# ROUNDOFF NOISE AND COEFFICIENT SENSITIVITY IN DIGITAL FILTERS

by

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CERTIFICATE

This is to certify that the thesis entitled, 'Roundoff noise and coefficient sensitivity in digital filters,' being submitted by Rakesh Kumar Patney to the Electrical Engineering Department, Indian Institute of Technology, Delhi, for the award of the Degree of Doctor of Philosophy, is a record of bonafide research work carried out by him under my supervision and guidance and in my opinion, it has reached the standard fulfilling the requirements of the regulation relating to the degree.

The results contained in this thesis have not been submitted to any other institute for the award of any degree or diploma.

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## ABSTRACT

The accuracy of a digital filter is limited by the finite word length used in its implementation. One effect of the finite word length is the accumulation of roundoff errors committed in the results of the arithmetic operations. This error is assumed to be uncorrelated random noise added to the signal and its effect at the output is characterized by its variance. This variance depends upon the transfer function from the noise source to the output (NTF) and therefore, depends upon the filter structure. The total output noise is the combined effect of the various noise sources in the filter. Another finite word length effect comes because the designed filter parameters have to be quantized before implementation. The resulting change in the filter characteristics is referred to as coefficient sensitivity. The extent of this change depends upon the method of quantization viz. rounding or truncation. This thesis reports some new results on the roundoff noise behaviour of digital filters and describes new methods for evaluation of roundoff noise. Also, new methods for quantized coefficient design of nonrecursive and recursive digital filters are given.

For the design of recursive digital filters with small roundoff noise, an in-depth understanding of their noise behaviour is required. The thesis starts with the analysis of noise in a set of canonic structures for second order notch filters. It was found that roundoff noise largely depends upon the zeros of

their NTF's. A new insight into the noise problem is obtained by decomposing a single NTF in terms of allpass functions. Such decompositions also lead to new methods of roundoff noise evaluation, which have computational advantages over conventional methods.

The fact that rounding and truncation of filter parameters do not minimize the deterioration in filter characteristics due to quantization, has been amply demonstrated in literature where the best values of quantized parameters are decided upon by various search techniques in a discrete parameter space. To partially overcome the inherent limitations of these techniques, namely large computation time and their inability to guarantee a global optimum, quantized coefficient design of digital filters using pseudo-Boolean (PB) methods has been proposed. FIR filters are shown to be easily designed by making use of linear PB methods; a nonlinear PB method is given for IIR filter design.

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