

## T-61.140 Signal Processing Systems

2nd mid term exam / final exam, Wed 15.5.2002 9-12 C, L (Simula, Parviainen)

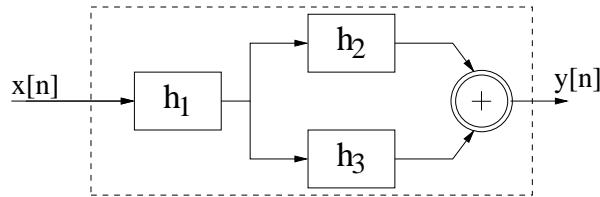
You may use your own graphical calculator. There are formulae on accompanying papers - use them!

**2nd MTE:** 3, 4, 5, 6, 7

**Exam:** 1, 2, 5, 6, 7

Notice! You are not allowed to take part in 2nd MTE, if you attended MTE on 3.5.2002.

- 1) (6p, EXAM) Properties of signals and systems.
  - a) (1p) With which value of  $\alpha$  discrete-time system  $y[n] = 0.5x[n] + 0.25\alpha x[n-1] + \alpha$  is LTI? Explain.
  - b) (1p) Is  $y[n] = \sum_{k=-3}^3 k^2 x[n-k]$  a stable LTI-system? Explain.
  - c) (1p) Is  $y[n] = x[-n]$  a causal discrete-time system? Explain.
  - d) (1p) Is signal  $x(t) = \cos(\frac{2}{9}t)$  periodic? If it is, what is the length of fundamental period  $T$ ?
  - e) (1p) Is sequence  $x[n] = \sin(\frac{4}{9}n)$  periodic? If it is, what is the length of fundamental period  $N$ ?
  - f) (1p) What is the fundamental period  $N$  of sequence  $x[n] = \cos(\frac{\pi}{6}n - \pi) + \sin(\frac{\pi}{9}n)$ ?
- 2) (6p, EXAM) LTI system, whose impulse response is  $h[n] = -\delta[n-1] + 2\delta[n-2] + 3\delta[n-3]$ , consists of three LTI subsystems  $h_1[n]$ ,  $h_2[n] = -\delta[n] + 2\delta[n-1] - \delta[n-2]$  and  $h_3[n] = \delta[n-1] + \delta[n-2]$ , see the picture below.



- a) (1p) Explain, how the impulse response  $h_1[n]$  can be derived.
  - b) (2p) Compute  $h_1[n]$ .
  - c) (2p) The input is  $x[n] = \{0, -1, 2\}$ . What is the output  $y[n]$ ?
  - d) (1p) The system is modified so that the block  $h_1$  is moved to be after  $h_2$  and  $h_3$  ( $h_2$  and  $h_3$  parallel, then  $h_1$  in cascade). The modified system has impulse response  $\hat{h}[n]$ . What can be said about impulse responses  $h[n]$  and  $\hat{h}[n]$ ?
- 3) (0-3p, 2. VK) Answer, if the statement is true (T) or false (F). Correct answer +1p, wrong -1p, no answer 0p. Explain briefly! **ATT!** There are four statements, max points 3.
    - a) Convolution of input signal and impulse response in time-domain corresponds the product of frequency response and Fourier-transform of input signal.
    - b) Averaging FIR filter (MA, moving average) is always stable, because it contains a feedback loop.
    - c) If the analog signal is band limited, and if the period length of quickest changing component is over two times long as the sampling period, there will not be any aliasing.
    - d) The rise time of the filter is defined to be time interval, when unit step response rises from 10% to 90% of its maximum value. Statement: The filter  $h[n] = (0.9)^n$  has shorter rise time than  $h[n] = (0.1)^n$ .

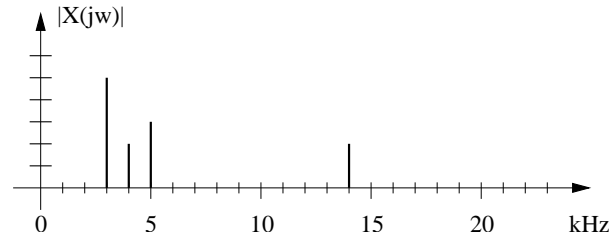
4) (3p, 2nd MTE) Answer with a few sentences.

- a) What do terms analog(ue), discrete and digital signal mean?
- b) Why is it useful to process signal digitally?

5) (6p, EXAM and 2nd MTE) LTI system is defined with impulse response

$$h[n] = (-0.8)^n u[n] - (-0.8)^{n-1} u[n-1]$$

- a) (2p) Calculate and draw the values of impulse response, when  $n = -2..3$ , and sketch the values approximately when  $n = 4..10$ .
  - b) (2p) What is the frequency response  $H(e^{j\omega})$  of the system?
  - c) (1p) Sketch  $|H(e^{j\omega})|$  in range  $0.. \pi$ . Is the system of type lowpass / highpass / bandpass / bandstop?
  - d) (1p) Calculate the corresponding difference equation using  $x[n]$  and  $y[n]$ .
- 6) (6p, EXAM and 2nd MTE) Let us know a continuous-time signal  $x(t)$ , which consists of four cosine components, and its Fourier spectrum  $|X(j\omega)|$ , which is depicted in the picture below. The highest signal component is 14 kHz. Let us assume that phase is 0 for each component.



- a) (1p) Is the signal  $x(t)$  periodic? If it is, what is the fundamental frequency of that?
- b) (1p) What is the smallest sampling frequency, where no aliasing exists?
- c) (3p) In order to use a digital application the signal  $x(t)$  is sampled with  $f_s = 12000$  Hz. Sketch the spectrum  $|X(e^{j\omega})|$  of the sampled signal  $x[n]$  in range  $0..6000$  Hz.
- d) (1p) The interesting band for the application is  $2500..5500$  Hz. Explain briefly with a couple of sentences the situation after sampling and the influence of the high-frequency (14 kHz) component.

7) (6p, EXAM and 2nd MTE) **Reply to either A or B.**

7A) LTI system is defined with difference equation

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

- a) (1p) Draw the block diagram of LTI system.
- b) (1p) The system computes the mean of two latest samples. Is the system of type lowpass / highpass / bandstop / bandpass?
- c) (2p) Replace each delay with a double delay. Write down a modified difference equation and frequency response  $H(e^{j\omega})$ ?
- d) (2p) Sketch the modified  $|H(e^{j\omega})|$  in range  $0.. \pi$ . Is the modified system of type lowpass / highpass / bandstop / bandpass?

7B) Write down an essay of frequency-selective LTI-filters and filtering on the basis of the course. The maximum length of the essay is two pages with line space of two; illustrations can be drawn to clarify the text.