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Dublin City University

SEMESTER 1 IN-CLASS TEST 2021/2022

MODULE: EE458 - Control Systems Analysis

PROGRAMME(S):

ECE	BEng Electronic & Computer Engineering
ME	B.Eng. in Mechatronic Engineering
ECSAO	Study Abroad (Engineering & Computing)
ECSA	Study Abroad (Engineering & Computing)

YEAR OF STUDY: 4

EXAMINER(S):

Dr. Mingming Liu	(Internal)	(Ext:8492)
Dr. Josep R. Casas	(External)	External
Dr. Rudi Villing	(External)	External

TIME ALLOWED: 1 Hour

INSTRUCTIONS: Answer Question 1.
Marks will be lost if all necessary work in not clearly shown.
Marks will be lost if **Matlab** figures are not clearly labelled.
This exam is total of 25 marks.

PLEASE DO NOT TURN OVER THIS PAGE UNTIL YOU ARE INSTRUCTED TO DO SO.
The use of programmable or text storing calculators is expressly forbidden.
Please note that where a candidate answers more than the required number of questions, the examiner will mark all questions attempted and then select the highest scoring ones.

Requirements for this paper:
1. Log Tables

INSTRUCTIONS FOR COMPUTER-BASED WORK

IMPORTANT: PLEASE READ THIS SHEET CAREFULLY BEFORE COMMENCING THIS EXAM.

GENERAL:

- Set up your own directory (called your student exam number) in `c:\temp` as saving to `c:\temp` is faster than saving to the USB flash drive.
- All m-files, script files, SIMULINK files, plot files and diary files (with extension `txt`) must be saved to the network drive `Q:\` and to the USB flash drive.
- Save your work regularly. No credit is given for work that has been 'lost'.
- At the end of the exam, it is your responsibility to ensure that all your work has been saved successfully to the network drive `Q:\` and to the USB flash drive.

SAVING PLOTS:

- The plot must be generated to your satisfaction in the Figure window. Do not minimize this window.
- Save your plot as type `*.fig` only. Other formats are not acceptable.
- **N.B.** Make sure that you save your plot to `c:\temp\....` Make sure that you use a unique name for the plots.

DIARY FILES:

- It is recommended that you use a separate diary file for each part of a question.
- To open/start a diary file, at the MATLAB Command Prompt, type:

```
>> diary c:\temp\examnum\diary1.txt
>> diary on
```

- To close a diary file, at the MATLAB Command Prompt, type: `>> diary off`

USEFUL MATLAB FUNCTIONS:

abs	acos	angle	asin	atan	axis
bandwidth	bode	break	c2d	cd	clear
clf	close	conv	cos	det	eig
else	evalfr	exit	exp	feedback	figure
find	for	function	grid	help	if
imag	impulse	inv	isstable	label	length
log	log10	logspace	lsim	margin	max
mean	min	norm	nyquist	ones	open
ode45	pi	pinv	plot	pole	poly
print	pzmap	quit	rand	rank	real
residue	rlocfind	rlocus	roots	round	semilogx
series	sign	sim	sin	size	sqrt
ss	ssdata	step	subplot	sum	tan
text	tf	tf2ss	tfdata	title	while
who	xlabel	ylabel	zeros	zgrid	zpk
zpkdata	zoom				

- **Please note**: the use of solve(), stepinfo(), sisotool(), rltool(), sgrid() or any of their related functions is not allowed as part of this assessment.

QUESTION 1 (COMPULSORY) *[TOTAL MARKS: 25]*

[See Appendix for applicable formulae]

Q1(a) **[4, 2, 2, 2, 10 Marks Total]**

The block diagram for a control system is shown in **Figure Q1a**:

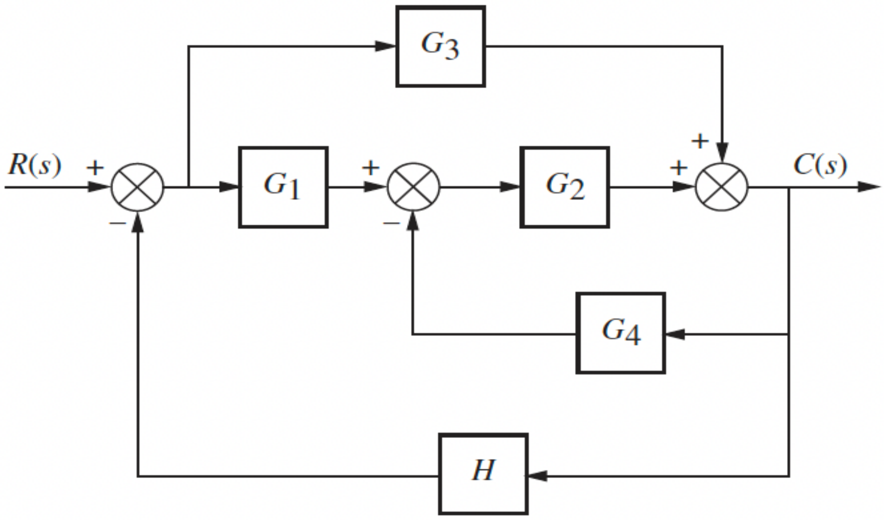

Figure Q1a

(i) Derive the mathematical expression for the transfer function of the system $T(s) = \frac{C(s)}{R(s)}$ in terms of $G_1(s)$, $G_2(s)$, $G_3(s)$, $G_4(s)$ and $H(s)$.

(ii) Let $G_1(s) = \frac{1}{s+1}$, $G_2(s) = \frac{1}{s+2}$, $G_3(s) = \frac{1}{(s+1)(s+2)}$, $G_4(s) = H(s) = 1$. Find out the exact expression for the closed-loop transfer function $T(s)$. To do this, you may either use **Matlab** or present your derivation steps on the paper. If using **Matlab**, please include your codes and comments in the coding script.

(iii) Present the characteristic equation and the type of the closed-loop system.

(iv) Check the stability of the system and present your results.

Q1(b) **[3, 3, 6 Marks Total]**

Given the system set-up in **Q1(a)(ii):**

(i) Use the Final Value Theorem (FVT) to calculate the steady-state value of the system output with a unit step input.

(ii) Use **Simulink** to generate the output of the system for a unit step input. Set the simulation time as 20seconds and step size equals 0.1second. Save your model and output. Note: an equivalent system model is doable.

Q 1(c) **[2, 2, 2, 3, 9 Marks Total]**

Given a typical feedback control system presented in **Figure Q1c:**

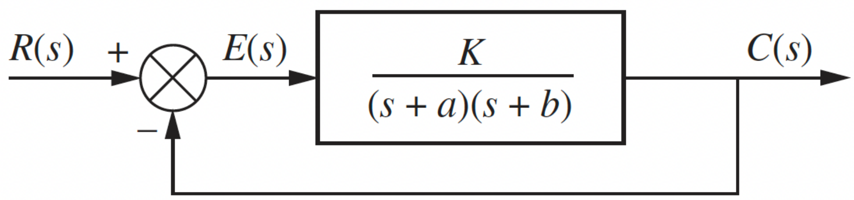

Figure Q1c

(i) Find the sensitivity of the steady-state error to changes in parameter K, $S_K^{E_{ss}}$, with a unit step input.

(ii) Find the sensitivity of the steady-state error to changes in parameter a, $S_a^{E_{ss}}$, with a unit step input.

(iii) Assume that a, b and K are positive, discuss the impact on the value of $S_a^{E_{ss}}$ with increasing value of b. Assume that all other parameters are fixed.

(iv) Let $a = K = 1$. Prove that for any $0 < b < 3$, the system is always stable. *Hint: a system is said as stable if all roots of its characteristic equation have negative real parts.*

[End of Question 1]

APPENDIX

Please note the use of `solve, stepinfo(), sisotool(), rltool(), sgrid()` or any of their related functions is not allowed as part of this assessment.

Selection of Laplace and Z-Transforms

f(t)	*F(s)*	*F(z),*
1	$\frac{1}{s}$	$\frac{T}{1-z^{-1}}$
t	$\frac{1}{s^2}$	$\frac{Tz^{-1}}{(1-z^{-1})^2}$
t^2	$\frac{2}{s^3}$	$\frac{T^2z^{-1}(1+z^{-1})}{(1-z^{-1})^3}$
e^{-aT}	$\frac{1}{s+a}$	$\frac{1}{1-e^{-aT}z^{-1}}$
te^{-aT}	$\frac{1}{(s+a)^2}$	$\frac{Te^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$

Product Rule:

$$y = uv \Rightarrow \frac{dy}{dx} = u\frac{dv}{dx} + v\frac{du}{dx}$$

Quotient Rule:

$$y = \frac{u}{v} \Rightarrow \frac{dy}{dx} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$$

Chain Rule:

$$y = u\big(v(x)\big) \Rightarrow \frac{dy}{dx} = \frac{du}{dv}\frac{dv}{dx}$$

[End of Appendices]