

# Multirate Filter Design System



## Momentum Data Systems

**The Multirate Filter Design System uses multirate signal processing techniques to design a variety of FIR filters and makes this highly specialized and time-consuming filter design technique readily available to the DSP engineer.**

Multirate Signal Processing consists of using different sample rates within a system to achieve computational efficiencies that are impossible to obtain with a system that operates on a single fixed sample rate.

Sampling frequency	50 KHz
Passband cutoff frequency	800 Hz
Stopband cutoff frequency	1 KHz
Maximum passband attenuation	1 dB
Minimum stopband attenuation	60 dB

As an example, consider the following lowpass filter:

The filter implemented as a standard Parks-McClellan algorithm design requires 681 taps or 681 multiplies and add combinations. However, if the sampling rate were changed to 2500 Hz, the filter would require only 35 multiply and add combinations. This leads to the concept of changing the sampling rates downward (decimation) to a lower sampling rate then filtering the signal and then changing the sampling rate upward (interpolation) to the original sampling rate.

Reducing the sampling rate by a factor of N is achieved by discarding every N-1 samples or equivalently keeping every Nth samples. However, to avoid aliasing of frequencies above the passband into the passband requires lowpass filtering the incoming signal prior to discarding every N-1 samples. On first glance, this appears to have not achieved any computational gain. However, samples which are discarded are effectively zero valued samples. Thus it should be possible to design the lowpass filter such that only the retained sample values take part in the calculation.

The filter running at the low data rate is achieved by embedding the downsampling into the filter and using an implementation structure called a polyphase filter.

To change the sampling rate back to the original system rate (interpolation by factor N), N-1 zeros are inserted into the output stream after every sample from the downsample filtering processes. However, to prevent imaging in the frequency band above the lowpass cutoff frequency, a second filter is required on the final output sequence. Again, this would appear to disallow any computational gain in efficiency since this output filter would have to run at the original sampling frequency. Zero valued samples clearly do not need to take part in the multiply accumulate operations of the filter. Thus the output filter is embedded in the interpolation process and a polyphase filter is used to simultaneously achieve the interpolation by a factor N and the anti-imaging output filter but running at the low data rate

Thus to design a multirate narrowband lowpass FIR filter, the time invariant classic FIR filter is replaced with a lowpass antialiasing filter and decimator followed by an interpolator and lowpass anti-imaging filter. The decimator and interpolator make the equivalent multirate system a time varying but still linear phase filter.

Returning to our example, a computational gain in efficiency of 25 to 1 is possible in a practical sense for this example. As the passband edge approaches zero for a fixed sampling frequency, the computational efficiency gain approaches infinity.

**The Multirate Filter Design system provides fully automated design of multi-stage polyphase filters. This eliminates the tedious and difficult process of specifying and computing a multi-stage multirate filter design.**

**Constructing a multi-stage polyphase filter manually is a time-consuming process with a high risk of error. The system provides complete C Code generation for all supported filter types, thus making the implementation of the filter a relatively simple task.**

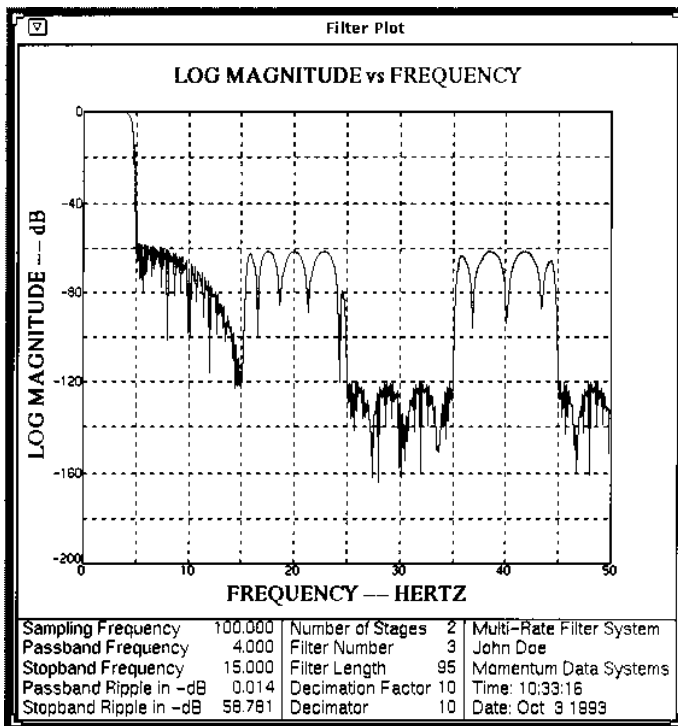
**This filter can be imported directly into DSPworks for filtering any desired signals.**

### System Features

- Analysis of possible decimation factors
- Suggested decimation factor
- Prime number analysis of decimation factor
- Analysis of multistage options for each decimation factor
- Automatic generation of all filter specifications
- Automatically calls Parks-McClellan algorithm for each filter design
- Designs:
  - narrow passband lowpass filters*
  - wideband lowpass filters*
  - wideband highpass filters*
  - narrow passband bandpass filters*
  - narrow band highpass filters*
- C Code generation for all filter types with multi-stage polyphase filters
- Calculates computational efficiency gain
- Significant time savings in the design of multirate filters
- Displays all filter responses including composite response

### Design Methods

Parks-McClellan Rectangular Window  
Triangular Window  
3 Term Cosine with Continuous 3rd Derivative Window  
Hamming Window  
4 Term Cosine with Continuous 5th Derivative  
Blackman Window  
Exact Blackman Window  
3 Term Cosine Window Hanning Window  
Minimum 3 Term Cosine Window  
4 Term Cosine Window Taylor Window  
Minimum 4 Term Cosine Window  
Gaussian Window  
Harris Flat Top Window  
Good 4 Term Blackman Harris Window  
Kaiser Window  
Dolph-Tschebyscheff Window



Example of the Composite Response of a Multirate Filter

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