**Academic Year 2024-2025**

**Exam 2 – Part II - Maximum duration: 3 hours**

**Problem 1 [3.5 points]**

For the dynamic system described by the transfer function:

considering unitary feedback and controlled with a gain :

* 1. Draw the root locus for , indicating the value of *K* at which the closed-loop system changes its stability condition, determining in which range of that gain it is stable and in which range it is unstable. **[0.5 points]**
  2. Plot the root locus for , indicating the value of *K* at which the closed-loop system changes its stability condition, determining in which range of that gain it is stable and in which range it is unstable. **[0.25 points]**
  3. Analyse the stability of the closed-loop system using Nyquist's stability criterion based on the value of the gain only for the case **[0.5 points]**
  4. Only for the case analyse and represent the phase margin and gain margin as a function of the gain in the Bode diagram, indicating the values at which the closed-loop system changes its stability condition. **[0.5 points]**
  5. Only for the case analyse and plot the phase margin and gain margin as a function of gain 𝐾 in the Nyquist diagram, indicating the values at which the closed-loop system changes its stability condition. **[0.25 points]**
  6. Calculate an internal description (state space) of the system represented by . Assuming that no sensors are available to measure the states (only the values of the system input and output are known), design a control system that allows a constant reference (without disturbances) to be achieved by imposing a closed-loop dynamics characterised by two equal real poles at nd an observation error dynamics characterised by two equal real poles at . Verify that the system is controllable and observable and draw the complete block diagram including the control and state observer with the highest possible degree of definition (using integrator blocks to represent the relationship between each of the states and their derivatives). You must also indicate the equations that provide the evolution of the estimated states and the control signal (write the equation that describes the dynamic evolution of each estimated state). **[1.5 points]**

**Problem 2 [1.5 points]**

Consider the minimum phase time-invariant linear system whose transfer function ) is described by the following Bode diagram:



2.1. Design a control scheme that rejects a step disturbance at the plant input without steady-state error and with critically damped dynamics with poles at , and that allows a step reference characterised by a closed-loop time constant of 2 seconds to be followed without steady-state error. **[0.75 points]**

2.2. Assuming that a delay of 0.1 seconds is added to , design a closed-loop control system that guarantees a steady-state error at ramp input of 0.1, a phase margin equal to 70 degrees, and a gain cutoff frequency equal to rad/s. Carry out the procedure and, if you encounter any difficulties in solving the problem, indicate the equations from which to obtain the controller parameters. **[0.75 points]**