HELSINKI UNIVERSITY OF TECHNOLOGY Exam October 28th, 2008 Dept. of Signal Processing and Acoustics S-88.3106 Digitaaliset Signaalinkäsittelyjärjestelmät (5 cr)

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, 27 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.** (6p) Consider a discrete-time signal x[n] with the following spectrum



Now consider the following multilevel filterbank, in which L(z) refers to an ideal lowpass filter with cutoff frequency  $\pi/2$  and H(z) is an ideal highpass filter with cutoff frequency  $\pi/2$ .



Plot the four spectra,  $Y_i(e^{j\omega}), i = 1, \cdots, 4$ .

2. (6p) Consider the sampling rate converter below:



Explain step-by-step by drawing block diagrams how this system can be transformed into a computationally efficient sampling rate converter.

3. (6p) Lagrange polynomials are given in general form by

$$P_k(t) = \prod_{\substack{l=-N_1\\l\neq k}}^{N_2} \left(\frac{t-t_l}{t_k-t_l}\right)$$

- (a) Deduce Lagrange polynomials when  $N_1 = N_2 = 1$ .
- (b) Give input-output relations in matrix form for an interpolator with a conversion factor of 3/2 using the polynomials above. Draw the block diagram as well.
- (c) Describe the implementation of the 3/2 interpolator as a Farrow structure.
- 4. (9p) Explain the three different ways for factorizing the product filter to make a perfect-reconstruction QMF bank. Compare the similarities and differences of these methdos.