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MINIMIZATION OF COEFFICIENT WORDLENGTH IN CASCADE IIR DIGITAL FILTERS

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Abstract. The investigation of coefficient wordlength minimization algorithms for cascade IIR digital low-pass filters is presented. The algorithms are based on a variation of initial parameters (one- and three-parametrical variation) and simple rounding of coefficients. Although the three-parametrical approach gives the minimal coefficient wordlength its advantage in comparison to more simple one-parametrical variation is 1-2 bit and only in 27 % of cases.

1.Using algorithms. The complexity and speed of hardware digital filters based on individual multipliers, multiplier blocks or distributed arithmetic depend on the coefficient wordlength. Therefore it is important to minimize the wordlength. For this two algorithms based on a variation of initial parameters (VIP) [1-3] can be used. Their efficiency is confirmed on a number of examples from different publications. The one-parametrical (VIP-1) and more difficult in programming three-parametrical algorithm(VIP-3) were considered in [1] and [2], respectively. The aim of the given work is to find out for cascade IIR low-pass digital filters what differences in minimal values of coefficient wordlength M_o can be obtained by using above algorithms and how they correspond to the low bound M_{LB} [2] and wordlength obtained by the widely known simple rounding method (SR).

All our algorithms are based on the repeated computation of Zolotarev-Cauer IIR low-pass digital filters with the subsequent quantization of their coefficients. The structure of second order sections in cascades is a direct form. A scaling is ignored. A search of a solution is carried until the first allowable solution will not be found, i.e. when the ripple $\Delta\tilde{a} \le \Delta a_{\max}$ in the nominal passband (0-f_{1n}) and the attenuation $\tilde{a}_0 \ge a_{0\min}$ in the nominal stopband ($f_{2n} - 0.5$). Here the sign ~ means conformity of a parameter to the quantized cefficients. The quantization with step 2^{-M} means the rounding. Here M is the fractional part wordlength of fixed-point coefficients.

2.Test generating. We use 70 variants of the tests obtained by a random-number generator. The ranges and steps of the change for the order N and parameters of digital filters are:

$4 \le N \le 12$, the step -1; $0.05\text{dB} \le \Delta a_{\max} \le 3\text{dB}$, the step - 0.05dB;

$40\text{dB} \le a_{0\min} \le 60\text{dB}$, the step - 5dB; $0.01 \le f_{1n} \le 0.4$, the step - 0.01;

$$F(\Delta a_{\max}, a_{0\min}, f_{1n}, N) \le f_{2n} \le F(\Delta a_{\max}, a_{0\min}, f_{1n}, N-1)$$

where $F()$ is the function of N and parameters of Zolotarev-Cauer low-pass digital filters [4].

3.Results of testing. For all 70 tests the minimal coefficient wordlength M_o is achieved by VIP-3 algorithm. In 73 % of tests VIP-1 and VIP-3, and in 16 % of tests SR and VIP-3 give equal values M_o. The application VIP-3 instead of VIP-1 allows to reduce M_o on 1-2 bit. For 59 % of tests the solutions in starting points in VIP-3 are allowable and the variation of parameters is not required. In relation to the low bound we have: $M_{LB} < M_o$ for 34 % of tests, $M_{LB} = M_o$ for 53 % of tests, $M_{LB} > M_o$ for 13 % of tests. The reduction of coefficient wordlength due to application of VIP instead of SR is 10-50 %.

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