EE4015 Digital Signal Processing
Semester A 2022-2023

Assignment 3

Due Date: November 22, 2022

Question 1 [25 marks]

Consider an ideal lowpass filter whose frequency response in $(-\pi, \pi)$ is given as:

$$H_d(e^{j\omega}) = \begin{cases} 1, & -\omega_c \le \omega \le \omega_c \\ 0, & otherwise \end{cases}$$

(a) Determine the impulse response $h_d[n]$ of the ideal lowpass filter based on the frequency response $H_d(e^{j\omega})$ by inverse Discrete-Time Fourier Transform (DTFT). **[6 marks]**

(b) Based on the impulse response $h_d[n]$ to design a length-5 causal and linear-phase FIR filter by window method using rectangular window. It is required that the sampled version of a continuous-time signal with frequency components of 800 Hz or below can pass through it with small attenuation. The sampling frequency is 8000 Hz. **[8 marks]**

(c) Use the Direct Form filter structure in the block diagram representation to implement the designed FIR filter. **[6 marks]**

(d) What is the main disadvantage of rectangular window? Suggest a solution to the problem of using rectangular window in FIR filter design. **[5 marks)**

Question 2 [20 marks]

Consider a continuous-time filter with transfer function:

$$H_a(s) = \frac{1}{(s+a)^2 + b^2}$$

Can $H_a(s)$ be a Butterworth lowpass filter? Explain your answer.

If $H_a(s)$ can be a Butterworth lowpass filter, find the corresponding cutoff frequency and poles and then determine its form.

Question 3 [30 marks]

Use the second-order Butterworth transfer function to design a **highpass** digital IIR filter with digital cut-off frequency $\omega_c = 0.5\pi$ by Bilinear Transformation Method with T=0.1.

(a) State the prototype of the analog second order normalized Butterworth **lowpass** transfer function $H_{LP}(s)$.

[4 marks]

(b) Determine the continuous-time cut-off frequency Ω_c by frequency warping of the bilinear transformation method.

[4 marks]

(c) Determine the continuous-time second order Butterworth **highpass** transfer function $H_{HP}(s)$ by applying analog-to-analog transformation with the cut-off frequency Ω_c

[4 marks]

(d) Determine the digital **highpass** filter transfer function $H_{HP}(z)$ with numerical values by bilinear transform.

[12 marks]

(e) Provide a diagram for the **Canonical Form** implementation of the second-order IIR filter and provide the values of all relevant parameters.

[6 marks]