

# Finding and Examining Pattern-Dependent Failures with FrameScan™ Acquisition Technology



COMPUTING  
COMMUNICATIONS  
VIDEO

## ▶ **CSA/TDS8000 Series sampling oscilloscopes address design and manufacturing challenges of high data rate testing.**

As bit rates increase to 10 Gbps and beyond, pattern-dependent failures become much more common in the generation, transmission, and reception of signals in various data and communication products and systems. Unfortunately with traditional test technologies, it has been very difficult and time consuming to reliably identify and observe these failures.

The normal way of examining these signals is to use a pseudo random bit stream (PRBS) from a pattern generator in conjunction with a digital-sampling oscilloscope triggered from a clock source synchronous to the data stream. The result is a display on the oscilloscope commonly referred to as an eye diagram. While these displayed data points accurately represent a statistical sampling of the digital data stream, they do not provide a way to view in detail the individual, complete waveforms or bit sequences leading up to a failure. Bit error rate testers can be used to determine the total number of bit

failures in the generated bit stream (sometimes referred to as a frame), but they can not identify the specific patterns that caused the failures.

In order to view the behavior leading up to a failure, the oscilloscope must first be triggered – not on the clock, but on a signal synchronous to the entire bit stream (i.e., frame) so that a complete representation of a single bit may be acquired and displayed. In addition, the user must either know where the failure is occurring, relative to the trigger signal, or manually scroll or increment the horizontal position of the oscilloscope to acquire each desired bit. Alternatively, the user could scroll or increment the location of the frame synchronization signal of the pattern generator to each successive bit, given the instrument provides this capability. In either case, it is a tedious and time-consuming process.

# FrameScan™ Acquisition Technology

► Application Note

Fortunately, Tektronix' CSA/TDS8000 Series digital sampling oscilloscopes with FrameScan™ acquisition technology are now available and offer a fast, reliable way to locate and examine these pattern-dependent failures. These oscilloscopes support automatic acquisition of successive individual bits – through an entire frame of data if needed – helping to uncover bit sequences, which lead to erroneous behavior.

As an added benefit, FrameScan acquisition technology is also useful for creating a clean eye diagram from low-powered, noisy communication signals (see **Examining Low-Power Communication Signals** at the end of this application note).

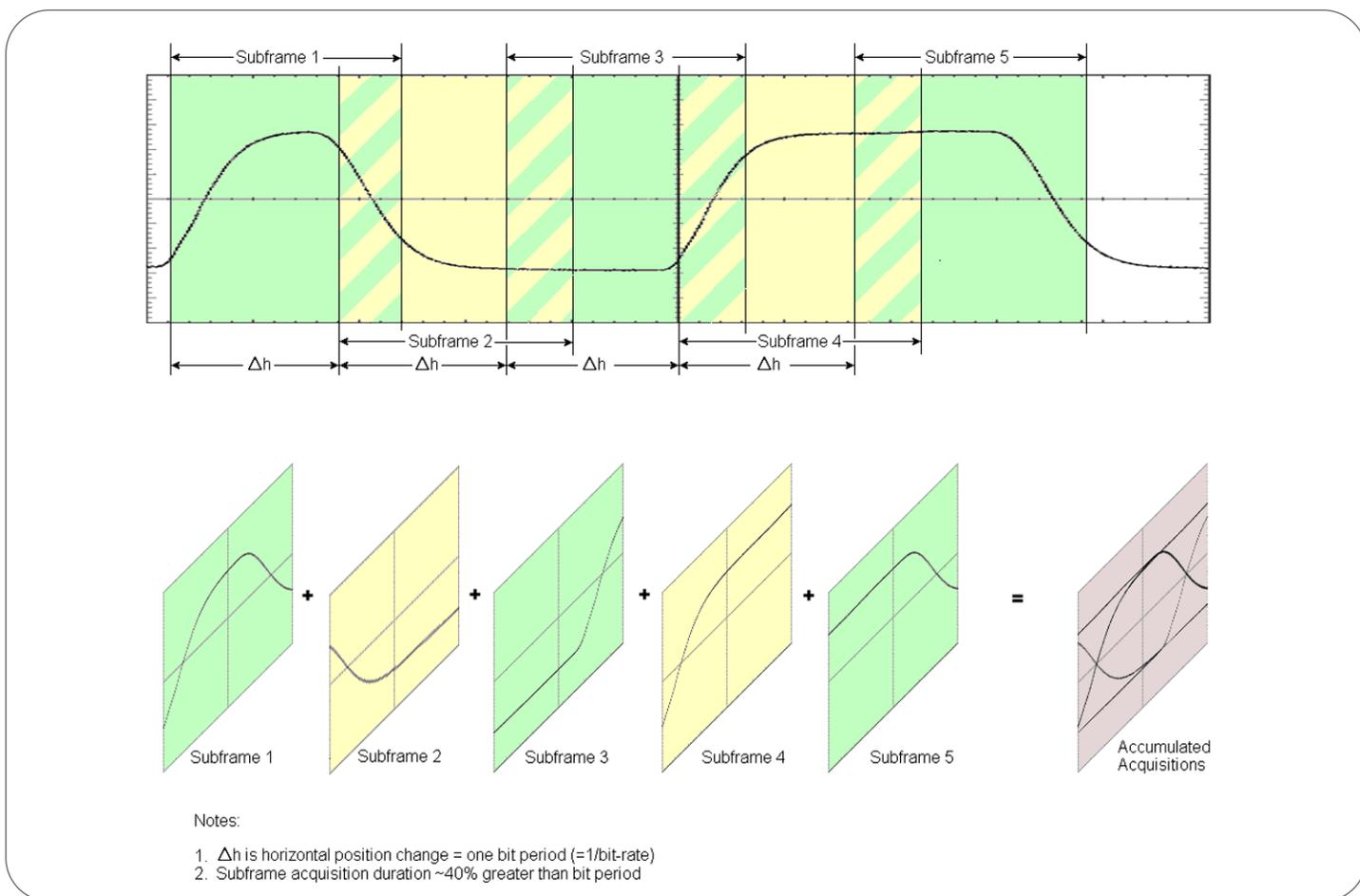
## How FrameScan Acquisition Technology Works

FrameScan acquisition technology is an acquisition technique that controls how successive acquisitions occur. It can be used with any source

that provides a “framing” signal – a signal synchronized to one location within the entire repetitive data stream – sometimes called Frame Sync or Frame Trigger.

The basic operation of FrameScan acquisition technology is to automatically sequence or skew the timebase such that each bit, or unit interval, of the data stream is acquired in increasing time order. The acquisition of each sample of each bit, and of each bit of the desired bit stream, is based on the trigger events derived from an externally provided Frame Sync or Frame Trigger signal, such as that provided by a pattern generator or a bit error rate tester (BERT). Because the sequencing or “scanning” of the timebase occurs automatically within the oscilloscope, there is no need to interact with the external signal source or the oscilloscope once they are appropriately set up.

Figure 1 illustrates the basic scanning sequence used for FrameScan acquisition. The upper section of this diagram shows a portion of a



► **Figure 1:** How FrameScan™ Acquisition Technology works.

127-bit pseudo random bit sequence (PRBS). Also shown is a representation of the portions of the signal that are captured for each subframe of data acquired during a FrameScan acquisition cycle.

Thus, when FrameScan acquisition is enabled, the CSA/TDS8000 Series sampling oscilloscope's horizontal position and scale are set to acquire the first bit of data (labeled Subframe 1).

Following acquisition of this subframe, the horizontal position is incremented by one bit period ( $\Delta h$ ) such that the instrument can acquire the second bit of data (labeled Subframe 2). This skewing of the horizontal position continues until all of the relevant data is acquired or the instrument is stopped due to a specific test condition (such as the failure of a mask test or the acquisition of a complete frame of data).

By turning on infinite display persistence or acquiring the waveforms into a waveform database, one can build a traditional eye diagram comprising all of these subframes of data. Such an accumulated eye diagram is shown in this illustration (labeled Accumulated Acquisitions).

Due to timebase technology in a sampling oscilloscope, all data is acquired relative to the trigger signal. For FrameScan acquisition, this is the frame trigger. However, if longer bit streams need to be acquired, or bits need to be acquired farther out in time relative to the trigger signal, performance can be degraded by accumulated horizontal jitter – a problem inherent in traditional sampling timebase technology – to the point that analysis is nearly impossible.

The CSA/TDS8000 Series sampling oscilloscopes overcome this limitation by providing breakthrough timebase stability on the order of 0.1 PPM of the delay from the trigger event to the acquired data point. Traditional sampling timebase technologies exhibit timebase stability on the order of 10 to 50 PPM. This (two orders of magnitude) improvement in timebase stability enables our CSA/TDS8000 Series sampling oscilloscopes to acquire signal information much further away from the trigger point than ever before; even to tens or hundreds of microseconds, with greatly improved jitter performance. This allows the oscilloscope to capture more information – possibly tens of thousands of bits or more (depending on the bit rate) – with higher signal fidelity and accuracy.

As a result, design and manufacturing engineers can now view signal activity for pattern dependent failures of almost any length. This is especially important for today's higher-speed data and communication signals, which require longer and longer patterns to identify and isolate data-dependent failures.

### **How to Use FrameScan Acquisition Technology**

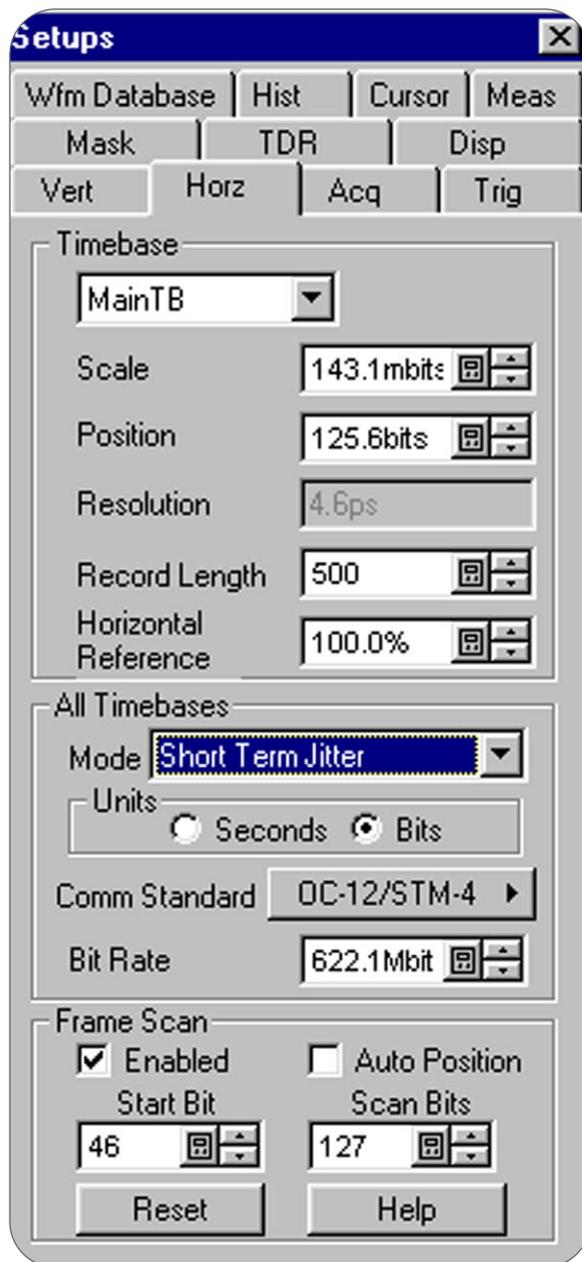
FrameScan acquisition technology used in conjunction with mask testing and an associated conditional acquisition feature (stop after mask hits) can automatically determine the bit at which a pattern-dependent failure may have occurred. The following describes the instrument controls and their use necessary to accomplish this task.

## Horizontal setup

Before enabling FrameScan acquisition, the user needs to determine the appropriate horizontal scale, the starting horizontal position, and the total number of bits for the desired FrameScan “cycle.” These controls are contained in the horizontal setup dialog of CSA/TDS8000 Series sampling oscilloscopes (see Figure 2).

The horizontal scale provides the time duration of the sub-frame window to be acquired. The starting horizontal position determines the point at which timebase sequencing or scanning begins at the start of each FrameScan cycle. One cycle is comprised of the entire sequence of acquisitions that are necessary in order to acquire the total number of requested bits.

While the duration of the FrameScan cycle must always be set manually via the **Scan Bits** control, the user may choose to have the instrument automatically determine one or both of the horizontal scale and starting horizontal position. In addition, while units of time is the default for these two controls, it is typically more useful, and generally recommended, to change the units from time (in seconds) to bits by selecting Bits in the Units control. This allows the user to manipulate these controls in the more likely horizontal domain of choice.



▶ **Figure 2:** Horizontal setup dialog.

**Bit Units, Comm Standard, and Bit Rate:** Using bit units becomes a distinct advantage for setting controls, in particular horizontal scale, when the bit rate under observation is known (the usual case). When bit units are selected, the **Comm Standard** and **Bit Rate** controls are enabled, allowing the user to easily specify, in their terms, what a bit is equivalent to in the time domain. The instrument automatically uses the resultant bit rate to translate the horizontal controls, now in units of bits, to the appropriate internal acquisition parameters necessary to achieve the desired setup. If the desired bit rate corresponds to a standard communication rate available in the instrument, use the **Comm Standard** control to specify the bit rate. Otherwise, **Comm Standard** may be set to **None** and the bit rate entered manually in the **Bit Rate** control.

***Important:** **Bit Rate** plays a critical role in the FrameScan acquisition process because it specifies directly the amount of time-base skew (i.e., adjustment of the horizontal position) from the acquisition of one bit to the next bit in the sequence. Note that this skewing of the horizontal position is not necessarily the same horizontal difference as that of the total acquisition duration set by the horizontal scale. In fact, the skewing value set by the bit rate is usually less than the total scale duration so that the second edge of the current acquired bit becomes the first edge of the next acquired bit. Therefore, if the rate specified by the **Bit Rate** control does not match that of the signal (or some integer multiple), subsequent acquired waveforms will appear to be skewed or have jitter, relative to one another.*

**Horizontal Scale (manual adjustment):** For manual adjustment, simply change the horizontal **Scale** control. Set this control to specify an overall time window greater than one bit period (if units are in seconds) or greater than one bit (if units are bits) so that both edge transitions of the acquired bits will be well within the acquisition window (given that the starting horizontal position is properly set up as described further below). For example, a scale of 0.125 bits/division would cause each opposite edge transition to appear approximately eight divisions apart on the display.

***Note:** If bit units are not active when the FrameScan acquisition is enabled, units will be automatically set to bits and the **Bit Rate** will be set directly to the inverse of the scale (e.g., 1/t). However, this will not provide the correct bit rate unless the scale was manually set to exactly the inverse of the bit rate (e.g., 1/bit-rate). This is another good reason why bit units are preferred over time units.*

**Horizontal Scale (automatic adjustment):** For automatic adjustment, bit units must be selected so that a bit rate is in effect (as just described). At this point, the user can invoke the **Standard Mask Autoset** (if a communication standard was specified) or **Bit/Eye Pattern Autoset** (if a manual bit rate was entered). This sets the horizontal scale based on either the standard mask autoset parameters or the bit rate value and will result in a total duration larger than one bit period (approximately 140% of one bit period).

**Starting Horizontal Position (manual adjustment):** For manual adjustment, set the FrameScan acquisition **AutoPosition** control to off. Each cycle, when FrameScan acquisition is enabled and acquiring, will begin at the location specified by the horizontal Position control. This can be useful, for instance, where it is desirable to manually align a bit or waveform to a mask on the display.

**Starting Horizontal Position (automatic adjustment):** For automatic adjustment, set the **AutoPosition** control to on and enter the desired starting bit location in the **Start Bit** control. When FrameScan is enabled, the instrument automatically calculates and uses a starting horizontal position for the beginning of the scan as close to the requested start bit as possible. Based on how it determines the alignment of the data stream to the acquisition window, it is possible to be one bit off from the requested start bit. Note that the valid values available for the start bit is dependent on the bit rate and the minimum horizontal position the timebase can attain. In other words, given a fixed horizontal position (i.e., time from trigger recognition to the horizontal reference), the equivalent number of bits is going to be different for OC-48/STM-16 than it is for OC-192/STM-16.

## FrameScan™ Acquisition Technology

► Application Note

Because **AutoPosition** can adjust the horizontal position of the waveform in the acquisition window, it can be less useful when used together with standard or user masks since there is potential for it to produce some misalignment of the waveform to the mask. For user masks, a better sequence would be to first allow the auto positioning to occur before defining the masks.

**Enabling the FrameScan acquisition technology:** FrameScan acquisition begins operation when the **Enable** control is turned on and is indicated on the screen with the text “SCANNING” in the upper right portion of the graticule. An additional side effect that occurs when the FrameScan acquisition technology is enabled is that the Horizontal Reference is set to 100% (right edge of the graticule). If other Acquisition and Mask setup is desired, it is preferable (easier) to set those up first before enabling FrameScan.

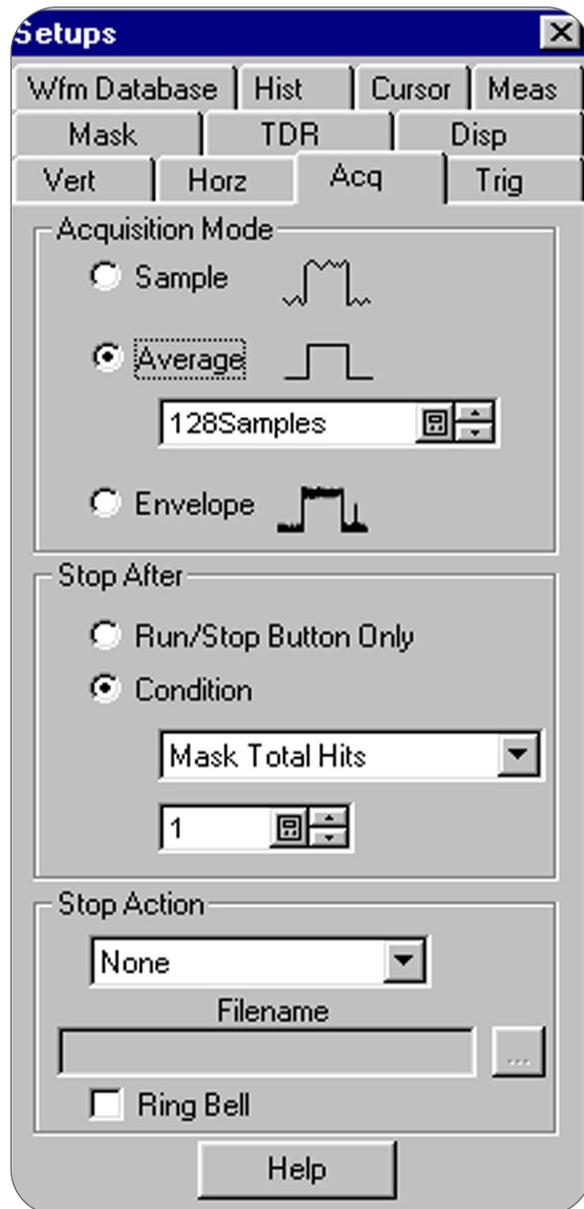
**Reset:** At any time, when FrameScan acquisition is active, the scanning may be reset to the starting horizontal position (i.e., starting bit location) by using the **Reset** control.

### Acquisition setup

Two acquisition-related features relevant to FrameScan acquisition and finding pattern dependent failures with mask testing are **Acquisition Mode** and **StopAfter** conditions.

**Acquisition Mode:** Only average and sample (or normal) acquisition modes are allowed with FrameScan. When averaging mode is active, the acquisition is “parked” on the sub-frame being acquired for the specified number of averages. Averaging is restarted when moving to the next sub-frame, eliminating the potential for artifacts from the previous sub-frame, which probably had different signal characteristics (e.g., presence of rising/falling edges, edge aberrations and overshoot/undershoot, etc.).

**StopAfter Condition:** When mask testing is active, the user may choose to stop acquisition when a specific mask counting condition is met, such as stopping after a specified number of mask hits are counted in a single mask or the total in all the masks. Under these setup conditions, the instrument will scan until the StopAfter condition is met. (In Figure 3, the instrument is set to stop whenever it sees 1 or more mask hits, in any mask.)



► **Figure 3:** Acquisition setup dialog.

Another StopAfter condition that may be useful, and applies only when the FrameScan acquisition technology is active, is one that stops acquisition after one complete cycle (i.e., after the instrument has acquired the number of bits specified by the **Scan Bits** control in the Horizontal Setup dialog).

**Run/Stop:** Any time FrameScan acquisition is active and acquiring, scanning may be paused by pressing the **Run/Stop** button or control (on either the front panel or the applications tool bar). Subsequently pressing **Run/Stop** causes scanning to resume from the current bit, assuming setup changes were not made which cause FrameScan acquisition to reset to the starting location. Again, using the **Reset** control (in the horizontal setup dialog), even when acquisition is stopped, will explicitly reset the scanning process.

### Mask test setup

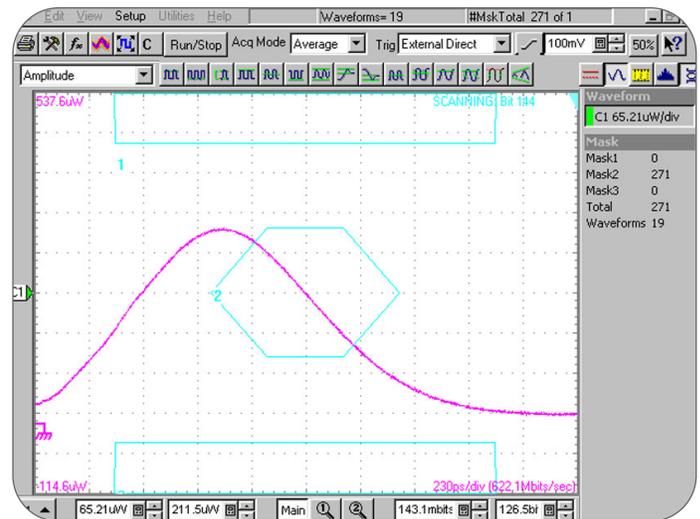
Since one of the primary uses of FrameScan acquisition technology is to find pattern-dependent anomalies, mask testing is fully supported in FrameScan acquisition mode. While FrameScan is basically an acquisition function, meaning that it applies globally to all active waveforms, mask testing is performed only on a specifically assigned source – similar to normal mask testing. Mask testing in conjunction with FrameScan acquisition can either be used with standard communication masks and bit rates or with user-defined masks and user-set bit rates.

Any valid waveform source allowed in normal mask testing is also allowed with FrameScan acquisition. For example, a Math waveform such as Ch1 – Ch2 would still be valid. In this case, the waveform data from sub-frame N of Ch2 would be subtracted from the waveform data from the same sub-frame N of Ch1 to create the Math waveform, which would then be tested against the mask regions. This math waveform construction is no different than what normally occurs when two channels are acquired using the same timebase.

When FrameScan acquisition is enabled, mask testing of each bit occurs “on-the-fly,” (i.e., the sub-frame of the selected source is tested against the masks as each bit is acquired. On-the-fly mask testing is performed so that StopAfter conditions, when satisfied, will force the acquisition to stop on the bit (or subframe) causing the StopAfter con-

dition. This allows the identification of the exact failed bit location since it will be present on the display when acquisition stops.

Figure 4 shows the result of stopping on a mask failure when in FrameScan Acquisition mode. Note that the failing bit is identified as “Bit 144.”



► **Figure 4:** Stop on mask failure.

Once the acquisition has stopped, the pattern leading up to the failure can be viewed as follows:

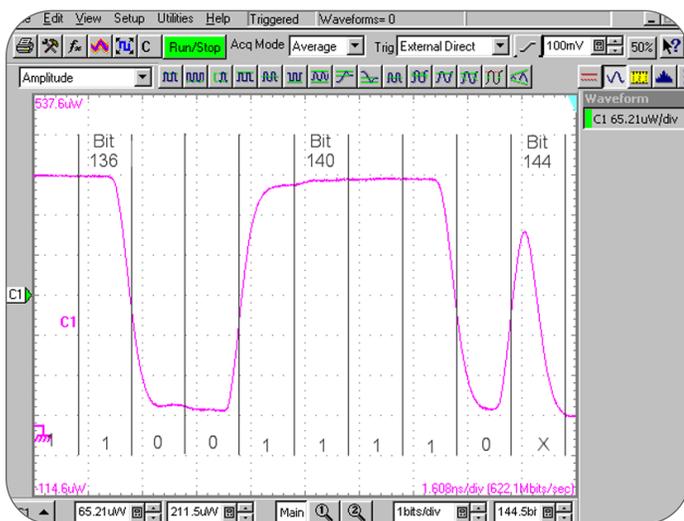
1. Note the failing bit (indicated in the upper right of the display as “SCANNING: bit 144”).
2. Disable FrameScan (using the **Enabled** check box in the horizontal setup dialog).
3. Disable the stop after condition (by setting the **Stop After** control in the acquisition setup dialog to **Run/Stop** button only).
4. Set the horizontal position to the previously noted failing bit number + 1.
5. Restart data acquisition (i.e., press the **Run/Stop** button).
6. Finally, change the **Scale** control in the horizontal setup dialog to display the desired number of bits preceding the mask test failure.

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### ► Application Note

The preceding bits are acquired as a result of the earlier setting of the Horizontal Reference to 100% when FrameScan acquisition was enabled. This causes the instrument to attempt to keep the right edge of the acquisition window fixed in time during Horizontal Scale changes, effectively expanding or contracting the left edge of the acquisition window.

Figure 5 is an annotated screen shot showing the eight bits preceding the failure detected in the previous setup. This data was acquired using the steps outlined above



► **Figure 5:** Bits preceding mask test failure.

## Waveform Database and Display Setups

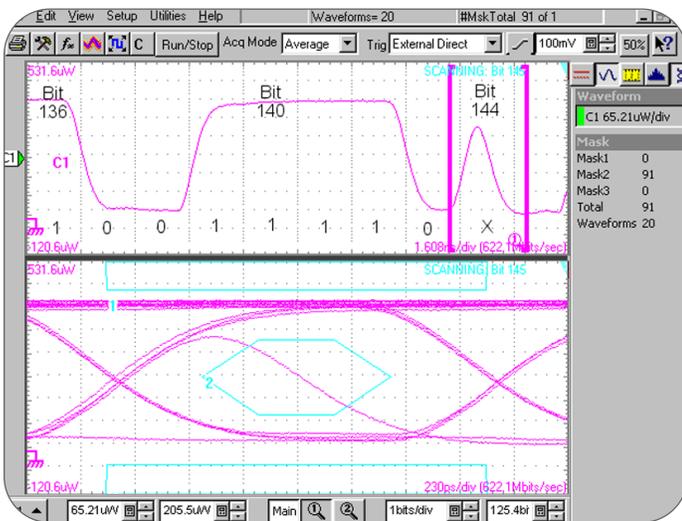
The CSA/TDS8000 Series sampling oscilloscopes have two flexible Waveform Databases which allow accumulation of waveform data with an added waveform dimension – density or pixel counts – which can be used to statistically analyze accumulated data during or after acquisition. By default, however, enabling FrameScan acquisition does not automatically cause accumulation of any of the active waveforms into a Waveform Database. This is due to FrameScan acquisition being a global acquisition mode, whereas Waveform Database accumulation is done by assignment of individual waveform sources to a Waveform Database.

If you wish to view accumulated acquired data and have it available for post acquisition analysis, assign the desired waveform source to a Waveform Database, turn it on, and activate its associated display. The Waveform Database display may also be turned off while still allowing it to be accumulated. In this case, another Display Style – Normal, Variable Persistence, or Infinite Persistence – may be chosen. The display of the Waveform Database may be turned on and off as desired. This versatility of display changes is independent of FrameScan acquisition operation.

## Dual Graticule Operation

Previously, we showed an example of detecting a mask failure using a CSA/TDS8000 Series sampling oscilloscope in FrameScan acquisition mode and then changing the setup of the instrument and reacquiring the signal to view the data pattern leading up to that failure. Using the magnification view capabilities, it is possible to capture the failing bit and view the preceding data pattern in a single pass with no need to change the instrument setup.

Figure 6 shows an annotated screenshot for such a dual graticule FrameScan Acquisition. This experiment uses the same failing data pattern examined in the previous examples.



▶ **Figure 6:** Dual graticule acquisition showing failing bit and preceding data pattern.

While the details of the setup for this experiment are beyond the scope of this application note, the high-level description of the dual graticule FrameScan acquisition setup is as follows:

1. In the main timebase, the horizontal scale was set to 1 bit/division and the bit transitions were aligned to the major divisions of the graticule.
2. The Magnification 1 (Mag1) timebase was turned on. The horizontal scale for Mag1 was set to 0.1431 (1/7) bits per division and the horizontal position for Mag1 was set to capture the bit shown in major division 9 of the main.
3. Acquisition mode was set to average and waveform database accumulation was setup for Mag1/Channel 1.
4. Mask testing was enabled for Mag1/Channel 1. The Mag1 Channel 1 signal was aligned to the mask. Stop After Condition was set to "Mask Total Hits = 1."
5. Finally, FrameScan acquisition mode was enabled.

As you can see, the result of this experiment is that all of the data leading up to the failed bit is shown in the eye diagram in the Mag1 graticule (bottom). In addition, the failing bit and the eight bits immediately preceding it are shown in the main graticule (top).

For more information on setting up magnification views, see the CSA/TDS8000 Series sampling oscilloscope User's Guide or Online Help.

### Conclusion

The ever-increasing speeds of data and communication signals result in new or changing design and test challenges, including the increased likelihood of pattern-dependent behavior and the use of lower-level signal amplitudes.

New acquisition technologies and techniques, such as those provided by the CSA/TDS8000 Series acquisition hardware and FrameScan acquisition features, help address these growing needs. The introduction of these types of features provide tools that aid in the identification and

examination of pattern-dependent anomalies and, at the same time, enable the extraction of useful signals in low amplitude and/or noisy environments.

## Examining Low-Power Communication Signals

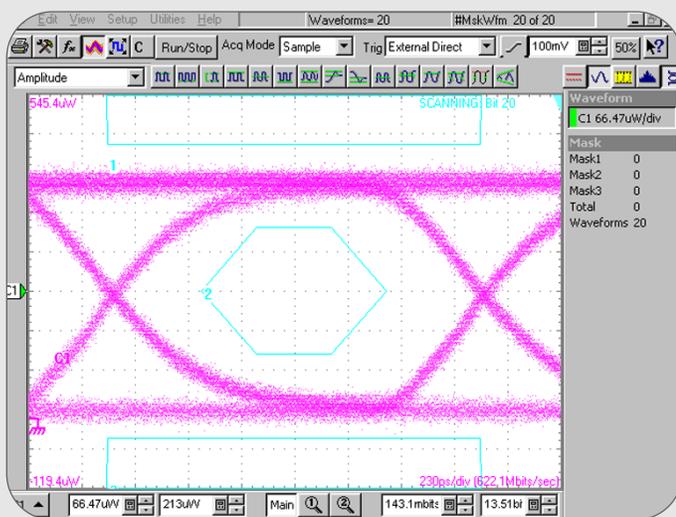
The ability to examine data one bit at a time with FrameScan acquisition is extremely useful when dealing with low-power communication applications. To minimize costs in data communications such as Gigabit Ethernet, manufacturers are using LEDs rather than lasers to transmit a portion of their signals. Another area where lower power levels are common is in long-distance, point-to-point communication links, such as undersea optical communication cables, where the goal is to minimize the number of repeaters and transponders in the system. Finally, as Dense Wavelength Division Multiplexing (DWDM) is gaining greater acceptance, the power for any individual channel within such systems is much lower than when a single wavelength was transmitted through the fiber interconnect.

These lower power levels create smaller signal-to-noise ratios, making it difficult to capture and examine the signal. Usually, one of the

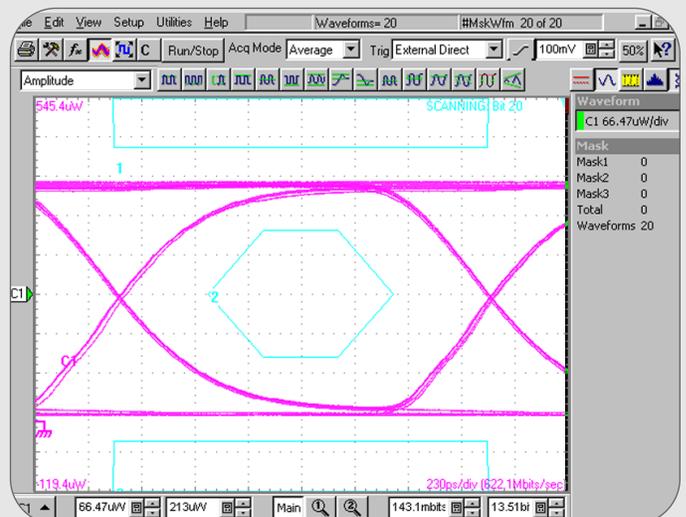
best ways to extract low-power signals from a noisy environment is to average the signal to remove the random noise. Unfortunately, averaging is not a viable technique for waveforms such as eye diagrams – typically acquired in a “random” or non-deterministic manner by triggering on the clock of the data stream – because it merely yields the average between the two logic levels. Using FrameScan acquisition, however, it is now possible to average the data, enabling the user to extract a clean eye diagram of a low-power signal from a noisy environment without distorting the waveform.

Figure A shows 20 bits of a typical optical communications signal acquired using normal acquisition.

Figure B shows the same signal with averaging ( $n = 128$ ) turned on. Averaging is only possible since the eye pattern is accumulated by sequentially acquiring each bit in order. FrameScan Acquisition Technology makes this possible.



▶ **Figure A:** Typical optical communications signal.



▶ **Figure B:** Typical optical communications signal acquired with averaging on.

## Contact Tektronix:

**ASEAN Countries** (65) 356-3900

**Austria** +43 2236 8092 262

**Central Europe & Greece** +43 2236 8092 301

**Belgium** +32 (2) 715 89 70

**Brazil & South America** 55 (11) 3741-8360

**Canada** 1 (800) 661-5625

**Denmark** +45 44 850 700

**Finland** +358 (9) 4783 400

**France & North Africa** +33 (0) 1 69 86 80 34

**Germany** +49 (221) 94 77 400

**Hong Kong** (852) 2585-6688

**India** (91) 80-2275577

**Italy** +39 (02) 25086 1

**Japan** (Sony/Tektronix Corporation) 81 (3) 3448-3111

**Mexico, Central America & Caribbean** 52 (5) 666-6333

**The Netherlands** +31 (0) 23 569 5555

**Norway** +47 22 07 07 00

**People's Republic of China** 86 (10) 6235 1230

**Poland** +48 (0) 22 521 53 40

**Republic of Korea** 82 (2) 528-5299

**Russia, CIS & The Baltics** +358 (9) 4783 400

**South Africa** +27 11 254 8360

**Spain** +34 (91) 372 6055

**Sweden** +46 8 477 6503/4

**Taiwan** 886 (2) 2722-9622

**United Kingdom & Eire** +44 (0) 1344 392400

**USA** 1 (800) 426-2200

For other areas contact Tektronix, Inc. at: 1 (503) 627-7111

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