Tik-61.145 Principles of digital signal processing

2nd partial test, May 8 1996

1. (6p) Consider a FIR filter having the transfer function

$$H(z) = 1 + 2.5z^{-1} + z^{-2}.$$

   (a) Draw the pole-zero diagram, and sketch $|H(e^{j\omega T})|$, the magnitude response of the filter. What kind of filter is this?

   (b) Draw the pole-zero diagram, and sketch the magnitude response of the same filter, when each delay of the original filter is replaced by four delays. What kind of filter we now have?

2. (6p) Consider the filter realization in Figure 1.

   (a) Determine $H(z)$, the transfer function of the filter corresponding to the figure. What is the order of the filter?

   (b) Is the filter type IIR of FIR? Why?

   (c) Compute the poles and zeros and sketch the pole-zero diagram in the z-plane. Realize the filter in the simplest possible form. What basic operations are needed in the realization? Draw the signal flow graph.

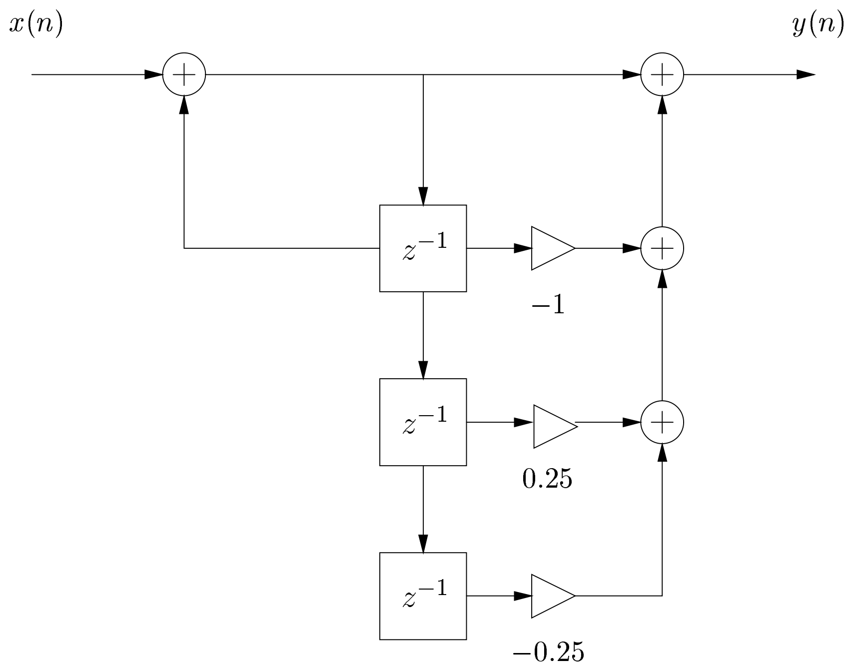

Figure 1: Filter realization.

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3. (6p) Here are some statements concerning the figures in table 1. In the table, there are three magnitude responses on interval $[0 \ldots \pi]$, two pole-zero diagrams and a rabbit. Are the statements true or false? Motivate your answers briefly. (All figures are IIR filters designed in the continuous domain, which are digitized using bilinear transform.)

   (a) The pole-zero diagram in the Figure (1) represents a 3th order elliptic lowpass filter.

   (b) There is a rabbit in Figure (2) (which likes the apple trees of the old farmer Ärjylä).

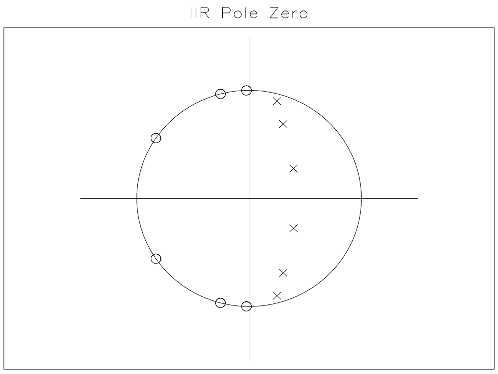
   (c) Figure (3) is a 5th order Chebyshev I bandpass filter.

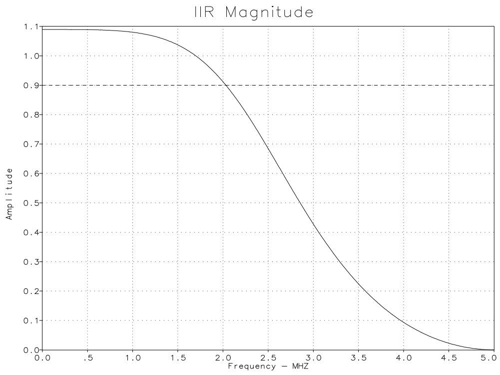
   (d) All Butterworth filters, like the filter in Figure (4), are monotonic on both the stop- and the passband.

   (e) The passband of the highpass filter in Figure (5) begins at frequency $\frac{\pi}{4}$.

   (f) The stopband of the filter in Figure (6) makes us think that the filter might be elliptic, but it is not, because the filter is not equiripple in the passband.

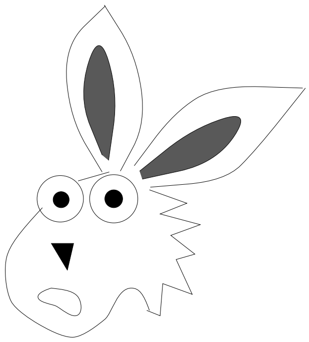
(1)

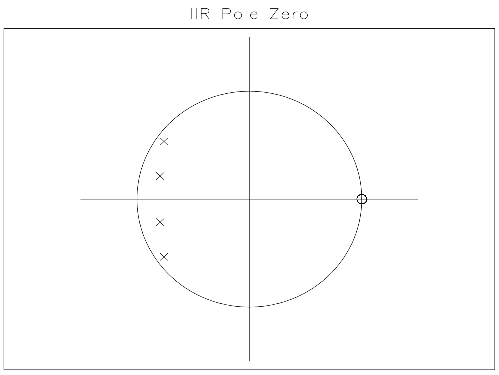




(4)

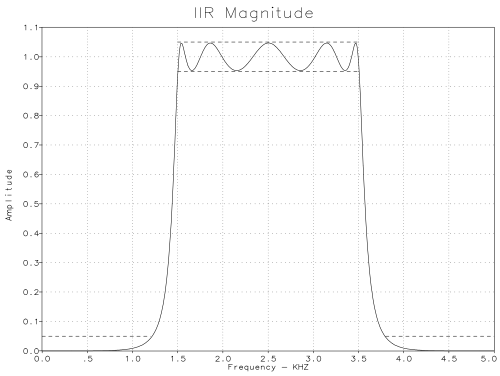
(2)

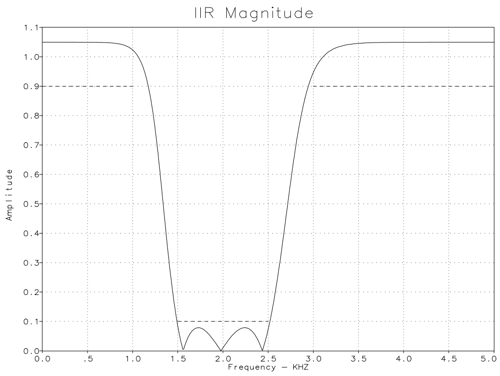




(5)

(3)





(6)

Table 1: Pole-zero diagrams and magnitude responses of IIR filters.

4. (6p) The quantization error may be compensated using so-called error feedback. In the method, the filtered error signal is added to the branch preceding quantization (Q). There is a second order error feedback structure in Figure 2.

   (a) Determine $H_e(z)$, the noise transfer function of the system, when

   $$E(z)_{tot} = H_e(z)E(z),$$

   where $E(z)$ is the z-transform of the quantization error $e(n) = Q[w(n)] - w(n) = y(n) - w(n)$, and $E(z)_{tot}$ is the z-transform of the total error $e(n)_{tot} = y(n) - x(n)$.

   (b) Determine the amplitude response of the noise transfer function $H_e(z)$. How does the spectrum of the noise change due to error feedback, when it is assumed that the noise is originally uniformly distributed (white noise)? What happens to the variance of the noise?

   (c) What is the advantage of this kind of error-feedback?

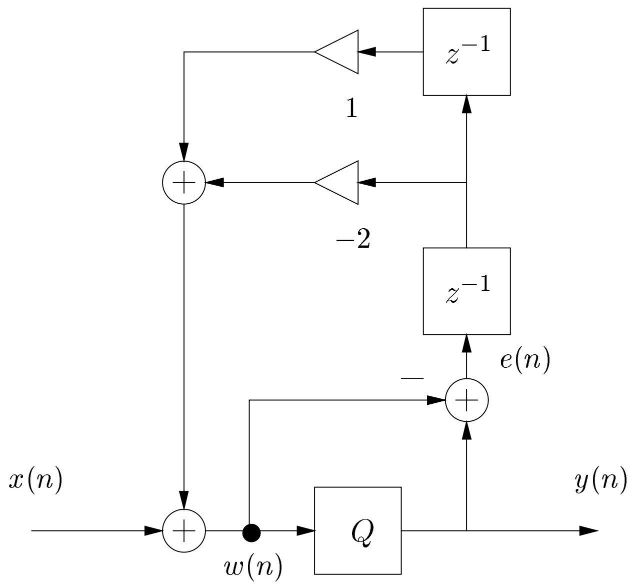


Figure 2: A second order error feedback structure.