Signal Processing Systems (521279S), Fall 2025
Part 5 : Frequency-domain processing
Design tasks, deadline for return Thu 4.12.2025 23:59

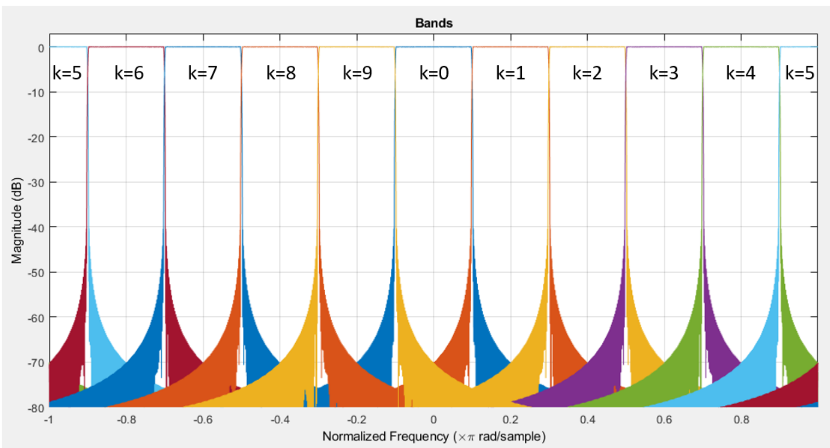
T1. (2p) Sequences $u(n)$ and $h(n)$ are provided in the Table 1 for each group. Using the values assigned to your group, compute the linear convolution of the sequences, that is,

$$y(n) = \sum_{i=0}^{N_h-1} h(i)u(n-i)$$

using both overlap-add and overlap-save sectioning. In both cases, you must use 16-point cyclic convolution. The parameter N_u is the section length, which you must use in the overlap-add method. Process the signal so that you get $y(n)$ for $n = 0, 1, ..., 31$. When there are not enough samples in $u(n)$ to make the last section complete, add zeros to the end of $u(n)$. Use also $u(n) = 0$ for samples $n < 0$ if a section contains samples in this region.

In the report, you can present the answers in the form of Fig. 8 of **intro5a.pdf**. See also Figs. 4 and 5. Some tools for Matlab are available in Optima. Cyclic convolutions can be evaluated with the **cyclic_conv** function. For convenience, the group parameters can be read with **readtable1.p**.

T2. (2p) Computational complexity of critically sampled modulated filter banks can be reduced using polyphase decomposition techniques and fast transforms. To study how effective the techniques are, let us consider implementation of the critically sampled 10-channel complex-modulated filter bank, whose frequency response for each band k is illustrated below. The prototype filter $H(z)$ is symmetric, has real coefficients, and its length is N. The input to the system is a stream of complex values and associated sample rate is f_{in}.



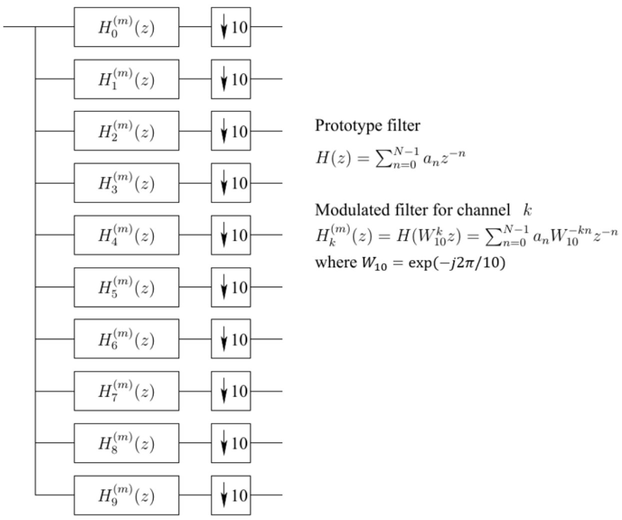
Pick numerical values of N and f_{in} from Table 2 for this task. Your task is to provide estimates for the numbers of multiplications (MPLYs) and additions (ADDs) needed per second (i.e., rates of these operations). Three alternatives for the implementation must be analyzed:

a. direct implementation based on the figure below, that is, each channel filter operates independently and is downsampled afterwards, that is, noble identities are not applied. Note that, except for the channels 0 and 5, the coefficients of the filters, $a_n W_{10}^{-kn}$, are complex-valued.

b. channel filters $H_k^{(m)}(z)$ $(k = 0, 1, 2, ..., 9)$ are considered as antialias filters for decimation (by the factor 10), and efficient decimation is implemented separately for each filter channel. The principle was discussed in Lecture 9 (see Slides 36-37).

c. polyphase decomposition and inverse DFT based structure with downsampling embedded to it. This structure was introduced in the Lecture 9 (see Slide 38).

Critically downsampled 10-channel complex-modulated filter bank ("direct implementation"):



Hints. The file **opcounts.pdf** discusses how the numbers of MPLYs and ADDs are estimated. A fast implementation of the 10-point inverse DFT for a complex input, which is used in the case (c), requires 20 MPLYs and 84 ADDs. Use these values for IDFT in your calculations.

Parameters for T1. system's impulse response $h(n)$ and its length N_h, input signal $u(n)$, and the section length for the overlap-add method (N_u). For $n < 0$ and $n > 31$, $u(n) = 0$.

Group number	N_h	$h(n)$, $n = 0, 1, ..., N_h - 1$	$u(n)$, $n = 0, 1, ..., 31$	N_u
1	7	(1,7,25,37,25,6,2)	(1,-2,-1,0,0,1,1,1,1,-1,2,1,2,-1,1,2,-2,0,-2,-1,2,1,2,-2,-2,2,0,2,1,2,-1,-1)	8
2	7	(-2,9,-24,33,-24,8,-1)	(1,1,0,2,-2,0,1,-1,1,2,-2,1,0,1,-1,1,2,-1,1,2,0,1,-1,2,-1,0,-2,-1,2,-1,-2,-1)	6
3	7	(2,9,24,34,24,8,3)	(1,0,0,0,2,0,-1,-1,-1,0,0,0,-2,2,-2,-2,1,2,-1,-2,0,-2,-2,0,-1,-2,0,-1,1,0,0,-1)	8
4	7	(2,9,24,33,24,8,3)	(1,1,1,0,0,2,2,-1,-1,-1,-1,1,-1,-2,-1,-2,1,-2,-1,1,-1,1,-1,-1,2,-2,0,0,-2,0,-2,-1)	7
5	5	(2,23,52,22,3)	(1,-1,0,1,-2,2,0,1,2,0,-2,0,2,0,-1,-2,0,-2,-1,-1,0,1,1,1,1,-1,-2,2,1,0,2,-1)	10
6	5	(2,23,53,22,3)	(1,1,0,2,1,1,1,-2,0,-1,0,0,-2,1,0,0,2,-1,-1,-2,2,2,2,2,1,0,0,1,0,1,2,-1)	9
7	5	(2,-22,55,-23,3)	(1,-2,-1,2,0,1,0,0,-1,1,-2,2,-1,1,-1,-1,0,-1,-2,1,-2,1,1,-2,-1,0,1,2,2,1,-2,-1)	10
8	5	(4,-25,45,-26,5)	(1,0,1,-2,1,-1,2,2,0,2,2,1,2,-1,1,2,-1,1,-2,-1,1,-1,-1,2,0,0,-1,2,1,-2,2,-1)	8
9	5	(5,-25,43,-26,6)	(1,0,-2,-1,2,-1,-1,2,-2,-2,2,-1,2,-1,2,0,2,2,2,-2,-1,1,1,2,2,1,-1,1,1,-2,-1,-1)	10
10	5	(4,24,46,23,5)	(1,-1,-2,1,-1,-1,0,-1,1,2,1,1,2,-1,-1,0,-1,-1,0,-1,0,1,1,-1,-2,-1,1,1,2,-1,2,-1)	8
11	5	(1,20,60,19,2)	(1,-2,-2,-1,1,-1,1,1,2,2,0,0,-1,-2,2,0,0,-1,0,2,2,2,0,-1,1,1,0,0,1,2,-1,-1)	10
12	7	(1,6,25,39,25,5,2)	(1,2,-1,0,0,2,-1,1,1,2,-2,1,1,2,1,0,-2,0,1,2,-1,0,1,2,-2,2,0,2,-2,0,-1,-1)	8
13	5	(3,-24,49,-25,4)	(1,2,1,-1,0,2,0,1,1,0,2,-1,-2,-1,0,-1,-2,-2,-2,-2,2,-2,0,-2,-2,1,0,1,-1,1,0,-1)	9
14	7	(2,9,24,34,24,8,3)	(1,0,-1,-1,-2,-2,-1,-2,2,0,1,1,1,-1,0,1,1,-2,1,0,2,-1,-1,-2,-2,0,1,-1,1,1,-2,-1)	8
15	7	(-2,9,-24,33,-24,8,-1)	(1,-1,1,2,2,-2,-1,1,1,0,1,-2,-2,2,1,0,0,-2,2,1,0,-1,-1,1,0,0,1,2,0,-1,2,-1)	7
16	7	(-1,7,-25,38,-25,6,1)	(1,0,2,0,1,1,0,2,-1,-1,0,-2,2,-1,-1,1,-1,-2,-1,-1,2,1,-2,2,-1,-1,1,2,-2,1,-1,-1)	6
17	7	(1,7,25,39,25,6,2)	(1,2,-1,2,-1,-1,-2,0,1,0,-1,1,-2,0,-2,0,1,1,2,-2,2,0,-1,0,1,-1,0,-2,2,2,-2,-1)	7
18	5	(2,-22,53,-23,3)	(1,-1,0,-1,2,0,0,-1,2,0,-2,1,-1,2,-1,0,1,1,-2,1,-2,1,0,-2,-2,0,0,-1,-2,-1,0,-1)	10
19	7	(-2,9,-24,33,-24,8,-1)	(1,-2,-2,-1,-1,-2,1,-2,1,1,1,0,-2,-2,-1,2,-1,-1,1,2,0,1,1,2,0,-2,2,-2,1,-1,2,-1)	8
20	7	(-1,5,-25,42,-25,4,1)	(1,-1,-1,-1,0,1,1,1,-2,2,2,2,-1,0,-1,2,2,0,2,1,0,0,1,2,-2,-1,2,2,-1,0,-2,-1)	8
21	7	(1,6,25,41,25,5,2)	(1,2,-1,-2,0,1,0,-1,0,0,2,0,1,-2,2,2,-1,-2,2,2,-2,2,2,-2,0,-2,-1,2,0,0,2,-1)	6
22	5	(2,-23,53,-24,3)	(1,1,1,2,0,0,0,2,-2,-1,0,2,1,2,-2,-1,-2,1,0,2,0,2,-2,2,-2,2,-1,-2,-2,2,-1,-1)	10
23	5	(2,-23,53,-24,3)	(1,2,2,1,-2,-1,2,0,0,-1,-2,-1,0,0,-2,1,-2,1,1,-2,-1,2,-1,2,0,1,-2,-1,0,1,1,-1)	8
24	5	(2,23,53,22,3)	(1,-2,0,-1,1,0,-1,1,1,1,-2,-2,1,0,-1,-1,-2,0,-2,-2,0,2,0,1,-1,2,-1,-1,-1,-2,0,-1)	9
25	5	(2,-23,53,-24,3)	(1,0,0,1,0,-1,0,1,1,1,0,2,-1,-1,0,1,-1,2,-2,2,-2,-1,0,1,-1,-1,-1,-1,1,1,2,-1)	10
26	7	(1,6,25,41,25,5,2)	(1,2,-1,-2,0,1,0,-1,0,0,2,0,1,-2,2,2,-1,-2,2,2,-2,2,2,-2,0,-2,-1,2,0,0,2,-1)	6
27	5	(2,-23,53,-24,3)	(1,1,1,2,0,0,0,2,-2,-1,0,2,1,2,-2,-1,-2,1,0,2,0,2,-2,2,-2,2,-1,-2,-2,2,-1,-1)	10

Parameters for T2. N is the length of the prototype filter $H(z)$ and f_{in} is the input sample rate.

Group number	N	f_{in} [kHz]
1	365	160
2	281	190
3	305	135
4	287	195
5	299	170
6	377	155
7	329	125
8	341	215
9	311	120
10	335	200
11	251	225
12	275	205
13	269	210
14	257	235
15	293	115
16	371	150
17	359	110
18	263	145
19	233	180
20	323	175
21	239	220
22	347	230
23	353	165
24	227	185
25	245	140
26	239	220
27	347	230