

T-61.3010 Digital Signal Processing and Filtering

Mid term exam 1, Fri 7.3.2008 at 12-15. Hall M (non-Finnish).

You are allowed to do MTE1 only once either 7.3. or 10.3.

You are not allowed to use any calculators or math reference books. A list of formulas is delivered in the exam. A special form is delivered for Problem 1.

Return a special form and the other answer paper separately. Both ones have to have at least student number and name written on. Problem paper and the formulas you may keep.

Write down all necessary intermediate steps in Problem 2. Problem 3 is a course feedback which is open from Wed 12-March to Wed 19-March 2008.

1) (10 x 1p, max 8 p) Multichoice statements. There are 1-4 correct answers, but choose **one and only one**. Fill in **into a separate form**, which will be read optically.

Correct answer +1 p, incorrect -0.5 p, no answer 0 p. You do not need to explain your choices. Reply to as many statements as you want. The maximum points of this problem is 8 and the minimum 0.

1.1 Examine a polynomial $f(x) = x^{2008} + 1$.

- (A) All possible roots are $x = \pm j$
- (B) One root is $x = j + \pi/2008$
- (C) Roots are on a circle with radius r , equally spaced with angle θ , where $r = 1$ and $\theta = \pi/2008$
- (D) None of above is true

1.2 Sequence $x[n] = (\sum_{k=-\infty}^{\infty} \delta[n - 3k]) + \cos((\pi/7)n) - 2 \sin((\pi/2)n)$

- (A) is not periodic
- (B) is periodic and its fundamental period $N_0 = 84$
- (C) is periodic and its fundamental period $N_0 = 168$
- (D) is periodic with period $N = 420$

1.3 Compute the linear convolution $y[n] = h[n] \otimes x[n]$ of impulse response $h[n] = \delta[n+1] + 4\delta[n] - 2\delta[n-2] - \delta[n-3]$ and input $x[n] = \delta[n+1] - 0.84\delta[n] - 0.231\delta[n-1] + 0.72\delta[n-3] - \delta[n-4] - \delta[n-5]$

- (A) $y[n] = \{1, 3.16, \underline{-5.591}, 0.476, 3.182, -6.2090, -2.72, 3, -1\}$
- (B) $y[n] = \{0, 0, 1, 3.16, -5.591, 0.476, 3.182, -6.2090, -2.72, -3, 1\}$
- (C) $y[n] = \{1, 3.16, \underline{-3.591}, -2.924, 1.4, 3.182, -4.769, -5.44, 1.28, 3, 1\}$
- (D) $y[n] = \{1, \underline{-3.36}, 0, 0, -0.72\}$

1.4 Two-point moving average filter

- (A) is of IIR type
- (B) order is 2
- (C) is lowpass filter
- (D) structure contains a feedback loop

1.5 The highest frequency component in a continuous-time signal is $f_h = 5$ kHz. No aliasing happens

- (A) when sampling frequency f_T is smaller than 10 kHz
- (B) when using sampling frequency $f_T = 5.0001$ kHz
- (C) when using sampling period $T > 5$ seconds
- (D) if sampling period is smaller than 0.1 milliseconds

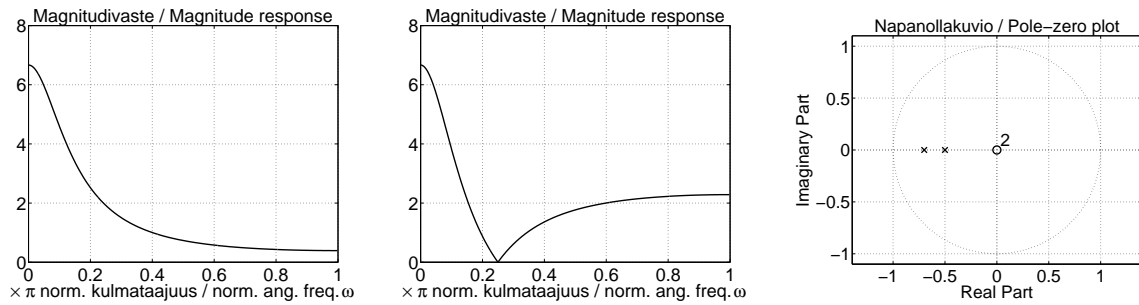
1.6 Real-valued sequence $x[n]$:

- (A) discrete-time Fourier transform (DTFT) is periodic with 2π
- (B) absolute value of discrete-time Fourier transform is even function
- (C) angle of discrete-time Fourier transform is odd function
- (D) discrete-time Fourier transform can be real-valued

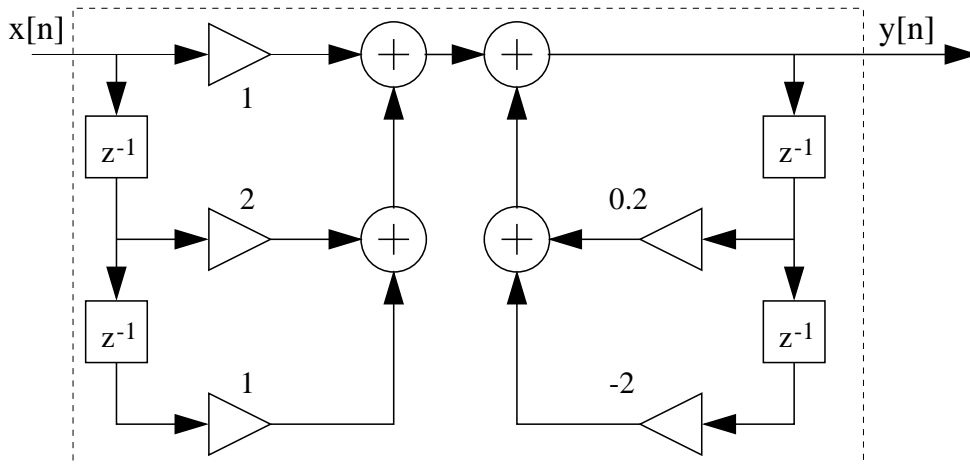
1.7 The impulse response of LTI filter is $h[n] = \delta[n] + \delta[n - 2008]$.

- (A) Zeros of the filter are on the unit circle at frequencies $\pm\pi/2$
- (B) Filter is symmetric comb filter
- (C) Phase response $\angle H(e^{j\omega})$ is nonlinear
- (D) Filter is not stable

- 1.8 The transfer function of LTI filter is $H(z) = \frac{1}{1-1.2z^{-1}+0.35z^{-2}}$.
- (A) Amplitude response is in Figure 1(a)
 (B) Amplitude response is in Figure 1(b)
 (C) Pole-zero plot is in Figure 1(c)
 (D) Filter is of allpass type
- 1.9 Transfer function is $H(z) = \frac{1}{1+0.8z^{-1}} \cdot \frac{1}{1+1.2z^{-1}}$ with region of convergence (ROC) $|z| < 0.8$. Inverse transform is then
- (A) $h[n] = 2h[n-1] + 0.96h[n-2] - 2\delta[n] + 3\delta[n-1]$
 (B) $h[n] = -2 \cdot (-5/4)^{-n-1}\mu[-n-1] + 3 \cdot (-5/6)^{-n-1}\mu[-n-1]$
 (C) $h[n] = -2 \cdot (-4/5)^{-n-1}\mu[-n-1] + 3 \cdot (-6/5)^{-n-1}\mu[-n-1]$
 (D) $h[n] = -2.5 \cdot (-5/4)^{-n-1}\mu[-n-1] + 2.5 \cdot (-5/6)^{-n-1}\mu[-n-1]$
- 1.10 Block diagram of the filter in Figure 2 is analyzed with Matlab. Correct commands are
- | | | | |
|-------------------------|-----------------|-----------------------|-----------------------------|
| (A) | (B) | (C) | (D) |
| den = [1 0.2 -2]; | A = [1 -0.2 2]; | A = [1 -0.2 2]; | B = [1 2 1]; |
| num = [1 2 1]; | B = [1 2 1]; | B = [1 2 1]; | A = [1 0.2 -2]; |
| figure(42); | figure(102); | [Z, P] = tf2zp(B, A); | subplot('Amplitude resp.'); |
| plot(freqz(num, den)); | freqz(B, A); | figure(1); | freqz(A, B, length(B)-1); |
| plot(zplane(num, den)); | figure(550); | plot(B, A, 'g'); | subplot('Pole-zero plot'); |
| | zplane(B, A); | hold on; | pzplot(A, B, length(A)-1); |
| | | plot(Z, P, 'k'); | |

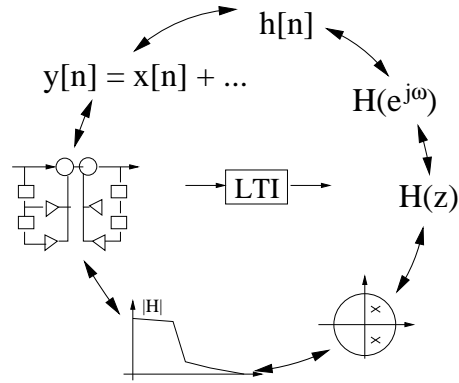


Kuva 1: Multichoice statement 1.8 (A) , (B) , and (C) .



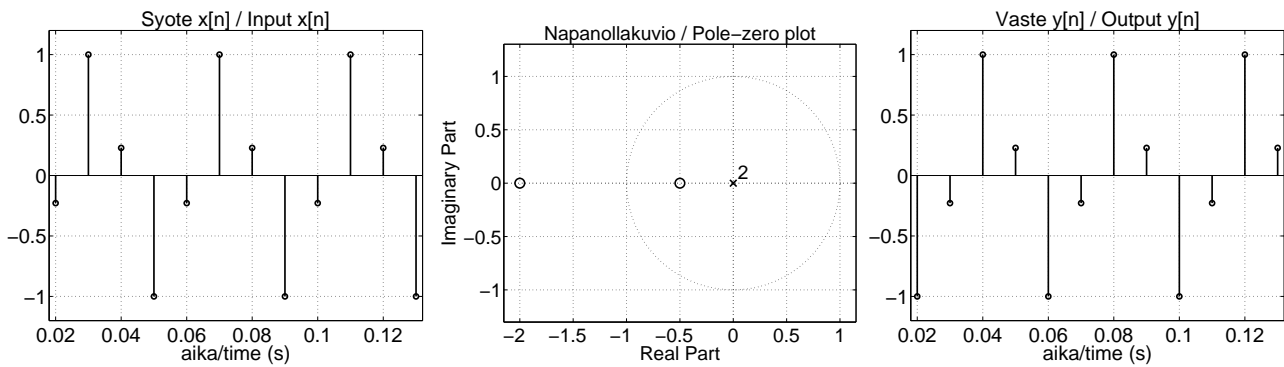
Kuva 2: Multichoice statement 1.10, block diagram.

- 2) (6p) In the beginning of this course we have analyzed digital signals and linear and time-invariant (LTI) filters. The analysis is both in time and frequency domain as shown in Figure 3.



Kuva 3: Tehtävä 2: A big picture of LTI analysis. The filter can be analyzed in time- and frequencydomain in various ways.

Let us examine now the case in Figure 4. There is a pure cosine sequence $x[n]$ with fundamental period $N_0 = 4$ as input. It is filtered with an LTI filter, which is given by a pole-zero plot. Zeros are at $d_1 = -0.5$ and $d_2 = \frac{1}{-0.5} = -2$, whereas all poles are in the origin. Note that one cannot see amplification G in pole-zero plot. Output sequence is given in rightmost figure; the amplitude of the cosine has remained unchanged.



Kuva 4: Tehtävä 2: Part of sequence $x[n]$, pole-zero plot of the filter, and part of output $y[n]$ (“steady-state response”).

Analyse and classify both signals and systems in time- and frequency domain using methods taught in this course. Show all necessary steps. Write down a few sentences where you describe what you have found out. Visualize with some figures.

- 3) Reply to course feedback questionnaire, which is open from Wed 12-March to Wed 19-March 2008. Instructions are sent by email. This is part of mid term exams and worth of +1 point.