**Academic Year 2022-2023**

**Exam 1 – Overall assessment - Maximum duration: 3 hours**

**Problem 1 [5 points]**

A dynamic system is described by the following system of differential equations:

where as usual, is the input, is the output and and are the states. The operating point around which the system should be linearised is

1. Obtain a linear internal representation in state variables. **[0.5 points]**
2. Obtain the transfer function of the linearised system and analyse its stability. **[0.5 points]**
3. Calculate and sketch the approximate free response of the system if it starts with an initial value of the linearised states . **[1 point]**
4. Calculate and plot the system response to a unit impulse input at time . What will be the system output if it starts from the equilibrium condition indicated in section 3? **[1 point]**
5. Draw a Simulink diagram that allows you to simulate and compare the non-linear and linear systems (both in internal description and transfer function) for the simulation scenario described above. Include the values of the input blocks, constants, and integrators. **[0.5 points]**
6. Draw an approximate Bode diagram (on the attached sheet) of the system. If a sinusoidal input , is introduced, indicate the time response that will be obtained in steady state using the previous section (without calculating inverse transforms). Compare the Bode diagram obtained with those shown on the following page and indicate in each case how the corresponding transfer functions differ in terms of gains, poles, and zeros. **[1.5 points]**

CASE A

**Gráfico, Gráfico de líneas

Descripción generada automáticamente**

CASE B

Gráfico, Gráfico de líneas

El contenido generado por IA puede ser incorrecto.

**Imagen que contiene biombo, edificio, jaula, reloj

Descripción generada automáticamente**

**Problem 2 [5 points]**

A dynamic system is described by the following transfer function:

1. Assuming that this system is controlled by a proportional controller , draw the root locus of the system when varies between 0 and infinity. Propose the simplest possible controller that stabilises the closed-loop system from a certain value of , indicating the range of values of K with which such stabilisation is achieved, as well as the range of values of in which the closed-loop system only has real poles. **[1 point]**
2. Analyse the stability of the closed-loop system when controlled by a proportional controller with gain using Nyquist's stability criterion. At what frequency does the sensitivity function of the closed-loop system become greater than or equal to 1? What implications does this have for the rejection of disturbances at the plant input? **[1 point]**
3. Design a controller for such that the phase margin of the closed-loop system is greater than or equal to 30º and the gain crossover frequency is in the range [5, 10] rad/s. Using the equivalence between the specifications in the time and frequency domains, indicate the approximate value of the overshoot and the expected rise time in closed loop. You can do the design analytically or using the Bode plot on the following page. **[1 point]**

|  |  |
| --- | --- |
| >> roots([1 0 0 0 -1 0 -4])  ans =  -1.3403 + 0.0000i  1.3403 + 0.0000i  -0.5450 + 1.0933i  -0.5450 - 1.0933i  0.5450 + 1.0933i  0.5450 - 1.0933i | >> roots([1 0 0 0 -1.4584e+03 0 -5.8334e+03])  ans =  -6.3286 + 0.0000i  6.3286 + 0.0000i  -0.0000 + 6.0004i  -0.0000 - 6.0004i  -0.0000 + 2.0113i  -0.0000 - 2.0113i |

1. Calculate an internal description of the system represented by and draw the block diagram representing that system using an integrator to represent the relationship between each state and its derivative. On that block diagram, indicate the input, output, and states of the system. **[0.5 points]**
2. Assuming that there are no sensors available to measure the states (only the values of the system input and output are known), design a control system that allows the states to be regulated to their origin (reference equal to zero and without disturbances) by imposing a closed-loop dynamic characterised by time constants of 0.5 seconds and an observation error dynamic characterised by time constants of 0.1 seconds. Verify that the system is controllable and observable and draw the complete block diagram including the control and state observer (to represent the observer, you can use the block diagram obtained in the previous section). Also indicate the equations that provide the evolution of the estimated states and the control signal. **[1.5 points]**

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