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Optimized Design of 2nd order tap 25 Digital Differentiator Using Genetic Algorithm

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Abstract: Digital Differentiator is a important signal processing tool. It is found in many applications, from low frequency biomedical equipment to high frequency radars. New developing fields such as touch screen tablets and online signature verification also has digital differentiators as basic building block. In this paper the design of second order digital differentiator is presented using one of the optimization techniques Genetic Algorithm. In this paper we have compared Genetic algorithm to McClellan Parks algorithm for second order digital differentiator of filter length twenty five.

Keywords: GA, FIR, DDs

Introduction

Digital filters form an important subsystem of a general digital signal processing systems. They possess certain desirable properties which make them attractive for DSP application. Digital filters like an analog filter is represented by a unique function of frequency referred to as a frequency spectrum of the signal and such a filter can be realized by means of a computer program.

Basic FIR filter is characterized by

$$y(n) = \sum_{k=0}^{N-1} h(k)x(n-k)$$

and the transfer function of the system is given by

$$H(z) = \sum_{k=0}^{N-1} h(k)z^{-k}$$

Where h(k) is the impulse response coefficients of filter, N is the filter length (number of coefficients). FIR filters can have exactly linear phase response.

Design flow of any FIR filter is shown below:

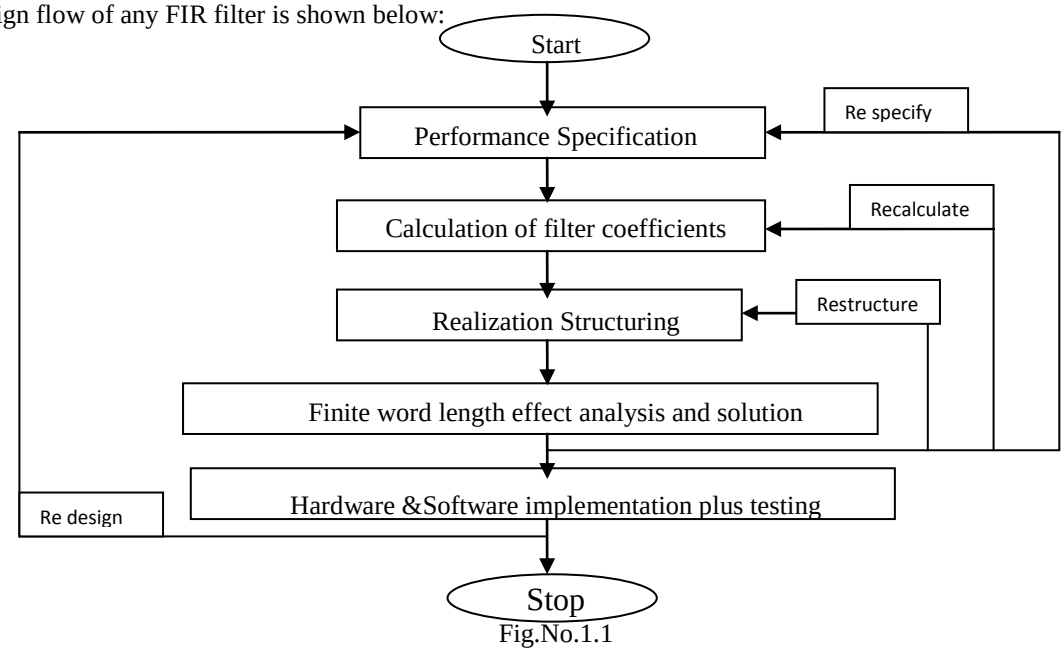


Fig.No.1.1

- Filter Specification: Include stating the type of the filter as LPF, desired amplitude/ phase response and tolerance, sampling frequency etc.
- Coefficient calculation: Determine the coefficients of a transfer function H(z), which satisfy the filter specifications.
- Realization: converting transfer function H(z) into a suitable filter network or structure.
- Analysis of finite word length effects: analyze the effect of quantizing the filter coefficients and the input data as well as the effect of carrying out the filtering operation using fixed word length on the filter performance.
- Implementation: Producing software code and hardware and performing actual filtering.

An ideal differentiator has the frequency response as defined below:

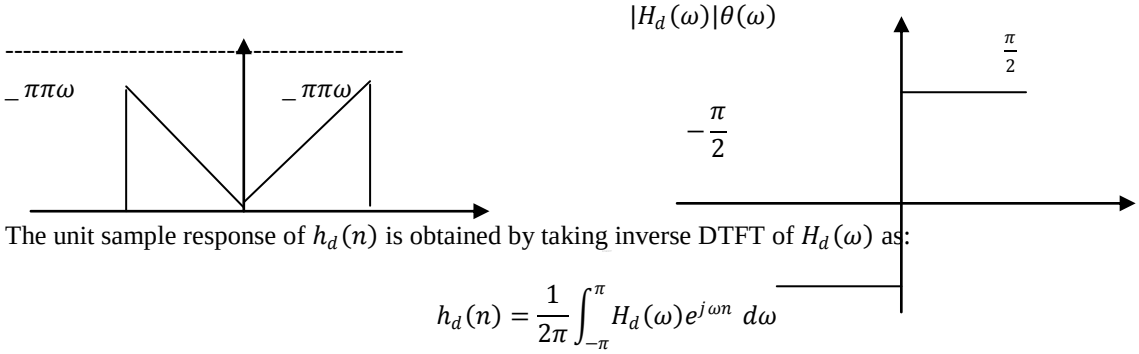
$$H_d(\omega) = j\omega \qquad -\pi \le \omega \le \pi$$

Hence, the magnitude and phase responses are

$$|H_d(\omega)| = |\omega| \qquad -\pi \le \omega \le \pi$$

and $$\theta(\omega) = \angle H_d(\omega) = \begin{cases} \frac{\pi}{2}, & \omega > 0 \\ 0 & \omega = 0 \\ -\frac{\pi}{2}, & \omega < 0 \end{cases}$$

The corresponding sketch of magnitude and phase responses of an ideal differentiator is shown below:



The unit sample response of $h_d(n)$ is obtained by taking inverse DTFT of $H_d(\omega)$ as:

$$h_d(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d(\omega) e^{j\omega n}\, d\omega$$

We can design digital differentiator of any order. Higher order digital differentiators have received considerable importance in some applications such as calculation of geometric moments and biological signal processing.

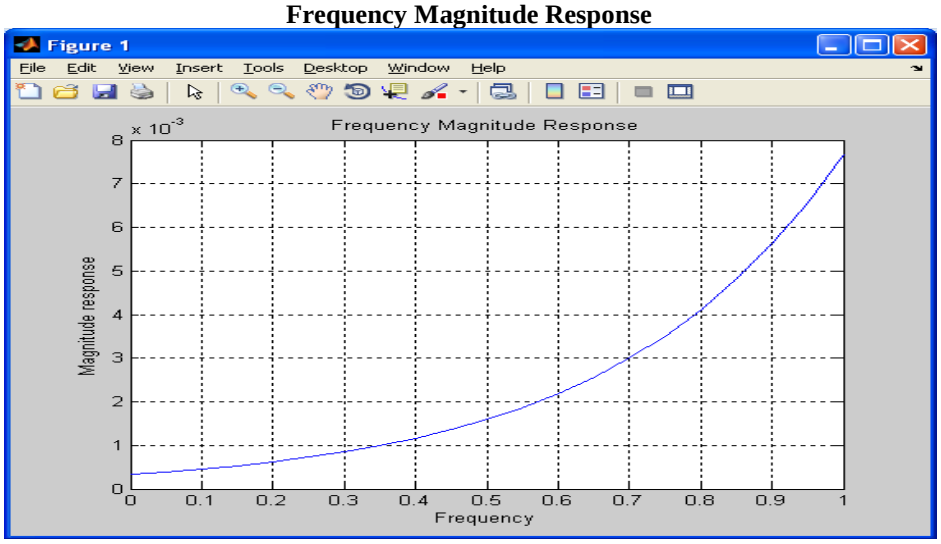
Use of GA in Design of Digital Differentiator

First of all a second order transfer function is assumed as an integrator, then absolute relative error of this integrator with respect to ideal integrator is defined as a fitness function. Initial values of coefficients were decided. A set of possible solutions (individuals) is generated randomly from within a pre-defined range, they are represented as binary strings.

Then fitness function is applied on them and on the basis of their performance a fitness value is given to each individual. The reproduction operator is used to privilege good individuals and remove bad ones. The population size has been kept constant while creating new population. Two individuals are selected on the basis of their fitness value (higher fitness value has higher chance for selection). These individuals are known as parents. In the next step, crossover and mutation processes has been applied over parents to form new individuals (children). The main idea of crossover is that the children should be better than their parents. Crossover can

Wp=pi; k=2; N=25;

Frequency Magnitude Response



Error Graph: Wp=pi; k=2; N=25;

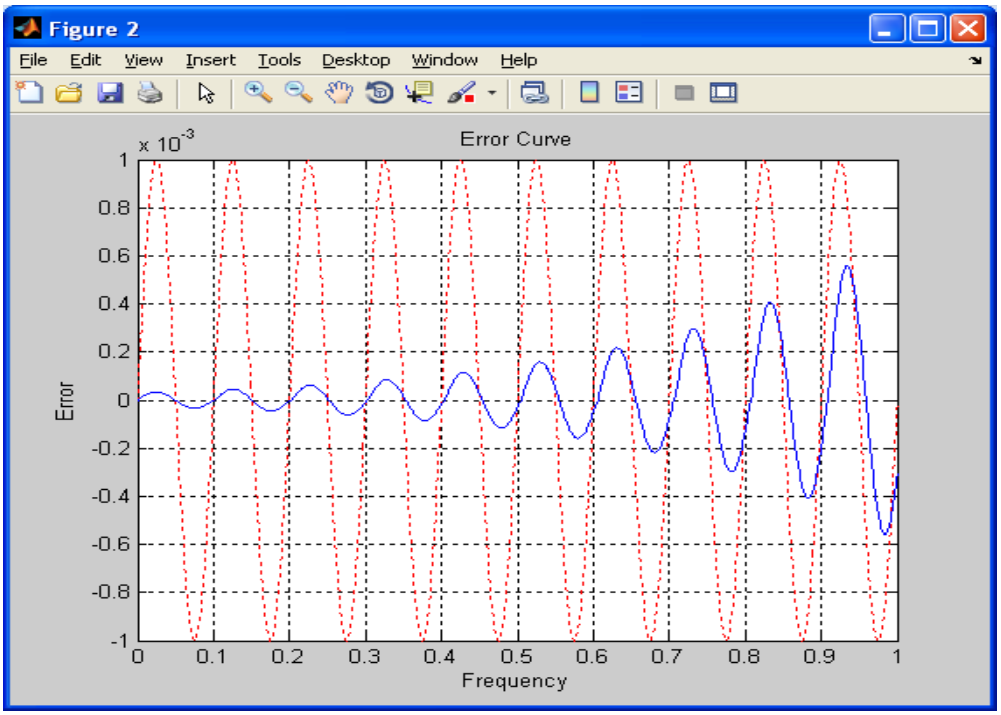


Table of Higher order digital differentiator design Examples

Differentiators	Second-order
Filter length	25
w_p: Highest	π
GA approach peak error	$0.5x10^{-3}$
McClellanParks algorithm equiripple error	$3.7x10^{-3}$

Digital Differentiator Applications In radars and sonar's, the velocity and acceleration are computed from the position measurements using differentiation. Velocity is estimated by first order differentiation and acceleration by second order. The rate of liquid flow in a tank (which may be part of a chemical plant) is estimated from the derivative of the measured liquid level. In biomedical investigations, it is often necessary to

obtain the first and higher order derivatives of the biomedical data, especially at low frequency ranges. For example in QRS complex detection in ECG.For geo-physical data processing, derivatives of the observation samples are usually needed for midband frequencies of the spectrum. Maximally flat differentiators near half Nyquist frequency are useful for this operation The derivatives at high frequencies are useful for solving the problems of image restoration and image texture enhancement (to detect various features, like an edge, for example, of an object in the picture).The use of derivatives of various signals in control engineering (in auto-follow, servomechanism, robotics, artificial eye etc.) is also well known.
Fractional dimension is used to measure some real-world data such as coastline, clouds, dust in the air, and network of neurons in the body. The fractional dimension has been applied widely to pattern recognition and classification. Fractional Order Differentiators are used to exploit such real world issues. Fractional Order Differentiators are also used in bar code readers.

CONCLUSION

In this paper we have used one of the optimization techniques to optimize the error rate that is Genetic algorithm. We have compared Genetic algorithm technique to well known McClellan Parks algorithm for second order digital differentiator of filter length twenty five. We found many applications of differentiators and mentioned in this paper. The future scope of this paper is to compare the same design optimization technique of higher order and different length to different optimization technique.

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