Correlation Measurements

Signal Detection And Propagation Studies Using Correlation

LeCroy oscilloscopes incorporate both auto and cross correlation to help analyze non-linear effects in partial read maximum likelihood (PRML) disk drives using the optional 93XX-PRML analysis package. Both functions are powerful general purpose signal processing tools that can also be applied to a variety of other electronic measurements.

A major use of cross correlation is the detection of signals buried in noise. Typical applications involve radar, sonar, ultrasound imaging, and other reflective ranging techniques. The waveshape of the signal is generally known and the problem is to detect the presence and location of the return echo even though it is not visible inside the noise envelope. The top trace in figure 1 is a simulated ultrasound application. The transmitted and return signal are contained in the waveform which has a very low signal to noise ratio. A copy of the transmitted pulse, shown in trace 3 in figure 1, is used as a reference waveform. The reference is cross correlated with the waveform in trace 2, as shown in trace A. This waveform is further enhanced by averaging in trace B. The existence and location of the return echo is easily determined in the lower trace even though it was invisible in the original signal.

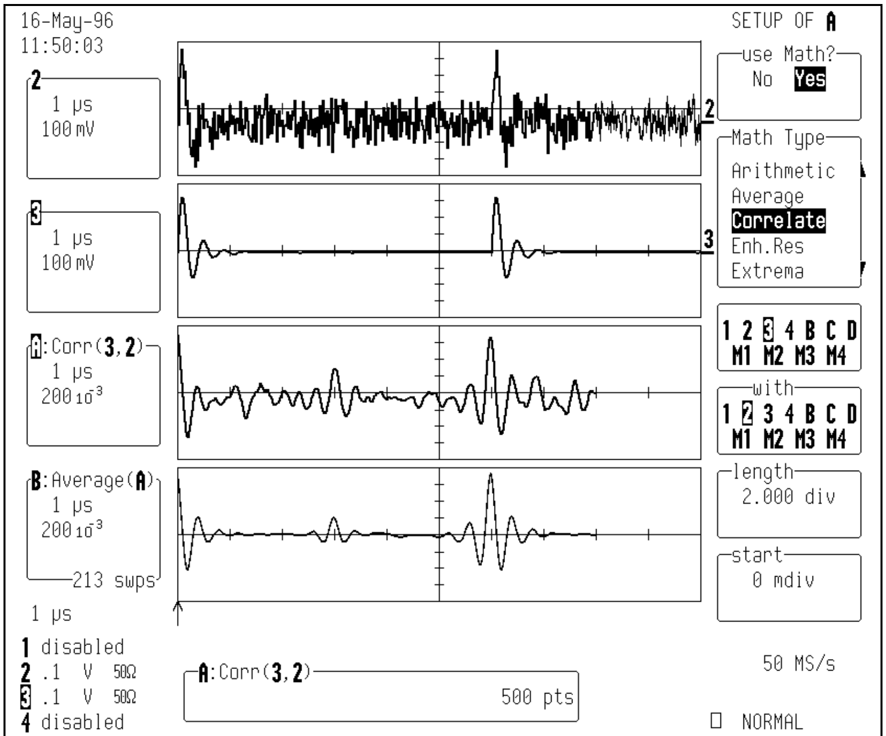

Figure 1-Cross correlation used to detect a signal buried in noise

The correlation process incrementally slides the reference waveform over the signal being processed looking for a matching signal. Signals that are not related to the reference waveform result in a correlation value of 0. If a matching signal is found the correlation value increases to a maximum value of 1 for a perfect match and -1 for a matching but inverted waveform. The correlation function for each time delay is plotted vs. the time delay to form the correlation function as shown in trace A.

While averaging can be used to extract a signal from random noise, correlation can detect a signal in the presence of a deterministic signal such as a sinusoid. In figure 2 a 10 MHz sine wave has been added to the ultrasound pulse. As in the previous example trace A contains the cross correlation of traces 2 and 3. It clearly shows the location of the echo. Trace B is now displaying the summed average of trace 2. Note that the interfering sine wave is not attenuated by the averaging process and is unable to extract the echo from the input signal.

This application is an excellent example of the power of the correlation function to detect signals which have suffered severe degradation. The correlation function can also be used to characterize signal propagation paths and provide information on path delay.

Figure 3 shows a simple example of using correlation to determine the propagation delay of a pulse. The 10.4 ns delay between the pulses acquired in channels 3 and 2 corresponds to the peak of the cross correlation function. In more complex studies multiple correlation measurements can be used to locate signal sources or to track down reflection paths even in the presence of interfering signals. This type of measurement is commonly used in acoustic and seismic studies.

Correlation is but one of many advanced signal processing tools available in LeCroy oscilloscopes.

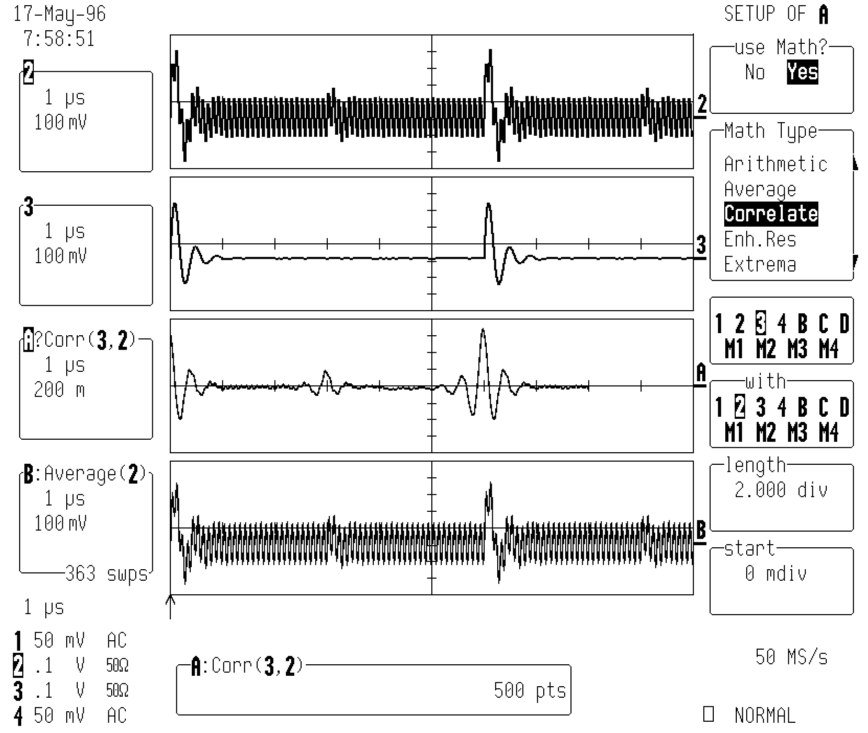

Figure 2 Cross correlation detects echo in interfering sine wave

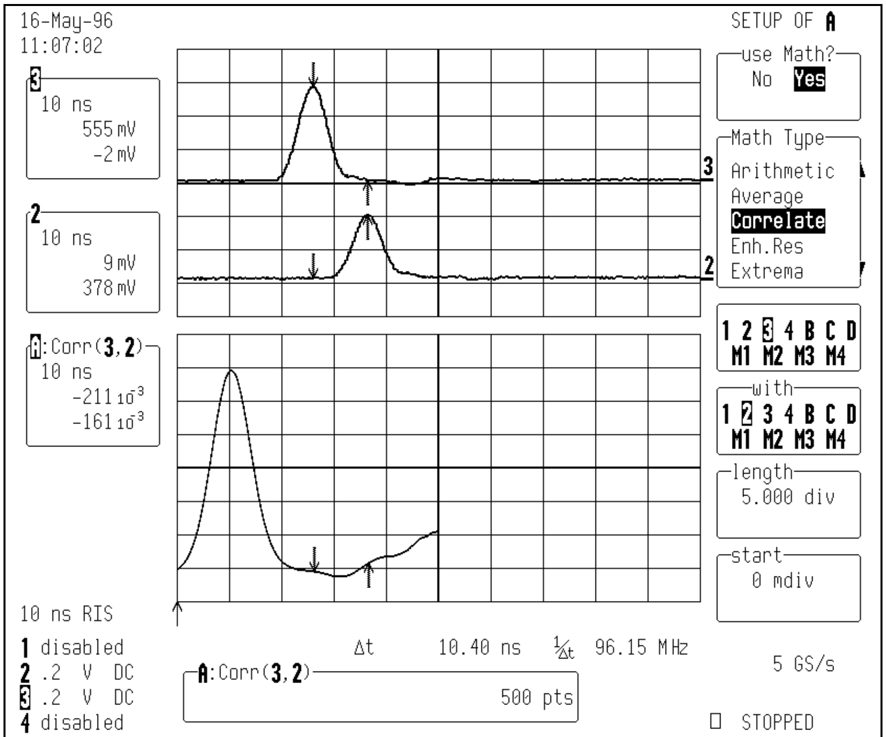

Figure 3 - Using cross correlation to determine propagation delay