Multi-Stage, Multi-Rate Filters

Extending the Range Of Digital Filter Cutoff Frequencies

LeCroy's Digital Filter Package (DFP) option allows users to select any of 7 standard types as well as define a custom filter and apply the filter to measured data. A range of pass band limits and rolloff widths can be specified for the filters which are implemented as digital finite impulse response (FIR) filters. The range of band edge frequencies is a function of the scopes effective sampling rate. Using the four available math traces it is possible to implement multi-stage, multi-rate filters to extend the range of the DFP package filter limits.

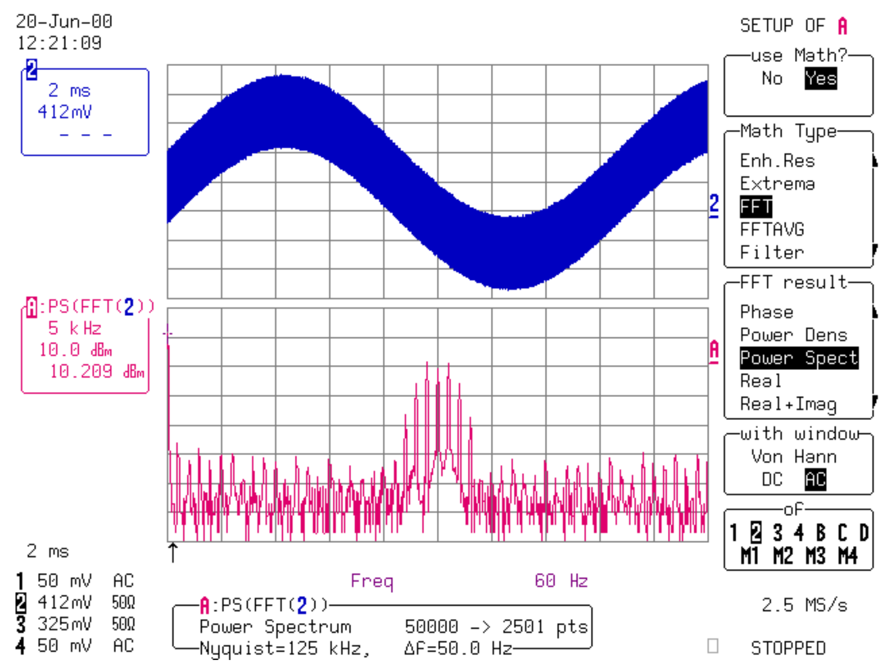

Figure 1– Separating the 60 Hz component from a 25 kHz pulse width modulated waveform requires a high pass filter

Consider the application shown in figure 1. This type of signal is common in switching power supply measurements. The measured waveform contains a 25 kHz pulse width modulated signal riding on top of a 60 Hz sinusoidal waveform. Removal of the 60 Hz component requires a high pass filter with a pass band edge above 60 Hz. This type of filter can be implemented in the DFP option with a lower cutoff frequency limited to 1% of the sampling frequency or 25kHz. In order to lower this cutoff frequency to a more useable value, the effective sampling rate must be reduced. There are two ways to accomplish this. The first is to reduce the length of the acquisition memory. The second is to decimate the data using the identity function. Reducing the sampling rate increases the possibility of aliasing the data, especially using harmonic rich signals like this one. To limit the possibility of aliasing, the data can be sampled at a high rate to prevent aliasing then low pass filtered, using a digital filter, before decimation. This combination of filtering and decimation prior to performing another filtering operation on the data is called 'multi-stage, multi-rate' digital filtering. It offers the ability to reduce the effective sampling rate with a minimum risk of aliasing.

The multi-stage, multi-rate filter implementation of this example is shown in figure 2. The upper trace is the acquired waveform sampled at 2.5 MS/s. The goal is to reduce the sample rate by 10:1. This is accomplished by first low pass filtering the acquired data with a bandwidth of less than 1/2 the desired effective sampling rate of 250 kS/s.

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Trace A is signal after being low pass filtered with a bandwidth of 125 kHz. Trace B is the identity function. This math function is used to decimate waveform data. The decimation ratio is set by the menu entry "for math use max points n ". This can be accessed via the Math Setup menu. In this example the maximum number of points for math operations is set to 5000. This is one tenth of the acquisition memory length of 50,000 samples. The resultant decimation is 10:1 and the effective sample rate is 250 kS/s.

Trace C is the set up for the high pass filter. With an effective sampling rate of 250 kS/s the lower limit for the cutoff frequency is now 2.5 kHz. Note that the 60 Hz component has been reduced significantly by the filtering process.

A comparison of the input and output frequency spectra in figure 3 reveals the significant reduction in the 60 Hz component on the left side of the upper trace. The spectra are computed using a fast Fourier transform (FFT) and displayed with a frequency scale of 5 kHz/division horizontally and 10 dB/division vertically. Note that the high pass filtering operation does not affect the spectral components above 2.5 kHz.

Multi-stage, multi-rate filtering provides a technique for increasing the useable range of the digital filters in the DFP option package. It allows more effective use of the acquisition memory in reducing aliasing.

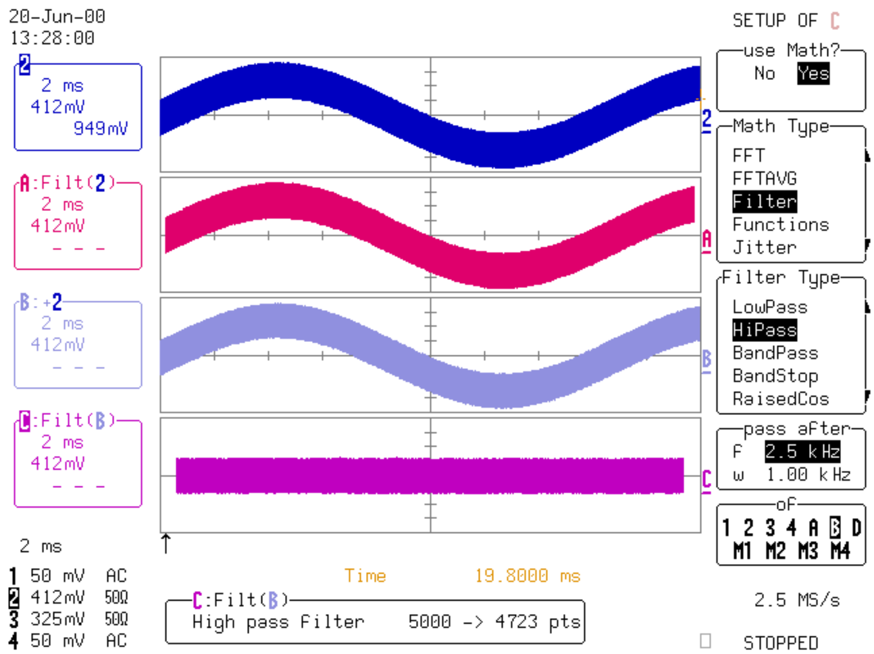

Figure 2 The series of math operation used to implement a multi-stage, multi-rate digital filter

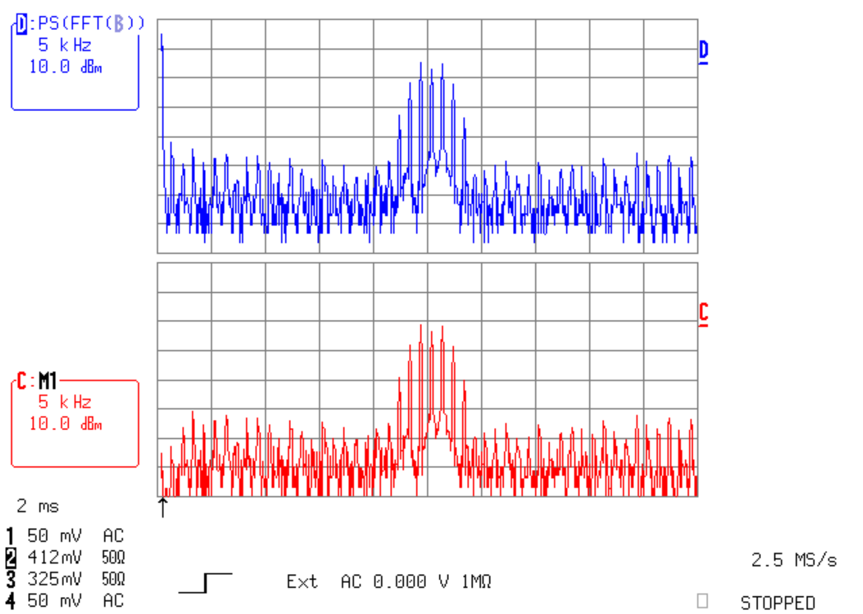

Figure 3 - Comparison of the input and output spectra with a reduction of the 60 Hz component in the lower (output) trace