

ERES vs. Boxcar Averaging

Examining the Differences Between Filtering Techniques

Boxcar averaging has, historically, been the method of choice for smoothing transient waveforms. LeCroy introduced enhanced resolution (ERES) as an option over ten years ago. Both techniques use digital filtering to improve signal to noise ratio and both methods are available in LeCroy X-Stream™ oscilloscopes. The purpose of this application brief is to look at the differences in these two

smoothing techniques.

Boxcar averaging adds N adjacent samples, divides the sum by N, and then writes that value into the Nth sample location. This technique is basically a finite impulse response (FIR) digital filter of N taps with uniform weighting.

ERES also processes N samples, but the sample values are weighted to produce a finite

impulse response (FIR) filter with a more desirable low pass frequency response. The principal advantage of the ERES technique is that it produces a frequency response which is Gaussian; it has no side lobes in the frequency domain and it never causes overshoot or undershoot or ringing in the time domain. Figure 1 shows a comparison of the two filtering techniques based on the analysis of an impulse function. The

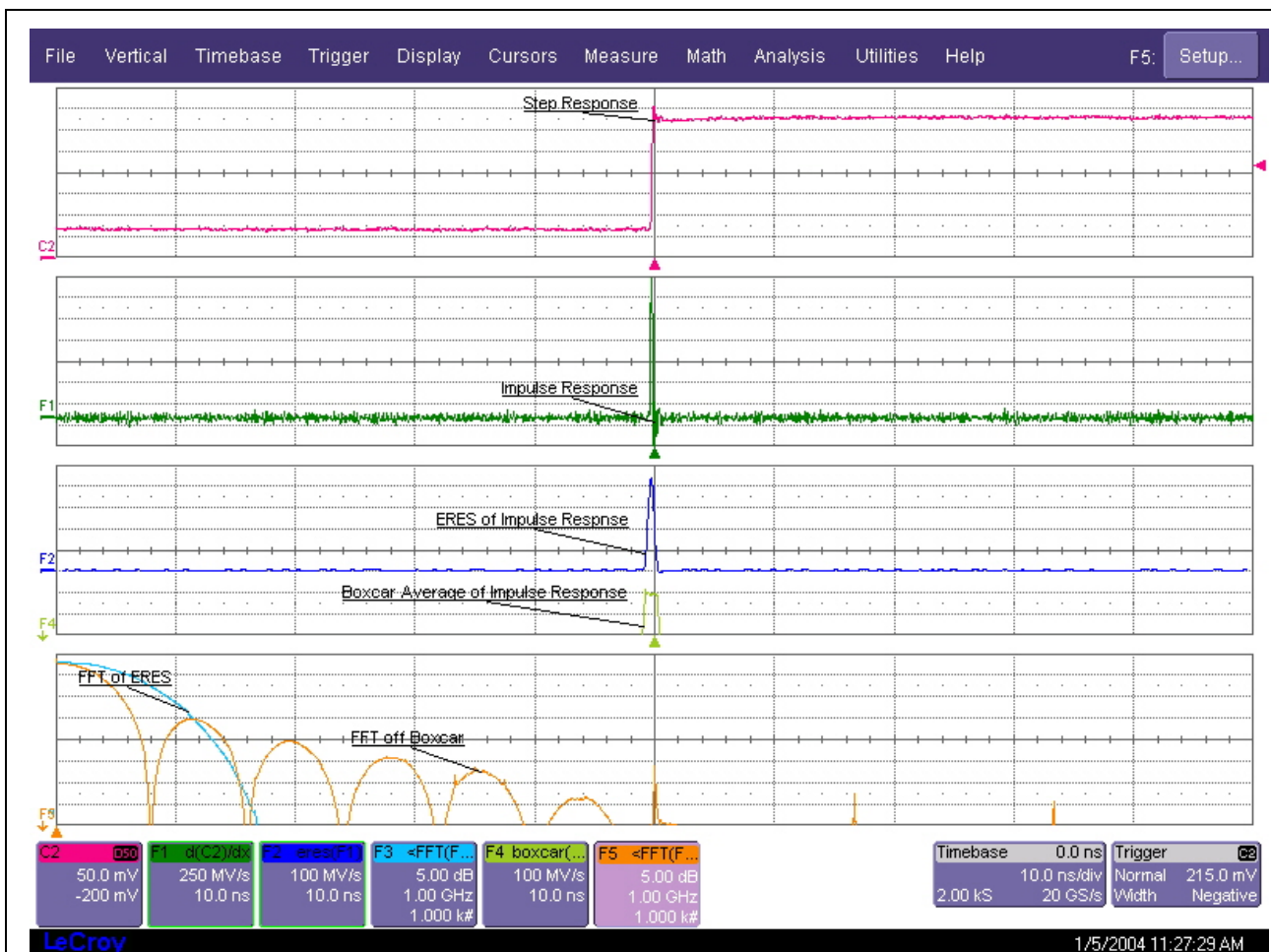


Figure 1 Comparing the impulse responses of ERES and Boxcar averaging

top trace in the figure shows an applied step function with a transition time of 32 ps. This signal was differentiated to obtain the impulse response shown in trace F1. The impulse was applied to both the ERES and Boxcar math functions. Both functions have been set to process the same number of samples (25). Traces F2 and F4 show the time responses of the ERES and Boxcar filters. The Boxcar filter shows uniform amplitude over 25 adjacent samples. The ERES waveform has weighted the samples to produce a Gaussian waveshape more closely resembling the input waveform.

The bottom grid contains the FFT of both the ERES and Boxcar waveforms. Note that the ERES response is a monotonic Gaussian response while the Boxcar response exhibits a classic $\text{Sin}(x)/x$ response. This is understandable since the rectangular time response of the Boxcar filter results in a $\text{sin}(x)/x$ frequency domain response. Similarly, the Gaussian time domain response of the ERES filter maps into a Gaussian frequency response.

This result implies that the ERES response will provide significantly better signal fidelity compared to the boxcar response for equivalent settings. The principle advantage of the Boxcar filtering is that it can be implemented for anywhere from 2-50 taps while the ERES filter is limited to six sample lengths (2, 5, 11, 25, 52, and 106 taps)

corresponding to resolution enhancements of 0.5, 1, 1.5, 2, 2.5, and 3 bits.

Another advantage of boxcar averaging is that in times when processing power in test instruments was limited this method provided a simple computation for smoothing waveforms and attaining higher vertical resolution. But newer instruments with more processing power can apply ERES to obtain the same gains with much less signal degradation. The ultimate tool for signal filtering is LeCroy's DFP2 package which can make optimally flat FIR low pass filters, with user specified allowed ripple, stopband attenuation and transition width, or digital approximations of classic IIR filters, or arbitrary user-defined filters of either type.