



OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

School of Engineering Report/Assignment Cover Page

| Student Name | Student ID Number |
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| Class and Year (4 th Electronic & Computer Engineering etc.): | |
| Subject Code and Name: (e.g. EI140 Fundamentals of Engineering) | EE445 Digital Signal Processing |
| Lecturer Name: | Edward Jones |
| Title of Report/Assignment: | DSP-2 Digital Filter Design |
| Submission Deadline: | 11:59 pm on Friday, November 29 th , 2024 |
| Submission Date: | |
| Name(s) of Lab Partner(s) (where applicable) | N/A |

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Student's signature

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Electrical & Electronic Engineering, University of Galway

EE445 DIGITAL SIGNAL PROCESSING

Octave Assignment DSP-2

DIGITAL FILTER DESIGN

Objective

The objective of this laboratory exercise is to use Octave to design FIR and IIR filters from a given specification, and to determine their characteristics, in particular their frequency responses.

Reports must be prepared in **electronic** form, and should be submitted preferably in Microsoft Word or PDF format. The report should consist of the following elements:

- Listings of the Octave code you develop during this assignment. Code listings should be copied into your report as text, and not as “screenshots” taken from e.g. the Octave editor. Code included as a screenshot cannot be properly tested and graded.
- Additional plots that are generated by your code (where required), and the answers to any additional questions that may be asked in each part of the assignment.

Note that it is not expected that Reports will be of excessive length – a shorter report is actually better, as long as it contains the required information. Furthermore, please include all of your code etc. in the main report itself, rather than submitting a number of separate Octave files (or including everything in a Zip file). This is to facilitate keeping everything in the one place.

Your report should be named according to the convention “DSP2_FirstnameSurname_StudentID” e.g. “DSP2_JohnDoe_12345678”. An assignment will be created on the EE445 Canvas page for you to upload your report (accessible under the “Assignment” menu on the left-hand side). Details of the submission deadline will be communicated by means of a Canvas announcement.

OBNOTE

1. *Please make use of appropriate comments in your code, for clarity. Marks will be lost if the code cannot be easily followed.*
2. *Please ensure that your Report clearly indicates your name and which class you belong to. Submissions that do not include this information cannot be marked.*
3. *Axes on plots should be labeled appropriately (including units, if applicable). Also, make sure that you include a caption with each figure. Marks will be lost if plots are not properly annotated.*
4. *Remember that Octave is simply a software tool, and is just a means to an end – as with any programming environment, it’s easy to make logical (not just syntax) errors that will give you the wrong result. So, you should always try to have some idea of what the answer should be, so that you can identify the presence of logical errors in the code that you’ve written.*

Background Material

DSP Notes, Sections 6 and 7

Note: To obtain help on any Octave function, you can use the Help menu in the Octave package. Alternatively, a quick way to get information is to type “help <function name>” at the Octave command window prompt. For example, to obtain help on the “fir1” function, use “>> help fir1” <Return>. Alternatively, you can browse the information on the “Documentation” tab in the Octave environment.

Exercises

1. IIR Filter Design. A digital low-pass filter has the following specification:

| | |
|-----------------------|--------|
| Sampling frequency | 10 kHz |
| Cutoff frequency | 3 kHz |
| Transition bandwidth | 400 Hz |
| Stop band attenuation | 35 dB |
| Passband ripple | 0.1 dB |

A Chebyshev Type I filter (Octave function `cheby1`) is to be designed to meet this specification (recall the details of the Chebyshev Type I filter from EE357 last year, in particular, recall that this filter has ripple in the passband).

The order of the filter can first be determined using the Octave function `cheblord`. This function takes the required specification (use the *help* command to determine what information you need to provide) and returns (i) the estimated order required, and (ii) the normalized cutoff frequency; these two values can then be passed as arguments to the function `cheby1`, which calculates the actual filter coefficients. The `cheby1` function returns numerator and denominator coefficients for the filter.

Using the Octave function `butter`, also design a Butterworth IIR filter **of the same order as the Chebyshev filter designed above** (use the *help* function to determine what parameters need to be passed to the `butter` function). Because the Butterworth filter does not have ripple in the passband, you will need to use a little imagination to choose the Butterworth specification to “align” with the Chebyshev filter specification (one simple approach would be to choose the Butterworth filter cutoff frequency to be the same as for the Chebyshev as determined by the `cheblord` function).

Plot the magnitude responses of the two filters on the same graph as a function of frequency in Hz. Comment on the relative performance of the filters, especially as regards “sharpness” of the filter roll off in the transition band, and pass band distortion.

2. FIR Filter Design. A digital lowpass filter with the following specification is to be designed:

| | |
|----------------------|-------------|
| Sampling frequency | 8 kHz |
| Cutoff frequency | 2 kHz |
| Transition bandwidth | 300 Hz |
| Stopband gain | 0 (desired) |

You are required to design an FIR filter to meet the above specification, using the Parks-McClellan optimization technique (Octave function `firpm`) and in particular, to examine the effect of different filter orders. Note that specifying a filter order of N with the `firpm` function will result in a filter of length $N+1$.

Experiment with the filter length (order) by designing filters of length ranging from 21 to 51 coefficients in increments of 5 (this is most readily done using a `for` loop). In the interests of brevity, you are not expected to include plots of the frequency response for all filter orders investigated in your Report - only include the frequency response for the filter of order 51.

Also, design a FIR filter of length 51 using the Window Method with the Octave `fir1` function (use the default Hamming window) and plot its magnitude response on the same graph as the FIR filter of length 51 obtained using the Parks-McClellan method (the magnitude responses should be plotted on a decibel scale). There is no need to plot the phase response as it doesn't give us much more information than we already have – can you say why this is the case?

From the graphs, estimate the actual transition bandwidth. This can be taken to be the difference between the point where the magnitude response is -3 dB, and the peak of the first ripple in the stop band. An “approximate” figure will be sufficient. The transition bandwidths should be given in Hz.

Comment on the relative merits of the two filter designs.