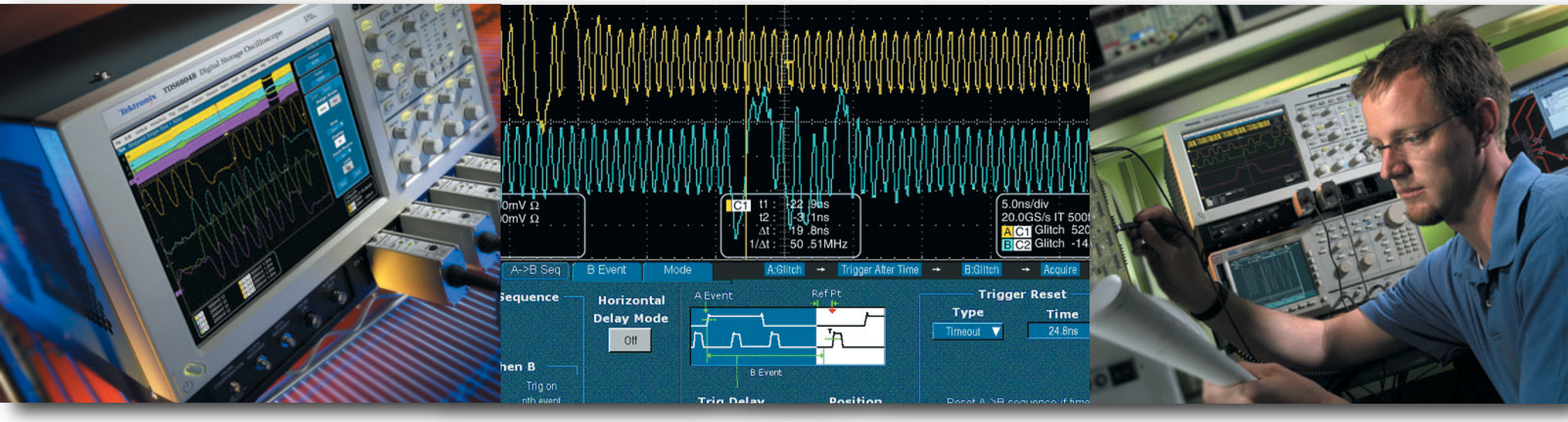
# Trigger at a New Level
# Pinpoint™ Triggering




## On TDS6000B and TDS/CSA7000B Oscilloscopes

Tektronix
Enabling Innovation

## Introduction

The oscilloscope provides a window into the world of electronic design. Early oscilloscopes could only display repetitive or continuous events, which limited their application. Then, in 1947, Howard Vollum implemented the first commercially available triggered sweep oscilloscope and Tektronix was born.

The first triggered sweep oscilloscope along with its calibrated graticule display transformed the oscilloscope from a “qualitative tool” that gave vague and impressionistic readings of electrical impulses into a quantitative measurement device that revolutionized the electronics industry. For the first time, engineers could capture transient (random) events and make accurate voltage and timing measurements. While electronics have changed in the last 60 years, it is often that elusive transient event that causes computer systems to crash or a device not to operate correctly.

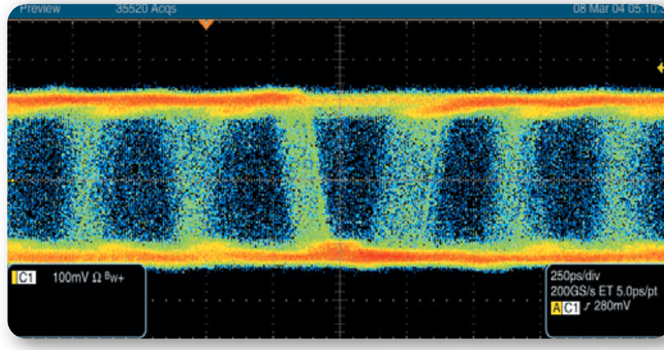
The trigger event defines the point in time where your “window” stops so you can see (capture) what is happening in your circuit. Imagine you are taking a trip in your car. You need to arrive at your destination in the minimum amount of time. However, you also need to take a picture of a point of interest along the way. You know you can get to your destination quickly because you have a very fast car, but what’s your strategy for capturing the point of interest on film? One choice would be to randomly snap pictures on your camera as you drive and hope you capture it. A second choice would be to video tape the whole trip while you drive and search through the video later to see if you captured it. Both of these options would likely result in a poor picture, if the point is captured at all. The third and most logical choice would be to give the driver instructions on where on the highway you want to stop so you can get a good clean picture of your point of interest. Waveform data in many oscilloscope applications is like the 99.99% of the scenery on your trip that you don’t care about. In a high speed debug application, your circuit may be working 99.99% of the time or even more. It is the .01% of the time that is causing your system to crash or is the portion of the waveform you care about for additional analysis. Your oscilloscope may have the banner specifications (bandwidth, sample rate, record length) to make the trip quickly, but if you cannot capture the data of interest it will be a limited debug and analysis tool.

Tektronix’ Pinpoint™ trigger system in the TDS6000B and TDS/CSA7000B (referred to in the rest of this document as simply ‘TDS oscilloscopes’) provide the most comprehensive, high performance trigger system in the industry. The Pinpoint trigger system also features Dual A- and B-Event Triggering, Logic Qualification, Window Triggering, and Reset Triggering providing almost unlimited flexibility in setting up the trigger event. Pinpoint triggering is implemented using Silicon Germanium (SiGe), which makes all the trigger features useful to the full analog bandwidth of the oscilloscope. The features and performance of Pinpoint triggering allow you to ‘pinpoint’ the most elusive events of interest in your high speed digital designs.

This document discusses some fundamentals of triggering, and how Pinpoint triggering takes triggering in real-time oscilloscopes to a new level.

## Triggering Fundamentals

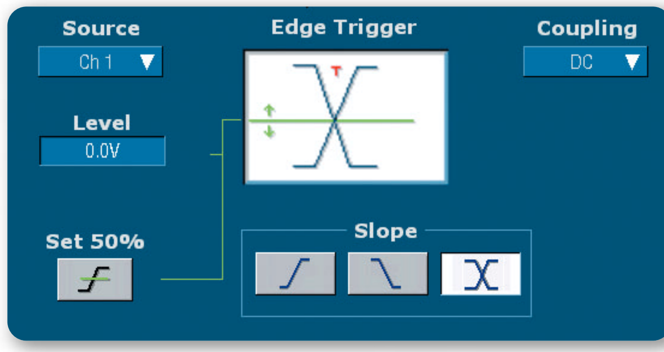
An oscilloscope's trigger function synchronizes the horizontal sweep at the correct point of the signal, essential for clear signal characterization. Trigger controls allow you to stabilize repetitive waveforms and capture single-shot waveforms. The trigger makes repetitive waveforms appear static on the oscilloscope display by repeatedly displaying the same portion of the input signal. Imagine the jumble on the screen that would result if each sweep started at a different place on the signal, as illustrated in Figure 1. Prior to the triggered sweep oscilloscope, this is what users were faced with.




▶ **Figure 1.** *Untriggered Oscilloscope Display.*

### Edge Triggering

Edge Triggering, available on all modern oscilloscopes, is the basic and most common type of triggering. Edge triggering is usually adequate to give you a look at the general amplitude and timing characteristics of the waveform. Figure 2 shows the controls available for Edge triggering in the Pinpoint trigger system.




▶ **Figure 2.** *Edge Trigger Menu.*

### Trigger Source

The oscilloscope does not necessarily need to trigger on the signal being displayed. Several sources can trigger the sweep:

- Any input channel
- An external source other than the signal applied to an input channel
- The power source signal
- A signal internally defined by the oscilloscope, from one or more input channels

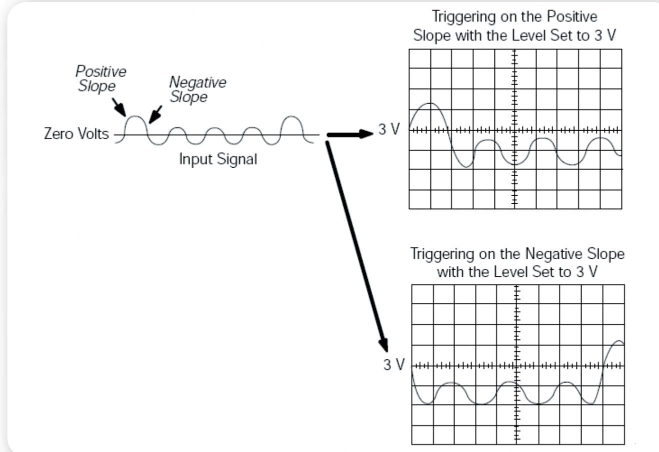
Most of the time, you can leave the oscilloscope set to trigger on the channel displayed. TDS oscilloscopes also provide a trigger output that delivers the trigger signal to another instrument. The oscilloscope can use an alternate trigger source, whether or not it is displayed, so you should be careful not to unwittingly trigger on Ch1 while displaying Ch2, for example.

### Independent Trigger Level Settings

Many designs include a variety of logic families with different voltage swings and offset levels. In the past, oscilloscopes shared trigger level settings across all source channels. This could result in users needing to adjust trigger level each time a different channel was selected as the trigger source. The Pinpoint trigger system provides a choice for legacy behavior (Shared) levels or new behavior (Independent) that provides unique trigger level settings for each input source.

## Trigger Level and Slope

The trigger level and slope controls provide the basic trigger point definition and determine how a waveform is displayed, as illustrated in Figure 3. You select the slope and level, and the oscilloscope triggers when your signal meets these conditions. The Trigger Level indicator is shown by a small arrow on the right hand side of the display (Figure 4). The color of the trigger level indicator corresponds to the selected trigger source channel.



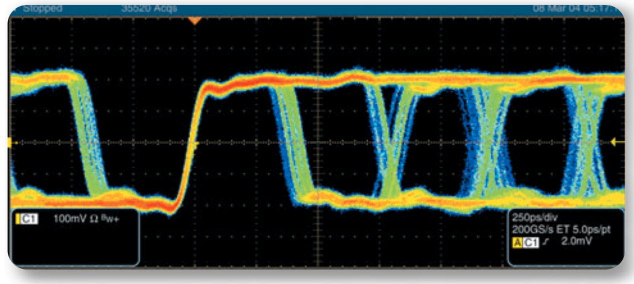

▶ Figure 3.

## Trigger Position

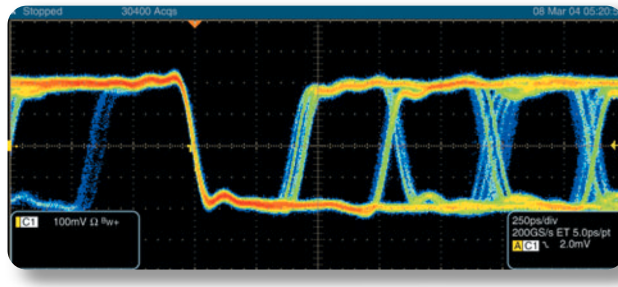
The Horizontal Position knob located on the oscilloscope's front panel is used to position where the trigger event is displayed on screen. Varying the horizontal position allows you to capture what a signal did before a trigger event, known as pre-trigger viewing. Thus, it determines the length of viewable signal both preceding and following a trigger point. Digital oscilloscopes can provide pre-trigger viewing because they constantly process the input signal, whether or not a trigger has been received. A steady stream of data flows through the oscilloscope; the trigger merely tells the oscilloscope to save the present data in memory. Pre-trigger viewing is a valuable troubleshooting aid. If a problem occurs intermittently, you can trigger on the problem, record the events that led up to it and, possibly, find the cause. In Figure 4, the trigger position is set to the third major horizontal graticule (or 30% of the horizontal sweep). The trigger point can be positioned anywhere from 0% to 100% of the record. At 100% position, the entire record occurs before the trigger point, allowing maximum trigger preview. At 0%, the entire record occurs after the trigger allowing maximum post trigger viewing. If you need to go beyond one full record after the trigger event, then a delayed trigger can be used. Delayed triggering will be discussed later.

### Triggering On Both Edges

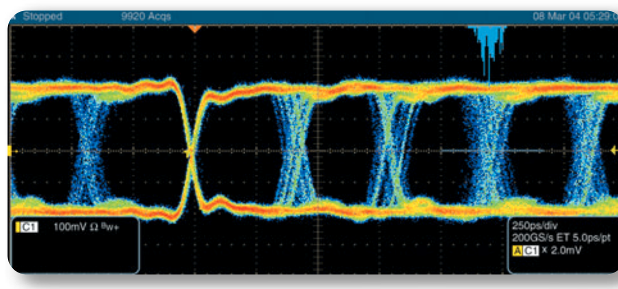
Positive and Negative (Figure 4a and 4b) slope have been offered in trigger systems for years. The Pinpoint trigger system also allows you to trigger on both Positive and Negative slope (Figure 4c) which is often useful when looking at jitter on high speed clock and data signals. Figure 4 shows the result of changing the trigger slope from Rising Edge, to Falling Edge, to Both Edges.



▶ **Figure 4a.**



▶ **Figure 4b.**



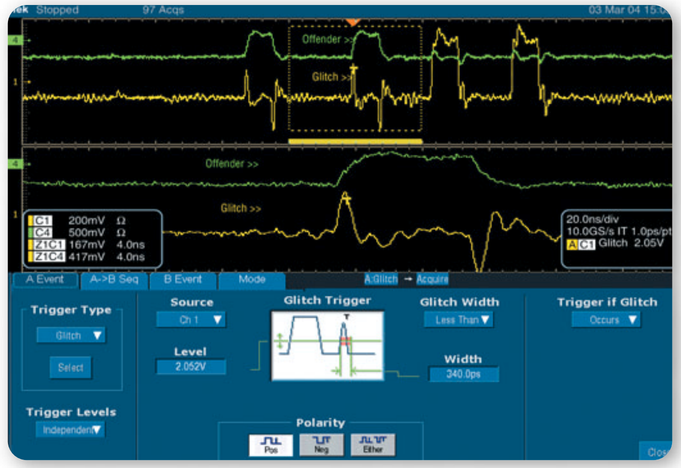
▶ **Figure 4c.**

▶ **Figure 4.** *Trigger Slope Positive (a), Negative (b), Both (c). Trigger Position is 30% indicated by orange 'pinpoint'. Trigger Level at 880 mV indicated by yellow arrow.*

## Advanced Trigger Types and Controls

Often relying on edge triggering to capture events of interest in a complex waveform is like randomly taking pictures from your car and expecting to capture the point of interest during your trip. This is where advanced trigger settings are useful for telling the oscilloscope where on the waveform to stop and capture the best picture.

Advanced triggers respond to specific conditions in the incoming signal, making it easy to detect, for example, a pulse that is narrower than it should be. Such a condition would be impossible to detect with edge trigger alone. Advanced trigger controls enable you to isolate specific events of interest. The Pinpoint trigger system gives you highly selectable control over the type event you are trying to capture. You can trigger on pulses defined by amplitude (such as runt pulses); qualified by time (pulse width, glitch, slew rate, setup-and-hold, and time-out); both amplitude and time using window triggering; or delineated by logic state or pattern (logic triggering). The intuitive user interface allows rapid setup of trigger parameters with wide flexibility in the test setup to maximize your productivity. The advanced trigger menu can be displayed by selecting the trigger setup menu item with a mouse or the oscilloscope's touch screen or by pressing the ADVANCED button in the TRIGGER section of the front panel. In previous trigger systems, advanced triggering was limited to the A-Event only. Pinpoint triggering has two identical trigger circuits allowing full advanced trigger qualification on both the A- and B-Events. This is referred to as Dual A- and B-Event triggering.




▶ Figure 5a.

### Pinpoint Triggering offers Dual A- and B-Event triggering[*1] with the following trigger types:

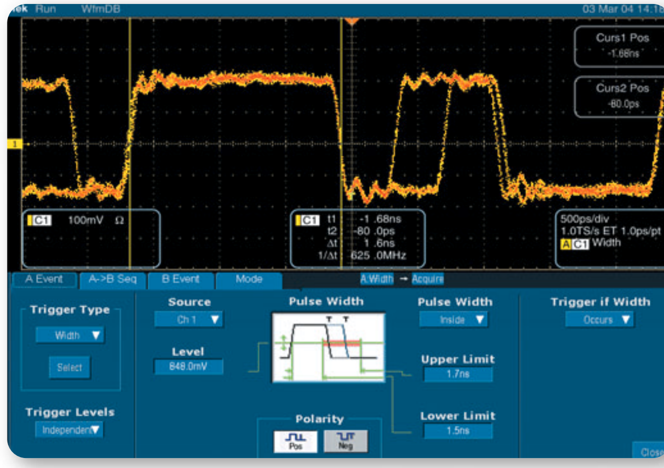
#### Glitch Triggering

Glitches in logic signals never result in desirable circuit behavior. Glitch triggering allows you to accept (or reject) only those triggers defined by pulse widths that are below a defined limit. A polarity of Negative, Positive, or Either can be selected. This trigger control enables you to examine the causes of even rare glitches and their effects on other signals. The Pinpoint trigger system's user interface allows you to search for glitches less than a minimum value of 320 ps and detect glitches down to 170 ps wide with a minimum rearm[*2] time of 250 ps. In Figure 5a, Glitch Triggering is used to debug crosstalk. Ch1 is used to trigger on the glitch that is causing logic uncertainty in the system, Ch4 is used to identify the offender signal from an adjacent data line.

[*1] Dual A- and B-Event triggering is available in firmware version 3.0.3 and above on TDS/CSA7000B Series. Previous firmware supports edge triggering only on the A-Event in the TDS/CSA7000B Series.
[*2] The trigger rearm time is the time it takes the trigger system to be ready to accept another trigger event after it has detected a previous event.

### Width Triggering

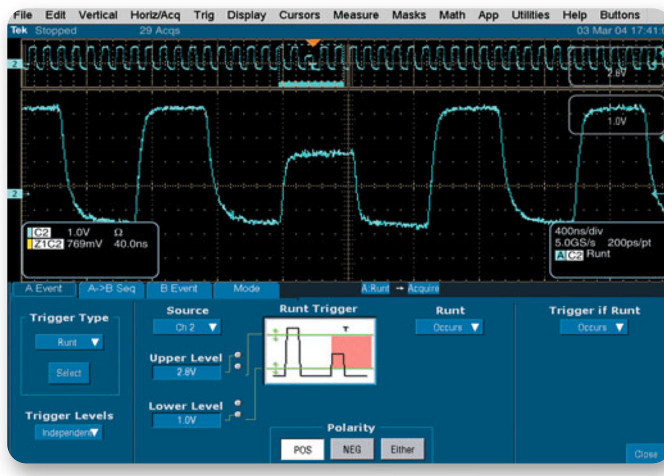
Inter-symbol Interference (ISI) is caused by large differences in pulse widths adjacent in serial bit stream. In 8B/10B encoding bit times can range from one to five bits. PRBS signals can have pseudo-random widths that vary even more. Width triggering allows you to accept (or reject) only those triggers defined by pulse widths that are between two defined time limits. A pulse polarity of Positive or Negative can be selected. Pulse Widths can range from 170 ps to 1 s with user interface control down to 225 ps and a rearm time of 250 ps. In Figure 5b, Width triggering is used to trigger only on positive pulses that are four bits long (1.6 nsec) in a 2.5 Gb/s serial bit stream.




▶ Figure 5b.

### Runt Triggering

Runt pulses in digital signals often represent meta-stable conditions that can throw a digital system into an unknown state. Runt triggering allows you to accept only those triggers defined by pulses that enter and exit between two defined amplitude thresholds. A runt can also be time qualified with a minimum pulse width of 360 ps and a rearm time of 450 ps. A runt polarity of Positive, Negative, or Either can be selected. In Figure 5c, the runt trigger levels are setup to be the minimum threshold values of a logic family (and a pulse that violates the specification is captured.)




▶ Figure 5c.

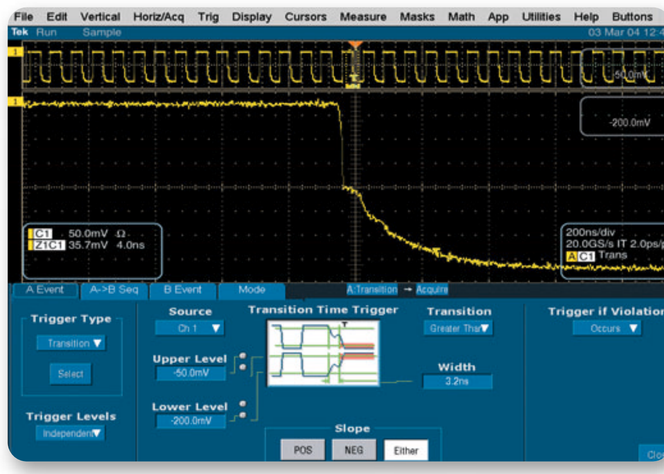
### Timeout Triggering

Unexpected dead times in clock or data signaling are sometimes designed into a system. However, if not properly timed with other system events, a dead time can cause system communications errors. It is often useful to trigger on these dead times to either discover whether they exist and then to investigate their timing with other signals. Using Timeout trigger, you can trigger on an event which remains high, low or either, for a specified time period, the period can be adjusted from 360 ps to 1 s using the timer control. In Figure 5d, timeout triggering identifies a dead time in a 2.5 Gb/s PCI Express serial data stream. The timer is set to 2.0 nsec, guaranteed to be larger than any data width in the signal. The dead time is 32 nsec (or 80 bits). The acquisition counter identified 9 timeout events in 10 seconds, indicating that this event occurs only .0000029% of the time in the repeating bit stream.


▶ Figure 5d.

### Transition Time Triggering

Edges (transition times) that are too fast can radiate troublesome energy. Transition times that are too slow (on a clock for example) can cause circuit instability. Transition Time triggering allows you to trigger if the time interval from the low-to-high and/or high-to-low thresholds is slower (larger) than, or faster (smaller) than a specified time, with Positive, Negative, or Either polarity selected. In Figure 5e, transition time triggering is used to identify a clock edge that is slower than 3.2 nsec.




▶ Figure 5e.

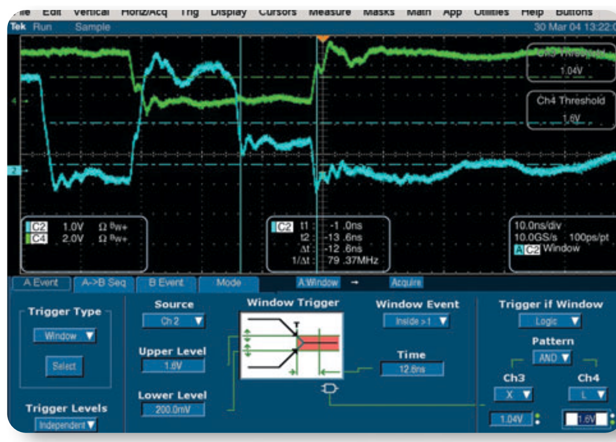
### Setup-and-Hold Triggering

Setup-and-Hold violations can cause data errors that may ripple through the system. Setup-and-Hold triggering makes it easy to capture specific signal quality and timing details when a synchronous data signal fails to meet setup-and-hold specifications. It allows you to trigger if a positive or negative data edge (transition) occurs within the defined setup and hold time window of the positive (or negative) clock edge. Only setup-and-hold triggering lets you deterministically trap a single violation of setup-and-hold time that would almost certainly be missed by using other trigger types. Figure 5f shows 1143 acquisitions captured with a setup violations less than 300 ps and hold times less than 200 ps.

### Window Triggering

In many high speed designs, several internal component buses share the same copper bus on a circuit board. An array of buffers controlled by either hardware or software is used to multiplex the correct data onto the main bus. The multiplexer logic is designed to only enable one set of bus data at any one time. Design errors can cause bus contention where a bus designed to only have two logic levels experiences a tri-state mode where the signal is neither a ‘1’ or a ‘0’. Window triggering can be used to easily capture bus contention events. With window triggering, the oscilloscope triggers on an event that enters (or exits) a window defined by two user-adjustable thresholds. Additionally, a time qualifier on the Window trigger can also be used to complete a rectangle window in time which in which if the signal enters or exits, the oscilloscope is triggered. The minimum window width is 225 ps with a minimum rearm time of 300 ps. Figure 5g illustrates where a bus contention event is captured. The trigger levels are set to the Hi and Lo threshold voltages of the logic family.


▶ **Figure 5f.**




▶ **Figure 5g.**

▶ **Figure 5.** *Seven advanced trigger types for qualifying complex waveform events. All are available for both A- and B-Events.*

## Logic Qualification

With Pinpoint triggering, all the advanced trigger types described above (Glitch, Width, Runt, Timeout, Transition Time, Setup-and-Hold, and Window) can also be optionally logic qualified adding another powerful dimension to isolating events. Figure 6 shows where Logic Qualification is used to capture a setup-and-hold where Ch1 (yellow) and Ch2 (blue) are Clock and Data. The trigger event is logic qualified by Ch3 (magenta) and Ch4 (green) both being high. Triggers only occur on setup-and-hold violations when the logic condition is satisfied.

## Logic Triggering

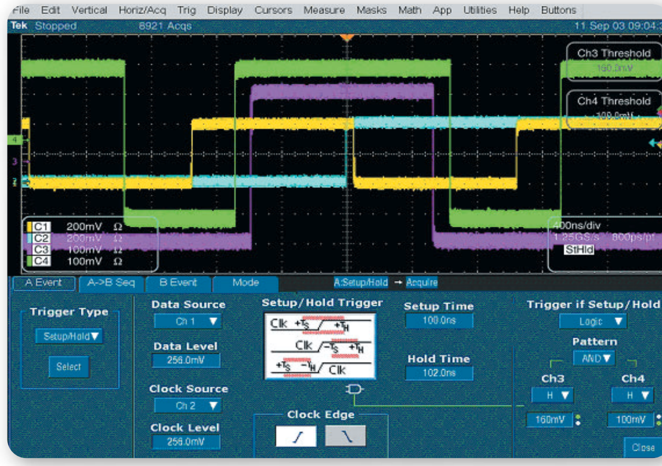
In digital circuits it is often desirable to define trigger conditions based on the logic states of the signals you are probing. A four channel oscilloscope provides the ability to use up to four logic states to trigger the scope. With Pinpoint triggering there are two types of logic triggering.

### Logic Pattern Triggering

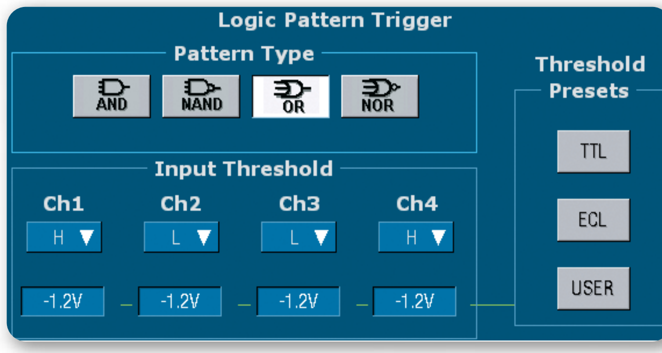
Logic triggering (Figure 7a) allows you to trigger on any logical combination of available input channels – especially useful in verifying the operation of digital logic. The oscilloscope triggers when a logical pattern (AND, OR, NAND, NOR) is satisfied by the input channels. Traditional logic families (TTL and ECL) provide pre-defined threshold levels, or USER can be used to set thresholds for logic families such as high speed CMOS.

### Logic State Triggering

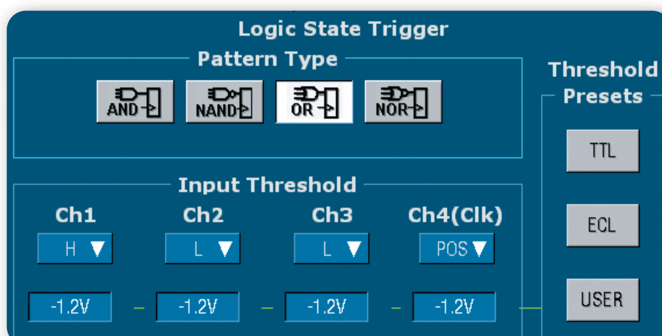
Similar to Logic Pattern triggering, with Logic State Triggering, the trigger is defined by any logical pattern of channels 1, 2, and 3 clocked by an edge on Ch4 (Figure 7b). The trigger can be on either the rising or falling clock edge. This type of trigger is very useful when de-bugging propagation delay and meta-stable issues in circuits containing flip-flops and shift registers. Logic State Triggering can be useful when troubleshooting parallel buses where there is a distributed clock and many data signals, while serial triggering (discussed later) is useful for triggering on embedded clock data in serial buses.




▶ **Figure 6.** *Logic Qualified Setup-and-Hold Triggering.*




▶ **Figure 7a.**




▶ **Figure 7b.**

### The Primary Trigger Event – The A-Event

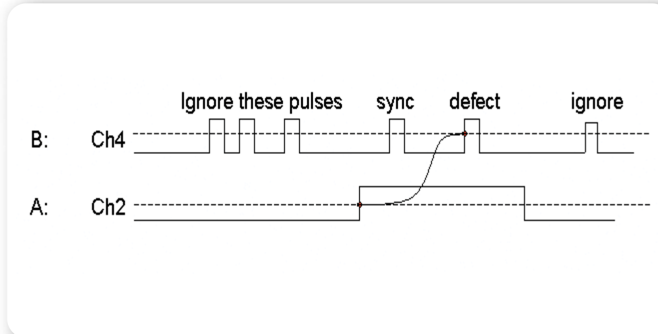
Thus far we've discussed ten different trigger types. All are used to tell the oscilloscope the set of conditions where to capture the waveform and display it with respect to the trigger position indicator on the graticule. For many applications, there is only one event of interest and A-Event triggering is sufficient.

### Delay Triggering

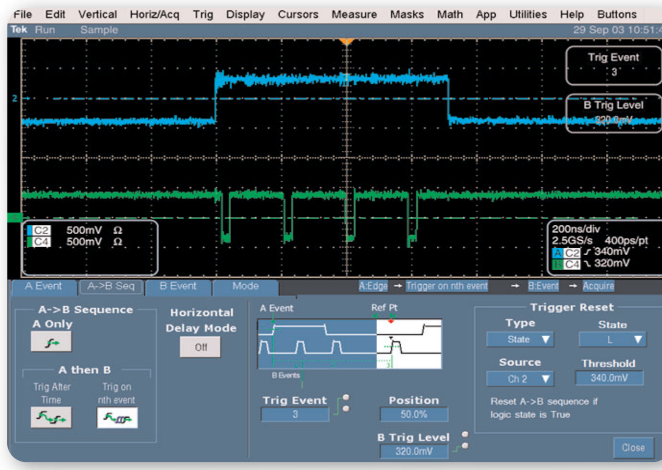
If the event of interest is more than one full waveform record length past the A-Event, delay must be used to display the event on screen. Delay from the A-Event can be specified in time (ranging from 4.8 ns to 3 Ms) or number of events (ranging from 1 to 2 billion events).

### A → B Sequence Triggering

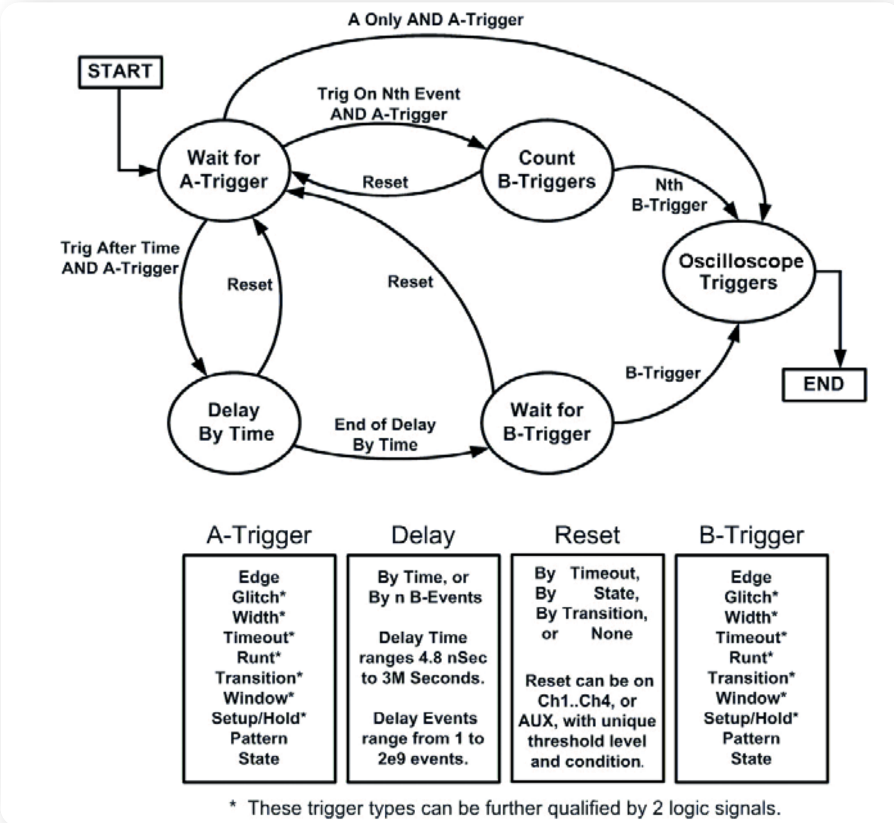
In the most demanding applications a single trigger event is not sufficient to fully define the circuit behavior that creates the event of interest. Going back to the trip we're taking in a car, imagine when you pull over to take your picture, you notice yet a more interesting detail, a lone eagle sitting on a perch. You use the features of your camera (zoom, shutter speed, etc.) to capture this even more interesting event. In high speed logic circuits it is often desirable to trigger based on a sequence of events. A second event or B-Event can be defined. The B-Trigger circuit can be setup to start looking for an event after a specified amount of time (known as Delay by Time), or number of events (known as Delay by Events). Once the time or number of events is satisfied, the B-Event circuit waits to capture the next event that comes along. In previous trigger systems, the B-Event trigger was limited only to Edge qualification. As discussed earlier, Pinpoint triggering has a unique dual trigger system that offers the same robust suite of trigger types on the B-Event as is offered on the A-Event. Both the A- and B-Event trigger menus are identical.




▶ **Figure 8.** *Disk Drive Read Gate Sequence.*




▶ **Figure 9.** *Triggering on Drive Defect.*




▶ **Figure 10.** *Pinpoint Trigger State Machine.*

### Reset Triggering

A → B sequences can be used to "navigate" through a series of pulse-events in a complex system. For example, a start-of-frame pulse can serve as the A-Event and clock pulses used for the B-Event. By selecting the $n^{th}$ B-Event you can view system activity n-clock cycles after the start-of-frame. Delay by Time triggering is often used to ignore activity until a specified time has 1 µs after a sync pulse.

The timing diagram in Figure 8 shows a common application in the disk drive industry, but also applies to other digital debug applications where you want the trigger system to ignore potions of the waveform. In this example, the need is to identify data defects only when the read gate signal of the drive is high. In this case Ch2 is connected to the read gate signal and Ch4 is observing the data being read. Thus, what is needed is a trigger that ignores the data signal when Ch2 is low and triggers on Ch4 if there are too many pulses in the data. Previous trigger systems do not allow you to "stop looking" for a B-Event, they simply will trigger on the next B-Event that comes along or wait indefinitely until the next even comes along.

Pinpoint triggering adds this Trigger Reset feature to the A → B Sequence system, directing the instrument to stop waiting for a B-Event when a certain reset criteria is met.

Reset triggering adds three new selections to the Sequence setup; Reset A Trigger after a specified amount of time reset after an amount of time (Reset By Timeout), Reset A Trigger after a specified rising/falling transition (Reset By Transition), and Reset A Trigger when a logic state is met (Reset By State).

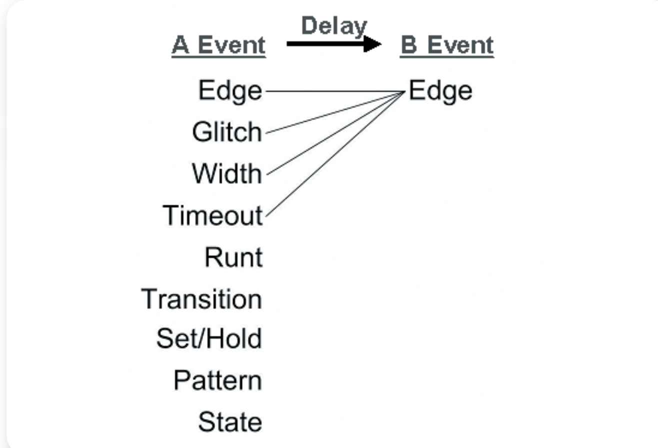
Figure 9 uses Reset By State to trigger on the second pulse (defect) after the sync pulse on the data signal (Ch4 - green trace). The A-Event is an Edge trigger on the Gate signal (Ch2 - blue trace) on the Data signal. A -> B Sequence By Events is used to trigger on the defect pulse. The trigger sequence is reset when the Gate signal satisfies the logic condition of returning to a low state. The trigger sequence ensures that the oscilloscope will only trigger when a defect is detected.

### Sequential Logic Triggering

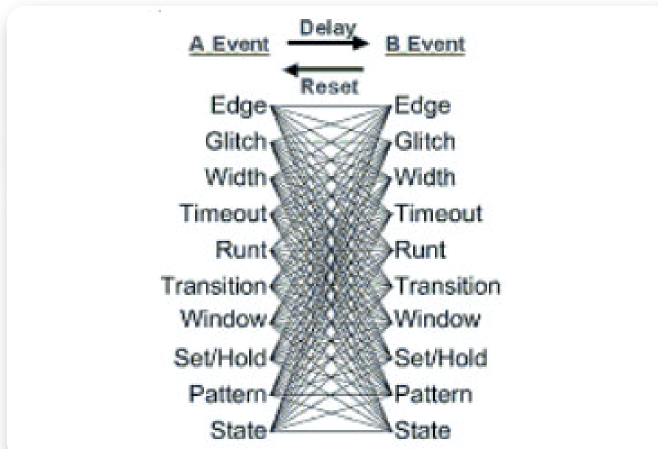
As discussed above, the two new features of Dual A- and B-Event Triggering and Reset Triggering allow the oscilloscope user to setup a sequence of events to trigger on (or not trigger on). The state machine that represents the Sequential Logic trigger event is shown in Figure 10.

## Out with the Old, in with the New

The addition of Reset Triggering and Dual A- and B-Event Triggering has opened up many new triggering possibilities. The previous generation of TDS oscilloscopes was limited to seventeen different trigger combinations. At that time, this trigger was considered industry leading. Today with Pinpoint Triggering, there are now over fourteen hundred combinations.




▶ **Figure 11a.** *Previous Generation Triggering - 17 trigger combinations.*




▶ **Figure 11b.** *Pinpoint Triggering - 1445 trigger combinations.*

## Application Specific Triggering

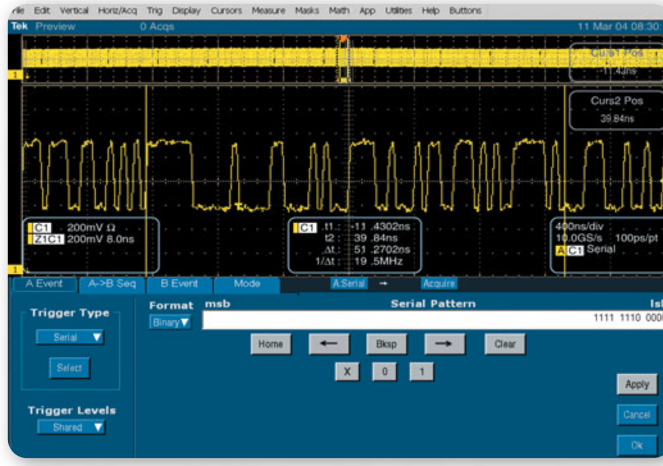
The A-Event menu in the Pinpoint Trigger system has two additional trigger types; Serial Triggering and Communication Triggering.

### Serial Triggering

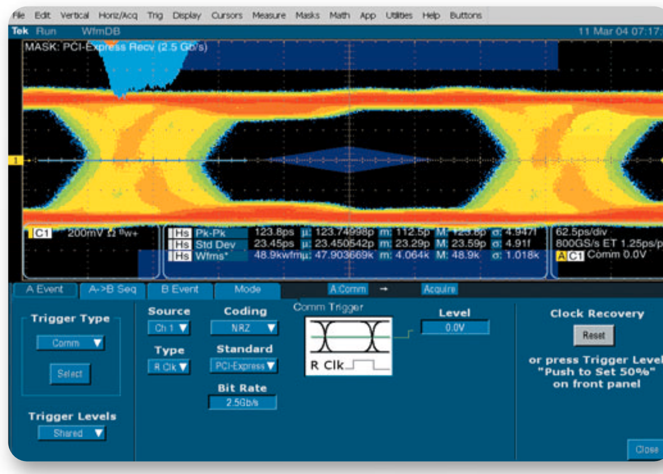
Serial Pattern triggering (enabled when Opt. ST is installed), provides pattern triggering useful on data in both serial and parallel data buses out to 1.25 Gb/s. The data in pattern triggering can either be serial (embedded clock) or parallel (separate clock). Serial pattern triggering can trigger on a specified pattern with length of up to 64 bits long, providing a tremendous debug tool for many of today's buses. Figure 12 shows a trigger on a 1111 1110 0000 1X Fibre Channel bit stream.

### Communication Triggering

The Comm (Communication) Trigger (enabled with Opt. SM – standard on the CSA7000B) appears in the A-Event menu in the Pinpoint trigger system. Mask testing involves triggering the waveform in such a way that it can be compared to an industry standard mask template. Selections of triggering are AMI, HDB3, BnZS, CMI, MLT3 and NRZ encoded communications signals up to 3.125 Gb/s. Figure 13 shows a 2.5 Gb/s eye diagram along with mask testing. A histogram is also used to measure the composite jitter in the signal.




▶ Figure 12.




▶ Figure 13.

## Using Pinpoint Triggering to Validate Serial Bus Designs

High speed serial buses are finding their way into many of today's designs across all industries. Standards such as PCI Express, XAUI, InfiniBand, Serial ATA, etc. transmit data and clock using a single differential pair for a transmission line. The clock is embedded in the data using NRZ (Non-Return to Zero) signaling and 8B/10B encoding. Pinpoint triggering is useful in performing validation and compliance measurements on these buses.

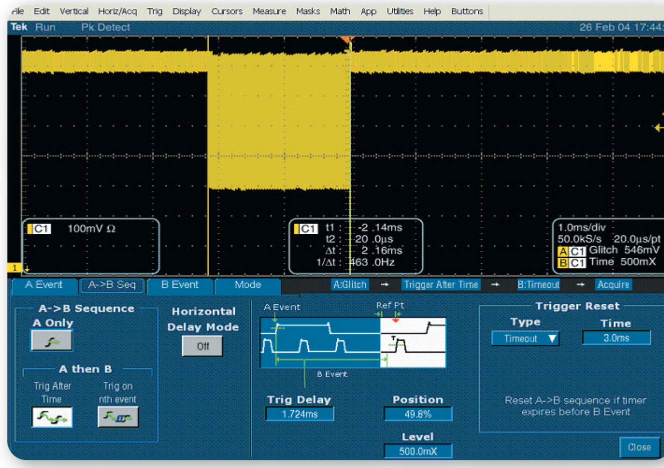
### Serial Lane Violation Triggering

Multi-lane high-speed serial communication links work effectively only when the multiple communication lanes are time aligned within specific tolerances. Oscilloscopes are sometimes used to measure the time skew between lanes by triggering on a single character in one data stream and observing the amount of skew time among the lanes. However, a few measurements do not indicate whether the lanes remain time correlated over time. Serial Lane Skew Violation Trigger solves this problem by triggering on out of tolerance time skew between any two lanes. Pass/Fail tests for lane skew violation may be performed by using the Pinpoint trigger system Dual A & B Triggering with Reset. The oscilloscope triggers on out of tolerance time skews between the lanes over any period of time: minutes, hours, days, etc. Any events that violate the skew time can be captured on the display and counted using the acquisition counter. The first trigger event (A-Event) from Lane0 is a comma character and is captured using Width trigger, the second trigger event (B-Event) on Lane1 represents a comma character is also qualified using Width. The specification requires that the same event on Lane1 must occur no more than 24.8 nsec after the event on Lane0. Delay is used to setup a minimum time to start looking for Event B and the Reset Trigger is set to 24.8 nsec, the specification tolerance. Figure 14 shows the scope triggering on a lane skew violation.


▶ Figure 14.

## Beacon Width Violation Triggering

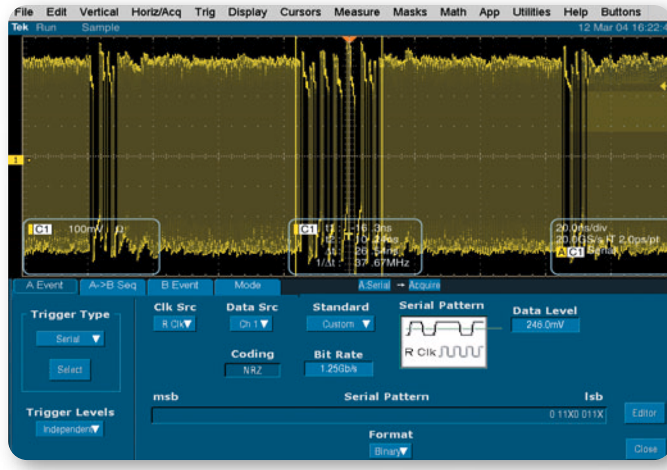
Serial communication devices based on standards often announce their presence on a communication channel at power up by emitting a “beacon” signal comprised of special packet headers and variable length data blocks. When the device powers up into an error condition, the beacon signal contains additional information and persists for a longer period of time. In the past, it has not been possible to trigger when these variable length beacon signals violate the limited width. The A-Event is used to detect the K28.5 comma character in the beacon signal header packet by triggering on the Width of the five ones or five zeroes in the K28.5 character. The trigger holdoff is set to be greater than the beacon signal width so the A trigger event only occurs at the beginning of the Beacon signal. The B-Event is set up to detect the end of the beacon signal by using the Timeout trigger to detect the idle state of the signal. The beginning of the beacon width violation time window is defined by the end of the Trig Delay time which is the Beacon width specification. The end of the beacon width violation time window is defined by the reset time out. With this trigger setup, the oscilloscope will trigger only when the end of the beacon signal occurs within the violation time window. Figure 15 shows a beacon signal that fails a minimum 3.0 msec specification.



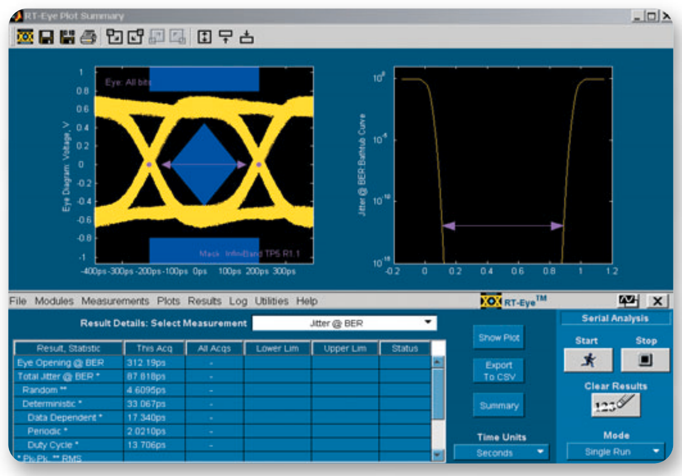

▶ Figure 15.

## Trigger Qualified Jitter Analysis

A primary concern in good serial transmission is that it is transmitted with a BER (Bit Error Ratio) less than $10^{-12}$ bits. Serial validation measurements; Timing, Amplitude, and Jitter can be made using RT-Eye™ Serial Data Compliance and Analysis software. The RT-Eye (Opt. RTE) software as well as TDSJIT3 (Opt. JT3 - Advanced Jitter Analysis) software use the spectrum approach to jitter measurements to provide an estimate of total jitter at $10^{-12}$ BER. While very accurate and repeatable, this approach requires that at least 100 repeats of a jitter test pattern (CJTPAT, TS1, etc.) appear in the acquisition. Unfortunately, when in a system, skip ordered sets (SOS) are added to the data being transmitted. If a jitter analysis is attempted on a signal that contains an SOS, the software cannot complete the analysis and gives an error message that a repeating pattern is not present. While the serial trigger does not support 2.5 Gb/s, one can be creative and use 1.25 Gb/s where the data is a known pattern of 11, 00, or xx combinations. Each single bit defined at 1.25 Gb/s is two bits at 2.5 Gb/s. In the case of InfiniBand, back to back TS1 used for jitter testing contains a comma character (K28.5:0011110110 1100000101) and a sequence of 1010 combinations that makes up a 320 bit pattern length. The total real time needed to perform the jitter analysis is 12.8 µsec (100 repeats x 320 bits x 400 ps/bit). Within this 12.8 µsec no SOS patterns can occur. The SOS uses a different control character (K28.0: 0011110100 1100001011). The SOS is scheduled to transmit approximately every 35 µsec. Thus, there is sufficient time between each SOS, to perform a jitter measurement. The serial trigger can be set to 1.25 Gb/s with a combination of '0 11x0 011x' to trigger on the K28.0 character in the SOS. Once the SOS is isolated by the trigger, the horizontal position can be positioned to 0%. The SOS will be ignored in the analysis and only back to back TS1s will be analyzed. Figure 16 shows the trigger setup and capture of signal. Figure 17 shows the result of the jitter compliance test after position has been adjusted to 0%.



▶ Figure 16.



▶ Figure 17.

## Record Length or Triggering, Which is More Important?

Is it better to use long record length to capture events or an advanced trigger setup? It is often thought that record length can be used as a substitute for a good trigger system. The answer becomes very clear when you consider how much real time is actually captured even with a very fast long record length oscilloscope. The TDS6000B captures and displays a long record of 32 mega-samples every 0.75 seconds. The amount of data captured in each acquisition is 1.6 msec. at full sample rate. Thus the amount of real time being captured is approximately 0.2%. Even if your post-processing software is infinitely fast, you will only see the event if you happen to capture it. If the event is random, this is highly unlikely. Going back to the trip we're taking where we're trying to capture a point of interest on film; using long record length with post processing software to capture the event is like taking several short videos and then searching through the videos frame by frame for the point of interest. This process is not very efficient and is very compute intensive.

An application where record length is important is jitter analysis. Jitter is a statistical measurement, so the more efficiency you have (measurements/sec) the faster you can arrive at a result with high statistical confidence. TDS oscilloscopes provide very high jitter efficiency[*3]. Efficiencies up to 100,000 TIE measurements/second or 6 x $10^6$ measurements per minute can be achieved. Worst case jitter can be measured with TDSJIT3. Once a worst case jitter waveform is captured, often a trigger condition can be setup to capture a new waveform that creates the worst case jitter allowing you to debug the source of the jitter.

Record length is not a substitute for triggering. However, both tools are very important in the characterization and debug of electronic devices. Record length options of up to 64 mega-samples on one channel (on TDS/CSA7000B Series) and 32 mega-samples across all four channels (on TDS6000B Series) are available on TDS high performance oscilloscopes.

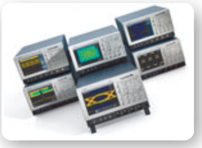
## Conclusion

Ever since Howard Vollum introduced his triggering sweep oscilloscope, triggering has been transforming the oscilloscope from an instrument that provides vague impressionistic results into a critical tool for capturing random events or qualifying data for analysis. Signaling speeds in modern Computer, Data-communications, and Communications devices need more advanced trigger systems due to their high speeds and complex nature. The new Pinpoint trigger system keeps up with the fastest and most complex signals using Silicon Germanium trigger chips and new trigger features such as Dual A- and B-Event Triggering, Window Triggering, Logic Qualification, and Reset Triggering. The following table summarizes the advancements made with the Pinpoint trigger system over previous generation oscilloscopes.

[*3] Benchmark test using TDS6804B, TDSJIT3. Record length of 4 mega-samples testing a 4 Gb/s Compliance Jitter Test Pattern (CJTPAT).

| Trigger Feature/Specification | TDS6000 and TDS/CSA7000 Series …with prior trigger system | TDS6000B and TDS/CSA7000B Series[4] …with Pinpoint Triggering |
|---|---|---|
| Trigger Sensitivity | 2.5 div @ 4 GHz on TDS6604<br>1 div @ 3 GHz on TDS/CSA7404 | 2.5 div @ 7 GHz on TDS6000B (typical)<br>2.5 div @ 4 GHz on TDS/CSA7000B |
| Trigger Jitter | < 7 $ps_{RMS}$ | < 1.5 $ps_{RMS}$ |
| Minimum Trigger Pulse Width | 1 nsec | < 170 ps |
| A-Event Trigger Types | Edge<br>Glitch<br>Runt<br>Width<br>Transition Time<br>Timeout<br>Pattern<br>State<br>Setup/Hold | Edge<br>Glitch*<br>Runt*<br>Width*<br>Transition Time*<br>Timeout*<br>Pattern<br>State<br>Setup/Hold*<br>Window*<br>* Includes selectable logic qualification |
| B-Event Trigger Types | Edge | Edge<br>Glitch*<br>Runt*<br>Width*<br>Transition Time*<br>Timeout*<br>Pattern<br>State<br>Setup/Hold*<br>Window*<br>* Includes selectable logic qualification |
| Trigger Sequences | Main<br>Delayed by Time<br>Delayed by Events | Main<br>Delayed by Time<br>Delayed by Events<br>Reset by Time<br>Reset by Events<br>Reset by State |
| Serial Pattern Trigger (Option ST) | 64-Bit serial word recognizer triggers on NRZ-encoded data up to 1.25 Gbaud. | 64-Bit serial word recognizer triggers on NRZ-encoded data up to 1.25 Gbaud. |
| Communications Standard Triggers (Option SM – standard on CSA models) | Supports AMI, HDB3, BnZS, CMI, MLT3 and NRZ encoded communication signals up to 2.5 Gb/s. | Supports AMI, HDB3, BnZS, CMI, MLT3 and NRZ encoded communication signals up to 3.125 Gb/s. |

[4] Available in version 3.0.3 firmware and above. Download free firmware upgrades from www.tektronix.com.



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OpenChoice is a collection of software libraries, utilities, samples, industry-standard protocols and interfaces offered with many Tektronix oscilloscopes and logic analyzers.

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TekConnect interface takes probe intelligence to the next level whether you are measuring high voltage, current, power, or even microvolt level signals.

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