Period of Examinations
Summer Semester 2020

HOCHSCHULE RHEIN-WAAL
Rhine-Waal University of Applied Sciences

Study Course: ______________________________

Module Title: **Controls**

Points: 100

Duration: 90 Minutes + 15 Minutes for scanning and upload = 105 Minutes

Please write legibly!

Date: ____________________

Family Name: ____________________

First Name: ____________________

Student No.: ____________________

I, ________________________ [full name, matriculation number], hereby confirm in lieu of an oath that I am the person who was admitted to this examination. Further, I confirm that the submitted work is my own and was prepared without the use of any unauthorised aid or materials.

With uploading the examination results, I confirm and agree that the examination is assessed and rated.

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Signature (Student)

If the exam / first page isn't signed, the examination won't be assessed.

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Points:

Question 1: **15**

Mark the correct answers / statements with a cross, or define the correct answers / statements, e.g. mentioning a.1). For each correct cross / definition you will receive 1.5 points, each cross which is not correct will subtract 1.5 points from the total score. The total score for the entire question cannot be negative.

a) An unstable system given in state-space form
- ○ a.1) is not observable.
- ○ a.2) can be stabilized when it is controllable.
- ○ a.3) can be stabilized only when it is controllable and observable.
- ○ a.4) is not controllable.

b) The poles of the observer for a closed-loop system
- ○ b.1) are located between the eigenvalues of the matrix $\boldsymbol{A}-\boldsymbol{BK}$ and the imaginary axis.
- ○ b.2) have to be located left to the eigenvalues of the matrix $\boldsymbol{A}-\boldsymbol{BK}$.
- ○ b.3) have to be equal to the eigenvalues of the system matrix $\boldsymbol{A}$.
- ○ b.4) are equal to the eigenvalues of the matrix $\boldsymbol{A}-\boldsymbol{LC}$.

c) An emergency stop switch is designed as a NC (normally closed) switch instead of a NO (normally open) switch, because
- ○ c.1) it is easier to produce, thus cheaper.
- ○ c.2) a NO switch cannot be connected to a PLC.
- ○ c.3) the PLC program can be simplified.
- ☒ c.4) of safety reasons in case of a cable break.

d) The Down-counter CTD
- ○ d.1) considers a priority of the reset input.
- ○ d.2) contains a reset input which has to be assigned in a logic program (input definition mandatory, not optionally).
- ○ d.3) resets the actual counted value, when the count down input CD goes from 1→0.
- ☒ d.4) sets the actual counted value to zero, when the defined counted value (threshold) has been achieved.

e) A time discrete system with the two poles $p_{1,2} = 0.8 \pm 0.56j$

- ○ e.1) is boundary stable for a sampling time $T = 1\ [sec]$.
- ☒ e.2) is stable.
- ○ e.3) is not controllable.
- ○ e.4) has a weak stability margin.

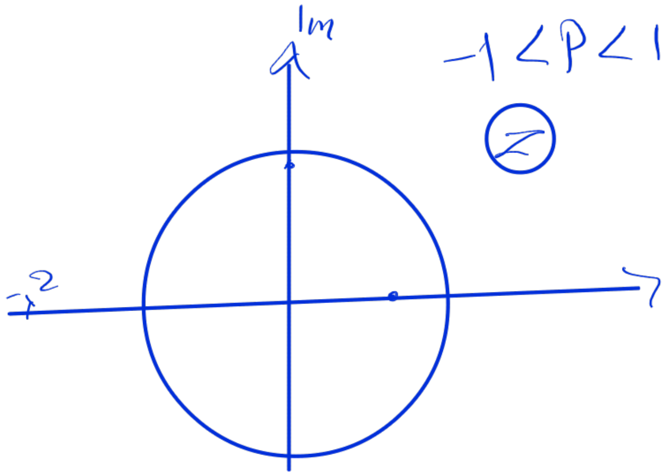
f) A time discrete system with the transfer function $G(z) = \frac{z}{z+4-4.5\,e^{-T}}$

- ○ f.1) is stable for a sampling time $T = 1\ [sec]$.
- ○ f.2) is unstable for any sampling time.
- ☒ f.3) is stable for a sampling time $T = 0.1\ [sec]$.
- ○ f.4) is representing the difference equation $y(k) + (4 - 4.5\,e^{-T})\,y(k-1) = u(k)$.

$P = -(4 - 4.5\,e^{-T})$

$-1 < P < 1$

z



Points:

Question 2: **10**

The output setting of a logical system is realized by four inputs A, B, C, D. The logic can be described through the Boolean equation

$$Y = A\bar{B}\bar{C}D + \bar{A}\bar{B}\bar{C}\bar{D} + AB\bar{C}\bar{D} + A\bar{B}CD + \bar{A}\bar{B}C\bar{D} + AB\bar{C}D + A\bar{B}\bar{C}\bar{D} + A\bar{B}C\bar{D}$$

a) Find the optimized/minimum Boolean equation.
b) Sketch the corresponding function block diagram (FBD).

Points:

Question 3: **11**

Transfer the given logic gate circuit with the inputs $A, B,$ and C and the outputs Y and Z, according to figure 3.1, to a corresponding ladder diagram (LAD).

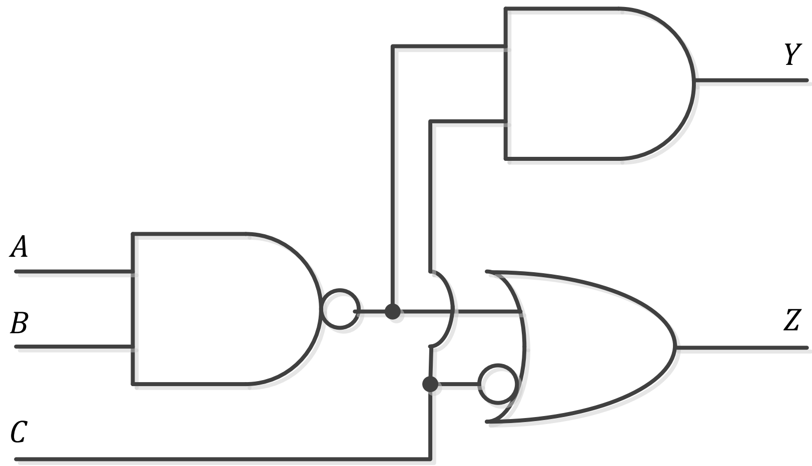


Figure 3.1: Logic gate circuit

Points:

Question 4: **18**

A system is characterized through the set of equations

$$2\,\ddot{x}_1(t) + 6\,x_1(t) = 8\,u_1(t)$$
$$\dot{x}_2(t) + a\,x_2(t) + 10\,\dot{x}_1(t) = 2\,u_1(t) + b\,u_2(t)$$
$$y(t) = 2\,x_1(t) + 5\,u_2(t)$$

where y is the output variable and u_1 and u_2 are the input variables.

a) Formulate a state-space model of the system and determine the matrices $\boldsymbol{A}$, $\boldsymbol{B}$, $\boldsymbol{C}$, and $\boldsymbol{D}$.
b) Formulate a condition for the coefficients a and b, so that the system is stable.

Points:

Question 5: **23**

A system is defined through the state space model

$$\dot{\boldsymbol{x}}(t) = \boldsymbol{A}\,\boldsymbol{x}(t) + \boldsymbol{B}\,u(t)$$
$$y(t) = \boldsymbol{C}\,\boldsymbol{x}(t) + D\,u(t)$$

with $\boldsymbol{A} = \begin{bmatrix} 0 & 4 \\ 1 & 8 \end{bmatrix}, \boldsymbol{B} = \begin{bmatrix} 2 \\ 0 \end{bmatrix}, \boldsymbol{C} = [1 \quad 0]$ and $D = 0$

a) Convert the state space model into a state space model in phase variable canonical form.
b) Is the given system controllable? Please explain.

In the following the system is controlled by a state space controller with the feedback vector $\boldsymbol{K}$.

c) Calculate the feedback vector $\boldsymbol{K}$, so that the closed-loop system has the poles at $p_{1,2} = -6 \pm j$.

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Points:

Question 6: **23**

A closed-loop sampled system with the reference input $r(t)$ and the actual output $c(t)$, as shown in block diagram fig. 6.1, consists of a system with the transfer function $G_1(s)$ in the feedforward path, a zero-order-hold in the feedforward path, two samplers which are synchronized with the sampling time T, and a system with the transfer function $H(s)$ in the feedback path.

The following transfer functions are given:

$G_1(s) = \frac{5}{s}$ and $H(s) = \frac{10}{s+10}$

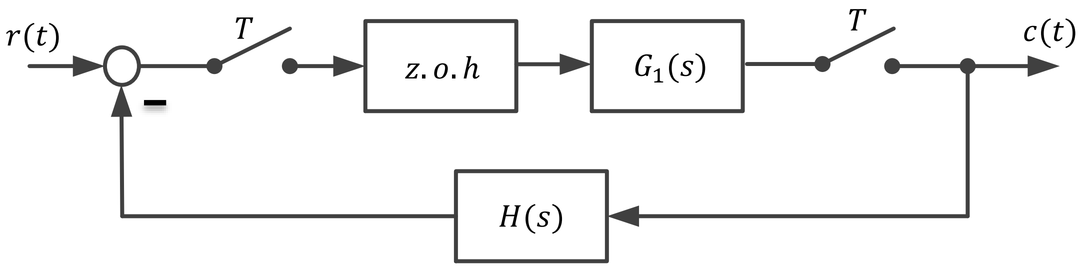

Figure 6.1: Block diagram of closed-loop system

a) Find the sampled-data transfer function $G(z) = \frac{C(z)}{R(z)}$ of the closed-loop system as a function of the sampling time T. *Hint: Check the sampler arrangement!*

b) Is the sampled closed-loop system stable for $T = 10\ [ms]$? Please explain.

Good luck!