33

EE 338 Digital Signal Processing

Filter Design Assignment: Spring Semester: August – December 2020

This is an individual filter design assignment for each student who has registered for the course. In the discussion below, the specification of each filter is provided according to its number. Each student who has registered for the course, for credit or audit, is required to design two Filters with the specifications as per the Filter Number M assigned to the student. The Filter Number M assigned to the student will be the same as his/ her serial number in the roll list for this course.

This assignment is in two parts. The first part (Part I) is mandatory for all students and the score earned in that part, upon 40, will count towards the saturated overall score for the concerned student. The second part (Part II) is optional. A student may attempt it and display his/ her achievement in that part to the Teaching Associates to earn additional credit, which will, however, count only towards the unsaturated overall score for the student.

Part I (Mandatory Component)

In the filter design, you are encouraged to partly make use of SCILAB or any equivalent open source software as available. You are encouraged to contact the Computer Centre/ the PC Laboratory in the Department of Electrical Engineering for more information on open source software available in the Institute. It is not mandatory to use any package, of course! You could write a C program / high level language program as well. For designing the IIR and FIR filters, you are NOT permitted to use “filter design” commands directly. Neither are you permitted to carry out the whole design simply by using a filter design package. You may use basic SCILAB or equivalent statements relating to matrix operations, window function generation, and so on. You may write small programs in these open source softwares. You are welcome to consult one another in the class during your designs, to assist one another. However, the final design must be done individually by each student, albeit with assistance from others.

In addition, in each group of the course, there will be a cyclic arrangement for review of the design. If there are only two members in a group, they will review and certify each other’s designs. If there are three members, let us designate the group members as I, II, III, in any way. Then, II will review and certify the designs of I; III will review and certify the designs of II and I will review and certify the designs of III.

Your final design submission must be as follows, in an electronic file to be uploaded appropriately as per instructions from Teaching Associates, to be given in due course.

A. Write, on top, your name, roll number, filter number M, group number and the name + roll number of your colleague in the group, who is to review and certify your designs.

B. The following data pertinent to each of the two filter designs assigned to you, must be submitted, in that order.

1. The un-normalized discrete time filter specifications: including whether the passband and stopband are equiripple or monotonic, respectively.

2. The corresponding normalized digital filter specifications.

3. The corresponding analog filter specifications for the same type of analog filter using the bilinear transformation.

4. The frequency transformation to be employed with relevant parameters.

5. The frequency transformed lowpass analog filter specifications.

6. The analog lowpass filter transfer function H_analog,LPF (s_L).

7. The analog transfer function for the appropriate type of filter.

8. The discrete time filter transfer function.

9. An FIR Filter Transfer function for realizing the same specifications using the Kaiser Window.

10. An overall comparison between FIR and IIR realizations, for the same specifications.

11. A review report from your group colleague, who is to review and certify your designs. Teaching Associates will specify the format of this review report.

You may use a statement for generating the Kaiser window coefficients directly. As it is tedious to write out coefficients and data by hand each time, you are welcome to include an electronic write-out of results/ data from a computer program, wherever appropriate. Further, you must give reliable evidence of the frequency response of the filters that you have designed. The evaluation scheme will be displayed on the course web-page in due course. The complete report is due to be submitted **by 9 November 2020**. .

The Filter Specifications: We wish to build a series of discrete time filters, as described below, to extract specific bands of an analog signal, or to suppress specific parts of the analog signal.

(i) For all filters, the passband AND stopband tolerances are 0.15 in magnitude. That is, the filter magnitude response (note: NOT magnitude squared) must lie between 1.15 and 0.85 in the passband; and between 0 and 0.15 in the stopband. For the IIR Filter, the passband magnitude response must lie between 1 and 0.85.

(ii) For bandpass filters, the transition band is ~~2 kHz~~ 4 kHz on either side of the passband. For bandstop filters, the transition band is ~~2 kHz~~ 4 kHz on either side of the stopband. Please correct to: the transition band being 4 kHz in both situations.

(iii) When realized as an IIR Filter, all these filters have a monotonic stopband. For FIR Filters, of course, we do not have a choice of the nature of stopband / passband.

First Filter Specification: An analog signal is bandlimited to 160 kHz. It is ideally sampled, with a sampling rate of 330 kHz. The first filter to be designed by each student is a bandpass filter. Filter numbers 1 to 80 have a monotonic passband, whereas filter numbers 81 to 160 have an equiripple passband. For filter numbers m and 80+m; m going from 1 to 80; the passband is from BL(m) kHz to BH(m) kHz, where BL(m) and BH(m) are numbers determined from m as follows.

Define: q(m) = greatest integer strictly less than 0.1m.

For example, q(5) = 0, q(30) = 2

r(m) = m – 10q(m).

For example, r(5) = 5, r(30) = 10

~~BL(m) = 5 + 1.7 q(m) + 6.1 r(m).~~ Replace by:- BL(m) = 25 + 1.7 q(m) + 6.1 r(m).

For example, ~~BL(80) = 5 + 1.7 (7) + 6.1 (10) = 77.9~~ BL(80) = 25 + 1.7 (7) + 6.1 (10) = 97.9

BH(m) = BL(m) + 20.

Second Filter Specification: An analog signal is bandlimited to 120 kHz. It is ideally sampled, with a sampling rate of 260 kHz. The second filter to be designed by each student is a bandstop filter. Filter numbers 1 to 80 have an equiripple passband, whereas filter numbers 81 to 160 have a monotonic passband. For filter numbers m and 80+m; m going from 1 to 80; the stopband is from BL(m) kHz to BH(m) kHz, where BL(m) and BH(m) are numbers determined from m as follows.

Define: q(m) = greatest integer strictly less than 0.1m.

For example, q(5) = 0, q(30) = 2

r(m) = m – 10q(m).

For example, r(5) = 5, r(30) = 10

~~BL(m) = 5 + 1.9 q(m) + 4.1 r(m).~~ Replace by:- BL(m) = 25 + 1.9 q(m) + 4.1 r(m).

For example, ~~BL(80) = 5 + 1.9 (7) + 4.1 (10) = 59.3~~ BL(80) = 25 + 1.9 (7) + 4.1 (10) = 79.3

BH(m) = BL(m) + 20

Use either Butterworth or Chebyshev approximation to design the IIR Filter as appropriate. For the FIR Filter, use the Kaiser window as stated above.

Total credit for filter design assignment (Part I): 40 marks (20 percent weight)

Part II: (Optional, for additional credit in the Unsaturated Overall Score):

Read up, from text books and reference books, about the design of Infinite Impulse Response (IIR) filters, using the Elliptic Approximation. Put down the steps involved.

Now modify the specifications of the first filter and second filter that you have been asked to design, by making BOTH the passband and the stopband equiripple and leaving all the other specifications unchanged.

Design the two filters with filter number M assigned to you, using the Elliptic Approximation. Demonstrate the design,with verification of frequency response, to the Teaching Associates, in the same manner as you did for the mandatory Part I, presenting a report in the same format, except that there will be no section on FIR filter design this time.

Compare your designs for Filter Number M in the mandatory Part I and optional Part II and explain what you observe. Particularly, compare the order, the magnitude response and the phase response and comment.

Maximum credit that can be earned for the unsaturated score from Part II: 40 marks.

(End of filter design assignment)