# EE3731C Tutorial - Classical Signal 3

## Department of Electrical and Computer Engineering

1. In lecture, we show the ideal lowpass filter with 0 phase, $H_{lp} = \begin{cases} 1, & |\omega| < \omega_c \\ 0, & \omega_c < |\omega| \leq \pi \end{cases}$ has the following impulse response $h[n] = \frac{\sin \omega_c n}{\pi n}$. Assuming $M$ is an integer, find the impulse response of an ideal

   (a) lowpass filter with linear phase: $H_{lp}^0 = \begin{cases} e^{-j\omega M/2}, & |\omega| < \omega_c \\ 0, & \omega_c < |\omega| \leq \pi \end{cases}$

   (b) highpass filter with linear phase: $H_{hp}^0 = \begin{cases} 0, & |\omega| < \omega_c \\ e^{-j\omega M/2}, & \omega_c < |\omega| \leq \pi \end{cases}$

2. Find the Kaiser window parameters $\beta$ and $M$, so that the resulting windowed highpass filter satisfies the following specifications:

$$\begin{aligned} |H(e^{j\omega})| &\leq 0.021, \ |\omega| \leq 0.35\pi \\ 0.979 \leq |H(e^{j\omega})| &\leq 1.021, \ 0.5\pi \leq |\omega| \leq \pi \end{aligned}$$

   What is the impulse response of the resulting highpass filter with linear phase?

3. We wish to use the Kaiser window method to design a discrete-time filter with generalized linear phase that meets the following specifications:

$$\begin{aligned} |H(e^{j\omega})| &\leq 0.01, \ |\omega| \leq 0.25\pi \\ 0.95 \leq |H(e^{j\omega})| &\leq 1.05, \ 0.35\pi \leq |\omega| \leq 0.6\pi \\ |H(e^{j\omega})| &\leq 0.01, \ 0.65\pi \leq |\omega| \leq \pi \end{aligned}$$

   (a) Determine the Kaiser window parameters $M$ and $\beta$ to meet the specifications

   (b) What is the delay of the filter?

   (c) Determine the ideal impulse response $h_I[n]$ to which the Kaiser window should be applied.

4. In this question, we will explore the use of FFT to compute discrete convolution in matlab. In matlab

   (a) Create a $1 \times 5$ vector $x$, which is all 1s. Plot this discrete sequence using the "stem" function in matlab.

(b) Create a $1 \times 5$ vector $y$, which is all 1s. Plot this discrete sequence using the "stem" function in matlab.

(c) Use the matlab function "conv" to convolve $x$ and $y$. Use the "stem" function to plot the result. What is the shape of the result?

(d) Use the matlab function "fft" and "ifft" to circularly convolve $x$ and $y$. Use the "stem" function to plot the result. What is the shape of the result?

(e) Use the matlab function "fft" and "ifft" to convolve $x$ and $y$. Use the "stem" function to plot the result and confirm that your result is now the same as the "conv" function.