Mask Testing with CSA7000, TDS7000 or TDS6000 Series Real-time Oscilloscopes

Designers use real-time oscilloscopes to perform signal quality and eye diagram measurements.

Use Waveform Database Acquisition Mode to Optimize Mask Test Time and Results

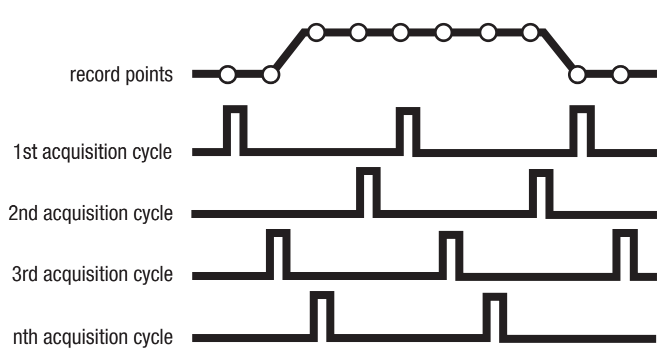
This application brief describes how to use the waveform database acquisition mode of a CSA7000, TDS7000 or TDS6000 Series real-time oscilloscope to perform physical layer testing of wired communication network signals. This brief focuses on the waveform database sample counting method and its influence on acquisition throughput and mask test time.

What is waveform database acquisition mode?

When performing eye diagram or pulse compliance mask testing of an optical or electrical signal with the CSA/TDS7000 and the TDS6000, the oscilloscope uses the waveform database acquisition mode (*WfmDB* on the oscilloscope's acquisition menu). The waveform database is a three-dimensional accumulation of source waveform data over several acquisitions (known as a "batch"). In addition to amplitude and timing information, the database includes the number of times a specific waveform point (time and amplitude) has been acquired. Using waveform database technology, the real-time oscilloscope processes a much larger sample of data than when using the sample acquisition mode.

How does the waveform database count samples?

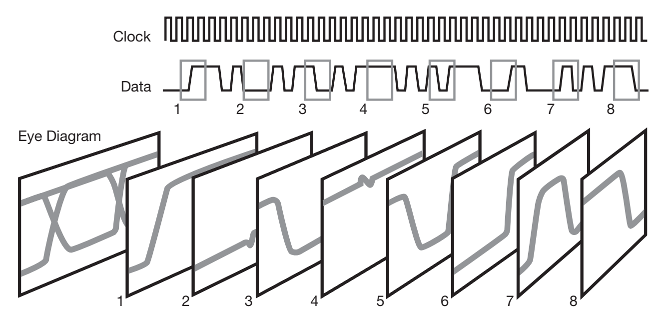
A waveform consists of a record length's worth of samples. For a single acquisition sequence, or in the case of Mask Pass/Fail Test, samples are only counted if they are within the graticule area, not above or below. If part of a signal trace is positioned off screen, or if it has too much vertical sensitivity, then although, for example, 5,000 samples are acquired, only the ones displayed are counted. In this case, it could take more acquisitions to acquire the requested number of samples. More samples may be counted than requested before the mask test completion. Therefore the test is >=, not ==. In single sequence, eligible samples in the acquisition will be counted, and in Mask Test, all acquisitions acquired in a "batch" are counted before completion is determined.



► ***Figure 1:*** *In equivalent-time sampling mode, a real-time oscilloscope makes **multiple** acquisitions of a **repetitive** waveform to obtain the sample density required for a waveform record.*

In real-time or continuous acquisition mode, if the entire trace is displayed, one triggered acquisition should be sufficient to acquire 5,000 samples for an equal record length of 5,000. If 5,001 samples are requested, you will get 10,000 samples and it will take two acquisitions. If fewer samples are requested than the record length, the number of samples would be the same as the record length. Like the fast frame, average, or envelope acquisition modes, **waveform database acquisition mode** minimizes the "down time" between acquisitions by acquiring a "batch" of acquisitions and then processing them. This also reduces the overhead time of displaying and processing other features such as measurements and histograms.

If you have a repetitive signal, you can use the **equivalent-time sampling mode** of your real-time oscilloscope to speed up acquisition throughput. In equivalent-time sampling mode, fewer samples are acquired per acquisition for a given record length, but potentially more acquisitions are acquired in a batch.



► ***Figure A:*** *Data is collected for display as an eye diagram.*

Compliance verification with an eye diagram

The "eye diagram" – the display that results from the overlap of a series of data waveforms – is the most common method of characterizing the quality of a signal. It is obtained when the oscilloscope is triggered synchronously to the data stream, while the input channel is connected to the data stream carrying random or pseudorandom bits. A synchronous clock signal, the data itself or the clock recovered from the data (if the oscilloscope has a clock recovery circuit) is used to trigger the oscilloscope. In one captured screen, all possible signal transitions of the signal are displayed, hence the eye opening, noise, jitter, rise and fall times and amplitude can be observed and measured from a single picture.

Measure transmission quality

An eye diagram is a very convenient oscilloscope display that presents the most important time-domain signal characteristics all at once, saving time and showing the interaction of rise and fall time, overshoot, undershoot, ringing, jitter and noise. This display can be used for qualitative analysis while adjusting the persistence, whereas the embedded statistical database of the oscilloscope can be used to make quantitative measurements from the eye diagram.

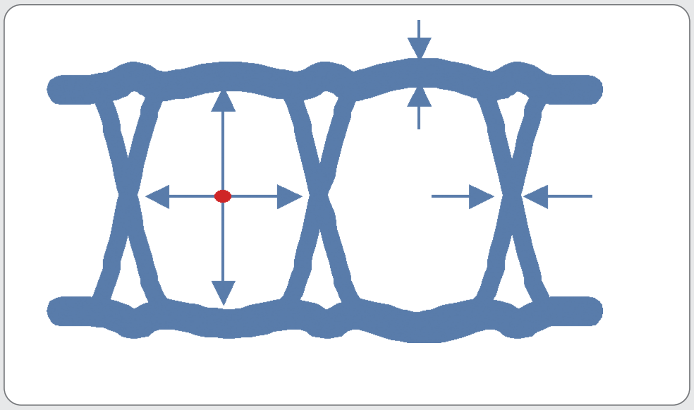


Figure B: *A larger opening indicates a greater tolerance for noise and jitter as well as better receiver sensitivity. A wide top, base and transition region indicate reduced receiver sensitivity.*

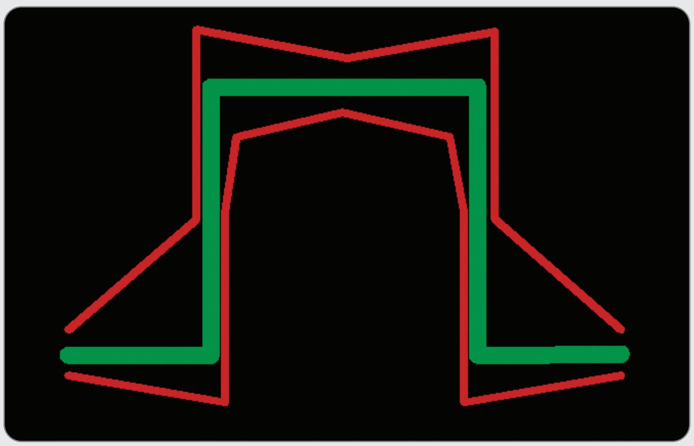


Figure C: *An example of an electrical pulse mask.*

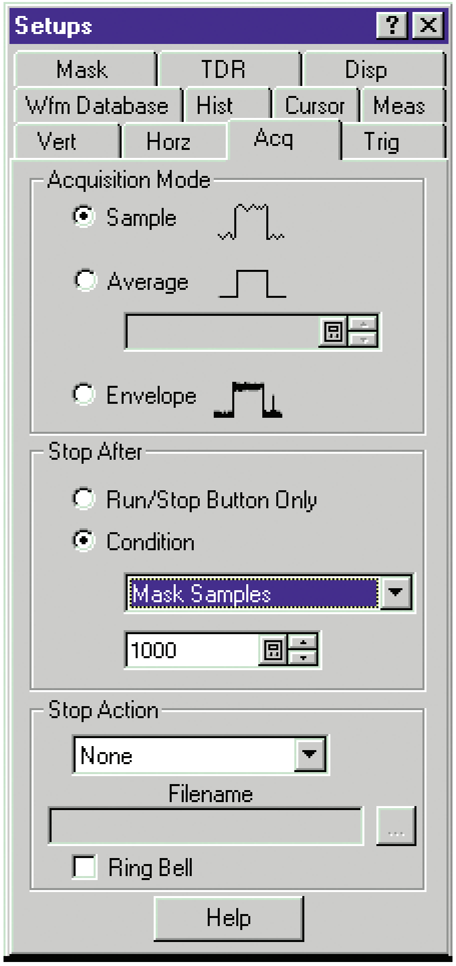
Prevent degradation of receiver sensitivity

Rather than extracting numeric information on the signal characteristics, the two-dimensional shape can easily be compared to a group of violation zones called a mask. (Examples of eye diagrams can be found throughout this document). Masks are defined by and for each standard. Comparing the shape of an eye or a pulse to a mask, is a very fast and efficient method of ensuring that the transmitter source signal will not cause excessive degradation of the receiver performance.

What is equivalent-time sampling?

A real-time oscilloscope uses equivalent-time sampling to extend its sample rate beyond its real-time maximum sampling rate. It takes a few samples with each trigger event and eventually (over many repetitions of the event) obtains enough samples to construct a waveform record. This method is called *random equivalent time sampling* because it takes samples continuously, independent of the trigger position, and displays them based on the time difference between the sample and the trigger. Although the samples are taken sequentially and regularly in time, they are randomly placed with respect to the trigger. Therefore, equivalent-time sampling should **only** be used on repetitive signals.

Equivalent-time sampling is different than the *sequential* sampling method of sampling oscilloscopes such as the TDS/CSA8000. Because sequential sampling is not random, sampling oscilloscopes depend on repetitive signals and multiple trigger events and acquisitions to build a waveform.



▶ ***Figure 2:*** *CSA/TDS8000 Acquisition Mode setup menu.*

How does a TDS/CSA7000 real-time oscilloscope compare to a TDS/CSA8000 Series sampling oscilloscope?

What a real-time oscilloscope such as the TDS/CSA7000 considers a waveform (a waveform being a record length worth of samples), a sampling oscilloscope considers an acquisition. The sampling oscilloscope acquires samples one at a time in sequential triggers. This method is comparable to a real-time oscilloscope acquiring groups of samples in multiple, random triggers in equivalent-time sampling mode, or in batches from sequential triggers when in waveform database mode.

For example, selecting the number of acquisitions or mask samples on the CSA8000's *Setup Menu* (Figure 2) under *Condition*, is the same type of operation as providing the *number of waveforms* on the TDS7000's *Mask Pass/Fail Test Menu* under *Number of Wfms* (when not acquiring in waveform database mode). In waveform database mode, the TDS7000's Samples are equivalent to the TDS8000's Mask Samples Conditions.

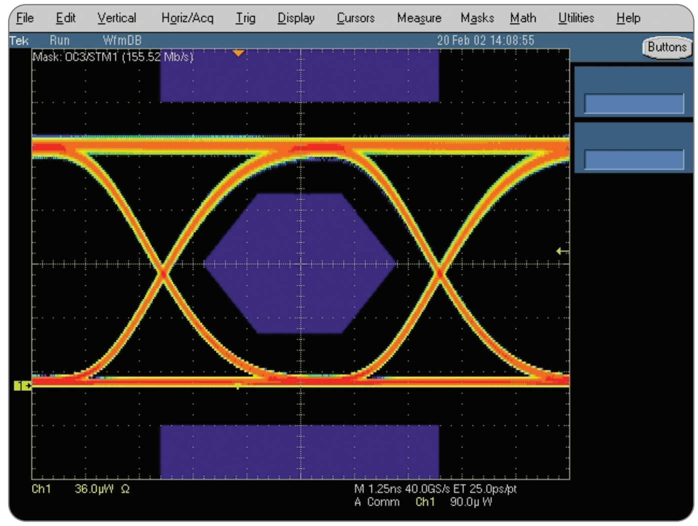
How does waveform database acquisition mode affect throughput?

As mentioned earlier, a waveform is a record length's worth of samples. (Samples divided by record length roughly indicates the number of waveforms in a batch of acquisitions.) The greater the number of samples acquired, the faster the acquisition throughput. To increase acquisition throughput, simply increase the number of samples (Figure 6 shows the User Interface Field where the number of samples can be updated). Keep in mind that acquisition throughput speed is ultimately controlled by the amount of acquisition memory on your oscilloscope—at a certain point, increasing samples will stop affecting throughput.

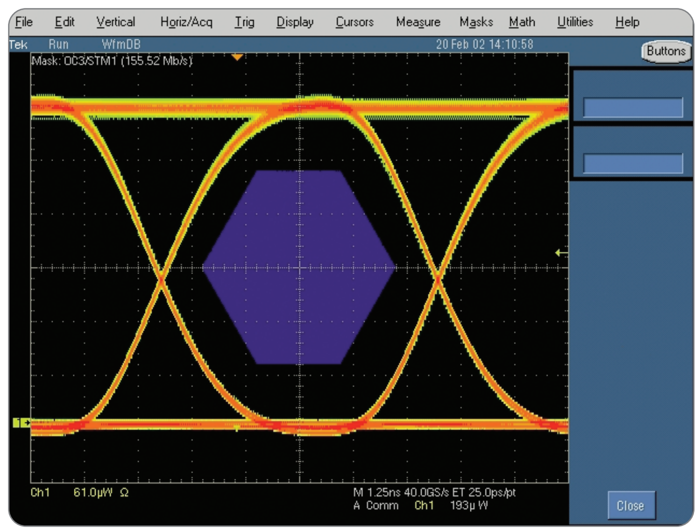
Setting up a mask in waveform database mode

Setting up the test

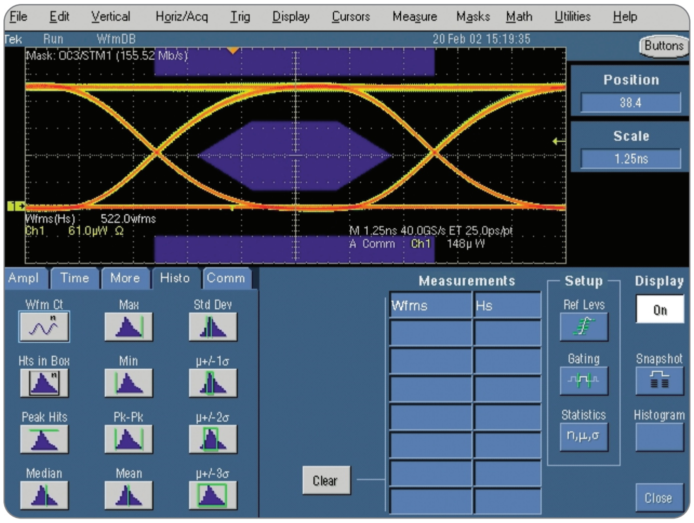
1. Before selecting a mask, verify that the signal is coming through as expected. An easy way to do that is by using the autoset function on the oscilloscope. Autoset works off of the edge trigger but lets you see that there is an actual connection to the signal source.
2. Select the mask, and reset the oscilloscope, using the mask autoset function.
3. The mask should still be centered and shown similarly to when first selected. If the signal exceeds the dynamic range of the O/E, the signal is overdriven and the mask will be now larger, and possibly partially off-screen as shown in Figure 4.
4. If your signal is overdriven, adjust it after turning off persistence and selecting a minimum number of samples. This is the best configuration for manipulation. This gives you the most responsive display and lets you view your current changes in isolation. See Figure 3.



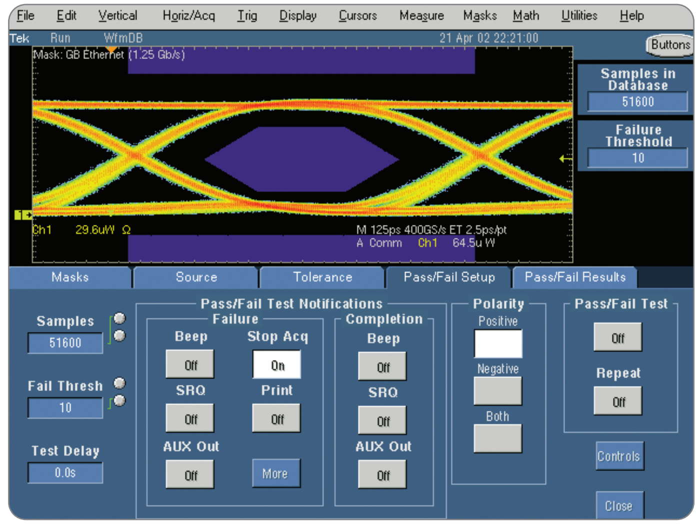
▶ ***Figure 3:*** *A signal that is not overdriven.*



▶ ***Figure 4:*** *An overdriven signal.*



▶ ***Figure 5:*** *Setting up Wfm Ct in the Histogram measurement menu.*



▶ ***Figure 6:*** *Setting up the pass/fail test parameters.*

5. Sometimes with a very clean signal, and after a very short period of time, with infinite persistence on, it may appear as if nothing is happening, even though the trigger light is on. This is because the samples are all being overlaid on each other and the color algorithms normalize those additions. To check that updates are occurring, turn off infinite persistence momentarily. Or, set up the "*Wfm Ct*" histogram measurement (Figure 5) and the number should increase. (See sidebar for details on Infinite persistence in waveform database mode.)
6. After you have set up the signal and mask, you can turn infinite persistence back on and increase samples as desired.

Running mask pass/fail tests

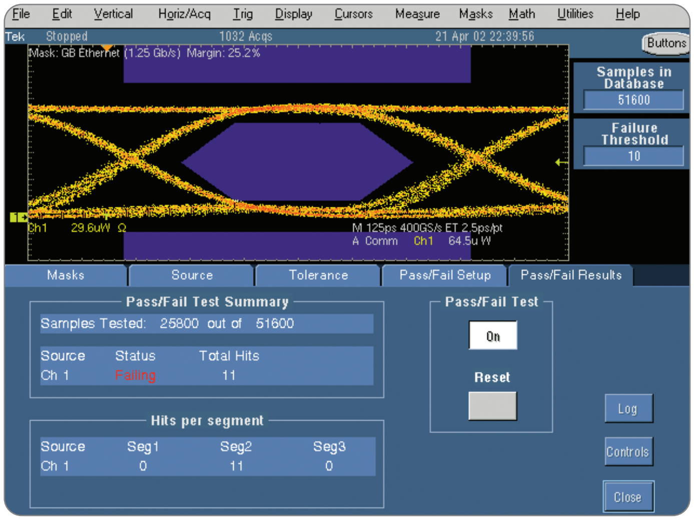
You can set up an automatic pass/fail mask test to determine whether a device exceeds the mask boundaries within a user-defined number of samples. To run a series of mask tests on a signal, set up:

1. The delay time. (The time from when the mask test starts to when the instrument begins sampling.)
2. The number of samples to test (when in waveform database mode).

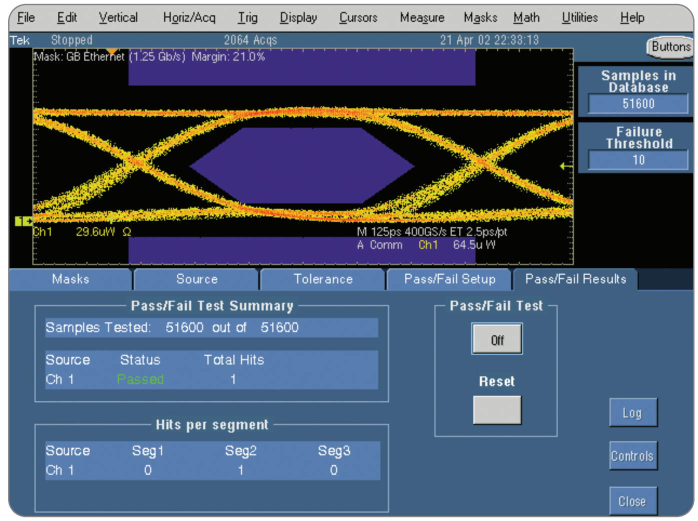
The pass/fail parameter is the failure threshold (the number of samples that must fail in order to fail the test). The test will declare a failure if the number of samples is more than or equal to the failure threshold.

You can also define what you want the oscilloscope to do when a mask test fails and what you want it to do when the mask test is completed. More than one action can occur concurrently. Some examples are:

1. Have the instrument beep (BEEP)
2. Send an SRQ out on the GPIB bus (SRQ)
3. Send a trigger pulse out on the AUX OUT connector (AUX Out)
4. Stop signal acquisition immediately (Stop Acq)
5. Print the instrument screen image to a printer (Print)
6. Save the waveform data of the first waveform that causes the test to fail to a .wfm file (Wfm)
7. Save time, date, and basic test information of the first waveform that causes the test to fail to an ASCII text (.txt) file (Log Date)



▶ ***Figure 7:*** *The test failed because the number of mask hits is higher than the failure threshold.*



▶ ***Figure 8:*** *The test passed.*

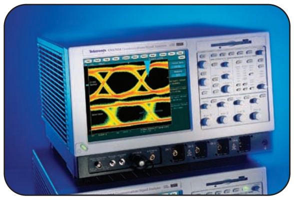
If higher throughput is your goal (for example, acquiring a statistical sample of data for measurement or collecting the most data in the shortest amount of time), increase the number of samples.

If throughput is less important than the most accurate failure threshold value, set up your test with fewer samples and use *Pass/Fail Test Repeat ON*. This will allow the test to continue running with smaller batches until the specified end-of-test condition is met.

Using infinite persistence in waveform database mode

In waveform database acquisition mode, *infinite* persistence is not handled by the display, but by the acquisition, so that the waveform accumulates all the samples acquired since the last reset. *Variable* and *no persistence* function the same way in waveform database acquisition mode. In both modes, samples will be accumulated to reach the number of samples requested by the user. You can turn on *variable persistence* and see signal changes degrade, but they are not reflected in the actual underlying, stored waveform as opposed to the way they are reflected in the waveform in infinite persistence. (In single sequence mode, infinite persistence refreshes at the first acquisition and accumulates acquisition data through multiple acquisition batches to the number of samples specified by the user.)

Measurements on a channel can cause acquisitions even when the channel is off. Acquisitions are not displayed while acquiring. However, if infinite persistence is on, you can turn on Channel 1 when stopped for a full display trace accounting. Infinite persistence can slow the display and measurement update rate when the samples are small, but do not have much effect if samples are long.

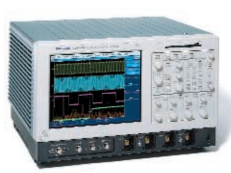


CSA7000 Series

Versatile, high-performance, real-time communications signal analyzers dedicated to rapid design analysis and verification of communications signals up to 2.5 Gb/s rates (OC-48/STM-16 or Fibre Channel FC2125).

TDS7000 Series
Digital Phosphor Oscilloscopes

TDS7000 Series oscilloscopes, with bandwidth from 500 MHz to 4 GHz and up to 20 GS/s real-time sample rate, are high-performance real-time oscilloscopes for verification, debug and characterization of sophisticated electronic designs.



TDS6604 DSO

The world's first 6 GHz oscilloscope delivers the performance you need for your most demanding signals. The TDS6604 will take you to a higher level of signal integrity for next-gen digital designs by providing you with the performance you need to verify the integrity of your signals and a suite of tools that simplify and accelerate your design process. With 6 GHz bandwidth and 20 GS/s sample rate on 2 channels, the TDS6604 provides unmatched signal integrity measurements.

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