Period of Examinations
Winter Semester 2015/2016 II

HOCHSCHULE RHEIN-WAAL
Rhine-Waal University of Applied Sciences

Study Course: **Mechanical Engineering / Mechatronic Systems Engineering / Electronics**

Module Title: **Controls**

Examination Part: **Controls**

Points: 100

Duration: 120 Minutes

Please write legibly!

Date: ________________

Family Name : ________________ ____________________

First Name: ________________ Signature (Student)

Student No.: ________________

FOR INTERNAL USE ONLY:

Question Number	Tick Questions Attempted	Points	Question Number	Tick Questions attempted	Transfer Points
1		/ 9	13		
2		/ 7	14		
3		/ 15	15		
4		/ 12	16		
5		/ 19	17		
6		/ 4	18		
7		/ 13	19		
8		/ 9	20		
9		/ 12	21		
10	Bonus points from laboratory	/ 10	22		
11			23		
12			24		
	SUM			TOTAL	/ 100

Graded by		Checked by

Final Grade

Regular grading key.	
Adjusted grading key. (Please add the adjusted grading key to the exam-results)	

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Question 1:

Points: **9**

A sampled data system consists of a transfer function (in the z-domain)

$$G(z) = \frac{2z^2}{z^2 - 2z + 4}$$

Determine the first four values of the sampled system.

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Question 2:

Points:
7

A plant with a PT1 characteristic and a transfer function $G_P(s) = \frac{1}{0.1s+1}$ is excited by the input signal $\tilde{u}_{zoh}(t)$ as shown in the block diagram, figure 2.1. The digital signal $\tilde{u}_{zoh}(t)$ is generated out of $u(t)$ by using a sampler and a zero-order hold element. The input signal $u(t)$ is shown in the graph, figure 2.2.

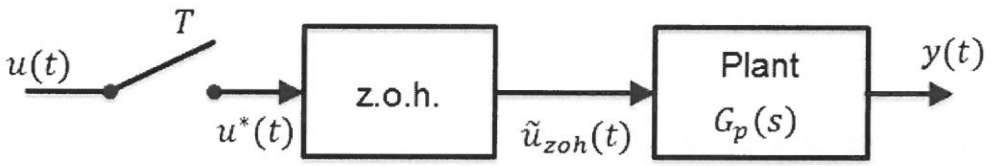

Figure 2.1: Block diagram of signal flow

a) Draw the signal $u^*(t)$ into the graph of figure 2.2, when the sampling time of the sampler is $T = 0.1\ s$.
b) Draw the signal $\tilde{u}_{zoh}(t)$ into the graph of figure 2.2, when the sampling time of the sampler is $T = 0.2\ s$.
c) Using the signal $\tilde{u}_{zoh}(t)$ from task b), sketch the output of the plant $y(t)$ into the graph of figure 2.2.

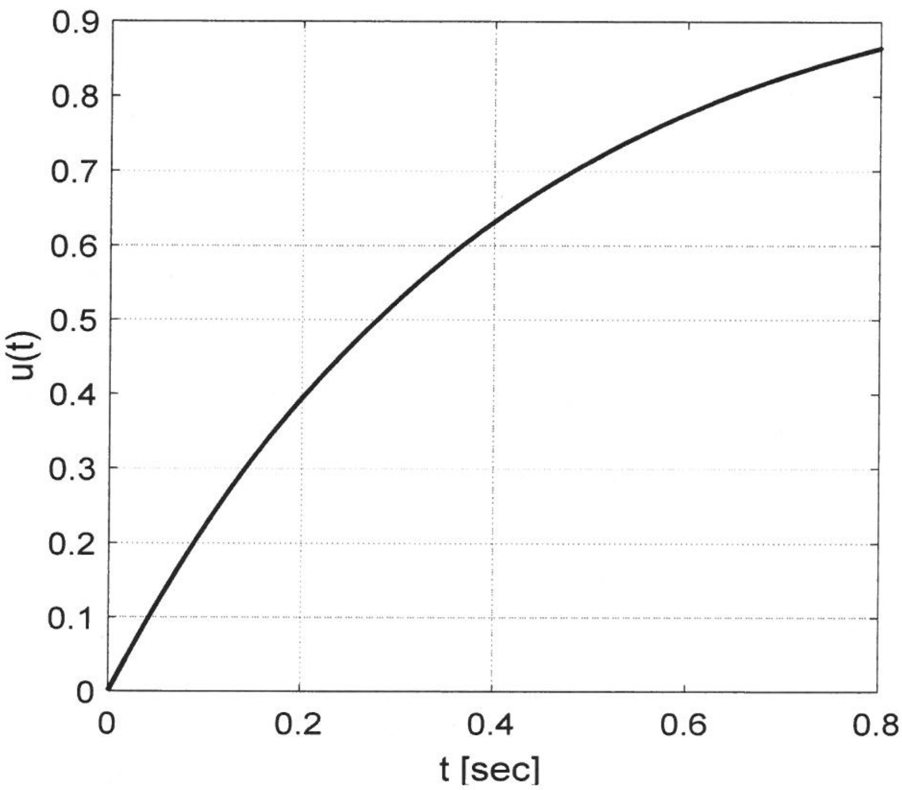

Figure 2.2: Signal graph

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Points:
15

Question 3:

Given is a transfer function

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

in a cascade with a zero-order sample and hold, hence

$$G(s) = \frac{1 - e^{-Ts}}{s} \frac{5}{s + 10}$$

The sampling period is $T = 0.1s$.

a) Find the samples-data transfer function, $G(z)$.
b) Is the sampled system stable? Please explain.
c) Determine the sampling time T_{crit}, for which the system is unstable.

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Question 4:

Points: **12**

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

$$Y = \bar{A}\,B\,C\,D + \bar{A}\,B\,C\,\overline{D} + \bar{A}\,\bar{B}\,C\,\overline{D} + A\,B\,C\,\overline{D} + A\,B\,C\,D$$

a) Find the optimized/minimum Boolean equation.
b) Sketch the corresponding ladder diagram.
c) Develop a logic gate circuit from the Boolean expression $Y = (A\,\bar{C} + B)\left(\overline{\overline{D} + A}\right)$.

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Question 5:

Points: **19**

An underground parking garage consists of two fans for ventilation. When at least one car has entered the parking garage one fan has to be activated. When at least 20 cars have entered the parking garage the second fan has to be activated, too. When cars leave the parking garage the fans should be still activated for 5 minutes before deactivation (2nd fan when less than 20 cars are inside the garage, 1st fan when no car is inside the garage). The maximum capacity of the garage is 40 cars. The operation of the fans can be sensed by a velocity sensor for each fan (switching function: output 0 V when speed is 0 rpm, otherwise constantly +24 V), see figure 5.1.

One photo-electric sensor detects when cars are entering the garage, another sensor detects when cars are leaving.

When the parking garage is full, a red full light is activated. Additionally the red light has to be activated when one of the fans is not operating although it should be. If there is enough space and the fans are working properly, a green light is activated.

The control of the underground parking garage should be done via PLC. Develop and create the logic using a Functional Block Diagram (FBD).

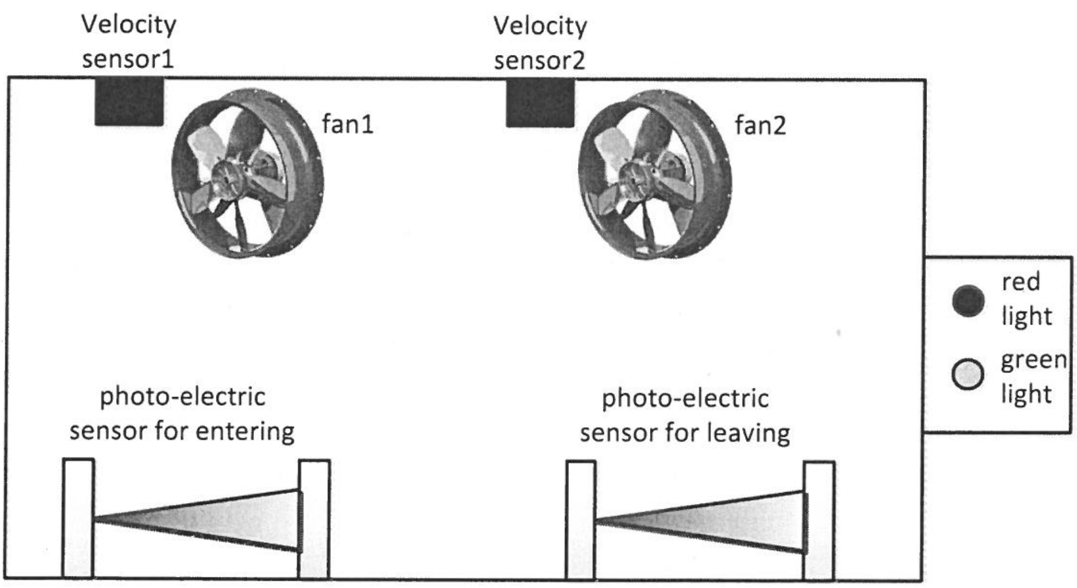

Figure 5.1: Underground parking garage

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Question 6:

Points:
4

Figure 6.1 shows a ladder diagram (LAD) for a given problem.

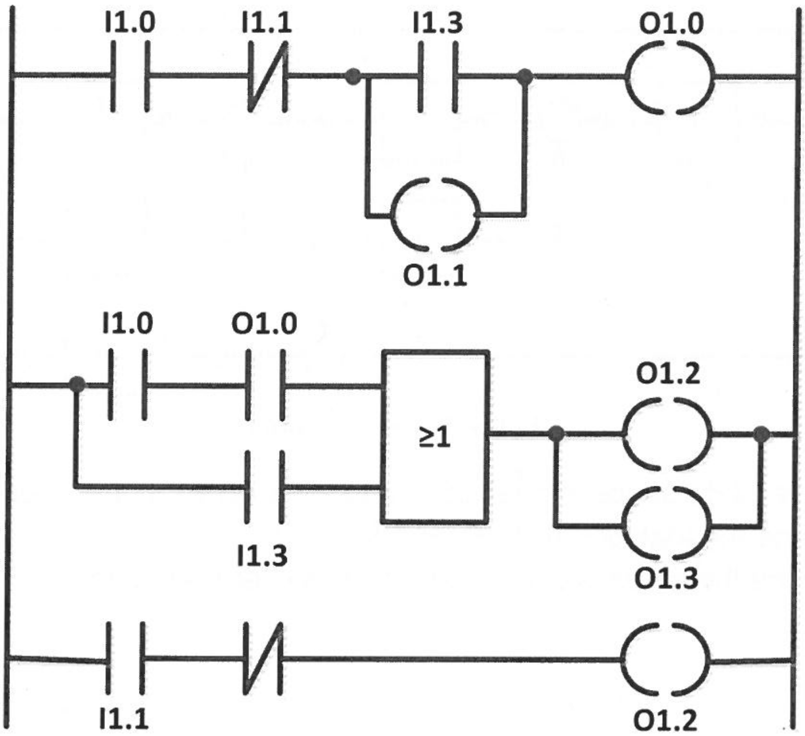

Figure 6.1: Ladder diagram

Find four syntax/logic errors in the diagram and explain the error.

1)

2)

3)

4)

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Question 7:

Points:
13

Given is a block diagram in figure 7.1 with the input $u(t)$ and the output $y(t)$.

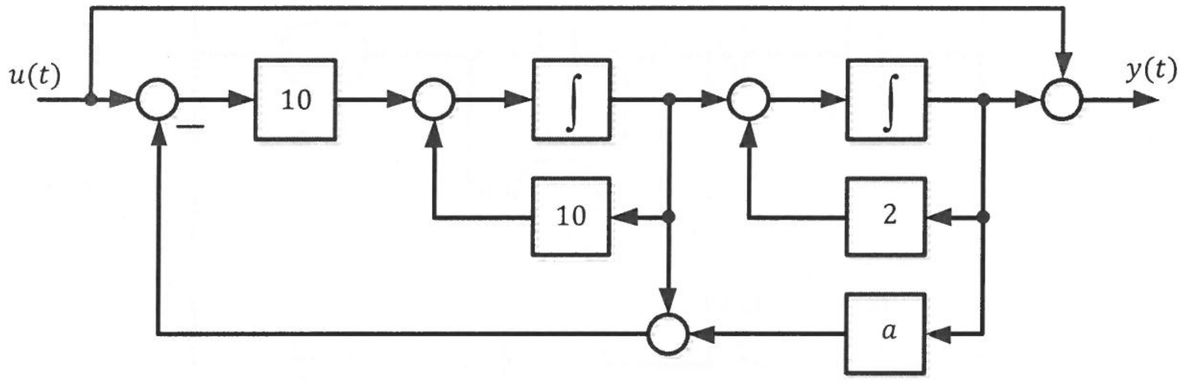

Figure 7.1: Block diagram

a) Derive a state-space model of the system given in the block diagram and determine the matrices $\boldsymbol{A}$, $\boldsymbol{B}$, $\boldsymbol{C}$, and $\boldsymbol{D}$.

b) Determine the parameter a for which the system is stable.

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Question 8:

Points: **9**

A control system is defined by the transfer function

$$G(s) = \frac{s + 4}{s^2 + k\,s + 3}$$

a) Convert the system model from the transfer function to a state space model.
b) Determine the condition for k so that the system is observable.

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Question 9:

Points:
12

A dynamic system is described through a state space model with

$$\boldsymbol{A} = \begin{bmatrix} 0 & 0 & 1 \\ 2 & 0 & 1 \\ 3 & 0 & 1 \end{bmatrix} \text{ and } \boldsymbol{B} = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$$

The system is controlled by a state feedback controller with the feedback matrix $\boldsymbol{K} = [43 \quad -48 \quad k_3]$.

a) Proof that the given system is controllable.
b) Calculate the feedback parameter k_3, so that the closed-loop system has poles at $p_{1,2} = -4$ and $p_3 = -3$.

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Good luck!