How Fast Must I Sample?

How Sampling Rate Affects Time Measurement Uncertainty

A common question that arises when making measurements of timing jitter is, "How fast must I sample the signal to achieve minimum measurement uncertainty?" The answer is relatively simple, if you sample at greater than 10 times the measurement bandwidth the uncertainty due to sample rate is minimized. This can be verified with a very basic experiment. Histogram a timing parameter and use the standard deviation of the histogram as a measure of timing uncertainty for a range of different sample rates.

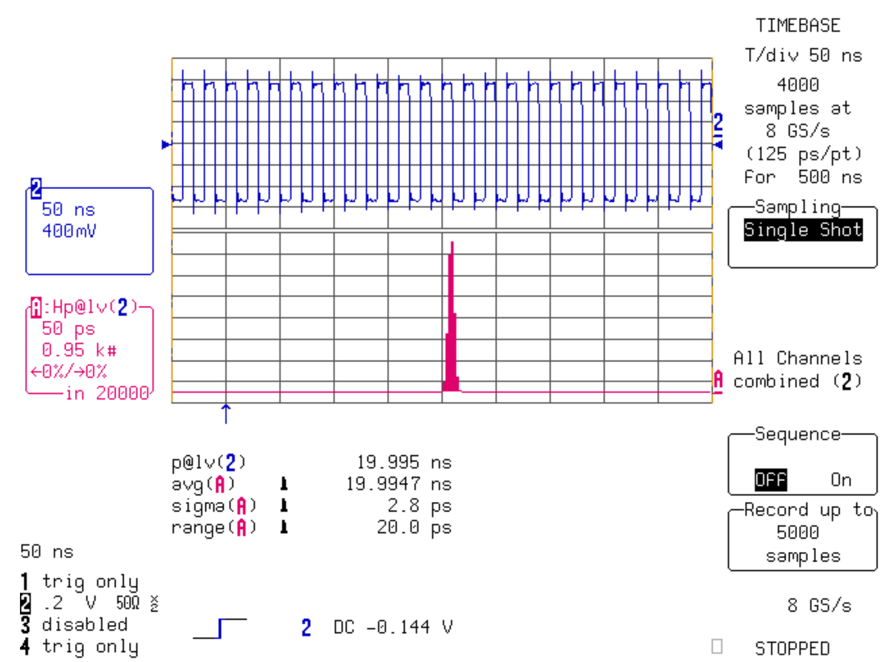

Figure 1 - A measurement of the key statistics of period at level (p@lv) parameter.

Figure 1 shows a typical timing measurement characterizing period at level. The source is a 50 MHz square wave. At a sample rate of 8 GS/s the standard deviation (sigma or σ) of the histogram is 2.8 ps. The standard deviation is a measure of the dispersion of measured parameter values about the mean. Physically, sigma is the rms jitter of the parameter, in this case the period of the signal. Over a large number of measurements the mean value of a parameter is an estimate of the parameter's true value. The standard deviation is an indication of how certain we are of the mean. For a Gaussian distribution 68% of all measured values fall within ±1σ. A narrow standard deviation indicates a high degree of certainty as to the mean value.

If we repeat the measurement of period over a range of sampling rates we will see how sampling rate affects the value of the standard deviation. Figure 2 shows the result of such an experiment using the period at level parameter. All other measurement settings, such as signal amplitude and transition times have to be fixed for this test.

The data, summarized in figure 2, was taken on a LeCroy LC584AXL and an LC684DXL with analog bandwidths of 1GHz and 1.5GHz respectively. The sample rate was varied from 1 GS/s up to 25 GS/s. The results, shown in figure 2, are predictable. For low sampling rates such as 1 GS/s the data is undersampled and doesn't meet the Nyquist criteria. For this sample rate the measured value shows a high standard deviation representative poor measurement precision. As the sampling rate is increased the standard deviation decreases indicating improved measurement certainty. The standard deviation of the measurement falls rapidly until the sampling rate is 4 to 5 times the analog bandwidth. At this point the rate of change begins to decrease. By the time the sampling rate is 8 to 10 times the analog bandwidth the improvement in measurement certainty flattens and there is little improvement for increased sampling rate.

This result is common to most timing measurements. Increasing the sampling rate, as related to measurement bandwidth, decreases measurement uncertainty. The improvement generally reaches a point of diminishing returns when the sample rate is about 8 to 10 times the bandwidth. Further increases in sampling rate produce a quickly declining improvement.

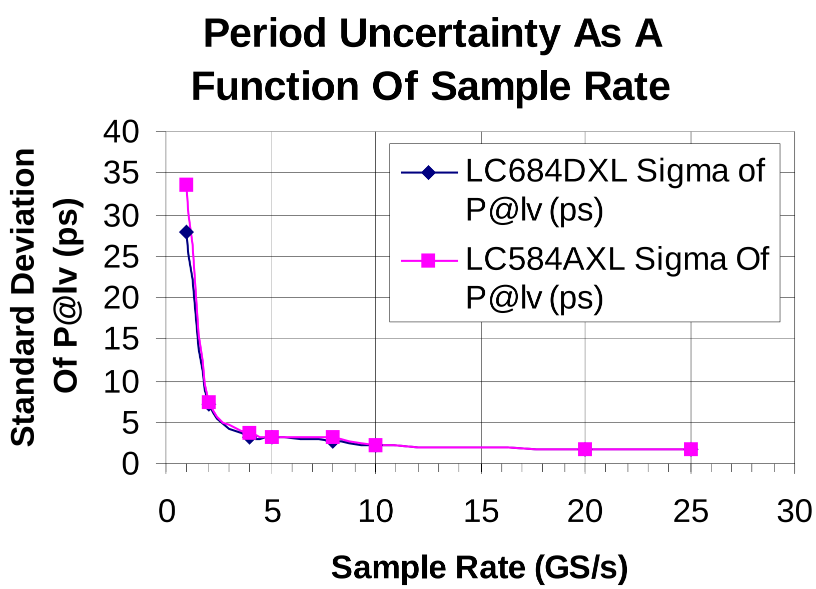

Figure 2 A plot of the standard deviation of the period at level parameter as a function of sampling rate.