<u>EEEE678</u> DIGITAL SIGNAL PROCESSING (DUE, Midnight Friday Dec 9)

MATLAB project #2 (This project has triple the weight of a single homework/project)

1. Designing digital IIR filters using continuous-time filters:

   Use the **Butterworth** filter and the **bilinear transformation** to design a digital lowpass IIR filter to meet the specifications given below. All plots should have clearly labeled axes, titles and a grid for ease of viewing.

   - Sampling frequency = 20 kHz
   - Passband = 0 – 2 kHz
   - Stopband = 2.8 – 10 kHz
   - Passband ripple = 1 dB
   - Stopband attenuation: –50 dB

   a) What is the order of the filter N and its cutoff frequency Ω_c?

   b) Plot the filter frequency response, $H(e^{j\omega})$, in the range of $(0, \pi)$. Additionally, provide two separate plots of an expanded view of the passband and the stopband, clearly indicating that the design specifications have been met in those regions.

   c) Test the filter using the following signal (plot the input and the output signals):

$$x_a(t) = \cos(2400\pi t) + \cos(12000\pi t + 0.5\pi) + \cos(16000\pi t + 0.3\pi)$$

2. Designing FIR filters using **windowing** techniques:

   Using the **Kaiser** window design methodology, design a highpass FIR filter to meet the specifications given below. All plots should have clearly labeled axes, titles and a grid for ease of viewing.

   - Stopband: 0 – 0.25π ($\omega_s = 0.25\pi$)
   - Passband: 0.375π - π ($\omega_p = 0.375\pi$)
   - Stopband attenuation: -40 dB ($\delta_1 = \delta_2$)

   a) What are the empirical values of M and β?

   b) Design the filter using Matlab. If necessary, adjust the value of M to satisfy the specifications. What is the final value of M? Compute and plot the discrete-time filter taps: $h[n]$, $n = 0, 1, 2, \ldots, M$.

   c) Plot the filter frequency response, $H(e^{j\omega})$, in the range of (0, π). Additionally, provide two separate plots of an expanded view of the passband and the stopband, clearly indicating that the design specifications have been met in those regions.

3. Designing FIR filters using **optimum approximation** (Parks-McClellan algorithm):

   Use the Parks-McClellan algorithm to design a Type I FIR zero-phase lowpass filter with the specifications given below. All plots should have clearly labeled axes, titles and a grid for ease of viewing.

   - Passband 0 - 0.25π (ω_p = 0.25π).
   - Stopband 0.35π - π (ω_s = 0.35π).
   - Passband gain of unity with a maximum of ±2% error.
   - Stopband gain of zero with a maximum of ±3% error.

   a) What are the empirical values of *M* and *L*?

   b) Design the filter using Matlab and show a plot of one failed iteration attempt. Adjust the order of the filter to satisfy the specifications if necessary. What is the final value of *M*?

   c) Plot the filter frequency response, $H(e^{j\omega})$, in the range of (0, π). Clearly indicate the alternation points on the plot. Additionally, provide two separate plots of an expanded view of the passband and the stopband, clearly indicating that the design specifications have been met in those regions.

   d) Compute and plot the discrete-time filter taps: $h[n]$, n = 0, 1, 2, …, M.