[ENG41]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSC SYSTEM ENGINEERING

SEMESTER ONE EXAMINATION 2018/2019

SIGNAL PROCESSING

MODULE NO: EEM7011

Date: Wednesday 16th January 2019 Time: 14:00 – 16:00

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

School of Engineering
MSc System Engineering
Semester One Examination 2018/2019
Signal Processing
Module No. EEM7011

Question 1.

a) Discuss briefly the conditions necessary for a realisable digital filter to have a linear phase characteristic and the advantage of filters with such characteristics.

[5 marks]

b) An FIR filter has its impulse response, h[n] defined over interval 0 ≤ n ≤ N-1. Show that if N=8 and h[n] satisfies the following symmetry condition:

h[n] = h[N-1-n],

the phase provided by the filter is linear in nature whose generic value is given by

$$Angle\ H\left(e^{jw}\right) = -\frac{N-1}{2}w$$

[20 marks]

Total 25 marks

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Question 2.

a) Given the Z-transform is given by x(z)= $\sum_{n=-\infty}^{n=+\infty} x(n)z^{-n}$, consider the system given by the following equation:

$$x[n] = \left[\left(\frac{1}{2}\right)^n + \left(\frac{1}{4}\right)^n\right]u(n)$$

For this system, calculate the Z-transform and its region of convergence (ROC).

[15 marks]

b) From the z function pole-zero diagram shown below (**Fig. Q2**):

(i) Derive the transfer function H(z) and comment on the filter stability.

[5 marks]

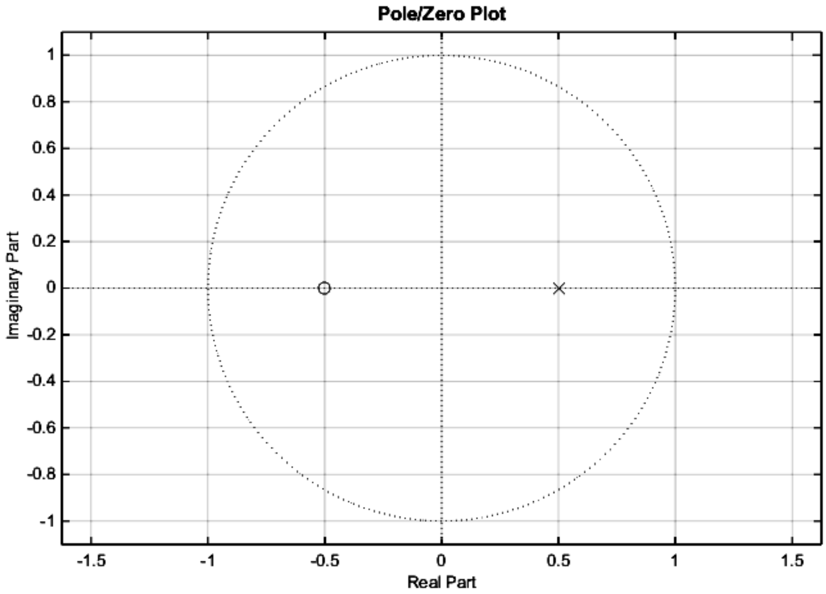

Fig. Q2

(ii) Find the unit step response impulse response of the filter y(n) for n=0, 1, 2, 3 and sketch this response.

[5 marks]

Total 25 marks

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School of Engineering
MSc System Engineering
Semester One Examination 2018/2019
Signal Processing
Module No. EEM7011

Question 3.

a) Discuss the different properties of Tchebycheff, Butterworth and Bessel filters such as: frequency, time and phase responses.

[5 marks]

b) Refer to **Table One**, calculate the component values for a low pass filter of order five (5). **The Butterworth** filter should have 3dB frequency of 50MHz and will be used in a 50Ω circuit. Sketch the design.

[5 marks]

Table One

k n↓	→ 2	3	4	5	6
1	1.4142	1.0000	0.7654	0.6180	0.5176
2	1.4142	2.0000	1.8478	1.6810	1.4142
3		1.0000	1.8478	2.0000	1.9319
4			0.7654	1.6810	1.9319
5				0.6810	1.4142
6					0.5176

c) The low pass filter described in section (b) is to be converted to band –pass filter having a bandwidth of 475 MHz to 525MHz. Sketch the new design and calculate the component values.

[10 marks]

d) Show how this filter can be converted or modified to become a band stop filter.

[5 marks]

Total 25 marks

PLEASE TURN THE PAGE….

School of Engineering
MSc System Engineering
Semester One Examination 2018/2019
Signal Processing
Module No. EEM7011

Question 4.

a) Find the frequency response for the digital filter with the following transfer function;

$$H(z) = \frac{1 + 2z^{-1}}{1 + 5.0z^{-1} - 9.0z^{-2}}$$

[8 marks]

b) Calculate the magnitude and phase if the sampling rate (f_s) is 20 KHz and the analogue frequency (f) is 4 KHz given that $\Omega = 2\pi \frac{f}{f_s}$

[8 marks]

c) Derive the difference equation.

[4 marks]

d) Show how this difference equation could be implemented using delays and feedback.

[5 marks]

Total 25 marks

PLEASE TURN THE PAGE….

School of Engineering
MSc System Engineering
Semester One Examination 2018/2019
Signal Processing
Module No. EEM7011

Question 5.

A block diagram for an analogue control system is shown in **Figure Q5** below:

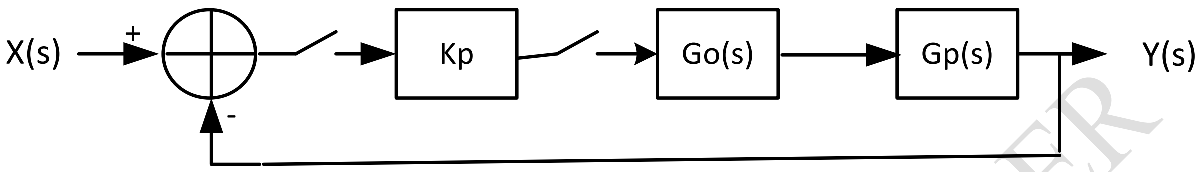

Figure Q5

Where the digital controller is Kp,

and the zero-order hold $G_0(s) = \frac{1-e^{-sT}}{s}$,

with the plant $G_p(s) = \frac{0.5}{s+0.5}$

a) Determine the closed **-** loop digital z transfer function for the system.

[10 marks]

b) If the gain of the digital controller Kp = 10, determine the range of the sampling interval T that will make the closed loop stable.

[7 marks]

c) If the sampling frequency f = 20 Hz, determine the range of the controller gain Kp which will make the closed loop stable.

[8 marks]

Total 25 marks

School of Engineering
MSc System Engineering
Semester One Examination 2018/2019
Signal Processing
Module No. EEM7011

Question 6

a) Determine using the BZT method, the transfer function and difference equation for the digital filter which can replace a first order low pass resistive capacitive analogue filter. Assuming a sampling frequency of 150Hz and a cut-off frequency of 30 Hz, develop the transfer functions;

$H_S = \frac{Y_S}{X_S}$ and $H_Z = \frac{Y_Z}{X_Z}$

Assume $s = \frac{T(z-1)}{2(z+1)}$ and pre-warped frequency $Wp = \tan(\frac{WcT}{2})$.

[10 marks]

b) Sketch the first order low pass filter and its digital replacement with the difference equation shown.

[10 marks]

c) Show how this low pass first order filter can be modified to become a high pass first order filter.

[5 marks]

Total 25 marks

END OF QUESTIONS

Formula sheet over the page….

School of Engineering
MSc System Engineering
Semester One Examination 2018/2019
Signal Processing
Module No. EEM7011

Formula Sheet

A Table of Basic Laplace and Z transforms

Time f (t)	**Laplace F(s)**	**Z transforms**
1. $\delta[t]$	1	1
1 **2.** $u(t)$	$\frac{1}{s}$	$\frac{z}{z-1}$
3. t	$\frac{1}{s^2}$	$\frac{Tz}{(z-1)^2}$
4. e^{-at}	$\frac{1}{s+a}$	$\frac{Z}{Z-e^{-aT}}$
5. $\frac{1}{a(1-e^{-at})}$	$\frac{1}{s(s+a)}$	$\frac{z(1-e^{-aT})}{a(z-1)(z-e^{-aT})}$
6. $\sin\omega t$	$\frac{\omega}{s^2+\omega^2}$	$\frac{z\sin\omega T}{z^2-2z\cos\omega T+1}$
7. $\cos\omega t$	$\frac{s}{s^2+\omega^2}$	$\frac{z^2-z\cos\omega T}{z^2-2z\cos\omega T+1}$
8. $e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$	$\frac{ze^{-aT}\sin\omega T}{z^2-2ze^{-aT}\cos\omega T+e^{-2aT}}$
9. $e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$	$\frac{z(z-e^{-aT}\cos\omega T)}{z^2-2ze^{-aT}\cos\omega T+e^{-2aT}}$
10. $\sinh\omega t$	$\frac{\omega}{s^2-\omega^2}$	$\frac{z\sinh\omega T}{z^2-2z\cosh\omega T+1}$
11. $\cosh\omega t$	$\frac{s}{s^2-\omega^2}$	$\frac{z(z-\cosh\omega T)}{z^2-2z\cosh\omega T+1}$

School of Engineering
MSc System Engineering
Semester One Examination 2018/2019
Signal Processing
Module No. EEM7011

A Table of Basic Sampled data and Z Transforms

signal x[n]	z Transform X(z)	Region of Convergence
1 $\delta[n]$	1	all z
2 $u[n]$	$\frac{z}{z-1}$	$\lvert z\rvert > 1$
3 $\beta^n u[n]$	$\frac{z}{z-\beta}$	$\lvert z\rvert > \lvert\beta\rvert$
4 $nu[n]$	$\frac{z}{(z-1)^2}$	$\lvert z\rvert > 1$
5 $\cos(n\Omega)u[n]$	$\frac{z^2 - z\cos\Omega}{z^2 - 2z\cos\Omega + 1}$	$\lvert z\rvert > 1$
6. $\sin(n\Omega)u[n]$	$\frac{z\sin\Omega}{z^2 - 2z\cos\Omega + 1}$	$\lvert z\rvert > 1$
7 $\beta^n\cos(n\Omega)u[n]$	$\frac{z^2 - \beta z\cos\Omega}{z^2 - 2\beta z\cos\Omega + \beta^2}$	$\lvert z\rvert > \lvert\beta\rvert$
8 $\beta^n\sin(n\Omega)u[n]$	$\frac{\beta z\sin\Omega}{z^2 - 2\beta z\cos\Omega + \beta^2}$	$\lvert z\rvert > \lvert\beta\rvert$

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