# Automatic Control A

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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 dynamical system

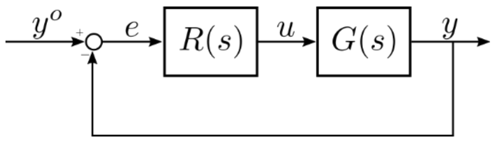
$$G(s) = \frac{s+1}{s^3 + 2s^2 + s + 1}$$

**1.1** Compute a state-space realization in controllable canonical form.

**1.2** Show that any 3rd order system in controllable canonical form is completely controllable.

**Exercise 2**

Consider the following control system




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

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

- $|e_\infty| = 0$ for $y^o(t) = \mathrm{sca}(t)$;
- $\varphi_m \geq 40°$ and $\omega_c \geq 0.3$ *rad/s*.

**Exercise 3**

Consider the following dynamical system

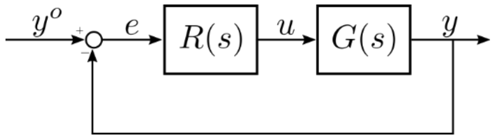
$$\begin{cases} \dot{x}_1 = -x_1 + u \\ \dot{x}_2 = x_1 - 2x_2 \\ y = x_2 \end{cases}$$

**3.1** Design a pole placement controller ($u(t) = Kx(t)$) that places the two closed-loop poles at -5.

**3.2** Can you design an output feedback controller ($u(t) = \tilde{k}y(t)$) to place the two closed-loop poles at -5? Motivate the answer.

**Exercise 4**

Consider the following control system




where $G(s) = \dfrac{5}{(1+s)(1+2s)}$ and $R(s) = \dfrac{(1+s)(1+2s)}{s(1+0.1s)}$.

**4.1** Compute the sampling period for a digital realization of the control system, so that the phase decrement introduced by the sample and hold is less or equal to 4.5°.

**4.2** Consider now a sinusoidal measurement noise with a frequency of 150 *rad/s*. Find the aliasing harmonic generated by this disturbance.

**4.3** Design an anti-aliasing filter introducing at least a 20 *dB* attenuation on the measurement noise. The resulting phase margin, considering sample and hold and anti-aliasing filter, should be greater than 30°.

**Exercise 5**

**5.1** Consider the design of a 3rd order and a 5th order polynomial trajectory, from $q_i = 10^\circ$ to $q_f = 50^\circ$, with $\dot{q}_{max} = 30\ ^\circ/s$ and $\ddot{q}_{max} = 80\ ^\circ/s^2$. Find the minimum positioning time for each type of trajectory.

**5.2** Explain the advantage of using a cascaded control architecture in a motion control system. In particular, why is it better to have a PID position/velocity control separated by the PI current control, instead of a single loop?

**5.3** Consider an elastic. Write the transfer function of a notch filter to be used for filtering the motor velocity reference and draw the block diagram of the position/velocity loops. Explain how the notch filter parameters can be selected.

**Exercise 6**

**6.1** Consider a pressure sensor, measuring a pressure in the range 0-100 *bar* and having an output in the range 0-12 *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 *bar*.

**6.2** Draw a schematic diagram of the conditioning circuit designed in 6.1, assuming a differential output for the sensor signal.

**6.3** What is a successive-approximation ADC? Sketch the functional diagram that shows how this converter works, and list and describe the steps of the conversion process.