# Using Long Fast Fourier Transforms

TECHNICAL BRIEF

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The Fast Fourier Transform (FFT) has become a standard feature on most modern oscilloscopes. It permits oscilloscope users to view the frequency spectrum of a signal as well as the time domain trace. This provides a useful, alternative view of the acquired data.

As oscilloscope memory depth has increased the use of the FFT has generally been confined to short records due to the long processing time. This limitation has been eliminated in LeCroy's WavePro 700Zi series oscilloscopes. In these scopes a 128 Mpoint FFT can be computed in less than 25 seconds. This allows long FFT's to be applied in cases where good frequency resolution and long time records are required.

Figure 1 shows an example of a spectral measurement of a 500 Hz frequency modulated carrier using a LeCroy WavePro 760Zi. The timebase setup shows that 6.4 ms of data has been acquired at a sampling rate of 20 GS/s. The sampling rate of the oscilloscope determines the span of the FFT which in this case is 10 GHz. The span has to exceed the carrier frequency in order to be able to see the spectral components of the carrier and its harmonics.

**Figure 1 Spectral analysis of a 500 MHz frequency modulated carrier using a 128Mpoint FFT for good resolution bandwidth.**

The acquisition time determines the resolution bandwidth of the transform. In this case the resolution bandwidth is 149 Hz. The resolution bandwidth determines the frequency resolution of the FFT spectrum. Long FFT's allow the scope to provide spectral analysis with resolution bandwidths much better than conventional RF spectrum analyzers. Figure 2 shows an expanded view of the FFT setup including the FFT Algorithm, transform size, span, and resolution bandwidth.

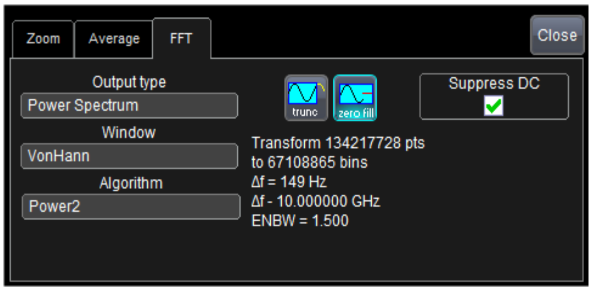


**Figure 2 The FFT Setup showing the transform size, span, and resolution bandwidth (Δf)**

Since the FFT computation time is only about 25 seconds it was possible to average the FFT without a terrible time penalty. In Figure 1 the FFT over the full span is shown in function trace F1 (yellow). Since the carrier is non-sinusoidal we can see the harmonic structure up to the scope's bandwidth of 6 GHz

Two zooms are also shown the first in trace F2 (red) shows the spectral structure near the fundamental carrier frequency of 500 MHz. The modulation waveform is also a square wave and you can see the images due to the harmonics in the modulation.

Trace F3 (blue) is another zoom showing the spectral line at the carrier frequency, the horizontal scale on this zoom is 200 kHz/division and it shows the FM deviation of the carrier. The modulation effects can be clearly studied due to the excellent resolution bandwidth of the FFT analysis.

The previous example has used FFT's of a long acquisition in order to obtain the good resolution in the frequency domain. Long acquisitions can also be used to study low frequency phenomena. Jitter studies frequently require looking at the spectral content of timing jitter. The longer the acquisition or capture time the lower the frequency that can be detected. Figure 3 shows an example of this type of measurement. Again, a 128 Mpoint record has been acquired in channel 3 (blue). In this case the Time Interval Error or TIE has been measured. Function trace F1 (yellow) is the track of TIE. The track function is a time synchronous plot of the value of TIE displayed on the same horizontal axis as the source trace. This shows us the time variation of the TIE measurement. Trace F3 (blue) is a zoom of the TIE track. It shows the periodic variation due to the frequency modulation of the trace. This occurs at the modulation rate of  1 MHz. In addition to this component the TIE track shows a one cycle variation over the capture time as well as some higher frequency variation. Trace F2 (red) is the FFT of the TIE track. It has been expanded horizontally to show the low frequency components in the jitter spectrum. The must notable spectral components occur at 9 kHz and its harmonics. This component is not really noticeable in the track function. There is also a very low frequency function at around 150 Hz which is the peak at the extreme left of the FFT. As you can see the FFT is useful for understanding the jitter components. If the FFT were only capable of handling 3Mpoints the lowest frequency we could detect would be about 6.7 kHz without dropping the sampling rate and losing timing resolution for the jitter measurement.

**Figure 3 Investigating low frequency jitter component**

LeCroy's WavePro 700Zi series scopes are able to handle 128 Mpoint FFT's due to the proprietary X-Stream II streaming architecture augmented with an Intel Core□ 2 Quad 2.5 GHz processor, 8 GB of processor RAM and a 64 bit operating system. Figure 4 shows the CPU and memory usage in a WavePro 760Zi while performing a 128Mpoint FFT. Only 5.6 GB of the 8 GB processing memory is being used.

The WavePro 700Zi series should certainly be considered as the next oscilloscope to meet your measurement needs.

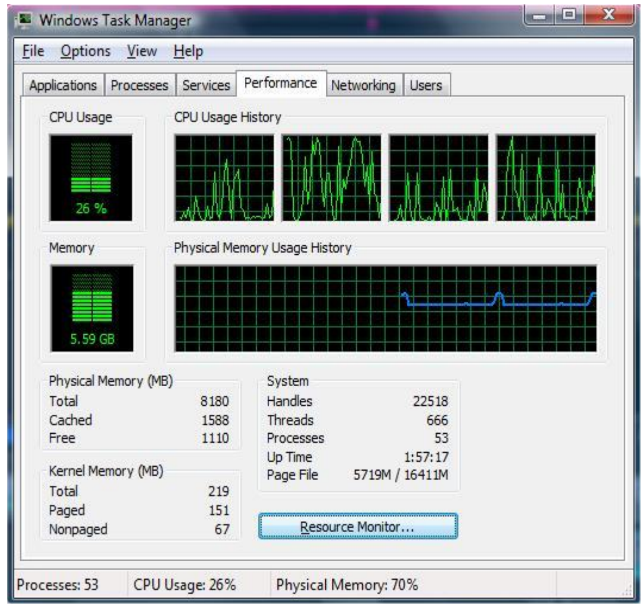


**Figure 4 CPU and memory usage for a 128 Mpoint FFT**