Biorthogonal Wavelet Filter Megafunction

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Target Applications:
Communications
Digital Signal Processing

Family: FLEX® 10K

Vendor:

FastMan compression technology

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Features

- Integrates low-pass and high-pass filters
- Parameters include coefficient precision, input and output data width
- Implements quadrature mirror filter pair
- Useful for a variety of applications including, image and audio compression, target identification in radar and imagery, seismic analysis, astronomy, acoustics, sub-band coding, magnetic resonance imaging (MRI), speech discrimination, optics, fractals, and pure mathematics such as solving partial differential equations

General Description

Wavelets are mathematical functions that decompose data signals into different frequency components so that signal characteristics can be examined at different resolutions. This solution brief discusses the advantages of wavelet filter analysis over traditional Fourier methods in analyzing discontinuities and sharp spikes in data signals. The biorthogonal wavelet filter described in this solution brief is one type of wavelet filter.

Functional Description

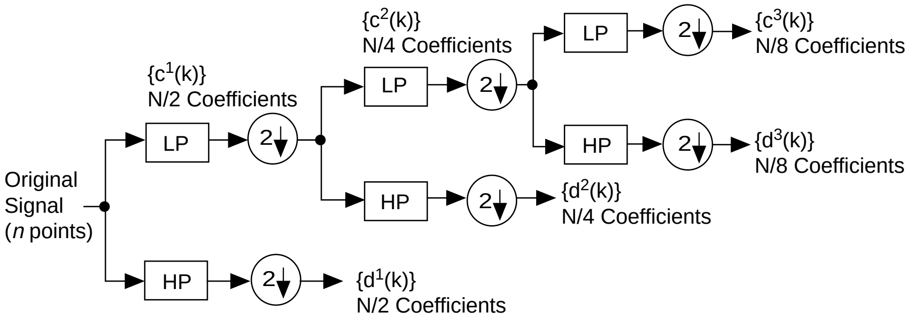
Wavelets are used to represent and approximate signals with discontinuities. Traditionally, the Fourier transform was used to analyze signals, but the sines and cosines used as the basis of Fourier analysis poorly approximate sharp spikes. Thus, wavelets are an ideal alternative.

In wavelet analysis, the scale, or resolution, that is used to look at the data signal plays an important role. In the Wavelet transform, high-resolution wavelets are used to examine the details and fast-changing characteristics of the signal, and low-resolution wavelets are used to examine the slowly varying characteristics of the signal. Wavelet approximating functions are contained neatly in finite time and frequency domains, which makes them well-suited for approximating data with sharp discontinuities.

A signal, or function, can be represented in terms of a wavelet expansion, similar to the way they are represented in terms of a Fourier expansion, and data operations can be performed using the corresponding wavelet coefficients. Techniques have been developed in which the best wavelets adapted to a data signal can be chosen, enabling the signal to be represented with a small number of coefficients. The ability to produce sparse codings for many signals makes wavelets an excellent tool for data compression.

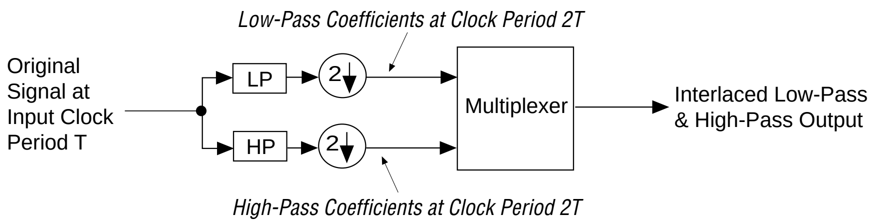
Wavelet coefficients are computed by applying multiple stages of a low-pass and high-pass filter pair, called a quadrature mirror filter pair, to the data signal. See Figure 1. At each stage (or scale) of the pyramid, the low-pass filter computes a smoother version of the signal and the high-pass filter brings out the signal's detail information at that scale. At the first stage, the filters are applied to the original, full-length signal. Then, at the next stage, the filter pair is applied to the smoothed and decimated low-pass output of the first stage. The wavelet coefficients consist of the accumulated detail components and the final smooth component.

Figure 1. Wavelet Filter Pyramid



When using wavelets for image compression, symmetric wavelet filters are more desirable because a symmetrical extension at the image edges can be used, providing less distortion and higher compression. The most common type of symmetrical wavelet filter is called a biorthogonal filter. FASTMAN has implemented a biorthogonal wavelet filter pair as a megafunction. This megafunction implements one stage of the wavelet filter pyramid. It takes an input signal at a clock frequency $\mathbf{f_0}$, computes the decimated high-pass and low-pass outputs (at clock frequencies $\mathbf{f_0}/2$), and then interleaves them to produce a single output containing alternating low-pass and high-pass coefficients. The megafunction uses the same biorthogonal wavelet coefficients used in the FBI's WSQ fingerprint algorithm, which is very effective for image compression. See Figure 2.

Figure 2. FASTMAN Biorthogonal Wavelet Filter Megafunction



FASTMAN can implement a variety of other wavelet filters through a custom design program. Controller megafunctions, which work in conjunction with the wavelet filter megafunction, are also available. Together, controller and wavelet filter megafunctions implement the pyramid algorithm and wavelet packet algorithms.

Table 1 lists typical device utilization of the FASTMAN biorthogonal wavelet filter megafunction.

Table 1. Typical Device Utilization

Implementation	Device Family	f_{MAX}	Logic Cells	EABs
12-bit coefficient precision 16-bit data width	EPF10K50-4	68 MHz	1,776	0

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