Setting Up An FFT In WaveMaster

A Logical Approach To Setting Up The FFT Function

The Fast Fourier Transform (FFT) converts time domain waveforms, acquired in an oscilloscope, into frequency domain spectra. This allows the oscilloscope to provide the same kind of information normally supplied by an RF spectrum analyzer.

The LeCroy WaveMaster™ Series oscilloscopes offer the most flexible FFT available in any oscilloscope. The user has the choice of least prime factor or power of 2 FFT, a selection of 5 weighting windows, true frequency domain averaging of both real and imaginary components and, the ability to truncate or zero-fill the source data. All of these are in addition to a computationally efficient floating point FFT, which maximizes amplitude dynamic range.

Where the RF spectrum analyzer has controls for span and resolution bandwidth, FFT span (Nyquist frequency) in the WaveMaster is related to the sampling rate, and the resolution bandwidth (Δf) is inversely proportional to the record length. Below, we will explain how to use these settings to control the FFT. These basic relationships for the FFT are illustrated in figures 1 and 2.

A logical approach to setting up an FFT starts at setting the frequency resolution, Δf. This parameter is the spacing of samples in the frequency domain display and is similar to the resolution bandwidth setting in an RF spectrum analyzer. The Δf is set by the time duration of the time domain signal being input to the FFT. If an acquisition channel (channel 1 - 4)

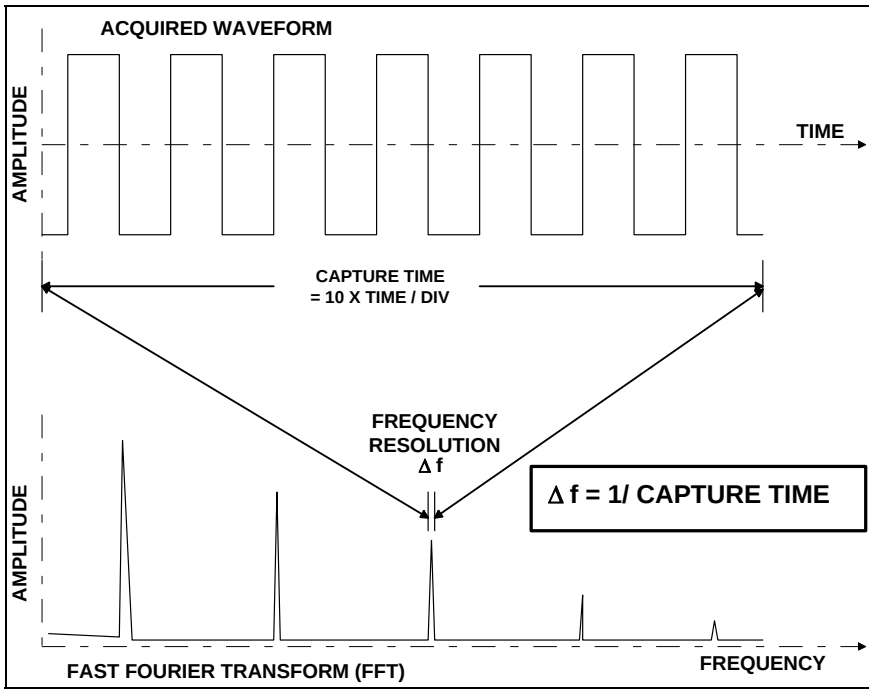

Figure 1 Capture time determines the frequency resolution, Δf

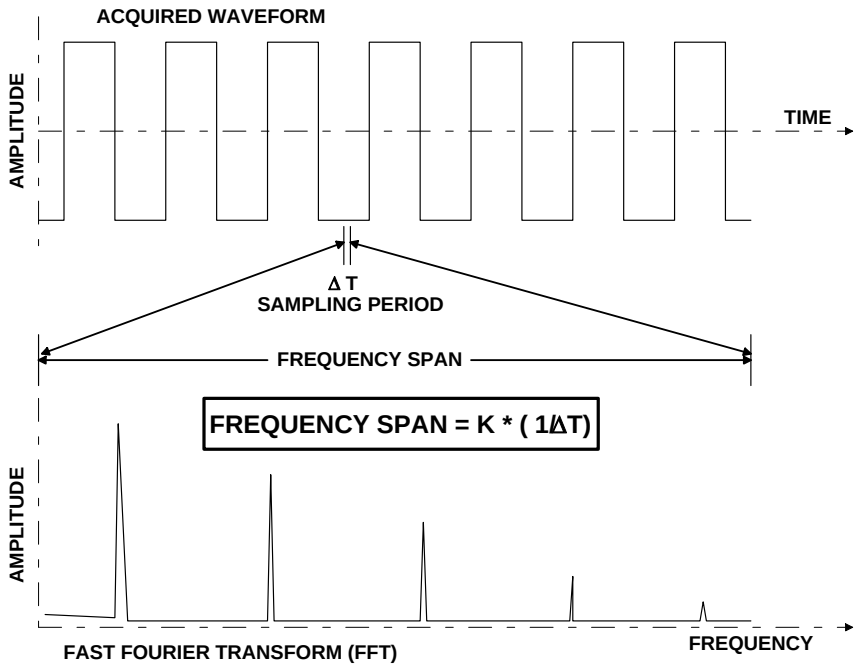

Figure 2 - The Span of the FFT is related to the sampling rate, 1/ΔT.

Figure 3- Setting up the resolution bandwidth and span of the FFT in a WaveMaster WM8500

is the source, the waveform duration is the capture time, which is ten times the TIME/DIV setting. The relationship between capture time and frequency resolution is illustrated in figure 1.

If the source waveform is a zoom trace, then the frequency resolution is, similarly, the reciprocal of the displayed zoom waveform's duration.

The frequency span of the FFT is called the Nyquist frequency and is one half of the effective sampling frequency of the time domain waveform. WaveMasters will generally default to the highest sampling rate and therefore the longest span. In figure 3, the sampling rate is 20 GS/s. The FFT, setup in trace F2 shows a span of 10 GHz (1 GHz / division times ten divisions). If you want to decrease the span the easiest way is to use zoom. This is illustrated in figure 3, where trace F3 is a zoom expansion of the FFT in trace F1. The zoom trace has a horizontal scaling of 20 MHz/division and it is centered about a spectral peak at 2.4378 GHz marked by the cross shaped cursor. The cursor horizontal readout is below the oscilloscope display and reads, "X1=2.4378 GHz". The resolution bandwidth , set by the capture time of 10 µs, is 100 kHz and remains constant regardless of the use of zoom to expand the FFT trace.

The span can also be reduced by using less acquisition memory or by using the math sparsing function. Both of these actions lower the effective sampling rate.

Let's take a look at some of the other features of the WaveMaster's FFT capabilities:

Like most FFT's, the WaveMaster offers a selection of several weighting Window functions. If you think of the FFT as synthesizing a bank of parallel bandpass filters, then the weighting windows control the shape of the filter frequency response. They effectively multiply the resolution bandwidth by a fixed factor, called the effective noise bandwidth (ENBW). Weighting functions help reduce the effects caused by performing FFT's on finite length records. They control sidelobe amplitudes and minimize scallop or 'picket fence' effect. All of these characteristics are summarized in figure 4.

FFT Window Filter Parameters				
Window Type	Highest Side Lobe (dB)	Scallop Loss (dB)	ENBW (bins)	Coherent Gain (dB)
Rectangular	–13	3.92	1.0	0.0
von Hann	–32	1.42	1.5	–6.02
Hamming	–43	1.78	1.37	–5.35
Flat Top	–44	0.01	2.96	–11.05
Blackman-Harris	–67	1.13	1.71	–7.53

Figure 4 - Characteristics of FFT weighting functions

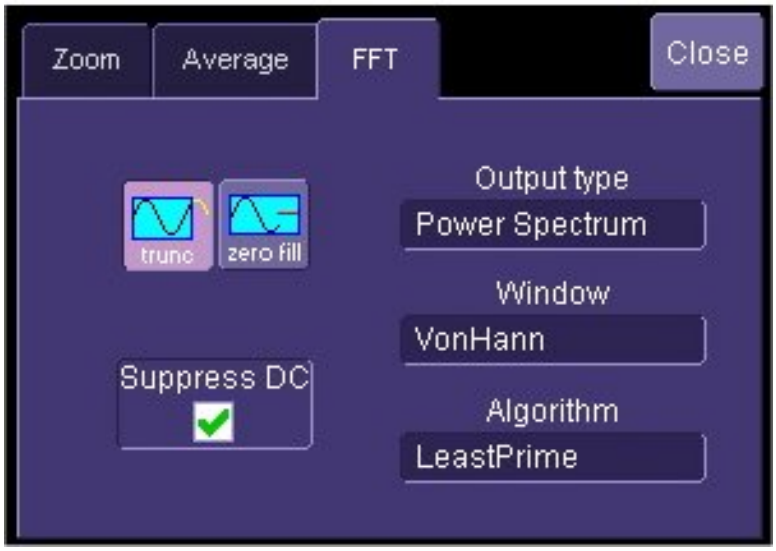

Figure 5 The FFT setup dialog box

Figure 5 shows the FFT setup dialog box. The Suppress DC checkbox allows the user to exclude the DC point (0 Hz) from the FFT display. This is useful if the data has a large DC offset. A feature, unique to the WaveMaster, is the choice of FFT algorithms. The default algorithm is a least primes algorithm that computes FFT's on transform sizes that have lengths that can be expressed as factors of 2^N*5^K. This is very compatible with the record lengths encountered in the oscilloscope, which are often multiples of 1,2, 4, 5, or 10. The other choice is a power of two algorithm where the record lengths are in the form of 2^N. The power of 2 algorithm generally runs faster than the least primes algorithm. The price that is paid is a record length which is not the same as the acquired signal. The power-of-two FFT uses the first 2^N points of the record. If you acquire 500 points in your trace the power-of-two FFT would only use the first 256 points.

The last feature is the user-selected choice of how to handle FFT transform sizes that don't match the record length. Users can select to truncate the record and perform an FFT on the shorter record. This will increase the resolution bandwidth. Alternatively, the user can select zero-fill.

Zero-fill is useful when the source data for the FFT comes from a math operation that shortens the record. This is commonly encountered in filtering operations like enhanced resolution. The missing data points are replaced by added data values, whose amplitudes are interpolated to fit between the last data point and the first data point in the record. This guarantees that there is not a first order discontinuity in the filled data. Since the data at the end of the record is 'filled' data, it is advisable to select a weighting window other than rectangular to minimize the effect of the fill on the resulting spectrum.

These enhanced features make the WaveMaster the best choice for waveshape analysis in the frequency, time, or statistical domains.