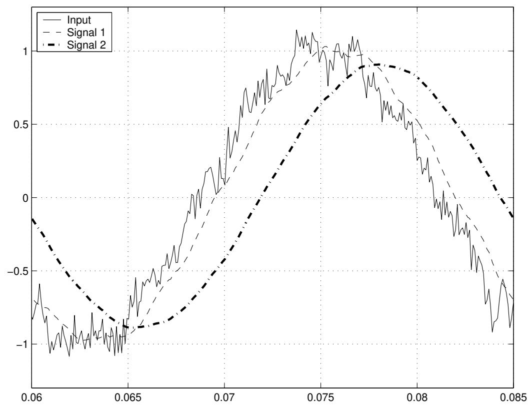
T-61.140 Signal Processing Systems

1st mid term exam, Mon 11.3.2002 15-18 hall M. Simula/Parviainen.
NO mathematical reference book, NO calculators are allowed. Formulae in the other side of this paper. Maximum points are 3+3+6+6=18.

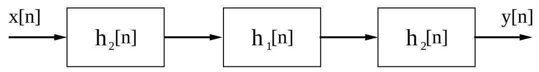
1. (5 x 1p, max 3p) Reply to **max three** claims, if they are right or wrong. Calculate or explain briefly.

   a) $y[n] = (x[n])^2$ is a time-invariant LTI system.
   b) $y[n] = 2\,x[n+1]$ is a stable LTI system.
   c) $y(t) = 2\,t\,x(t-1)$ is a causal LTI system.
   d) The operations in digital image processing (still-picture, gray scale) are always time-invariant (=shift-invariant), because the pixels do not carry any information of time.
   e) The Fourier analysis used in LTI systems was developed in 1960's, in the era of the breakthroug of computers, in order to ease digital signal processing.

2. (3p) In the figure below there is a signal (continuous –), whose "fundamental frequency" is 40 Hz (including some noise). A normal signal processing operation is executed with two different LTI systems, and the outputs are signals 1(- -) and 2 (thick - .), respectively. What is this operation? How does it relate to basic filter types (lowpass/highpass/bandpass/bandstop)? Comment also the differences of systems/signals 1 and 2. Write down a few sentences, max one half page.



3. (6p) Examine a cascade system of three LTI systems below. It is known that $h_1 = \delta[n] - \delta[n-1]$ and the impulse response of the whole system is $h_c[n] = \delta[n-2] + \delta[n-3] - \delta[n-4] - \delta[n-5]$.



   a) Calculate the impulse response $h_2[n]$.
   b) What is the output, when unit step $u[n]$ is fed into the system $h_c[n]$?

4. (6p) The impulse response of a continuous-time LTI systems is defined by

$$h(t) = \delta(t) - e^{-t}\,u(t)$$

   a) Calculate $H(j\omega)$.
   b) Is $H(j\omega)$ lowpass or highpass filter? Hint: compute $|H(j\omega)|$ with few interesting frequencies.
   c) Let the input be a rectangular pulse $x(t) = \begin{cases} 2, & 0 < t < 1 \\ 0, & \text{elsewhere} \end{cases}$

   Define the F-transform $Y(j\omega)$ of the output.