Jitter Analysis:

- Accuracy
- Resolution
- Jitter Noise Floor
- Delta Time Accuracy

Jitter Analysis

Period Jitter can be described as timing variation in the period of non-adjacent pulses. This measurement is useful for characterizing short and long-term clock stability.

Accuracy

Parametric measurements require known accuracy to ensure adequate tolerance and testing margin. Jitter measurements are not excluded. Tektronix specifies jitter measurement ability using several factors: base instrument timing and amplitude accuracy; base instrument noise floor; and interpolation error.

Interpolation error is less than 0.3ps RMS (measuring signals with 100ps t_r, detecting 50% threshold). This error can be minimized and in many cases improved using SIN(X)/X interpolation.

Base instrument noise floor is a result of ADC aperture error, which includes amplitude noise and clocking errors, and is typically less than 1.5ps on a TDS7404 and typically less than 0.7ps on a TDS6604. This measurement is made using TIE – comparing the measured test signal (from a BERT or other exceptionally stable clock source) against a recovered clock.

Base instrument accuracy is the heart of jitter measurement accuracy. This is the traceable measurement. Tektronix specifies Delta Time Accuracy. This specification states that for any measurement made using the oscilloscope, the absolute timing error will be no larger than a given amount. This is generally specified as an equation that takes several factors into account, such as sample rate, measurement time, and oscilloscope front end. More details about Delta Time Accuracy are shown below.

Resolution

Measurement resolution is the limit of detectable change. It is not measurement accuracy or repeatability. The ability of a system to resolve change is limited by many things. With timing measurements, resolution is the ability to discern small changes in a signal's timing, whether the change is intentional or not. Timing resolution can be limited by items as substantial as the hardware's ability to count fast, or by things as obscure as software averaging.

In hardware timers, like the typical Time Interval Analyzer (TIA, SIA), timing resolution is limited in hardware to hundreds of femto-seconds. This means the hardware can't detect a change any smaller than 0.2ps.

In real-time oscilloscopes, resolution is limited by sample rate, interpolation accuracy and software based math libraries. Using sample rates of 20GS/s and SIN(X)/X interpolation, resolution of tens of femto-seconds is possible. Since the resolution in this case is based on math libraries, the real resolving power is sub-femto-seconds (0.0001ps), but this is unusable resolution.

In a statistical sense, resolution implies the ability to measure a change, but the overall system noise floor must be considered. Is the detected change due to the signal or is it due to system noise? Simply knowing the system resolution is not helpful in understanding the true limit of resolution or overall accuracy.

Jitter Noise Floor

What is Jitter Noise Floor? Essentially, it is the measurement result with no signal applied, or Measurement Floor. Since jitter by definition is – the timing variation of a signal from its intended incident placement – or a measurement of transient events relative to an expected or known time, noise floor is an AC parameter. The important characteristic to factor into overall system ability is the effect noise floor has on measurement resolution and accuracy. If a system can resolve 10ns, but it has 100ns of noise, is the 10ns useful resolution? Only if the signal being measured is larger than the 100ns noise level. The same is true of jitter noise. If the jitter being measured is greater than the system jitter noise floor, changes in jitter amplitude can be detected. If the jitter is less than the jitter noise floor, changes in jitter will be effectively masked.

An important aspect of this is that overall system accuracy is limited to the noise floor of the system. Accuracy can't be any better than the noise floor. If a system has 2ps of noise, how can it be specified to have 1ps accuracy? It can't.

Delta Time Accuracy

For the TDS6604, the DTA specification is:

$$DTA = \pm 0.3 \times SI + 3.5\,ppm \times MI$$

Where: SI is the SAMPLE INTERVAL in seconds.

MI is the MEASUREMENT INTERVAL in seconds.

± 0.3 is the fixed CONSTANT for the oscilloscope acquisition system.

This specification states that for any timing measurement, you know the accuracy the result. An accuracy that is traceable to the NIST agency.

This is important for several reasons, the obvious being you can trust the result. But what does the formula actually mean the accuracy is? Looking at two examples, one short period clock, and one long delayed pulse.

In a fast 1.0GHz clock, the period is being measured using the TDS6604 sampling real-time at 20GS/s. Using the DTA equation we find:

$$DTA = \pm 0.3 \times 50\,ps + 3.5\,ppm \times 1ns = \pm 15\,ps$$

This will be the peak measurement error in any one measurement made in a single shot or real time acquisition. Over a significant sample size, about 1000 measurements, the standard deviation of the error is typically 0.06xSI+3.5ppmxMI. In this example, it amounts to about 3.0ps RMS.

In a longer period measurement, the short term effects dictated by the constant 0.3 is overwhelmed by timebase stability:

$$DTA = \pm 0.3 \times 50\,ps + 3.5\,ppm \times 10us = \pm 50\,ps$$

In this case we see that when measuring a 100kHz clock the measurement error can be as large as 50ps peak. The rms result will be similarly affected since timebase errors are deterministic.

It is interesting to note that this is the accuracy specification for the TDS7404, CSA7404 and TDS6604 for the specified calibration period. That means that over the specified temperature range and for a period of one year after calibration, the largest measurement error will be less than the Delta-Time-Accuracy specification. For typical serial data rates, that error is less than 15ps peak, or 3ps RMS.

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03/03