

ECE503 Spring 2014 Project 2

This project is worth 100 points
and is due by 6:00pm Monday 28-April-2014

In this project, you will design a bandstop discrete-time filter using the bilinear transform. The filter specifications are such that the order of the filter is small and you can perform all of the design calculations by hand (a calculator may be useful). You will then design the filter in a step-by-step MATLAB script to confirm your analysis and verify that the filter meets the requirements.

1 Problem Statement

The specifications of the filter design are:

Parameter	Value
Filter type	IIR
Design method	Butterworth
ω_{p1}	0.1π
ω_{s1}	0.2π
ω_{s2}	0.3π
ω_{p2}	0.5π
passband gain (both passbands)	between -1dB and 0dB
stopband attenuation	at least 15dB

You are required to design your filter by first computing an appropriate continuous-time filter and then using the bilinear transform. The suggested steps are:

1. Pre-warp the discrete-time band edge frequencies to continuous-time frequencies.
2. Transform your continuous-time BSF specifications to the specifications for a continuous-time prototype LPF. This may require adjusting one or more band edge frequencies. At the end of this step you should have the band edge frequencies for a LPF $\{\Omega_p, \Omega_s\}$ with corresponding minimum/maximum gains.
3. Design the continuous-time prototype LPF by determining the required filter order N and the cutoff frequency Ω_c .
4. Transform the prototype continuous-time LPF to a continuous-time BSF via the LPF \rightarrow BSF spectral transformation.
5. Transform the continuous-time BSF to a discrete-time BSF via the bilinear transform.

Alternatively, steps 4-5 can be swapped as

- 4'. Transform the prototype continuous-time LPF to a prototype discrete-time LPF via the bilinear transform.
- 5'. Transform the prototype discrete-time LPF to a discrete-time BSF via the appropriate spectral transform in Table 7.1 of Oppenheim and Shafer.

2 Analysis

In this part of the project, you are required to perform the recommended filter design steps by hand. You can type up your analysis if you like or submit scanned handwritten analysis if your handwriting is reasonably clear. Your analysis should result in a transfer function $H(z)$ with explicit numerator and denominator coefficients. Discuss any choices you had to make with regards to adjusting any band edge frequencies with respect to the original specification.

3 Step-by-Step Matlab Implementation

In this part of the project, you are required to perform each step of your analysis via a step-by-step MATLAB script. To receive full credit, your code must perform the same steps as your analysis without using `fdatool` or any functions like `buttord`, `butter`, `lp2hp`, `fdesign`, `design` etc. You may use the `bilinear` function. The main point of this exercise is to automate the steps you did by hand in the previous part of the assignment but not to just have MATLAB do the whole filter design for you.

Your MATLAB analysis should result in identical filter coefficients as determined by your previous analysis. If not, you can check each step of your analysis with respect to the step-by-step MATLAB code to determine where the discrepancies occur. You may need to go back and correct your analysis if the MATLAB code reveals calculation errors.

You should verify your discrete-time filter meets the original specifications by plotting the magnitude response of your filter along with dashed lines explicitly showing the passband and stopband frequencies and gain parameters. Be sure to include explicit axis labels and legends as appropriate.

4 Express Matlab Implementation via fdatool

In this part of the project, you are required to implement the same bandstop filter in Matlab using `fdatool`. Is it possible to select `fdatool` parameters to generate the same filter coefficients that you derived with your step-by-step MATLAB script? Do you understand what the “match exactly” option does? Be sure to discuss any discrepancies in your report.

5 Project Submission

Submit the following to the TA and instructor via email prior to the due date/time:

- Your step-by-step Matlab code. Your code should be well commented, properly indented, and should have your name in the header. If you wrote any custom functions, they should also be included. The TA/instructor should be able to run your code directly without errors. Part of your grade will be based on the clarity of your code.

- A report in .pdf format, no longer than three single-sided pages, explaining your code and the main results. Be sure to include at least one plot of the magnitude response of your filter with explicit dashed lines for the band edges and passband/stopband specifications showing that the filter meets the specifications. Your font size must not be smaller than 10 point. Your typed or handwritten analysis can be attached as an appendix and does not count against the page limit. Your analysis should include some explanation as to what steps you performed (it should not just be pages of pure algebra). Explain your methodology and summarize the main results. Also be sure to discuss any deviations between different parts of the assignment. You are encouraged to include block diagrams and other plots, e.g., pole-zero plots, as necessary to explain your work.