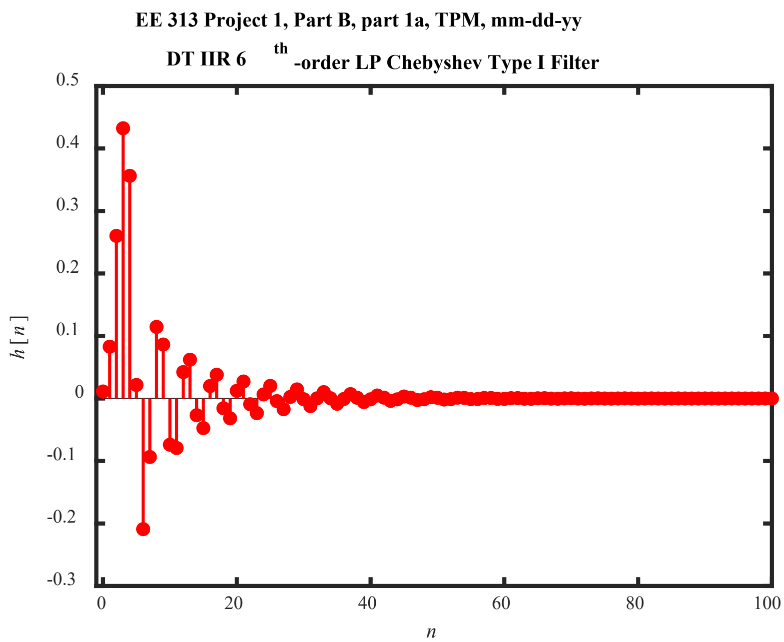
EE 313 Signals and Systems (Fall 2024)
Project 1 Unit Pulse Response/Convolution Representation, Part B

<snip>

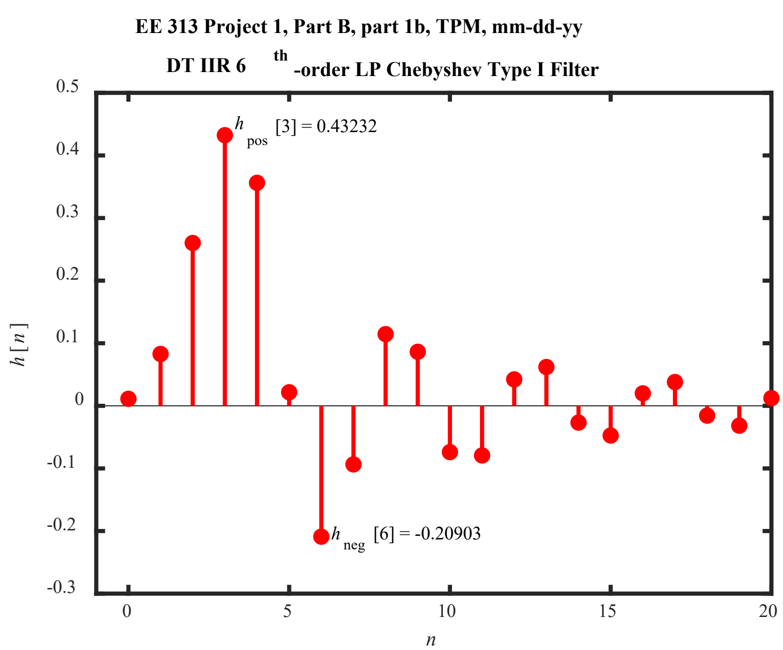
Project

1) Write an m-file to compute the unit pulse response $h[n]$ of the filter for $0 \le n \le N_{\max}$ -1. Start with $N_{\max}$ = 101. The filter has no initial energy, i.e., $y[n < 0] = 0$. Then, perform the following tasks.

   a) <snip> create a stem plot of $h[n]$ with <snip> $-1 \le n \le N_{\max}$ -1 & a vertical scale from -0.3 to 0.5.

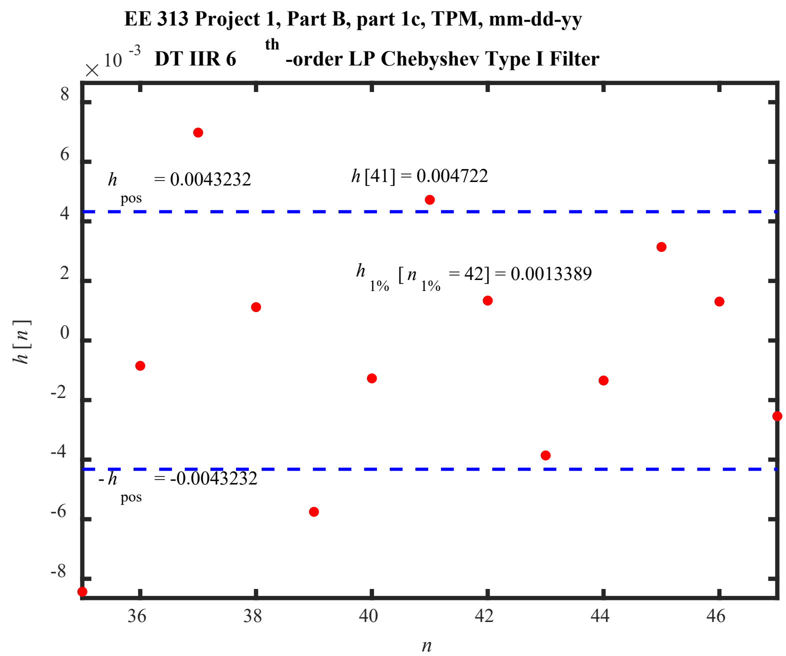


   b) Also, create a stem plot of $h[n]$ with a horizontal scale of $-1 \le n \le 20$ and the same vertical scale. Find and label (value and index) the largest positive $h_{pos}[n_{pos}]$ and negative $h_{neg}[n_{neg}]$ swings <snip> on stem plot. <snip> determine the maximum swing <snip> $h_{\max} = \text{maximum}\{h_{pos}[n_{pos}], |h_{neg}[n_{neg}]|\}$.



- $h_{\max} = \text{maximum}\{h_{pos}[n_{pos}], |h_{neg}[n_{neg}]|\} \quad \Rightarrow \quad$ **$h_{\max} = 0.43232$**

c) Next, find $h_{1\%}\,[n_{1\%}]$, i.e., the point where <snip> $|h[n]|$ becomes (and stays) **less than** 1% of $h_{\max}$<snip> Also, give the value and index $h[n_{1\%} - 1]$ <snip> If necessary, increase $N_{\max}$.



➢ <u>$h[n_{1\%} - 1] = h[41] = 0.004722$</u> and <u>$h_{1\%}\,[n_{1\%}] = h\,[42] = 0.0013389$</u>

d) Is $N_{\max} = 101$ sufficient to find $h_{1\%}\,[n_{1\%}]$? <snip> Give value of $N_{\max}$ used.

➢ Yes, $N_{\max} = 101$ was sufficient to find $h_{1\%}\,[n_{1\%}]$. Use <u>$N_{\max} = 101$</u>.

e) Using the stem plot of $h[n]$, is the filter stable? Why?

➢ The filter is stable. As shown in part 1a, $h[n \to \infty] \to 0$.

f) Give a listing of the m-file.

<snip>

2) Next, use DT convolution representation to calculate the output from the filter. The DT input signals $v_{\text{in}}[n]$ should each be calculated for $0 \le n \le 100$. They are sampled from <snip> $v_{\text{in}}(t) = V_0 \sin(2\pi f t)\, u(t)$ where $V_0 = 100$ V and $f = f_c/3$, f_c, $1.1\, f_c$, and $1.25\, f_c$ <snip>. The specific results required are:

a) Analytically determine the index n_{acc} and corresponding time $t_{\text{acc}} = n_{\text{acc}}\, T_S$ <snip>

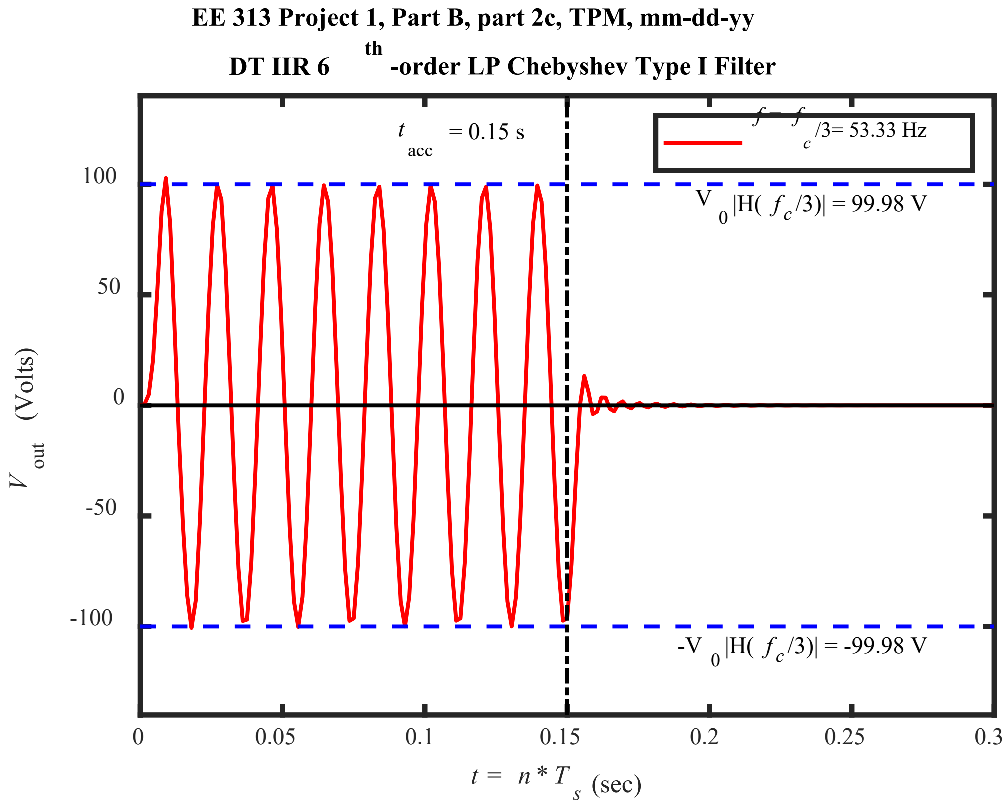
$$\boldsymbol{n_{\text{acc}} = \min\{\, q = N_{\max} - 1 = 100,\ r = 100\}} \qquad \Rightarrow \qquad \underline{\boldsymbol{n_{\text{acc}} = 100}}$$

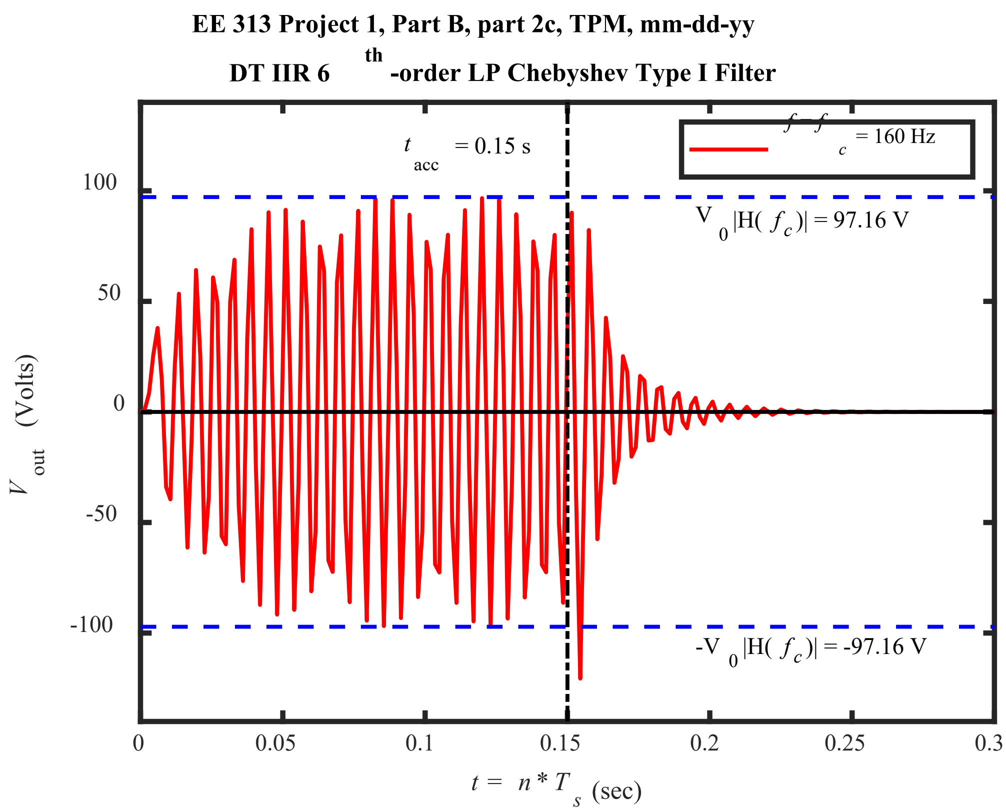
$$\boldsymbol{t_{\text{acc}} = n_{\text{acc}} * T_S = 100 * 1.5\ \text{ms}} \qquad \Rightarrow \qquad \underline{\boldsymbol{t_{\text{acc}} = 0.15\ \text{s}}}$$

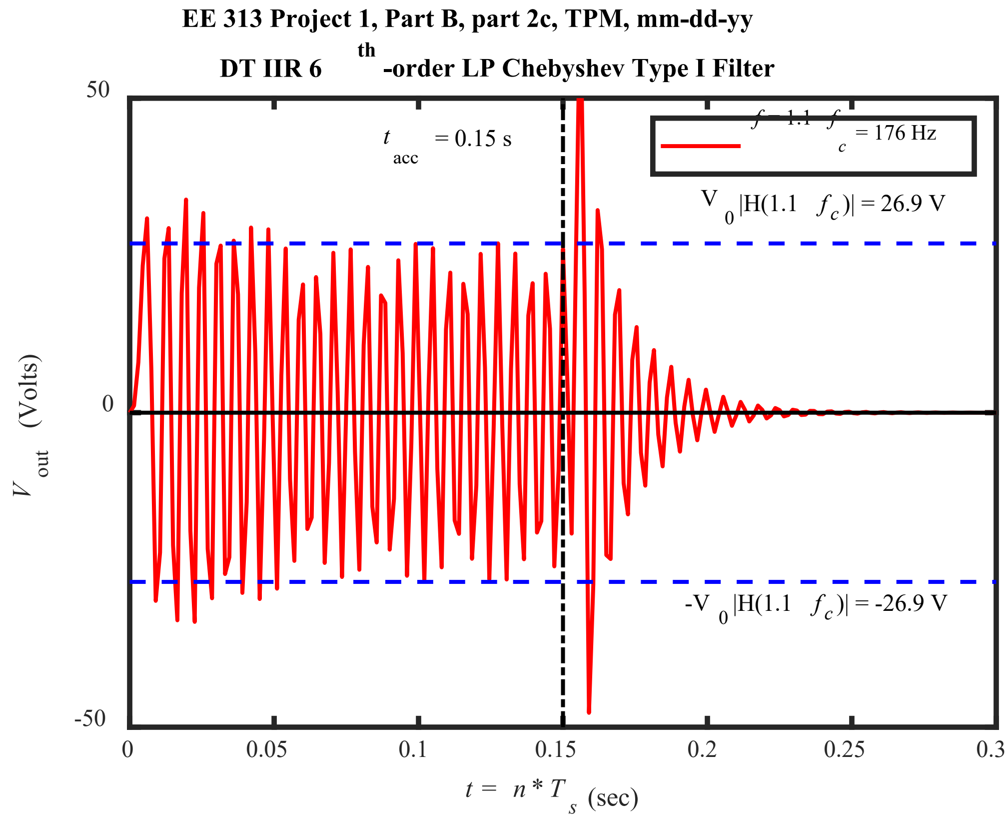
b) At <snip> $f_c/3$, f_c, $1.1\, f_c$, & $1.25\, f_c$, find & **tabulate** the expected maximum voltage magnitudes for the output $v_{\text{out}}[n]$ after passing through the filter. <snip>

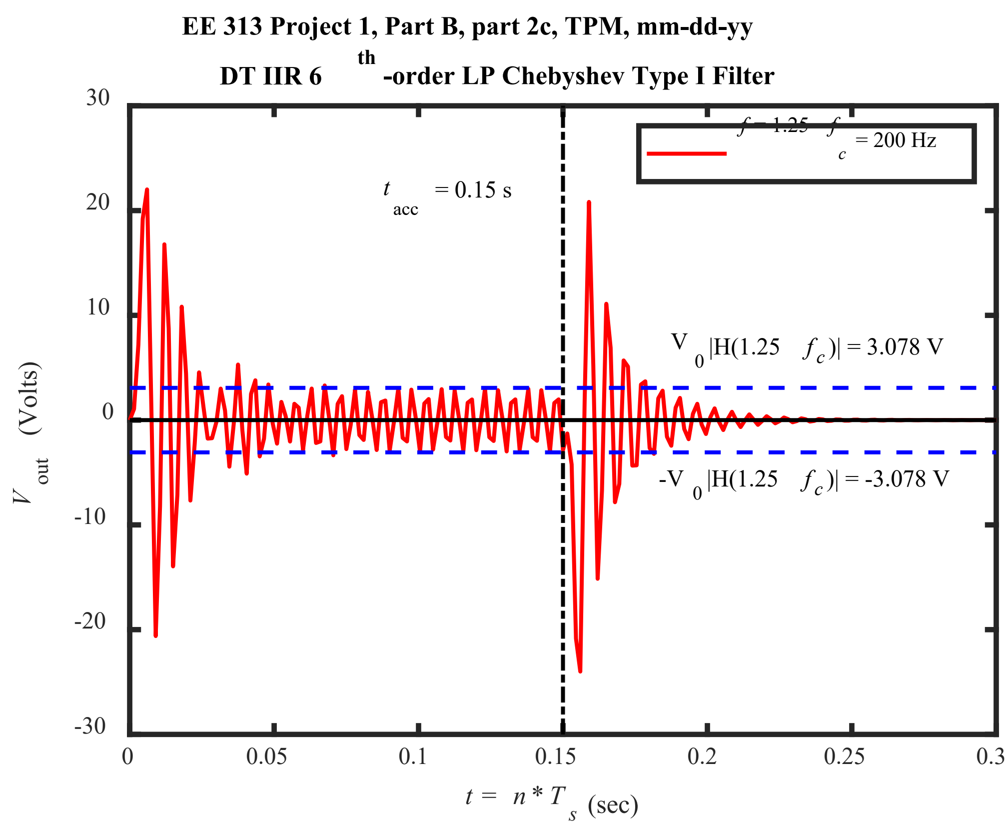
f (Hz)	V_0 (V)	$\lvert H(f)\rvert$	$V_0\,\lvert H(f)\rvert$ (V)
$f_c/3 = 53.33$	100	0.99975612218873	99.97561
$f_c = 160$	100	0.971627951577114	97.162795
$1.1\, f_c = 176$	100	0.26904114404264	26.90411
$1.25\, f_c = 200$	100	0.030779282453405	3.07793

c) <snip> plot $v_{out}(t)$ (solid line) vs time ($t = n\,T_S$) for the **full length** of the 'conv' output at each of the specified frequencies f (**four** separate plots). Identify/label each plot by <snip> f. <snip> put a labeled vertical dashed line at time t_{acc} and put labeled horizontal dashed lines at the voltage levels $\pm V_0\,|H(f)|$.






EE 313 Project 1, Part B, part 2c, TPM, mm-dd-yy
DT IIR 6th-order LP Chebyshev Type I Filter
t acc = 0.15 s
f = 1.1 f c = 176 Hz
V 0 |H(1.1 f c)| = 26.9 V
-V 0 |H(1.1 f c)| = -26.9 V
V out (Volts)
t = n * T s (sec)
50
0
-50
0
0.05
0.1
0.15
0.2
0.25
0.3


EE 313 Project 1, Part B, part 2c, TPM, mm-dd-yy
DT IIR 6th-order LP Chebyshev Type I Filter
t acc = 0.15 s
f = 1.25 f c = 200 Hz
V 0 |H(1.25 f c)| = 3.078 V
-V 0 |H(1.25 f c)| = -3.078 V
V out (Volts)
t = n * T s (sec)
30
20
10
0
-10
-20
-30
0
0.05
0.1
0.15
0.2
0.25
0.3

d) Over the accurate time range, examine the magnitude of $v_{out}(t)$ at each of the specified frequencies. Does the DT filter work as expected? Comment on any anomalies, transitions, or other interesting features in the plots. [Prompts: In light of $v_{out}(t)$ shown in the plots, roughly how long Δt_{SS} does it take for the filter to start working or reach a steady-state? After t_{acc}, roughly how long Δt_{stop} does it take for the output to die off? In light Δt_{SS} and Δt_{stop}, roughly how many points would these correspond with in the unit pulse response $h[n]$? Discuss pros and cons of digital versus analog filters.]

- The DT LP filter works as expected.
- At each f, we see a time-lag $\Delta t_{SS} \sim 0.025$ s before the filter starts operating efficiently. This corresponds to around 16 points in $h[n]$ where it has died down to about 10% of its maximum value. I.e., the input signal and **leading edge** of $h[n]$ need to overlap sufficiently in the DT convolution representation.
- The filter operates as expected until the convolution of the two finite-length DT signals starts separating at $t_{acc} = 0.15$ s. Again, there is a time lag $\Delta t_{stop} \sim 0.05$ s (corresponds to around 33 points in $h[n]$) after t_{acc} before the output dies off to zero. I.e., input signal and **tail end** of $h[n]$ need to overlap for output to go to zero.
- At $f = f_c$, $1.1 f_c$, & $1.25 f_c$, we see some ripple in the maxima and minima. This is due to the sampling not being as tight at these frequencies, i.e., fewer data points per period. Therefore, we don't 'hit' the maxima and minima exactly when sampling.
- **Pros-** DT filter works, filter characteristics can be easily changed by changing the coefficients which is not easily done with analog filters.
- **Cons-** DT filters have a time lag before they start working whereas analog filters do not, sampling rate affects results.

e) Give a listing of the m-file.

<snip>

Project report format

The results should be organized into a word-processed short report.

- In addition to syllabus HW format requirements, use font size ≥ 12 points and line spacing ≥ 1.1.
- Include: 1) cover page, 2) Introduction, 3) body (broken down into subsections based on the steps in project), and 4) Summary & Conclusions.
- Put the calculations, results, m-files, and plots/figures **in the body** of the report in the order specified as they occur. Do not use appendices.
- On all plots, label horizontal and vertical axes, and insert a horizontal axis at 0. Put "EE 313, Project # & part #, *your initials*, date" in the title.
- Numerical results that are specifically requested should be put on separate line(s), not 'buried' in the middle of a paragraph.
- To enhance readability, figures/plots should span width of page and face either the bottom or right of page. Also, remember that text on figures/plots that is too small to read might as well not exist.
- For all m-files, put the filename, EE 313, Project # & part #, *your name*, and date in comment lines.

- Staple results together and turn-in the project report on **Wednesday, October 16, 2024**.