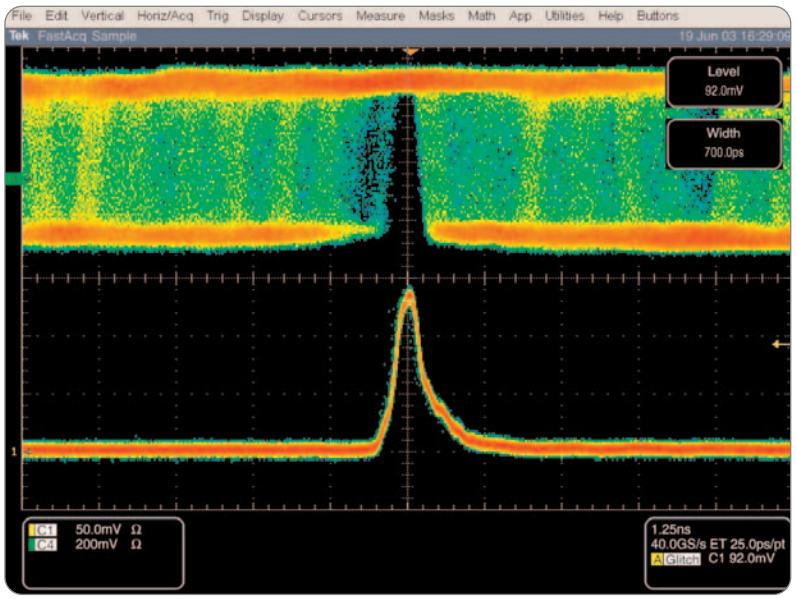
Advanced Statistical Analysis Using Waveform Database Acquisition



▶ This brief provides an overview of the specialized acquisition capabilites of the TDS/CSA7000B, TDS6000 and TDS5000 Waveform Database acquisition mode and the corresponding statistical data generated for measurement and compliance work.

Introduction

Advanced digital systems and the adoption of high-speed serial buses are placing greater demands on test equipment to handle the acquisition and analysis of increasingly complex signals. This can range from debugging and characterizing jitter and setup-and-hold conditions in synchronous system to validating compliance for the latest serial data technology. In addressing these challenges, oscilloscopes have become indispensable instruments to handle the data acquisition and analysis. In order to handle measurement, analysis and compliance requirements, the oscilloscope has continued to advance with more specialized features that provide more statistical and pass/fail compliance capabilities.

Part of the challenge for oscilloscopes is dealing with greater signal complexity. Today's waveform signals are often a representation of changing data that might include capturing data, control and clock signals or reassembling data from a serial data stream. This often results in a waveform display image that has been generated from multiple acquisitions. One commonly seen example would be the classic eye-pattern.

To be able to handle these acquisition and analysis requirements, this brief provides an overview of the specialized acquisition capability of the CSA7000, TDS7000 and TDS6000 Waveform Database acquisition mode and the corresponding statistical data based for measurement and compliance work.

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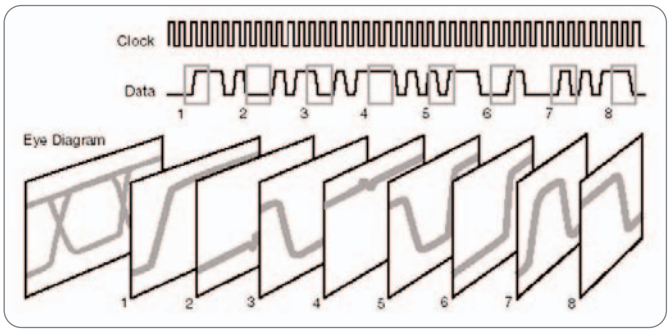
Acquisition modes

The TDS/CSA7000B, TDS6000 and TDS5000 products provide several high-speed acquisition modes. Each mode has been optimized for fast throughput using specialized hardware. Included are FastAcq (TDS5000/7000), Sample mode, Averaging, Peak-detect, Envelope and Waveform Database (WfmDB on scope acquisition menu) acquisitions.

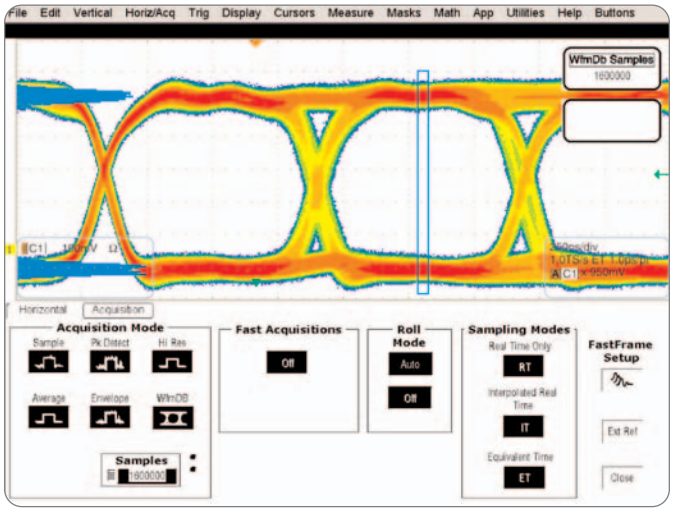
FastAcq Acquisition Mode

FastAcq is a unique acquisition mode only available on the TDS5000 and TDS7000 Digital Phosphor oscilloscopes. Using custom hardware the oscilloscope is able to provide amplitude, time and distribution of amplitude over time with a maximum waveform capture rate of over 400 thousand waveforms per second. This ultra high capture is orders of magnitude faster than conventional digital oscilloscopes providing the ability to capture infrequent events, complex waveform, and reduce signal aliasing while generating a color persistence or intensity graded display. As seen in Figure A a digital design fault was captured in seconds versus minutes and hours for a digital oscilloscope.



▶ ***Figure 1.*** *Complex signal is captured using multiple acquisitions.*

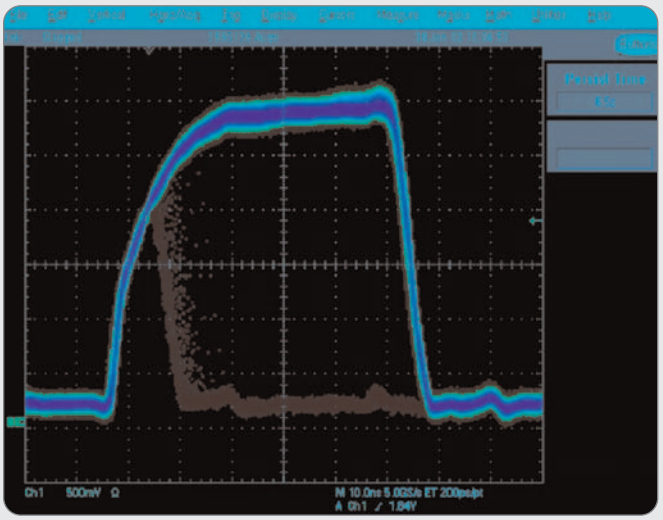
In normal (Sample) acquisition mode, waveform points are displayed as they are sampled and refreshed with each new acquisition. The captured samples are overwritten with each new acquisition and are not saved in memory unless set in single acquisition mode or the user has initiated “Stop” acquisition. While normal acquisition can be used for simple data capture, more complex signals require optimized acquisition capabilities. Since complex signals also require more sophisticated analysis, the Waveform Database (WfmDB) was designed to provide acquisition, measurement, analysis and compliance support.



▶ ***Figure 2.*** *Acquisition menu showing different modes with acquisition set to WfmDB.*

Unlike normal acquisition modes, which can produce only a two-dimensional view, the WfmDB adds a third dimension called sample density. Sample density is represented on the display with color grading using a persistence display mode. Colors are assigned according to the number of times each point on the waveform is acquired relative to the number of times all other waveform points are acquired.

The oscilloscope keeps track of the number of times each waveform point is sampled with an on-board statistical database (Waveform Database). An array of 64 bit software counters (64-bit words) is used to count the number of times each waveform point is "hit". The number of samples taken per trigger event is dependent on whether the oscilloscope is operating in real-time sampling (up to a maximum sample rate of 20 GS/s) or acquiring using Equivalent Time sampling.



▶ ***Figure A.*** *Design metastable condition captured on a DPO using FastAcq.*

While these capabilities greatly enhanced the visual content and can dramatically reduce debugging tasks, FastAcq also has the ability to perform measurement and analysis by generating a statistical database. A database is used to create the display image but is also available for measurement and analysis. This includes all automatic measurements, statistics and histogram analysis. Embedded in the hardware running FastAcq are 21-bit counters. FastAcq are optimized to provide fast waveform updated so the 21 bits are mapped to the 4-bit display 30 times per second. While measurement and analysis is supported in FastAcq, any measurement or analysis that requires greater statistical results should use the WfmDB acquisition mode.

It should be noted that while the statistical database can handle up to 64 bits, the actual bit count is determined by the specific user setup.

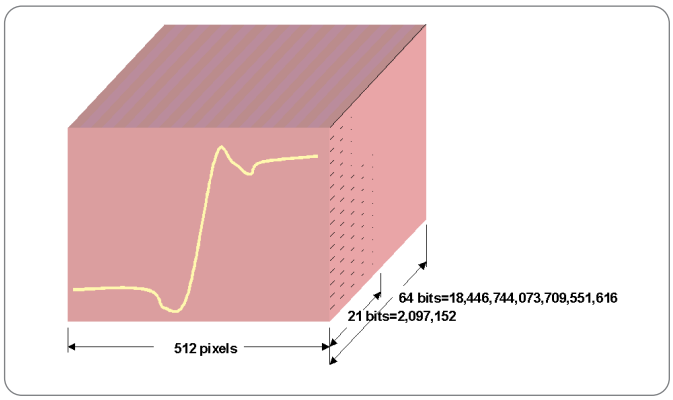
Display Modes

Digital oscilloscopes offer several display modes to enhance the visual results. Most common are the use of variable and infinite persistence modes. When operating in either display mode the oscilloscope will provide a display only waveform image (mapped to a 4-bit color index or 16 levels). While this can be useful for visual displays it is generally limited for extended measurement and analysis. As seen in Figure 4, some measurements and histogram results are generated but the actual waveform data is limited. It should be noted that while most scopes can generate persistence displays, many do not support creating a statistical database. This is due to not having the ability to store and manage the data after acquiring multiple waveforms. When using the WfmDB acquisition mode, it works in tandem with the display persistence modes where infinite persistence is handled by the acquisition and not the display. The actual statistical data based is converted into the 4-bit display data which still allows histogram measurement and analysis to be performed on the larger underlining data. Since the users can adjust the WfmDB acquisition, they will have a direct influence on the display behavior. For example, if more samples are required to produce a greater statistical population the oscilloscope will trade off display updates to better optimize waveform throughput. The oscilloscope does provide periodic updates so the user can confirm that the oscilloscope is correctly acquiring the waveform along with updates to the histogram results, measurements and mask counts.

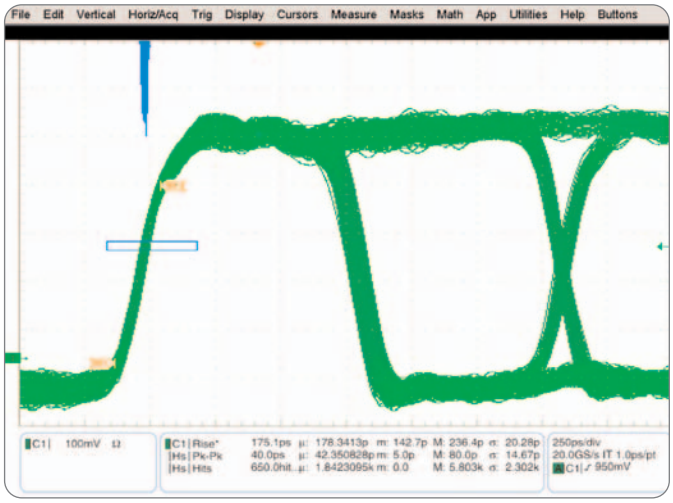
Statistical Database

While the statistical database is mapped to the display, the real performance comes from being able to derive quantitative results using the measurement system, statistics, histograms and mask analysis. The database can be stored as a reference waveform and later recalled to compare prior test results and make additional measurements. If required, the database can also be transferred over the Ethernet or GPIB interfaces for external analysis or data storage. Since the data is stored, the user can select additional histogram measurements without reacquiring new waveform data. This includes resizing or relocating the histogram box and assigning additional histogram measurements either to a single channel or another channel that was active during the original acquisition.

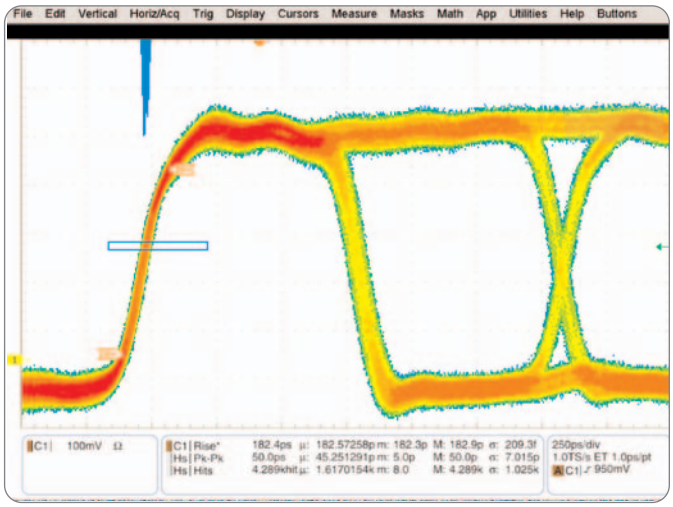
Previously, other instruments or acquisition modes required taking new data for each new histogram measurement. Waveform acquisitions may have taken several minutes or longer and would need to be reacquired to satisfy statistical criteria. Note in Figure 5 the waveform display is the same as the Figure 6 but the histogram has been repositioned to characterize the falling edge.



▶ ***Figure 3.*** *Statistical database created using WfmDB (64 bits max) or FastAcq (21 bits hardware mapped to 4 bits with batch accumulation in Infinite Persistence) acquisition modes.*



▶ ***Figure 4.*** *Waveform captured using sample mode and infinite persistence showing 650 histogram hits.*



▶ ***Figure 5.*** *Waveform display, measurements & histograms showing over 4000 histogram hits using statistical database.*

Specifying the Waveform Count

An oscilloscope defaults to 16,000 samples when set to WfmDB acquisition. The user can reconfigure the number of sample points acquired from a minimum of 5000 to a maximum of 2,147,400,000 samples. This flexibility allows the user to only specific the number of sample needed to satisfy the statistical or pass/fail criteria needed for a meaningful result. If in single acquisition mode the oscilloscope will continue to acquire data until the instrument has acquired the specified number of samples. If the acquisition is set to continuous, the oscilloscope will keep acquiring and updates the database until halted by the user. Since the total acquisition time will vary dependent on sample rate, sample mode and the number of samples specified, the oscilloscope will still performed mask testing, histogram updates and measurements until the specified setup conditions are met. Depending on the application requirements reducing the number of samples increases the display updates while increasing the sample count will optimize the oscilloscope for faster acquisition throughput.

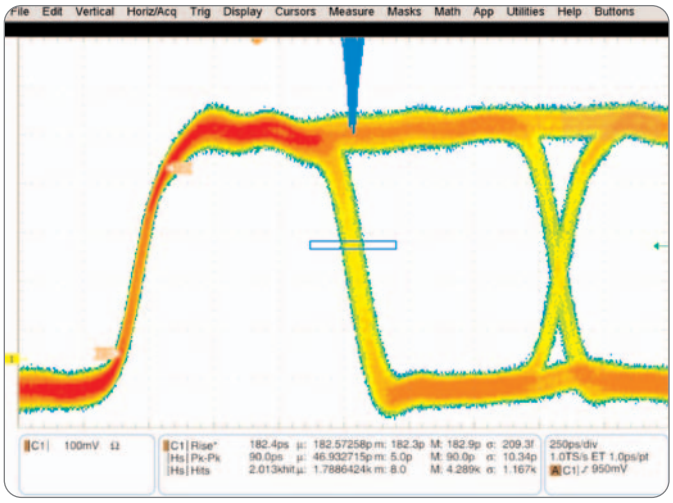
Measurement & Analysis

Statistical Database Measurements and Histograms

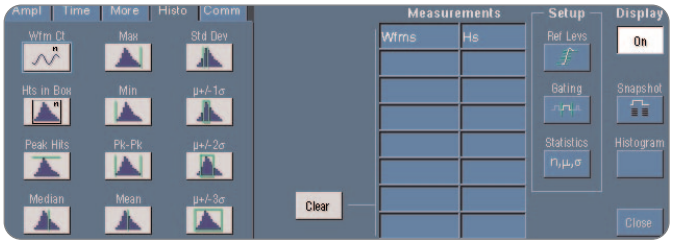
Most complex signals today require greater measurement and analysis. This has been driven by the need to derive higher quality results, ensure greater design margins and reliability and adhere to industry specific standards. This requires the scope to offer greater measurement choices and the ability to use statistical measurement techniques.

In support of these requirements the TDS/CSA7000B and TDS6000 products offer extended measurements like peak-to-peak, mean and standard deviation but also uses the statistical database for greater measurement confidence and flexibility. The flexibility of these measurements is also extended through the use of display histograms that can be easily generated and assigned to any part of the waveform. This quickly extends the analysis by providing graphical representation of the sampled data.

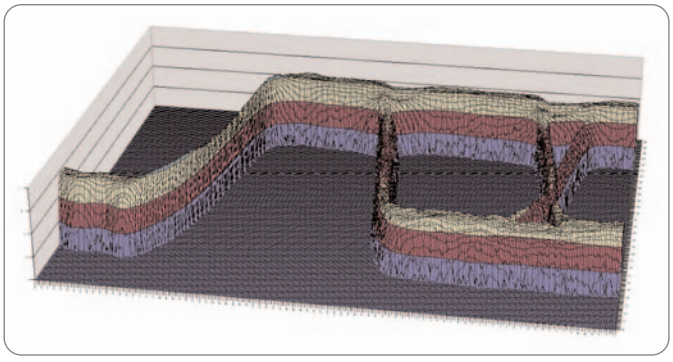
If additional analysis or storage is required, the statistical database as shown in Figure 8 can be stored within the oscilloscope or exported to an external computer for off-line analysis.



▶ ***Figure 6.*** *Note the number of histogram hits (2.013 K) is less than rising edge, which is also visible through the color persistence display.*



▶ ***Figure 7.*** *User selectable histogram measurements.*



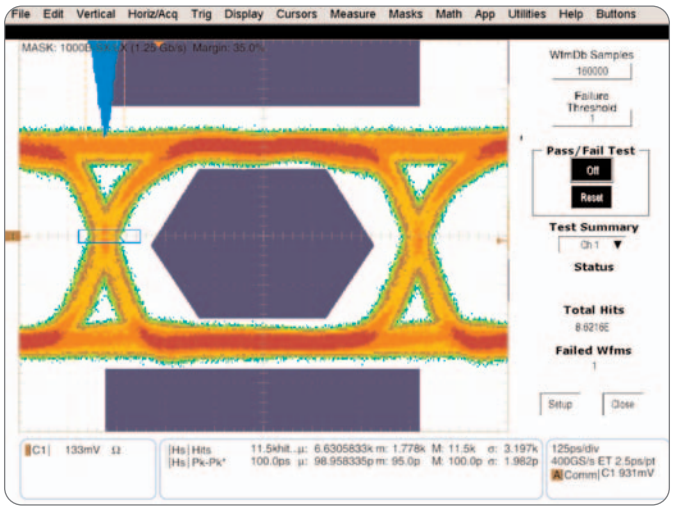
▶ ***Figure 8.*** *Statistical database exported to external computer as a .csv (comma delimited) file.*

Compliance Testing

New technologies and buses like Rapid IO, PCI-Express, Infiniband, Xaui and others have driven the requirement to perform compliance testing. One of the most common requirements is to perform Pass/Fail compliance test against a predefined mask. Again to ensure quality testing there is a need to acquire enough samples to validate the test against internal or externally defined requirements. The statistical database is used to compare sampled data against the predefined test mask. As shown in Figure 9, the oscilloscope is doing an automated pass/fail test using the Waveform DB acquisition mode while generating a histogram of the rising and falling edges.

Summary

The design validation process today has created greater demand to go beyond basic characterization. This has been driven in part by tighter design margins and the need to ensure interoperability between different designs and vendors. Often the measurement requirements have been defined through various industry working groups.



▶ ***Figure 9.*** *Mask testing and histogram analysis of a 1000 base T Ethernet signal.*

To address these requirements requires test equipment that has the performance, flexibility and analysis capabilities. The ability for an oscilloscope to produce a statistical database provides the foundation needed for advance measurements, statistical results and complete pass/fail testing. These key capabilities can further be augmented by application specific software (Jitter, USB, PIC-Express, etc.) tailored to industry specific requirements. Since modern oscilloscopes may offer multiple acquisition modes, Table 1 summarized the differences between Sample, FastAcq and Waveform DB modes.

Table 1: This is a simple summary comparing the different capabilities based on the acquisition modes. For details specification, please reference data sheets or product manuals.

Acquisition mode	Sample	Waveform DB	FastAcq (TDS7K)
Application use	Single shot data capture, general use, simple measurements	Advanced statistical analysis on complex data, compliance test	Complex signal capture, advanced debug, general measurement & analysis
Data storage	Single waveform array	Statistical database (64 bits)	Statistical database[1] (4 bits)
Waveform capture rate[2]	>50 wfm/sec	>3500 wfm/sec	>400,000 wfm/sec
Real-time sample rate[3]	20 GS/s	20 GS/s	1.25 GS/s
Set samples acquired	No	Yes	No
Analysis[4]	Measurements Statistics Histogram	Measurements Statistics Histogram	Measurements Statistics Histogram
Display Type	Vector, Infinite and variable persistence (16 levels)	Dot, Infinite and variable persistence (16 levels)	Dot, Infinite and variable persistence (16 levels)
Display Format	YT, XY	YT	YT, XY, XYZ
Mask Pass/Fail	Visual and automatic	Visual and automatic	Visual
Storage	Internal save/recall and Export	Internal save/recall and Export	Internal save/recall and Export

1. 21 bit using acquisition hardware mapped as 4 bits into database, > 4 bits accumulated when set to Infinite persistence as 4 bit batches

2. Maximum capture rate may vary depending on model and specific setup (TDS5K 100 K wfm/sec in FastAcq)

3. Max sample rate may vary between models. Supports equivalent time sample to 1 TS/s.

4. Histograms measurements and statistics can be added or reassigned without reacquiring data when using WfmDB or FastAcq

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