SGN-2016 DIGITAL LINEAR FILTERING I

Final Examination: **25.11.2008**

NO literature in the examination, short, compact, and pithy answers are preferred.

1. Explain shortly (using formulas and/or words) the meanings of the following terms:
   (a) Difference equation (1pt)
   (b) Cascade form structure (1pt)
   (c) Zero-phase frequency response (1pt)
   (d) Type I linear-phase FIR filters (1pt)
   (e) Bilinear transform (1pt)
   (f) Limit cycle (1pt)

2. (a) Under certain conditions an FIR filter is defined to have a linear-phase (four cases). What are these conditions in terms of the impulse response of the filter? (2pt)
   (b) The frequency response $H(e^{j\omega})$ of an FIR filter of order $N=3$ with a real impulse response has the following values: $H(e^{j0})=3$, $H(e^{j\pi/2})=2+3j$, and $H(e^{j\pi})=0$. Determine the transfer function $H(z)$. (2pt)
   (c) The sampling frequency of a digital system is $f_s=2000$ Hz. The system is designed to reject (attenuate to zero) signal frequencies $f_0=400$ Hz and $f_1=900$ Hz. It is obvious that such a system (filter) has at least two zero pairs in its transfer function. Where are those zeros located in the z-plane? (2pt)

3. (a) Describe the basic steps in Remez algorithm. (3pt)
   (b) It is desired to design a lowpass FIR filter by windowing. The maximum allowed passband and stopband ripples are $\delta_p=0.01$ and $\delta_s=0.001$. Which fixed widow or windows can be used for designing such a filter? Give an explanation. (2pt)
   (c) Name 4 adjustable windows used for FIR filter design. (1pt)

4. Design a Butterworth digital filter with the aid of the bilinear transformation to satisfy following design criteria: $\omega_p=0.25\pi$, $\omega_s=0.65\pi$, $A_p=3$dB, and $A_s=30$dB. (6pt)
   For estimating the minimum order of a Butterworth filter satisfying the given criteria following expression is valid: $N \geq \dfrac{\log_{10}\left[(A^2-1)/\varepsilon^2\right]}{2\cdot\log_{10}(\Omega_s)}$

5. It is desired to implement the transfer function
$$H(z)=\frac{K}{1+0.88z^{-1}}$$
   using two's complement arithmetic. The data wordlength is 1+6 bits. Determine the largest value for K (implemented before the feedback loop) for which there are no overflows (the worst case scaling). What is the variance of the output noise due to the multiplication roundoff errors? (6pt)