HELSINKI UNIVERSITY OF TECHNOLOGY
Department of Signal Processing and Acoustics
S-88.3106 Signaalinkäsittelyjärjestelmät (5 cr)

Exam May 12th, 2009

Write in each answer paper your name, department, student number, the course name and code, and the date. Number each paper you submit and denote the total no. of pages. 4 problems, 32 points total. Exam problems in English only. Please feel free to answer in Finnish or English. No additional material is allowed in the exam.

1. (8p) Explain *briefly* the following concepts:

(a) Noble identities

(b) Input-output relations of interpolator in time and frequency domains

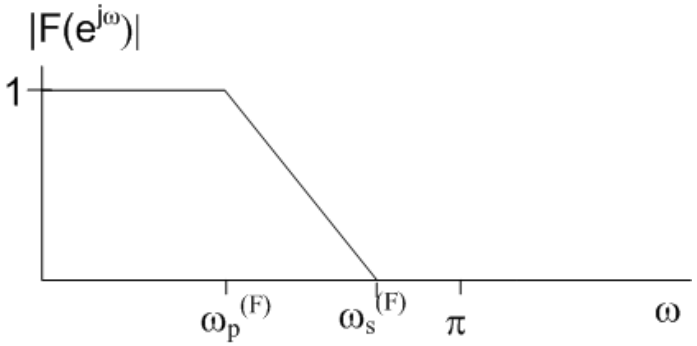
(c) Nyquist filter

(d) Farrow filter

2. (8p) Consider the frequency-response masking approach:

$$H_{FM}(z) = H(z)I_1(z) + G(z)I_2(z)$$

where $I_1(z)$ and $I_2(z)$ are interpolation filters, $G(z)$ is the complementary filter of $H(z)$. $H(z)$ in turn is obtained from shaping filter $F(z)$ using the upsamping factor (sparsity factor) $L = 3$. The magnitude response of $F(z)$ is given below



(a) Sketch $H(z)$ and $G(z)$.

(b) Sketch the 9 different single-band filters (i.e. no multiple pass-bands and excluding the trivial all-pass and all-stop filters) $H_{FM}(z)$ that can be implemented using the frequency-masking approach.

3. (8p) Consider the product filter given by

$$P(z) = az^2 + bz + c + dz^{-1} + ez^{-2}$$

(a) Determine a, b, c, d, e so that the resulting filter is a perfect reconstructing one.

(b) Factorize $P(z)$ to analysis and synthesis filters so that the resulting filter bank is orthogonal.

4. (8p) Design a three-channel perfect reconstruction QMF filter bank whose analysis filters are given by

$$\begin{aligned} H_0(z) &= 1 + z^{-1} + 2z^{-2} \\ H_1(z) &= 2 + 4z^{-1} + z^{-2} \\ H_2(z) &= 1 + 2z^{-1} + z^{-2} \end{aligned}$$

and draw a block diagram of a computationally efficient realization of the filter bank.