**DSPA, 2006, March 29-31, V.1, pp. 138-139.**

# ROUNDOFF NOISE AND COEFFICIENT WORDLENGTH OF FOUR IIR FILTER STRUCTURES

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The choice of digital filter structure is one of the important problems in DSP system design. Really, for concrete specifications different structures have various roundoff noise properties, levels of small limit cycles, conditions for absence of the overflow oscillation, coefficient wordlengths and implementation complexity. We can not give always precise recommendations. In such case we should carry out additional researches with the purpose of choice a suitable filter structure [1]. In this paper four fixed point IIR filter structures are studied in relation to their roundoff noise performances and coefficient wordlengths. Two sets of specifications are considered for bandpass filters of 6-th and 10-th order at the edge frequencies varying in very wide range from 0.0006 (the very low frequency) up to 0.2 (the frequency from the area of average frequencies). The sampling frequency is equal 1.

We use following four filter structures for the analysis. These are two cascade structures, one uses direct form sections (second order), and another uses normal form sections, and two structures based on parallel connection of two allpass networks, and in one case the each networks represent a cascade of direct form allpass sections, and in another case a cascade of wave form allpass sections. We use $L_\infty$-norm for scaling and we shall put that the rounding is carried out after adders. In the cascade structures the roundoff noise-to-signal ratio depends on pole-zero pairing and ordering of the filter sections. For minimization of this parameter we apply heuristic procedure from [2]. For each of the considered structures we minimize the wordlength coefficient by an algorithm based on variation of initial parameters (VIP-1 [3]).

The 6-th order bandpass filter specifications are the passband = 0.01; the passband ripple $\le 3$ dB; the minimum stopband attenuation $\ge 60$ dB; the squareness ratio (it is a parameter $\alpha$ in [4]) = 5.

The 10-th order bandpass filter specifications are the passband = 0.005; the passband ripple $\le 0.5$ dB; the minimum stopband attenuation $\ge 40$ dB; the squareness ratio = 1.4.

For these two filter specifications, in almost overall the mentioned above range excepting some area of middle frequencies the cascade filters using the normal form sections and filters based on the wave form allpass sections have considerably best roundoff noise properties in comparison to the cascade filters using the direct form sections and filters based on the direct form allpass sections. The filters based on the direct form allpass sections have the best noise properties in the area of middle frequencies. The cascade filters using the normal form sections have considerably smaller coefficient wordlength in a neighbourhood of very low frequencies in comparison with other three structures.

In that time for the first set specifications all four structures in the field of adjoining to average frequencies have approximately equal coefficient wordlength, and for the second set - the cascade structures have essentially smaller coefficient wordlength in comparison to the filters based on the allpass sections. All these resumes are true both for frequencies 0.0006…0.2 and for 0.4994 … 0.3 because of a known symmetry.

## References

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