T-61.3010 Digital Signal Processing and Filtering

(v. 1.0, 5.2.2009), Paper #3 (24.2., 25.2., 26.2.2009)

The problems marked with [**Pxx**] are from the course exercise material (Spring 2009), where **Pxx** refers to the problem.

In the end of this session **you should know**: (a) basics of filter analysis for FIR and IIR filters, (b) recognize linear-phase FIR filters, (c) connection between pole-zero plot and magnitude response.

You are allowed to do 1st mid term exam (MTE) **only once either on Sat 7.3.2009 or Fri 13.3.2009.** Sign up in WebOodi. You are **not** allowed to use any calculators or math tables of your own. A table of DSP formulas is delivered in the exam, see `http://www.cis.hut.fi/Opinnot/T-61.3010/Laskarit/taulukko_tiiviskooste.pdf`.

There are 12 multichoice questions and one essay. **In Problem 1 (==multichoice) you must fill in and return a specific paper.** Each correct multichoice answer gives you +1 p, each wrong answer −0.5 p, and not answered 0 p. The minimum is 0 and the maximum 12 points. The essay is worth of 6 points. In addition, there will be a mid term feedback questionnaire open after the mid term exams. Replying to this gives you +1 p. Instructions are sent by email after the exam.

The exam area contains roughly (*Mitra 2Ed Sec. 1–5 / 3Ed Sec. 1–7*) as discussed in the lectures. Typical problems can be found in [**P14-P61**] with required math background [**P1-P13**]. Check also old exam papers given in the course web site.

1. [**P42**] A LTI filter is characterized by its difference equation

$$y[n] = 0.25x[n] + 0.5x[n-1] + 0.25x[n-2]$$

   a) Draw the block diagram
   b) What is the impulse response $h[n]$
   c) Determine the frequency response $H(e^{j\omega}) = \frac{\sum p_k e^{-j\omega k}}{\sum d_k e^{-j\omega k}}$
   d) Determine the amplitude response $|H(e^{j\omega})|$
   e) Determine the phase response $\angle H(e^{j\omega})$
   f) Determine the group delay $\tau(\omega) = -\frac{\mathrm{d}\angle H(e^{j\omega})}{\mathrm{d}\omega}$

2. [**P55**] Consider the filter described in Figure 1.

   a) Derive the difference equation of the system.
   b) Calculate the transfer function $H(z)$.
   c) Calculate the zeros and poles of $H(z)$. Sketch the pole-zero plot. Is the system stable and/or causal?
   d) If the region of convergence (ROC) of $H(z)$ includes the unit circle, it is possible to derive frequency response $H(e^{j\omega})$ by applying $z = e^{j\omega}$. Do this!
   e) Sketch the magnitude (amplitude) response $|H(e^{j\omega})|$ roughly. Which frequency gives the maximum value of $|H(e^{j\omega})|$? (If you want to calculate magnitude response explicitely, calculate $|H(e^{j\omega})|^2 = H(e^{j\omega})H(e^{-j\omega})$ and use Euler's formula.)

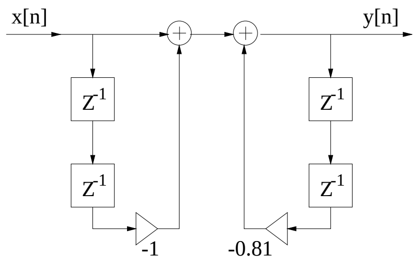

Figure 1: LTI system of Problem 2.

   f) Compute the equation for the impulse response $h[n]$ using partial fraction expansion and inverse z-transform.

3. [**P54**] Consider the pole-zero plots in Figure 2.

   a) What is the order of each transfer function?
   b) Are they FIR or IIR?
   c) Sketch the amplitude response for each filter.
   d) What could be the transfer function of each filter?

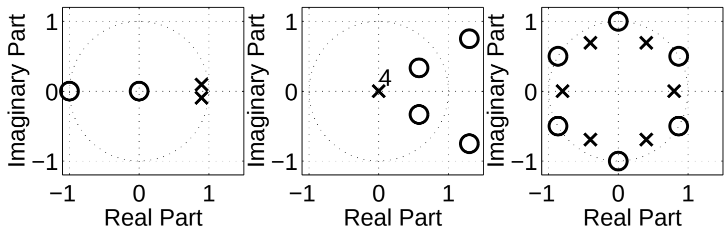

Figure 2: Pole-zero plots of LTI systems in Problem 3.