UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSC SYSTEM ENGINEERING

SEMESTER ONE EXAMINATION 2019/2020

SIGNAL PROCESSING

MODULE NO: EEM7011

Date: Wednesday 15th January 2020 Time: 14:00 – 16:00

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer 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.

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Question 1

(a). Contrast the different properties of ; Bessel, Butterworth and Chebyshev filters, giving examples of suitable applications. **(6 marks)**

(b). Refer to Table Q1 and calculate the components values, for a low-pass 5-order passive Butterworth filter design. The filter should have a 3dB frequency of 500MHz and be designed for use in a 50Ω source and load circuit, sketch the design. **(7 marks)**

(c). Using Table Q1, design a high-pass passive filter circuit. **(7 marks)**

(d) Describe how low pass filter can be modified to become a band stop filter. **(5 marks)**

Table Q1. Butterworth normalised parameters

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

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Question 2

It is required to design a digital filter to replace an analogue filter with the following transfer function; $H(s) = \dfrac{1}{s^2 + \sqrt{2}s + 1}$

(a). Using the BZT method derive the digital transfer function $H(z)$, assuming a 3dB cut off frequency of 150Hz and a sampling rate of 1.28kHz, if $s = \dfrac{z-1}{z+1}$. **(10 marks)**

(b). Show your design for H(z) using delays and feedback. **(10 marks)**

(c). Derive the recurrence equation for y[n]. **(5 marks)**

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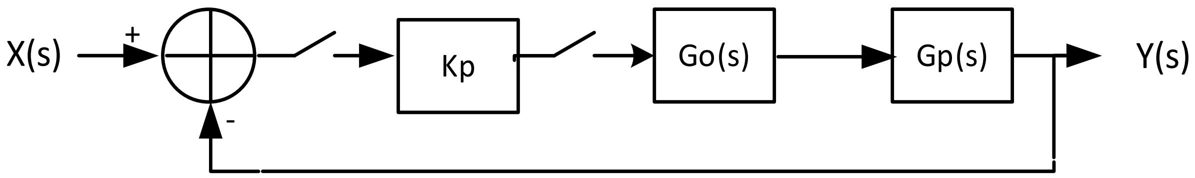
Question 3

A closed loop control system in shown in the block diagram below:



Where the analogue control law Kp = $4(2s + 1)/(10s + 1)$ and the plant Gp = $(0.125)/(s + 0.125)$.

(a). It is recommended to to replace the analogue controller Kp with a digital controller with sampling time T = 0.2 seconds, design that digital controller.

(5 marks)

(b). Determine the closed loop transfer function in the z domain assuming Go is a zero order hold.

(10 marks)

(c). Analyse the stability of the closed loop digital system in **(b).**

(5 marks)

(d). Calculate the discrete-time response of the closed system to a unit impulse input For the first four steps.

(5 marks

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Question 4

(a) Describe the difference between stable and unstable system **[2 Marks]**

(b) In the design of a system to be used in detecting heartrate pattern of unwell patients, a biomedical engineer desires to show a maximum voltage response of 1V when a heartrate pulse is received and discretely zeros otherwise. If the output signal sequence of the patient's heartrate is given by

$$x[n] = 7\left(\frac{1}{3}\right)^n u[n] - 6\left(\frac{1}{2}\right)^n u[n]$$

where $u[n]$ is a unit step function applied to ensure unity voltage when the pulse is received and zero otherwise and $u[n]$ given by

$$u[n] = \begin{cases} 1 & n \geq 0 \\ 0 & otherwise \end{cases}$$

i). Find the z-transform of the signal **[10 Marks]**

ii). Determine the poles **[5 Marks]**

iii). Determine the zeros **[5 Marks]**

iv). Using an ROC plot, determine if the system is stable or unstable **[3 Marks]**

Question 5

(a) Explain why analogue filters are usually referred to as IIR filters **[2 Marks]**

(b) Differentiate, with one example each, between causal and non-causal signals. **[4 Marks]**

(c) Identify any four different types of signals processed in frequency domain. **[4 Marks]**

(d) i) State any four methods of designing IIR filter **[4 Marks]**

ii) To approximate the transfer function of an analogue filter to realise its digital IIR filter equivalent, consider the following transfer function

$$H(s) = \frac{2}{1 + s/\omega_c}$$

determine the equivalent z-transform transfer function using bilinear transform method at $\omega_c = 12 \text{ rad/s}$ and 1.6Hz sampling frequency. **[11 Marks]**

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Question 6

(a) State any two difference between recursive and non-recursive filters.

[2 Marks]

(b) State any four advantages of frequency domain analysis over time domain analysis. **[4 Marks]**

(c) The discrete Fourier transform of a signal $x[n]$ is given by

$$X(k) = \sum_{n=0}^{N-1} x_n e^{-j\frac{2\pi nk}{N}}, \quad \forall k = 0, 1, \cdots, N-1$$

where k and n are the frequency and time indices, respectively. Considering a signal sequence $x[n] = \{0, 1, 1, 0\}$, find the DFT of the signal. **[8 Marks]**

(d) Both Z-transform and Fourier transform are generally used for signal processing in discrete-time domain, explain why Z-transfer may be preferred than Fourier transform.

[4 Marks]

(e) Using Z-transform method, find the frequency response of the follows system

$$y[n] = \frac{1}{6}x[n] + \frac{1}{3}x[n-1] + \frac{1}{6}x[n-2]$$

[7 Marks]

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END OF QUESTIONS

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Formula Sheet

A Table of Basic Laplace and Z transforms

Time f (t)	Laplace F(s)	Z transforms
1. $\delta[t]$	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. $\cosh\omega t$	$\frac{s}{s^2-\omega^2}$	$\frac{z(z-\cosh\omega T)}{z^2-2z\cosh\omega T+1}$

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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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