ELEN90058 Signal Processing

Matlab project: Digital filter design. (Workshop week 8)

Aim: To design digital IIR and FIR filters.

Project: The project is Matlab based and deals with design and implementation of digital filters using Matlab.

Assistance: The usual workshop times in week 8. You can also get help in week 9, but priority will be given to students working on Workshop 3.

Assessment: The project is assessed based on a written project report. The project constitutes 6% of the overall assessment of the course.

Submission of the reports: The students are to submit the report to the demonstrator in the workshop in week after the mid-semester break (2nd to 6th of October). You also have to sign a declaration that the report is your own work.

Student groups: The students should work in groups of three.

Reports: The reports should be clearly written and explain in a logical way how the different tasks in the project have been carried out. Choices you make (e.g. filter order, cut off frequencies, allowed ripples, etc.) should be explained and justified. Results obtained using Matlab should be explained, i.e. it is not sufficient to copy the output of Matlab without further explanations of what the numbers or graphs mean. Figures should be included where it is appropriate. The Matlab code should be included in an appendix. The maximum length of the reports is 15 pages excluding the appendix. More details are given in Section A.3.

Collaboration between and within groups: It is perfectly OK to discuss problems and possible solutions with other groups. However, each group has to carry out the project independently, and e.g. copying of other groups' mathematical derivations or Matlab code is not acceptable. Both group members should do an equal amount of work on both the project itself and the writing of the report. It is not acceptable that one group member does the project and the other writes up the results.

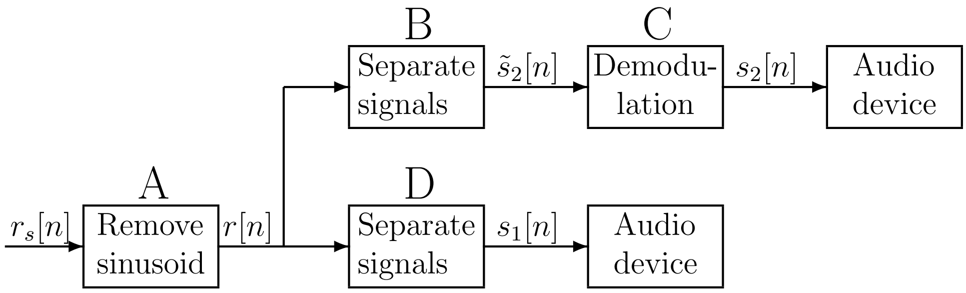

Figure 1: Signal removal and separation

m	0-2	3-6	7-9
F_c	12.288	11.264	10.240

Table 1: File number and carrier frequency

A Filter design and implementation using Matlab

Consider the system in Figure 1. The signal $r_s[n]$ is made up of three components

$$r_s[n] = r_1[n] + r_2[n] + w[n]$$

$r_1[n]$ and $r_2[n]$ are the two important signal components and they occupy two separate frequency bands. $r_1[n]$ has a bandwidth of 4096 Hz, and $r_2[n]$ is a DSB-SC (double side band, suppressed carrier) modulated signal. The carrier frequency is F_c kHz, and the bandwidth of the original signal is 4096 Hz. $w[n] = A\sin(\omega_w n + \phi)$ is a sinusoidal disturbance signal. The sampling frequency of $r_s[n]$ is 32.768 kHz.

In block A the sinusoid $w[n]$ is removed. The two signal components of $r[n]$ are then separated in block B and D such that output of block B, $\tilde{s}_2[n]$ contains the high frequency signal, and the output of block D contains the low frequency signal. The high frequency signal $\tilde{s}_2[n]$ is demodulated in block C, so that the original signal is recovered. Both signals are played through audio devices.

A.1 Practical information

The signal $r_s[n]$ is stored in the Matlab file `projsignal`m`.mat` on the course web page. m is the last digit in the sum of your student numbers (you are supposed to work in groups of three). The carrier frequency F_c in kHz is given in Table 1. The Matlab variable name of the signal is `rs`.

The signal $r_s[n]$ is long, and it can therefore be time consuming to process the whole signal. However, in order to estimate frequency contents and test designs you can use a part of the signal, say the first 25 000 data points.

You can use the Matlab command `sound(sx,Fs)` where `sx` is the output signal of block C or D and `Fs` is its sampling frequency in order to test your design.

For information on DSB-SC modulation, see page 8, Section 1.2.4 in Mitra (3rd and 4th edition).

A.2 Tasks

Note: Students can introduce additional assumptions which do not violate the main design specifications.

A.2.1 FIR filters

1a. Determine the frequencies/frequency bands occupied by the signals $r_1[n]$, $r_2[n]$ and $w[n]$, and design the system blocks A, B, C and D according to the following specifications.

In block A the gain at the frequency ω_w must be -60 dB or less. Let $H_1(z)$ be the filter obtained by cascading the filters in block A and D. The ripple in $H_1(z)$ in the frequency band occupied by $r_1[n]$ must be less than 0.01. The total ripple for the cascade of the filters in block A, B and C must be such that the the magnitude spectrum of the demodulated signal $s_2[n]$ is within 2% of the magnitude of the original signal (the one which was modulated) for each frequency. All filters must have linear phase.

1b. Calculate the total group delays for the cascade $H_1(z)$ and for the cascade of the filters in blocks A, B and C. Try to minimise the total group delays while still satisfying the design specifications.

A.2.2 IIR filters

2a. It is no longer necessary that the filters have linear phase. The other specifications must still be satisfied. Redesign blocks B, C, and D using different types of IIR filters. In addition redesign block A using a second order notch filter. Compare the number of filter parameters in the FIR and IIR design. Compare the sound quality of the designs using FIR and IIR filters. Any comments?

2b. Try to design the filters such that the filter orders are minimal.

A.2.3 Additional information

You can carry out the design of the FIR and IIR filters in any order. In **1a** and **2a** the emphasis is on deriving reasonable design specifications and designing filters which satisfy these specifications. These designs do not need to be optimised, although gross overdesigns compared to the specifications will not be favourably viewed.

A.3 Further information about the report

This project will be assessed based on the lab report. It must be clearly written. Furthermore it must contain detailed design specifications for each block and explain how you arrived at those specifications. All choices of design parameters should be discussed and well motivated. The report should give details on how each block was designed, and show that each block carries out the desired function. Moreover you must show that the overall design specifications are satisfied.

A design with few or no explanations will not be awarded a high mark even if it satisfies all the specifications.

B Approximate weighting

Question **1a** and **2a**:	75%
Question **1b** and **2b**:	25%