DUBLIN CITY UNIVERSITY

SEMESTER 1 IN-CLASS TEST 2016/2017

MODULE: EE458 – Control Systems Analysis

PROGRAMME(S):

ME	B.Eng. in Mechatronic Engineering
ECE	BEng Electronic & Computer Engineering
EE	BEng in Electronic Engineering

YEAR OF STUDY: 4

EXAMINER(S):

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Prof. Matilde Santos Penas
Prof. Gerard Parr

TIME ALLOWED: 1 Hour

INSTRUCTIONS: Answer Question 1.

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.

INSTRUCTIONS FOR COMPUTER-BASED WORK

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

GENERAL:

- Set up your own directory (called your student ID 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\IDnum\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 *`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]

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

A closed-loop control system is described by the block diagram in **Figure Q1.**

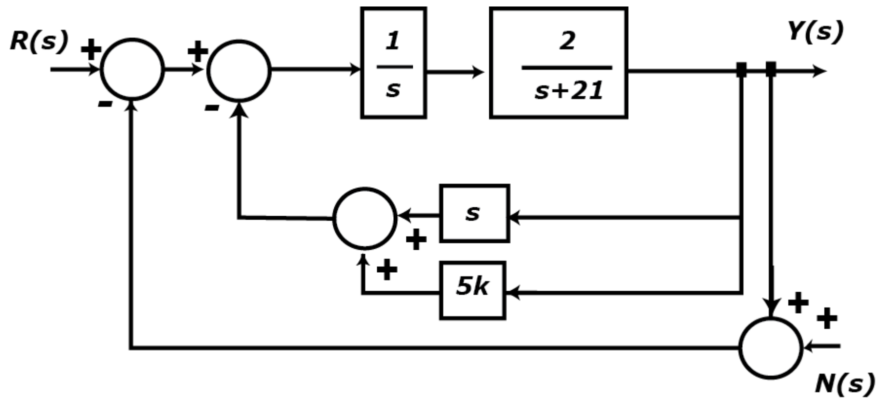

Figure Q1

(i) Use the fact that the closed-loop transfer function (CLTF) is given as:

$$T_{Generic}(s) = \frac{C(s)G(s)}{1 + C(s)G(s)H(s)}$$

for a generic system with $G(s)$ and $C(s)$ in the forward path and $H(s)$ in the feedback path to find the CLTF, $T(s) = Y(s)/R(s)$ for the system in **Figure Q1**.

(ii) Find the sensitivity, in terms of the Laplace variable of the closed-loop transfer function to variations in the gain, k.

Q 1(b) **[8 Marks]**

(i) Derive an expression of the reference input error signal, $E_R(s)$, in terms of $T(s)$ and the $R(s)$ signal in **Figure Q1**.

(ii) Derive an expression of the noise error signal, $E_N(s)$, in terms of the $N(s)$ signal in **Figure Q1**. Arrange this expression in terms of $T(s)$ and $N(s)$.

(iii) Present the Final Value Theorem formula for the steady-state error. Design the gain, k, to give a steady-state error of **1.8** when $r(t) = 5u(t)$ and $n(t) = u(t)$.

Q 1(c) **[3 Marks]**

For the system in **Q 1(a)** with the value of k found in **Q 1(b)**, use **MATLAB** commands to:

(i) predict the steady-state error solely due to a reference input, $r(t) = 5u(t)$

(ii) predict the steady-state error solely due to a disturbance input, $n(t) = u(t)$

(iii) predict the steady-state output when the inputs of **Q 1(b)(iii)** are applied

Q 1(d) **[8 Marks]**

(i) Use **SIMULINK** with the layout given in **Figure Q1** to simulate the system for the value of k designed in **Q 1(b)** in response to both inputs described in **Q 1(b)(iii)** for 125 seconds; the *'s' block* should be implemented using the **SIMULINK** *d/dt* block. The error response signal should be captured with **SIMULINK** blocks.

(ii) Plot the output response signal and the reference input signal on the same plot and then save this plot.

(iii) Use **MATLAB** to measure the steady-state error value and the steady-state output value. Do these values match the values designed for in **Q 1(b)(iii)** and predicted in **Q 1c(iii)**? Briefly comment on why they do/do not match.

[End of Question 1]

APPENDIX

Please note: the use of `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	$\frac{2}{s^3}$	$\frac{T^2 z^{-1}(1+z^{-1})}{(1-z^{-1})^3}$
e^{-aT}	$\frac{1}{s+a}$	$\frac{1}{1-e^{-aT}z^{-1}}$
te^{-aT}	$\frac{1}{(s+a)^2}$	$\frac{Te^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$

Transient Performance formulae - 1st order system:

$$s = -a$$

$$\tau = \frac{1}{a}, \quad t_s = \frac{4}{a} \quad t_r = \frac{2.2}{a}$$

Transient Performance formulae - 2nd order under-damped system:

$$\boldsymbol{s = -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}}$$

$$\%\ \boldsymbol{Overshoot = 100e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}}\%, \quad \boldsymbol{t_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}}$$

$$\boldsymbol{t_s = \frac{4}{\zeta\omega_n}}, \qquad \boldsymbol{t_r = \frac{\pi - \tan^{-1}\left(\sqrt{1-\zeta^2}/\zeta\right)}{\omega_n\sqrt{1-\zeta^2}}}$$

2nd order under-damped transient performance – frequency domain formulae:

$$Phase\ Margin = \ tan^{-1}\left[2\zeta\left\{\frac{1}{(4\zeta^4+1)^{1/2}-2\zeta^2}\right\}^{1/2}\right]$$

$$M_P = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$$

$$\omega_b = \frac{4}{\zeta t_s}\sqrt{(1-2\zeta^2)+\sqrt{4\zeta^4-4\zeta^2+2}}$$

$$\omega_b = \frac{\pi}{t_p\sqrt{1-\zeta^2}}\sqrt{(1-2\zeta^2)+\sqrt{4\zeta^4-4\zeta^2+2}}$$

[End of Appendix]

[End of Examination]