SEMESTER 1 IN-CLASS TEST 2019/2020

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):

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Dr. William O'Connor	(External)	External
Dr. Josep R. Casas	(External)	External
Dr. Simon Watson	(External)	External

TIME ALLOWED: 1 Hours

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) **[8 Marks]**

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

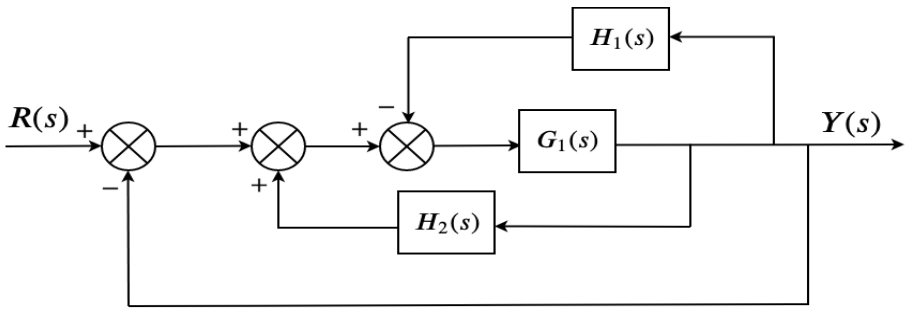

Figure Q1a

(i) Derive the mathematical expression for system's closed-loop transfer function $T(s) = \frac{Y(s)}{R(s)}$ in terms of $G_1(s)$, $H_1(s)$ and $H_2(s)$.

(ii) Let $G_1(s) = \frac{1}{s}$, $H_1(s) = \frac{1}{s+1}$, and $H_2(s) = \frac{1}{s+2}$. Use **Matlab** to find the exact expression for the closed-loop transfer function $T(s)$. Present the order and type of the system $T(s)$.

(iii) Given the $T(s)$ in **Q1(a)(ii)**, use **Matlab** function to plot the zeros and poles of $T(s)$. Present the pole(s) with the maximum magnitude. Save the plot.

(iv) Use **Simulink** to simulate the system described above with **(a)** individual blocks according to the original block diagram; and **(b)** the overall closed-loop transfer function. Then, plot the difference between the output of two simulations against time (with a unit step input, stop time equals 20seconds with step size equals 0.01second). Save your Simulink models and the plot.

Q1(b) **[4 Marks]**

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

(i) Use **Matlab** to examine the stability of the system, and comment on your results.

(ii) Use the Final Value Theorem (FVT) to calculate the steady-state value of $Y(s)$ with a unit step input. Present the steady-state error.

Q 1(c) **[6 Marks]**

(i) Explain the meaning if a system is said to have zero sensitivity.

(ii) Discuss two reasons why Laplace transform is useful for analyzing systems modelled by differential equations.

(iii) Let the closed-loop transfer function $T(s)$ be in the form of:

$$T(s) = \frac{3s + k}{(s+1)(s+2)}$$

Present the formula for the sensitivity of $T(s)$ with respect to parameter k.

Q 1(d) **[7 Marks]**

Determine the output $\boldsymbol{Y(s)}$ and the steady-state error $\boldsymbol{E(s)}$ of the system presented in **Figure Q1d**.

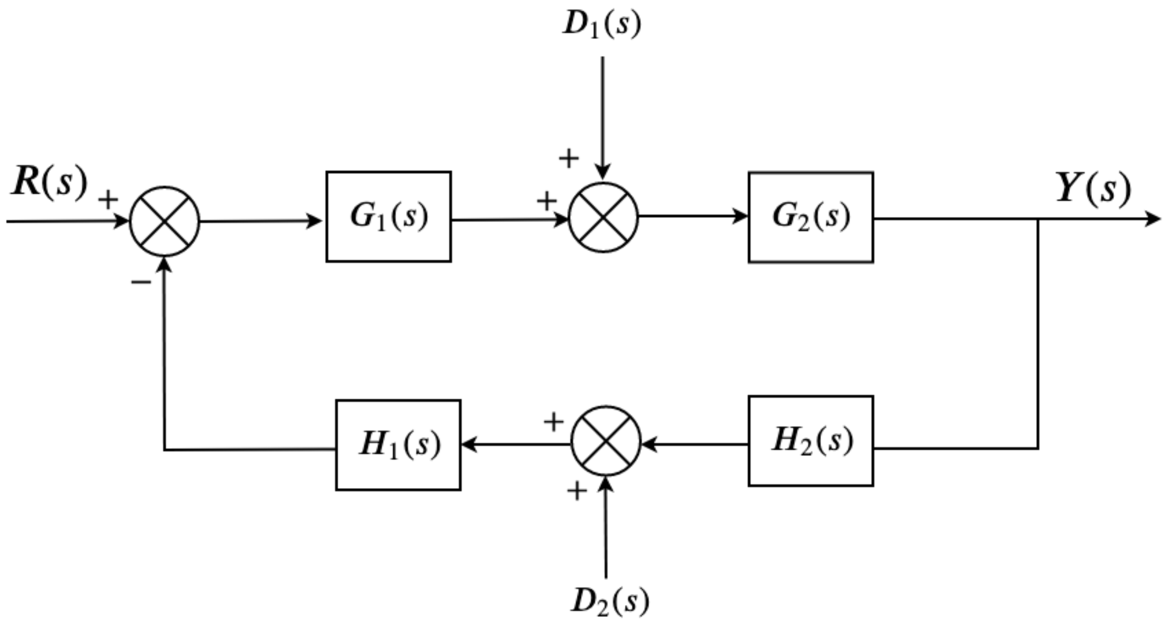

Figure Q1d

[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]