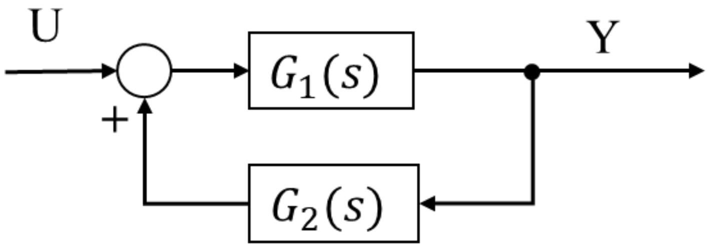
**Last name** **Name** **student ID No.:**

## Section 4: STABILITY OF LINEAR DYNAMIC SYSTEMS

A dynamic process $\mathbf{G_P(s)}$ is here considered that is a "recirculative process"[1]:




Where U(s) is the **manipulated variable**:

$$G_1(s) = \frac{-1.5}{0.5\,s + 1}$$

and

$$G_2(s) = \frac{1}{2\,s - 1}$$

and their combination with the block algebra introduces a **positive zero**.

I. What is the **process transfer function $\mathbf{G_P(s)}$**?

In order to put the dynamic process $G_P(s)$ in a feedback control configuration, a unity gain element represents the measuring device and a proportional-integral controller is used:

$$G_C(s) = K_c\left(1 + \frac{1}{\tau_I s}\right)$$

where $\tau_I$=1.

II. What is the **open loop transfer function $\mathbf{G_{OL}(s)}$**?

[1] Koichi. Iinoya and Roger J. Altpeter, Industrial & Engineering Chemistry 1962 54 (7), 39-43

## Part A: *Root locus*

A1.Plot the *root locus* **by means of MATLAB or SisoTool** and attach it here.

A2. Which rules are applied to build the root-locus, direct or the inverse root locus?

A3. If any, find the Kc=Kc* of the controller for which the system in closed-loop is marginally stable.

**A design requirement** is available for this process, the **percentage of overshoot must be lower than 10%**.

A4.Find $Kc=Kc_{design}$ of the PI controller for which the system respects the design requirement.

A5. Report here a screenshot of the *root locus (from Sisotool)* for the previous defined value showing the placement of the closed-loop poles (*Hints: it may be useful to look also at question C1 at this point*).

## Part B: Frequency response

Considering the previously found **open loop transfer function $G_{OL}(s)$** and with Kc=1 in the PI controller:

B1)Plot the **Bode Diagrams** by means of MATLAB or SisoTool resources and attach it here

B2)Does a **crossover** frequency exist? How much is it?

B3)Decide if the Bode stability criterion is applicable.

B4)If yes, is the above system closed-loop stable?

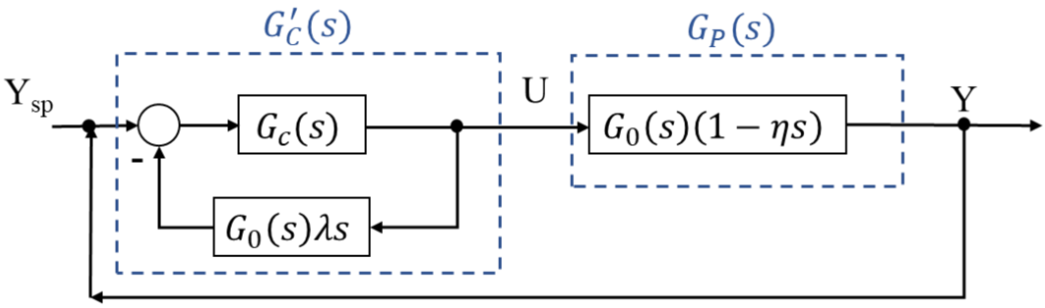
B5)Plot and attach here the **extended Nyquist diagram** *together with the unit circle* by means of MATLAB or SisoTool resources, then discuss it in detail.

B6)Check, on the base of the **Nyquist** stability criterion, if the above system is closed-loop stable

## Inverse Response Compensator

I. Find a rational transfer function $G_0(s)$ such as that $G_P(s) = G_0(s)(1-\eta s)$ where $(1-\eta s)$ represents the position of the positive zero of the original $G_P(s)$

According to "Iinoya and Roger", an **inverse response compensator** can be built using the following feedback architecture:




where $\lambda$ is an optimizable parameter, that can be set to $\lambda = 2\eta$ for optimal results[2].

II. How much is the value of $\lambda$?

III. Write the new transfer function of the **compensated controller** $G_c$'(s), using for $G_c$(s) (PI controller) the value of Kc=Kc* previously found.

## Part C: Dynamic responses in the time domain

Considering the feedback control system with the controller block given by the **uncompensated PI controller** $G_c$(s), with the gain $Kc_{design}$ previously determined

C1. Plot the **closed-loop** system dynamic response to a unit step in **set point** by means of MATLAB or SisoTool resources with the rise time and peak response and attach it here.

Considering the feedback control system with the controller block given by the **compensated controller** $G_c$'(s), with the gain Kc=Kc* previously determined

C2. Plot the **closed-loop** system dynamic response to a unit step in **set point** by means of MATLAB or SisoTool resources with the rise time and peak response and attach it here.

C3. Does the inverse response compensator improve the closed-loop stability of the system? Why?

C4. Does the inverse response compensator maintain or remove an inverse response pattern in the time domain?

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[2] Ray, W. H., Ogunnaike, B. A. (1994). Process Dynamics, Modeling, and Control: Oxford University Press.

## Part D:

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