Application Note No. L.A.B. 714

Setting Up FFT Span And Resolution

A Logical Approach To Setting Up The FFT Function

LeCroy's 93XX-WP02 FFT Processing option adds the power of frequency domain analysis to the 9300 series oscilloscopes. The FFT converts a time domain waveform into frequency domain spectrum similar to the display of an RF spectrum analyzer. Although the output displays are similar the operation of the FFT and an RF spectrum analyzer are very different.

Where as the RF spectrum analyzer has controls for span and resolution bandwidth, FFT span (Nyquist frequency) 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.

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) is the

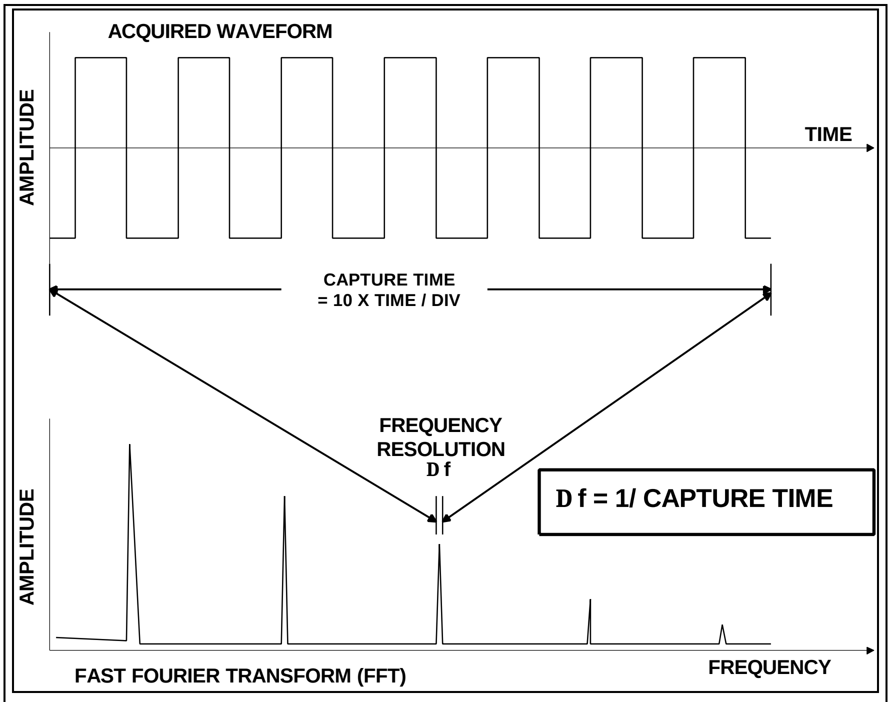

Figure 1- Capture time determines the frequency resolution, Df

source then the waveform duration is the capture time, which is the 10 X 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 waveform's duration.

The frequency span of the FFT is called the Nyquist frequency and is related to the sampling frequency of the time domain waveform. If the math memory size, set using the FOR MATH USE MAX POINTS menu field, is identical to the number of samples in the acquired waveform, set in the TIMEBASE menu, then the span is one-half of the sampling frequency, hence the name Nyquist frequency. If the max points for math is less than the number of points in the acquired waveform then the waveform is decimated and the FFT span is reduced by the same ratio. Figure 2 shows this relationship between the span of the FFT and the sampling rate ($1/\Delta T$).

The constant K includes the decimation factor described previously as well as automatic display scaling factors. The display scaling is required to make sure that the horizontal display scale of the FFT falls into a 1,2, or 5 factor.

In essence the oscilloscope automatically adjusts the span (and hence the FFT transform size) to account for the user entered max points for math and the display scaling. In some combinations of these factors it also adjusts the length of the displayed trace. The user can determine the span by looking at the trace label for the math trace which contains the FFT. It shows the horizontal calibration in MHz/DIV . The span is also explicitly shown as the Nyquist frequency in the information box that appears when the math setup menu, as shown in figure 3, is displayed.

To achieve a desired span the user should first make sure that the sampling rate is greater than twice the span. The sampling rate is controlled by the TIME/DIV knob and the acquisition memory length setting in the TIMEBASE menu. If the sampling rate is too high it can

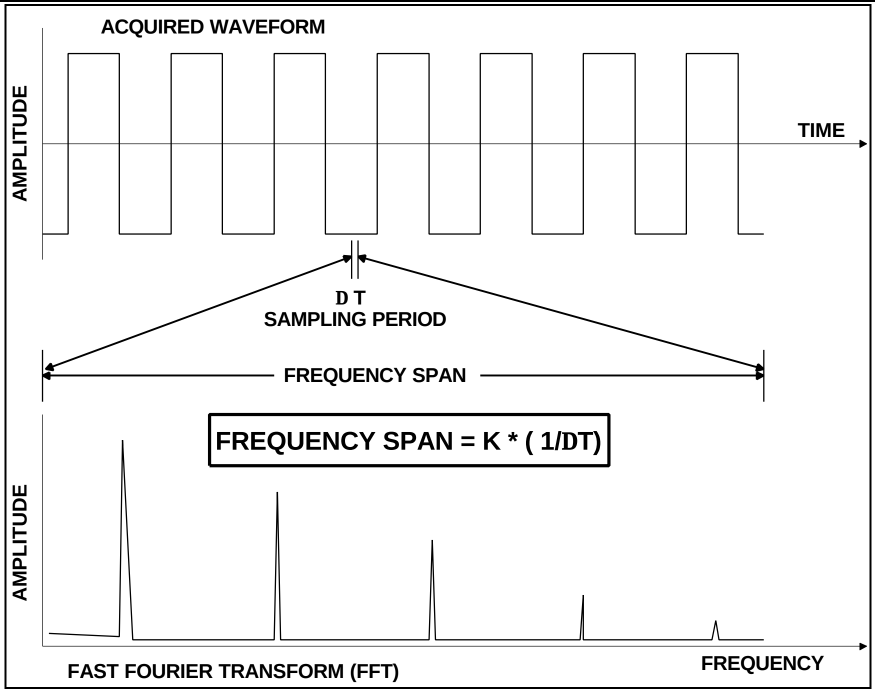

Figure 2 - The Span of the FFT is related to the sampling rate, 1/DT.

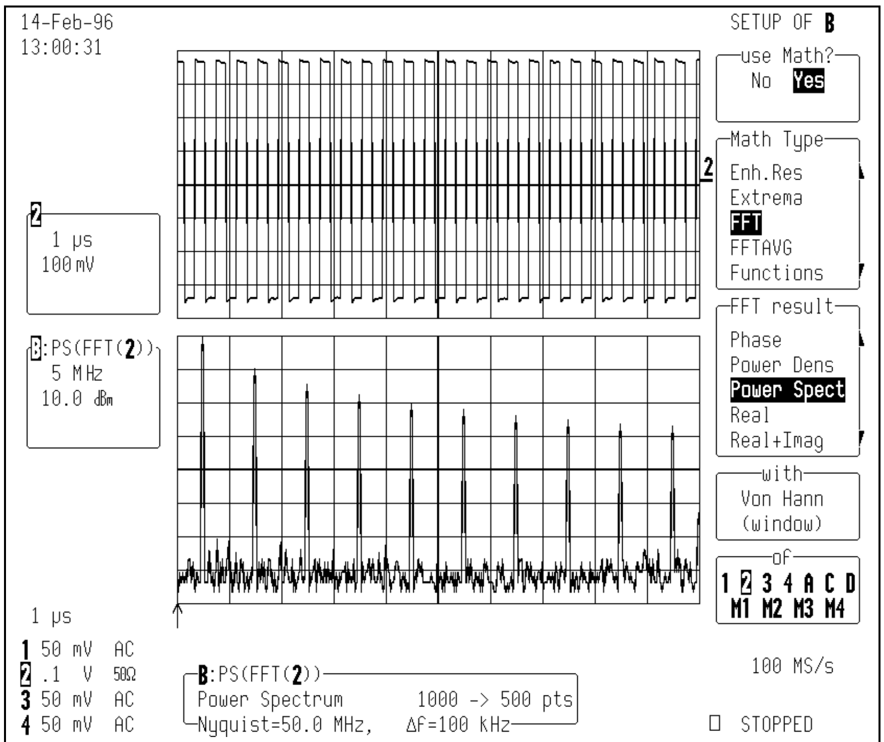

Figure 3 - The math setup menu for the FFT showing the information box which includes the Nyquist frequency (Span) and frequency resolution (Df).

be reduced by limiting the Max. Number Of Points For Math, found in the MATH+ZOOM menu. Consider the following example:

<u>Set up a 9354AL DSO for an FFT with a span of 10 MHz and a frequency resolution of 10 kHz to analyze a continuous, periodic waveform.</u>

<u>1.</u> The required frequency resolution of 10 kHz requires a waveform duration (capture time) of 100 µs. Setting the TIME/DIV to 10 µs achieves the necessary Δf of 10 kHz.

<u>2.</u> To obtain the specified 10 MHz span, the effective sampling rate must be > 20 MS/s. The 9354AL, using the 50 kS default memory length on the 10 µs TIME/DIV setting, samples at 500 MS/s.

The sampling rate can be reduced in either of two ways:

<u>a.</u> In the TIMEBASE menu by decreasing the number of samples. Setting the RECORD UP TO field in the menu to 2500 results in a sampling rate of 25 MS/s.

<u>b.</u> In the ZOOM + MATH menu set the field labeled FOR MATH USE MAX POINTS to 2500. This leaves the sampling rate at 500 MS/s but decimates the waveform data before the FFT by 20,000:1 reducing the effective sampling rate to 25 MS/s. This results in a span of 12.5 MHz which is the closest achievable span > 10 MHz.

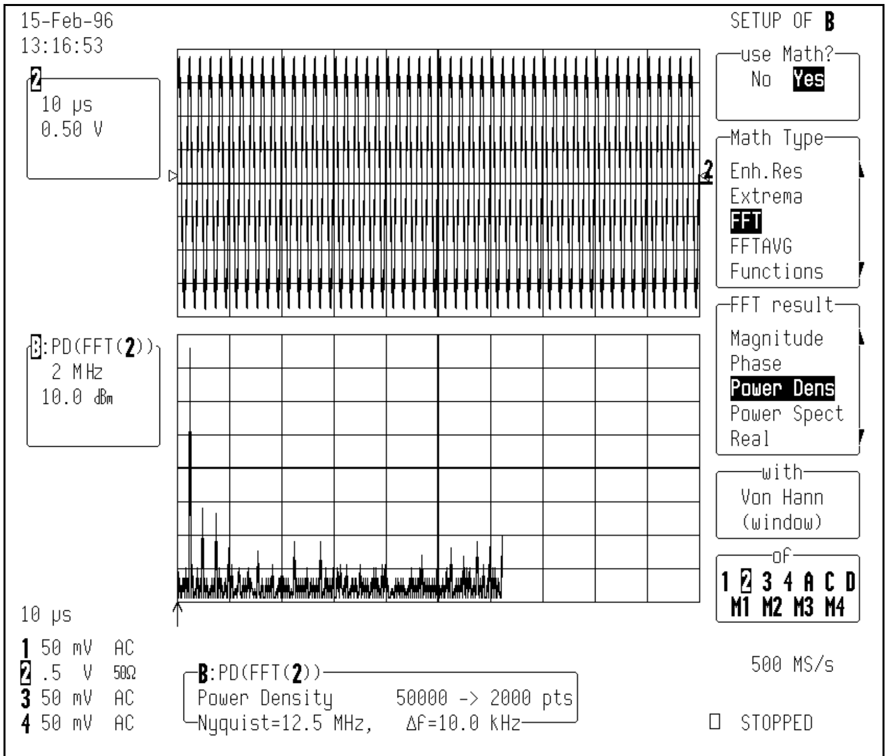

Figure 4

Note that using the technique described in <u>b</u>. is preferable. It keeps the input sampling rate high, reducing the risk of aliasing the acquired data.

This example shows how the oscilloscope maintains the display factor. A sampling rate of 25 MS/s would result in a full scale range of 12.5 MHz or 1.25 MHz/Div. To maintain a display scale factor of 1,2, or 5 it decimates the acquired waveform by 25,000:1 and calculates the FFT using a 2000 point transform. This results in a scale factor of 2 MHz/Div. Note that the display is truncated at 6.25 divisions to retain the original 12.5 MHz span.