1. What is the role of the two circuits in boxes A and B? For each of them write the corresponding transfer function.

2. What is the role of the circuit in box C? What are the differences between this circuit and a standard operational amplifier?

3. Sketch the circuit diagram of an operational amplifier in differential configuration that could substitute the circuit in box C.