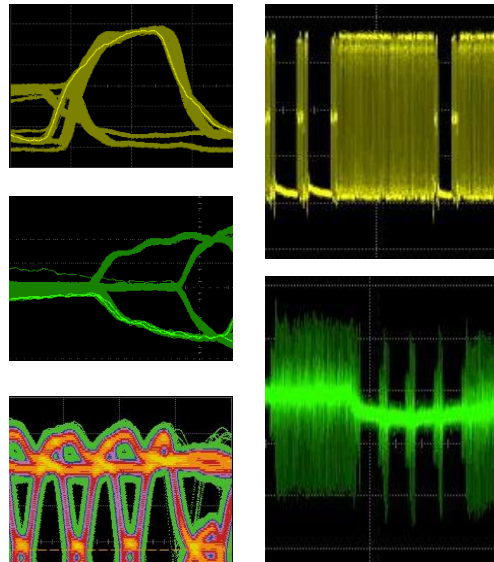# Debug Your Design As Never Before Using Advanced Oscilloscopes Triggering

Oct 8, 2015

Min-Jie Chong
Product Manager
High Performance Scope

KEYSIGHT
TECHNOLOGIES

Agenda

- Introduction
- Oscilloscope Triggering Architecture
- Hardware Triggers
- Trigger Sequencing
- Software Triggers
- Triggering Case Study
- Protocol Software Triggers
- Gbit Serial Trigger
- Digital Logic Trigger
- Summary/Resources

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Real-Time Scopes With Advanced Triggering

V-Series is used in this webcast to introduce advanced triggering

- Up to 33 GHz (80 GSa/s)
- Deepest 2 Gpts/ch memory
- Longest 160b, 12.5 Gb/s HW serial trigger
- Fastest 20 GSa/s 16-channel digital logic trigger

Z-Series

V-Series

90000A Series

S-Series

9000-Series

Infiniium
- **500 MHz to 63 GHz**
- **Win7 OS**

InfiniiVision
- **70 MHz to 6 GHz**
- **Embedded OS**
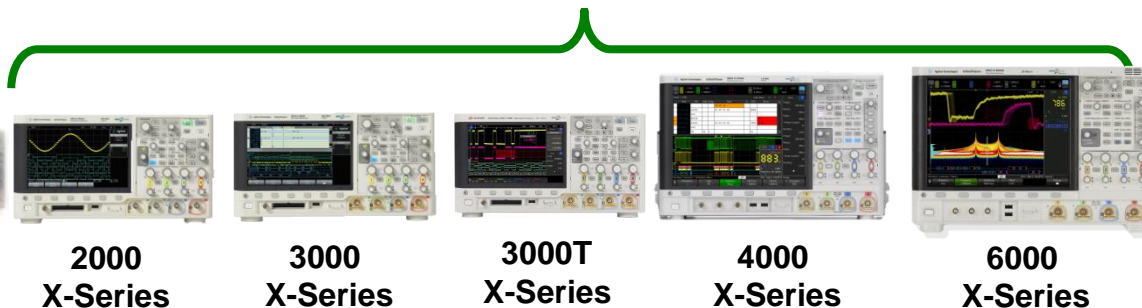
| U1600 Series | U2700 Series | 1000 Series | 2000 X-Series | 3000 X-Series | 3000T X-Series | 4000 X-Series | 6000 X-Series |

Most of the advanced triggers are available across the scope portfolio

KEYSIGHT
TECHNOLOGIES

Advanced Oscilloscope Triggering

Page 4

Understanding Oscilloscope Triggering

Triggering is often the least understood function of a scope, but is one of the most important capabilities that you should understand.

- Think of oscilloscope "triggering" as "synchronized picture taking".

- One waveform "picture" consists of many consecutive digitized samples.

- "Picture Taking" must be synchronized to a unique point on the waveform that repeats.

- Most common oscilloscope triggering is based on synchronizing acquisitions (picture taking) on a rising or falling edge of a signal at a specific voltage level.

A photo finish horse race is analogous to oscilloscope triggering

Why is it important to understand scope triggering?

- Most of you probably use the standard "edge" triggering

- Triggering on more complex signals requires advanced triggering options to solve real world problems.

- Effective use of trigger allows you to trigger on the issue rather than searching for it after the scope trigger at the waveform with the standard "edge" trigger.

- It also helps you pinpoint the issue when your scope has limited memory to acquire long waveform acquisitions.
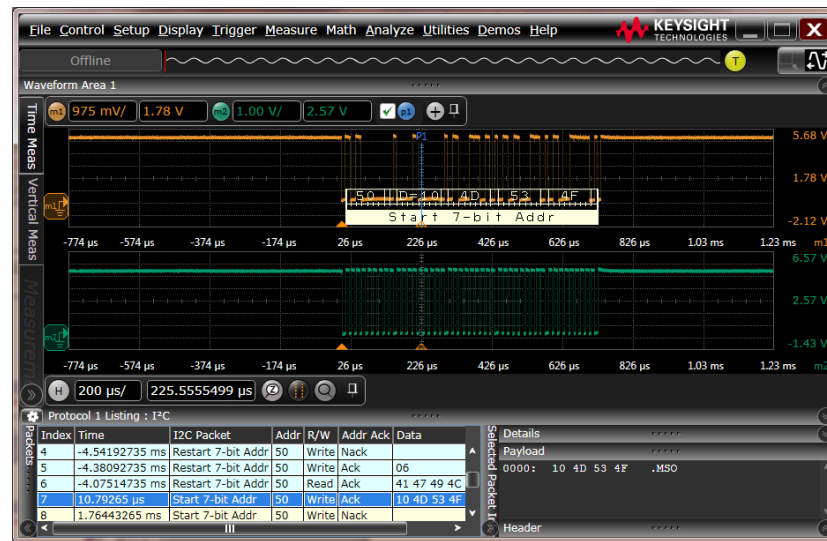
**Example: Triggering on an I²C serial bus**

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KEYSIGHT
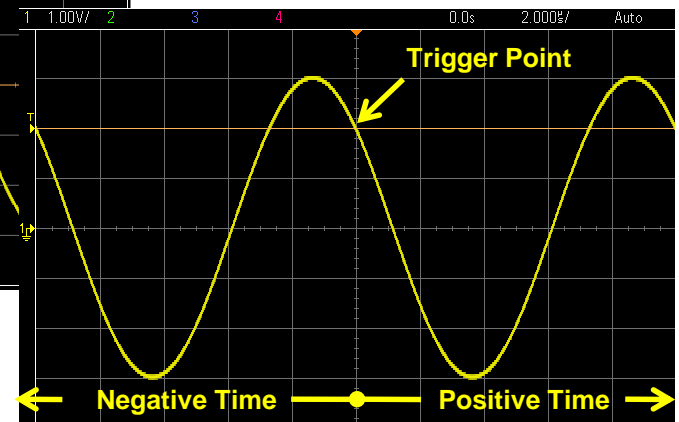TECHNOLOGIES

When Scope Triggers

- Default trigger location (time zero) on scope = center-screen (horizontally)

- <u>Only</u> trigger location on older analog scopes = left side of screen

Trigger level set above waveform
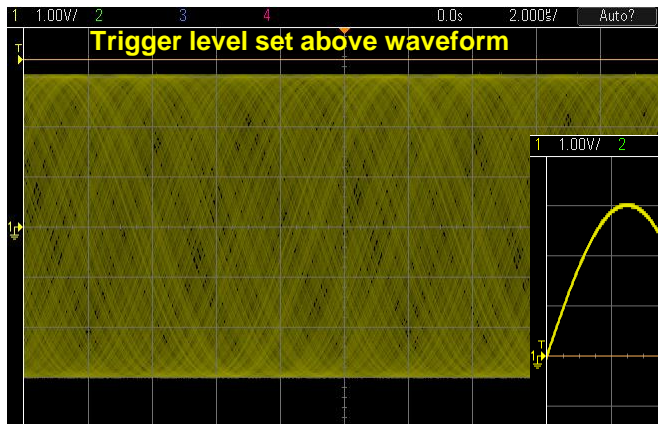
Untriggered
(unsynchronized picture taking)
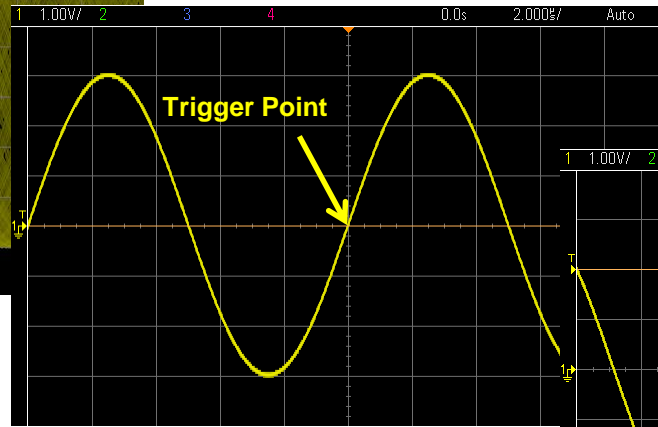
Trigger Point

Trigger = Rising edge @ 0.0 V

Trigger Point

← **Negative Time** —●— **Positive Time** →

Trigger = Falling edge @ +2.0 V

KEYSIGHT
TECHNOLOGIES
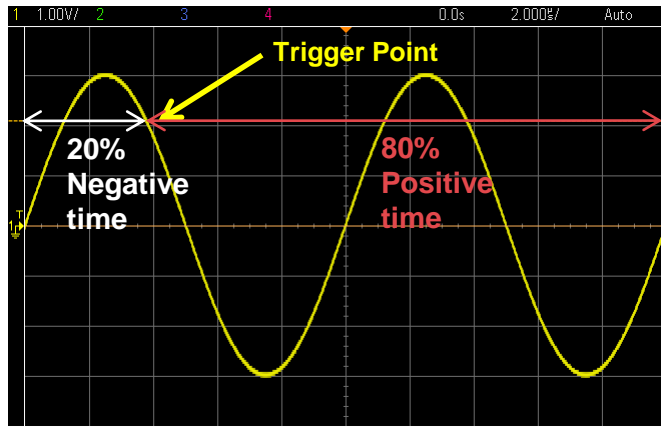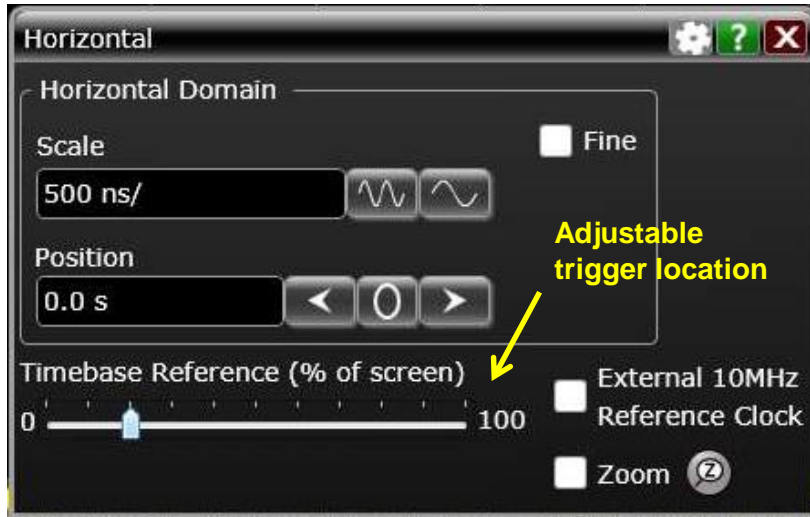
Adjustable Trigger Location

Set how much time to capture before and after trigger point

Trigger = Falling edge @ + 2.0 V

- Adjustable trigger location allows you to specify how much time before and after the trigger point that you want the waveform captured.

- The setting is important to maximize the waveform capture prior to or beyond the trigger point for analysis and debug.

- The example here shows 20% and 80% are captured before and after the trigger point.

Trigger Sweep Modes

Auto and triggered modes for waveforms display

- The scope defaults to Auto sweep trigger mode. The scope displays and aligns the edge of the signal to the middle of the scope whether there is a valid trigger or not. This allows waveforms to be displayed instead of blank screen.

- The Triggered mode is selected when you want the waveform to be displayed only when a trigger condition actually occurs.

- It is important to set to the Triggered mode when you only want to view the triggered waveform or when there's a one-time event you want to trigger and display.

Trigger Holdoff Setting

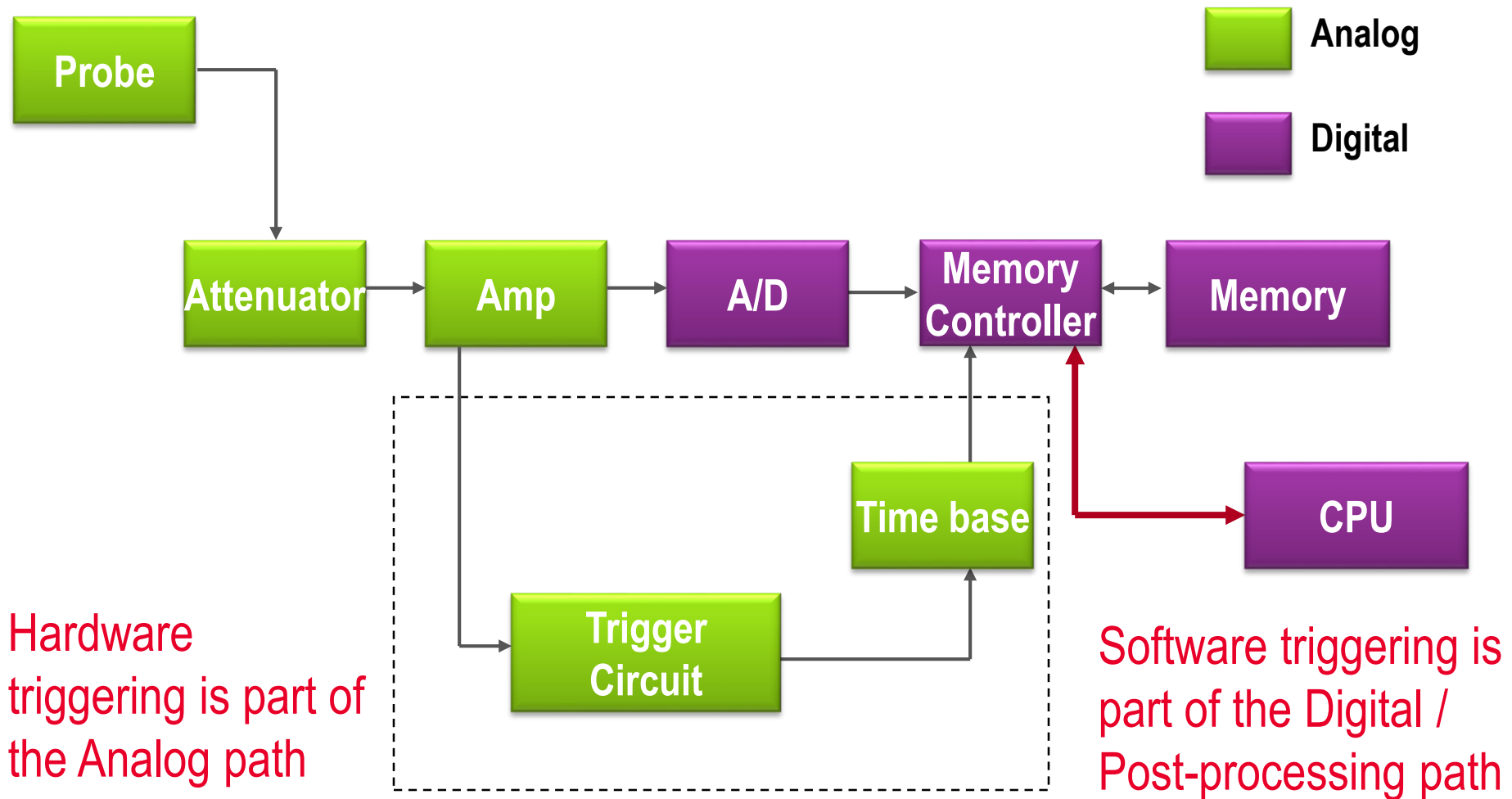Fixed to stabilize and random to increase probability of trigger events
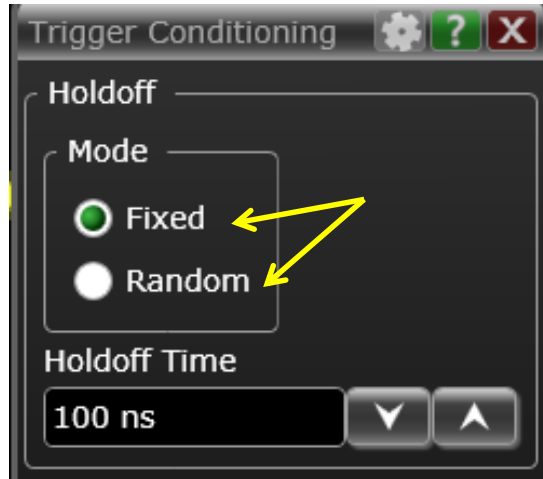
- Fixed — The Fixed trigger holdoff mode can be used to stabilize the display of complex waveforms. The Holdoff Time control sets the amount of time that the oscilloscope waits before re-arming the trigger circuitry.
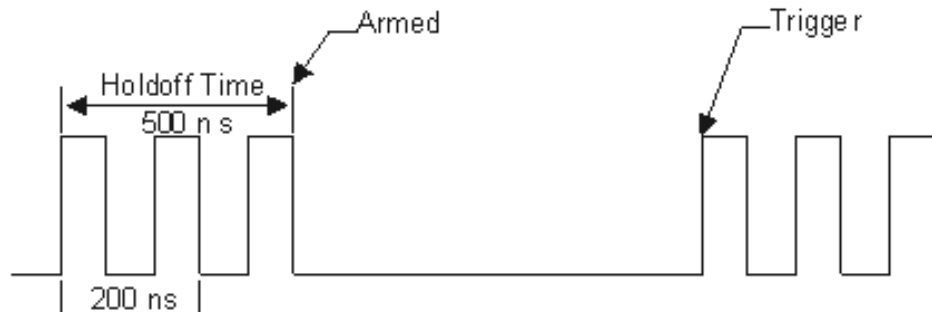
- Random — This mode varies the trigger holdoff from one acquisition to another by randomizing the time value between triggers. The randomized time values can be between the values specified in the Min Holdoff Time and Max Holdoff Time fields. Randomizing the holdoff increases the likelihood that the oscilloscope will trigger on different data phases of a multi-phase burst.

# Type of Triggers: Hardware and Software

Probe

Analog

Digital

Attenuator → Amp → A/D → Memory Controller ↔ Memory

Time base

Trigger Circuit

CPU

Hardware triggering is part of the Analog path

Software triggering is part of the Digital / Post-processing path

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Basic Hardware Triggers

- Basic triggering can solve basic digital and analog problems
  - Edge triggers
  - Pulse width
  - Glitch
 - Timeout
 - Pattern/State
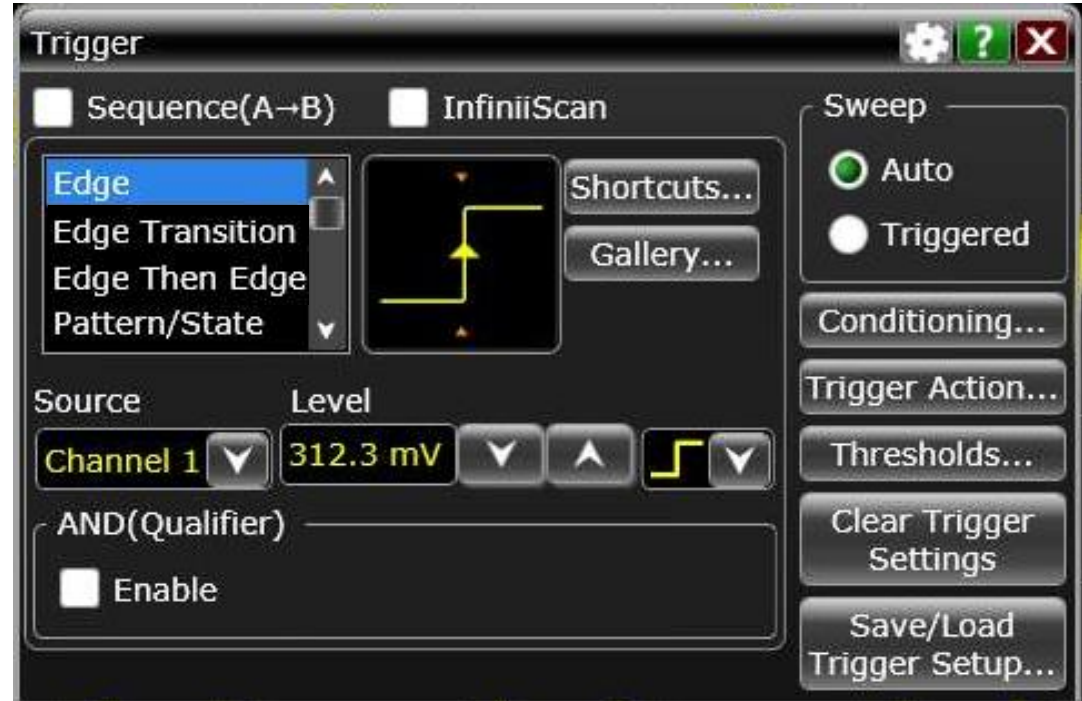
Complex Problems may need more Complex triggers

- Practical limitations on real world systems limits the usability of basic triggers
    - Noise
    - Complex signals
    - Asynchronous events
    - High-speed serial data rates
    - Parallel bus designs
    - Modern encoding schemes
- Why do I need Advanced Triggering?
    - Advanced triggering systems can help solve complex problems in real systems
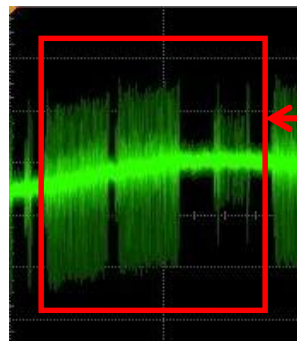
Noise and common mode variations on signal get in the way of basic triggers

Trigger Gallery and Shortcuts

Select the trigger with gallery feature
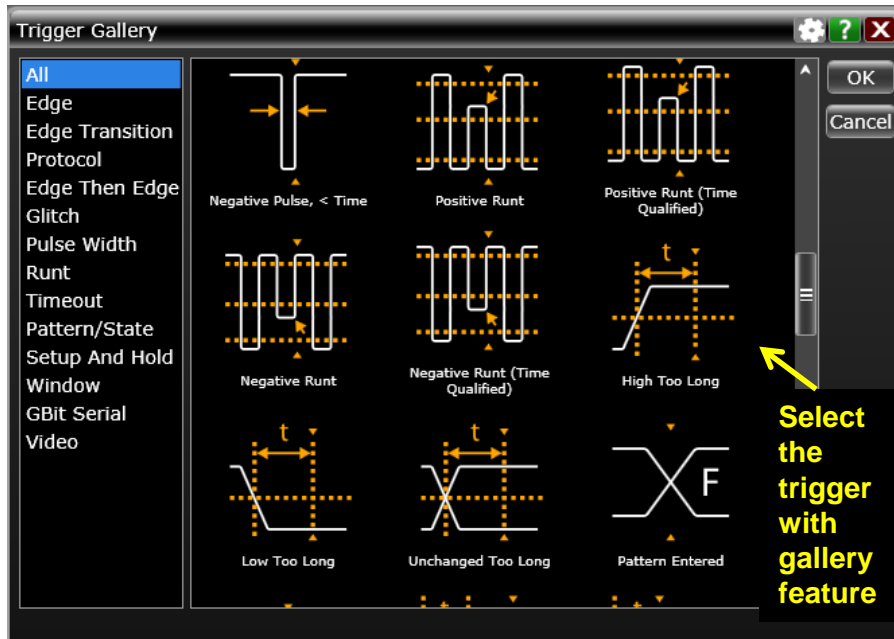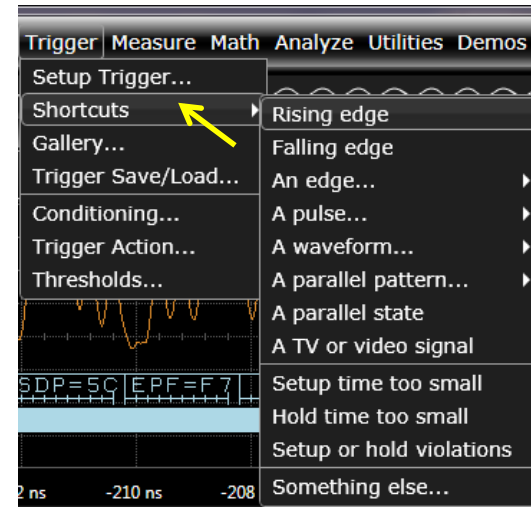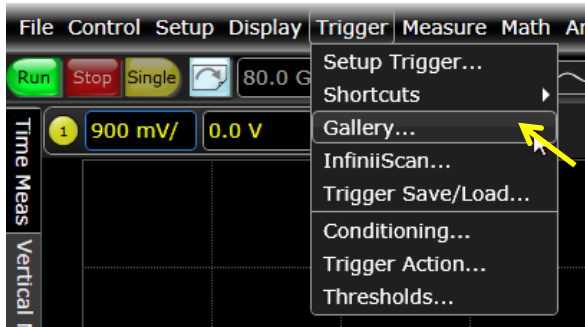
- Learning and accessing the triggers can be overwhelming.

- Use trigger gallery with graphical representation to assist in selecting the trigger that you want.

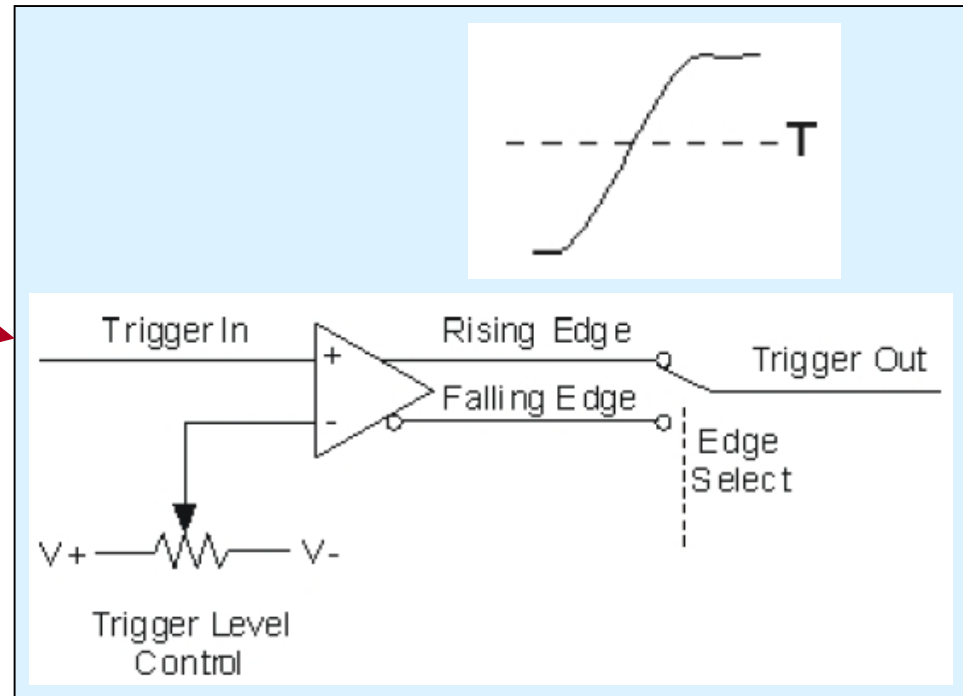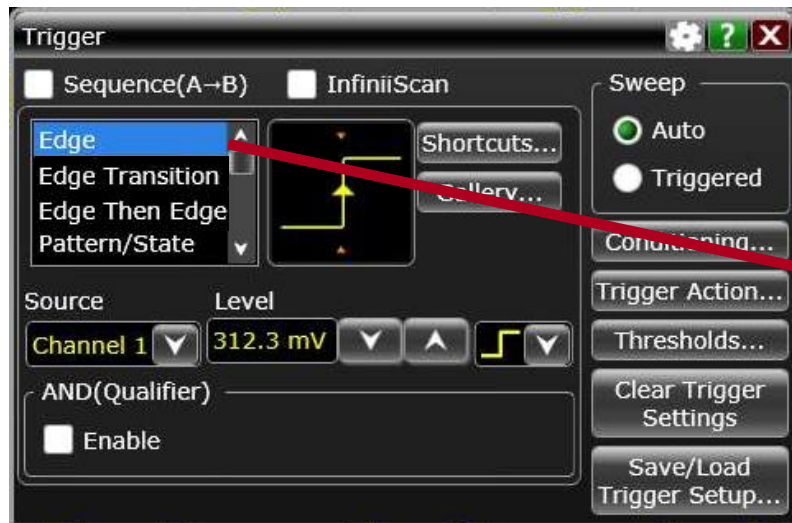- Use shortcuts to help you access your trigger needs

Scope Basic and Advanced Hardware Triggers

- Edge
- Edge transition
- Edge then Edge
- Pulse width
- Glitch
- Runt
- Timeout
- Pattern/State
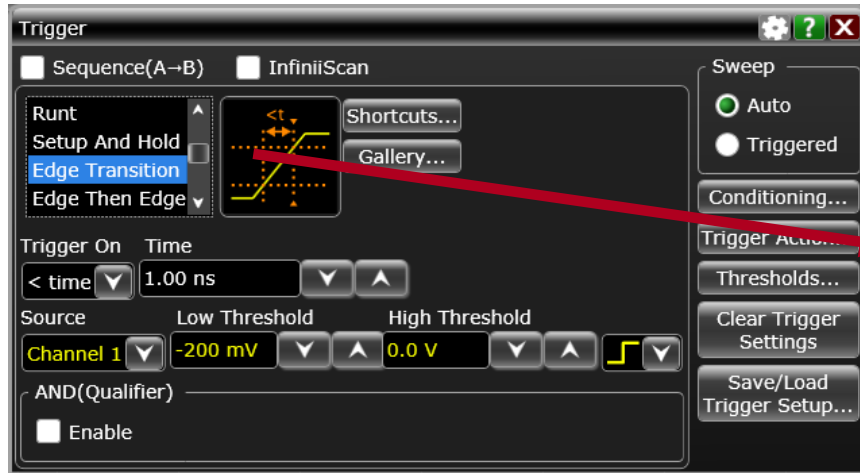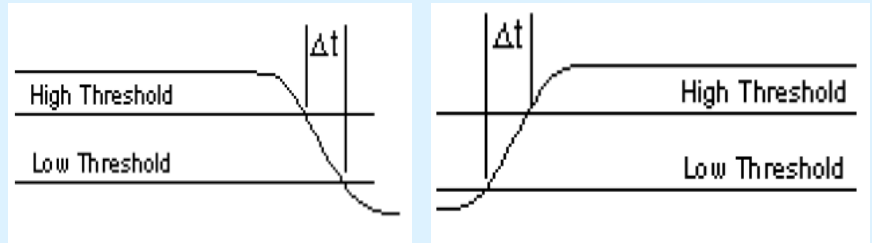- Setup and Hold
- Window
- Video
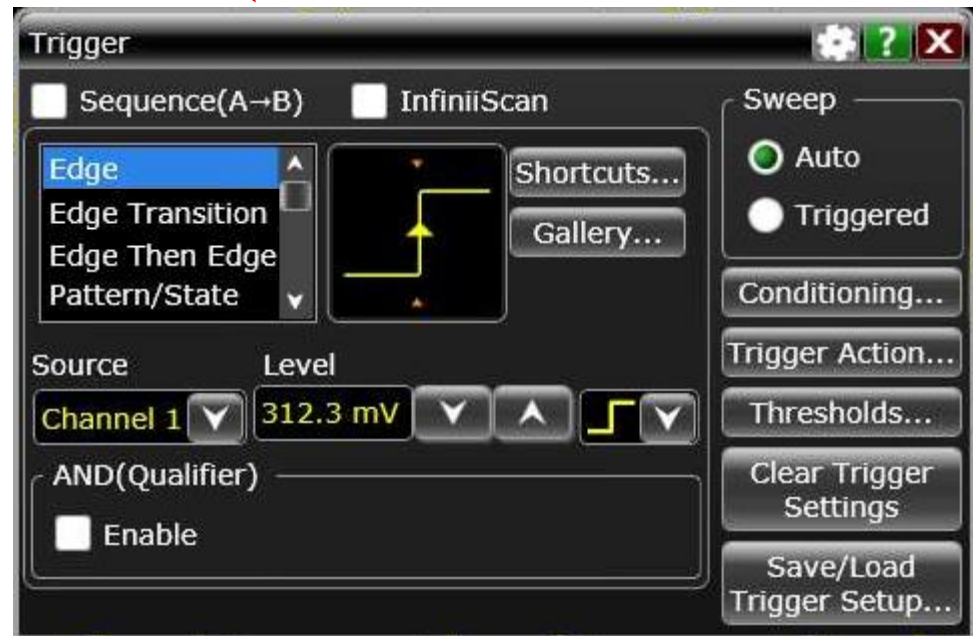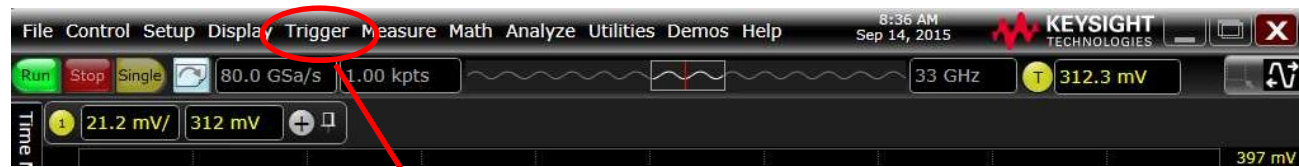
Edge Trigger

- The most basic trigger.
- Trigger on either rising or falling edge.
- Specify the voltage trigger level.

The V-Series has > 22 GHz of trigger bandwidth that can trigger at 14 ps rise time
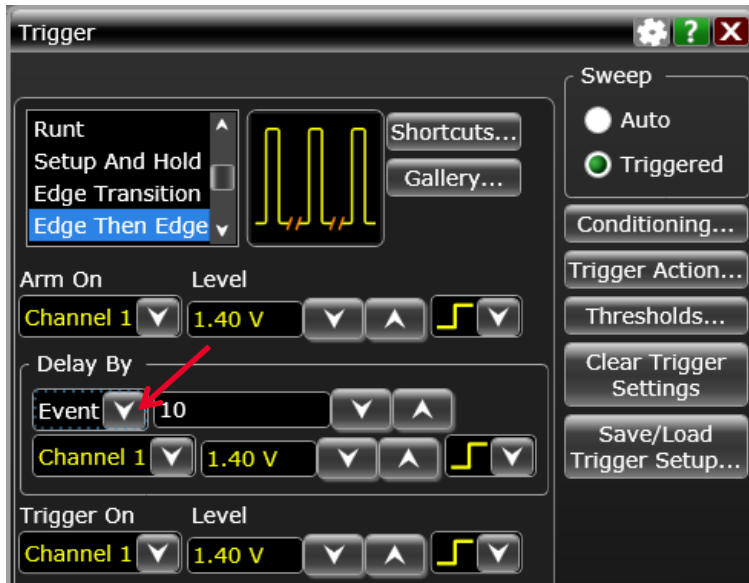
Edge Transition Trigger


Edge Transition (Rise/Fall time)

- Find any edge in your waveform that violates a rise time or fall time specification.
- Rise and fall time defines by the two voltage thresholds.

Edge Then Edge Trigger

Two sub-modes:

- Delay by Event — Identifies a trigger by arming on the edge you specify, counting a number of events, then triggering on the specified edge. This sub-mode is used to view pulses in your waveform that occur a number of events after a specified waveform edge.

- Delay by Time — Identifies a trigger condition by arming on the edge you specify, waiting a specified amount of time, then triggering on a specified edge.

Edge Then Edge (Delay Trigger)
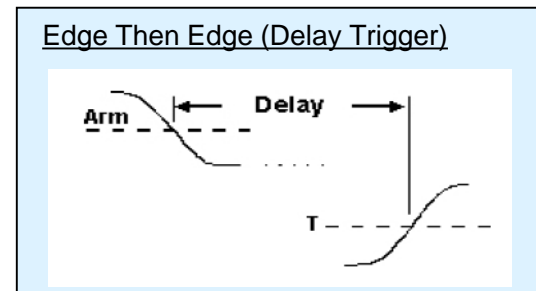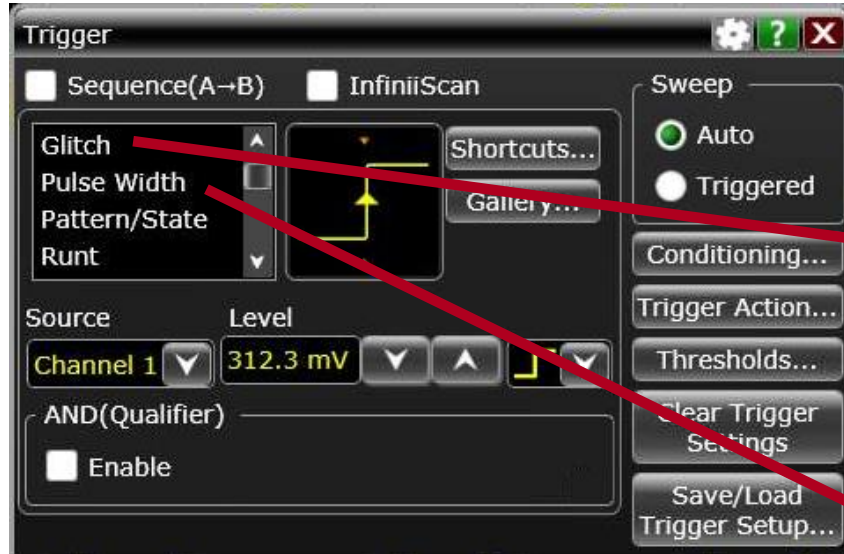
Pulse Triggers
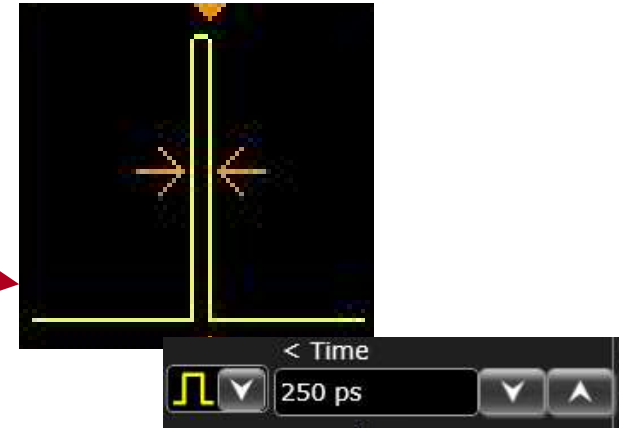
Glitch

Pulse Width
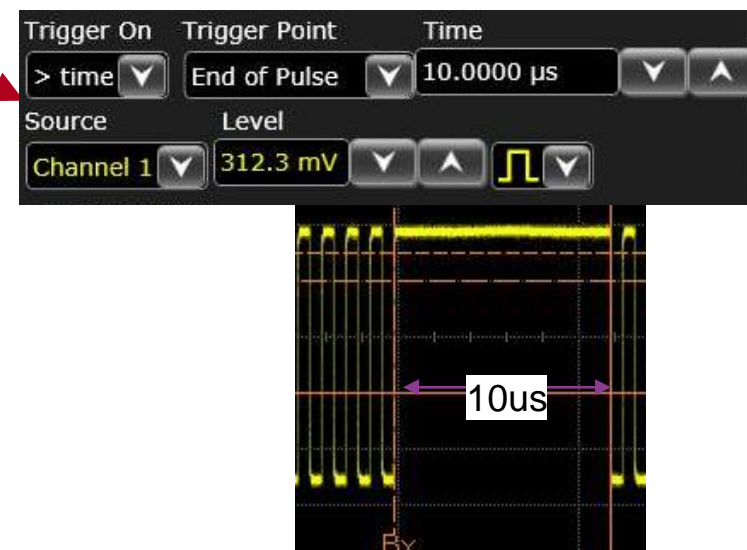
- They essentially work the same way but the different names are more intuitive to users.

Glitch and Pulse Width Trigger Key Specs

Scope detectable glitch and pulse width
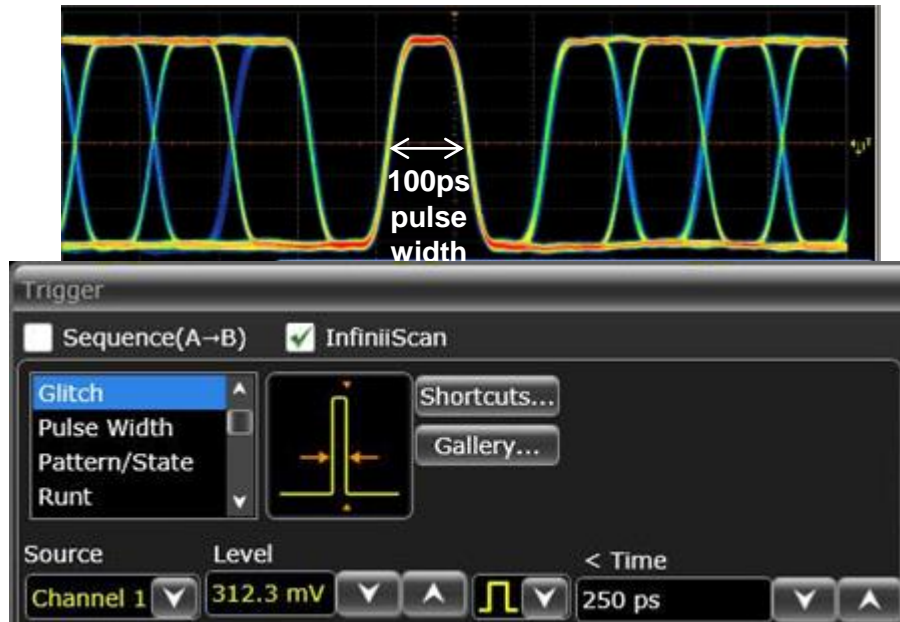
- Glitch triggering is one of the most useful tools in the trigger toolbox.

- Allows you to easily find pulses less than desired width.

- The scope can be specified to trigger less than 250 ps but the detectable width is less 100 ps. Due to physics, the analog trigger can't differentiate the pulse widths below 250 ps.

- One way to trigger on 100 ps pulses is to use a 2nd stage software trigger (InfiniiScan) to further qualify the pulse.

KEYSIGHT TECHNOLOGIES
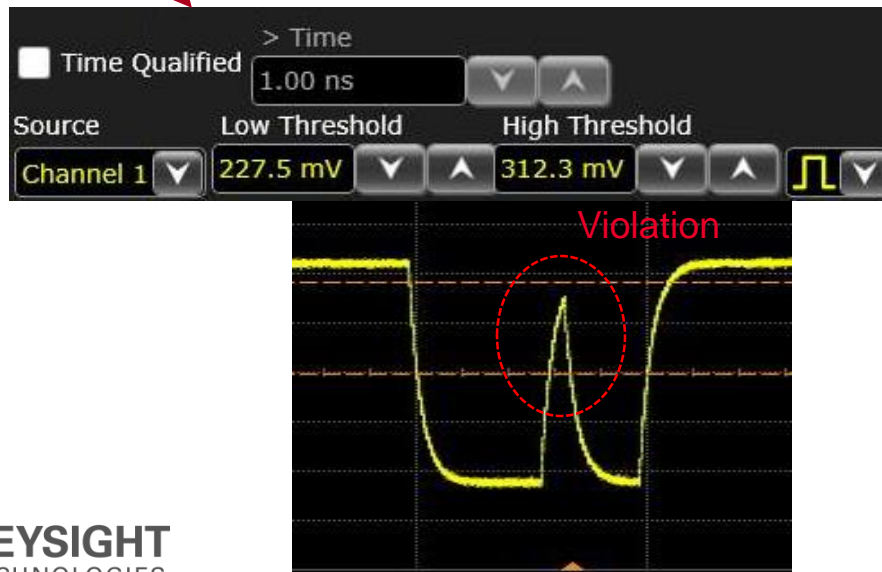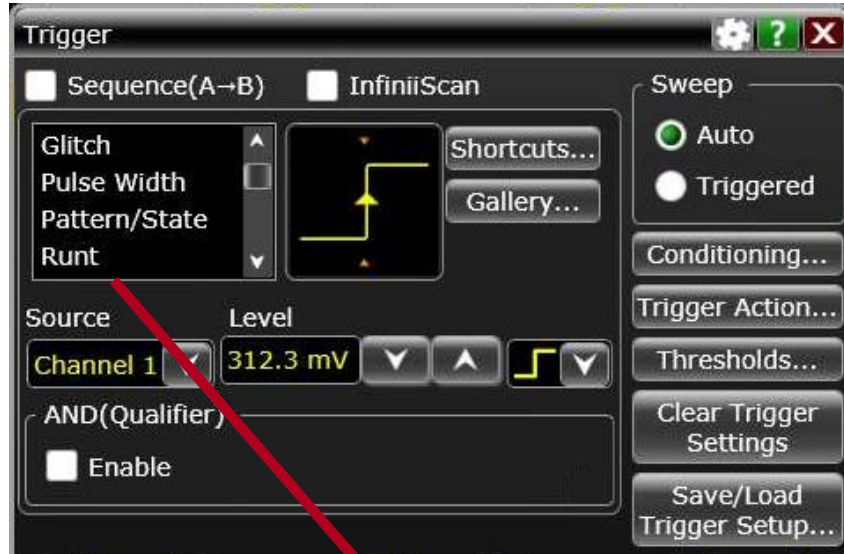
Runt Trigger

- Use Runt triggering to find a positive or negative pulse that has a smaller amplitude than the rest of the pulses.
- A low and high threshold are established with this trigger.
- The oscilloscope then looks for pulses that fall between these two thresholds and triggers when one is found.

Timeout Trigger
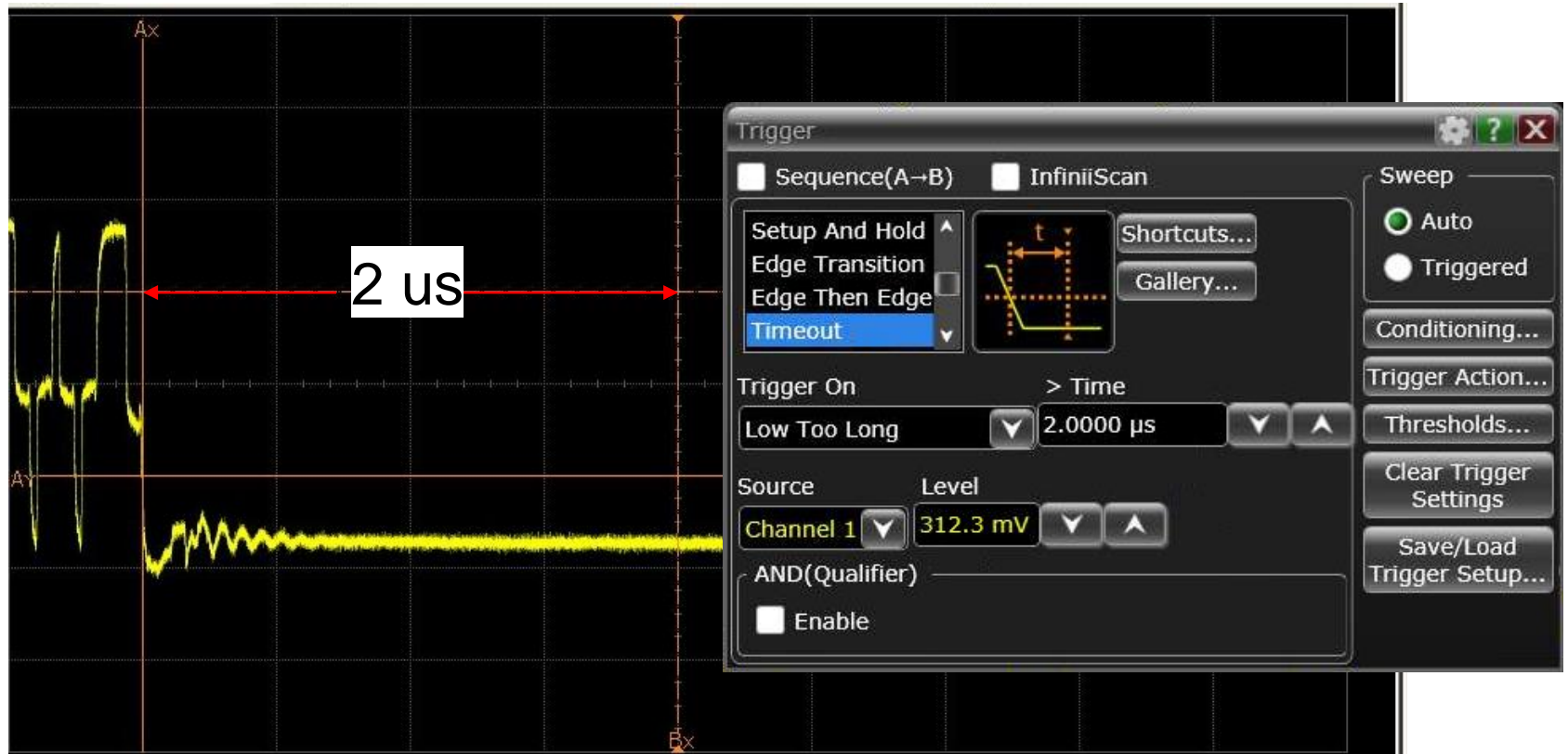
This mode triggers the oscilloscope when the waveform has been at a higher voltage than the voltage specified by the Level control for too long (High Too Long) or when the waveform has been at a lower voltage than the Level voltage for too long (Low Too Long).

Pattern/State Trigger

State triggered: "01"
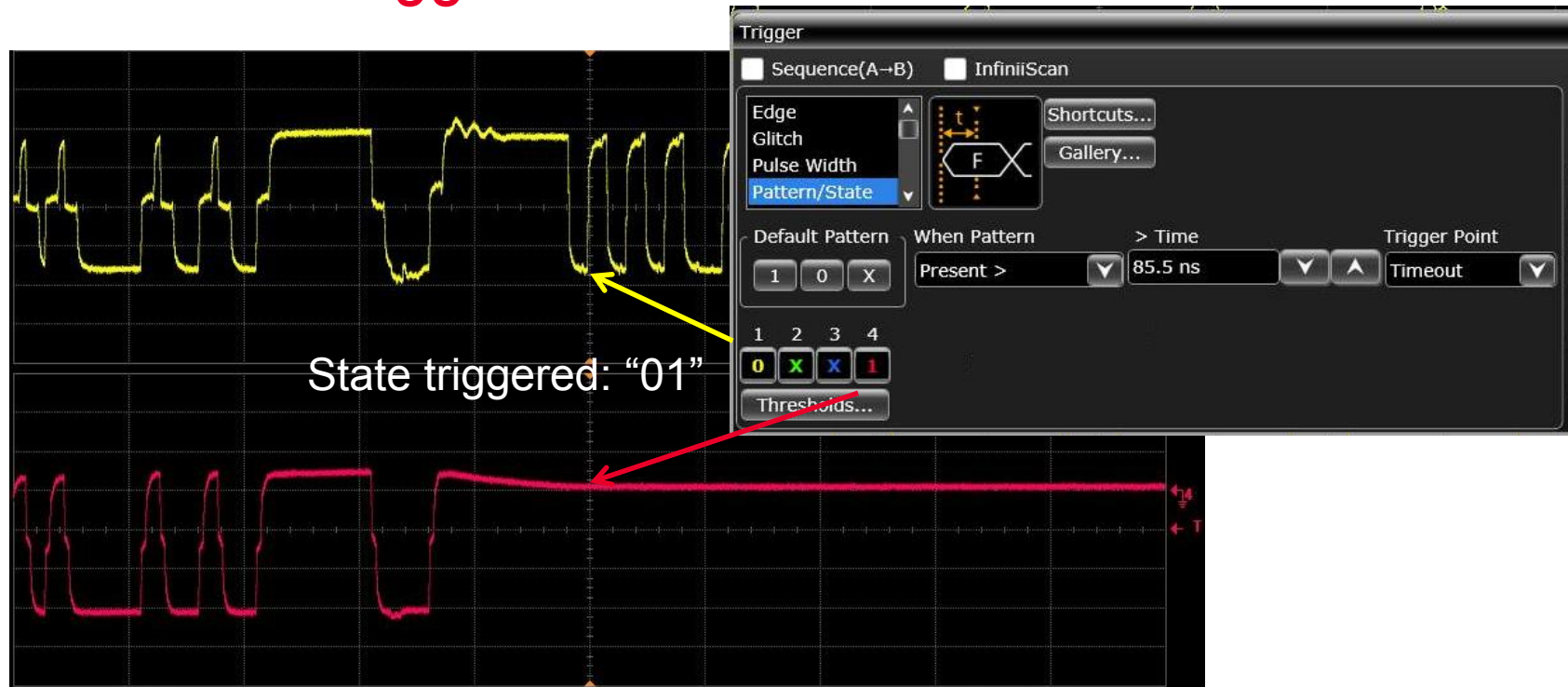
- The Pattern trigger identifies a trigger condition by looking for a specified pattern. A pattern is a logical combination of the channels. Each channel can have a value of 1 (High), 0 (Low) or X (Don't Care). A value is considered a High when your waveform's voltage level is greater than its trigger level and a Low when the voltage level is less than its trigger level. If a channel is set to Don't Care then it is not used as part of the pattern criteria.

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Setup/Hold Trigger
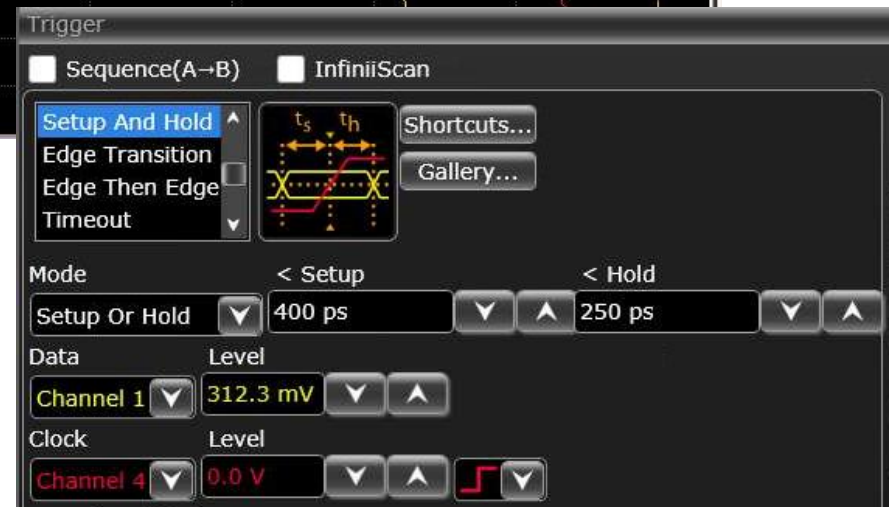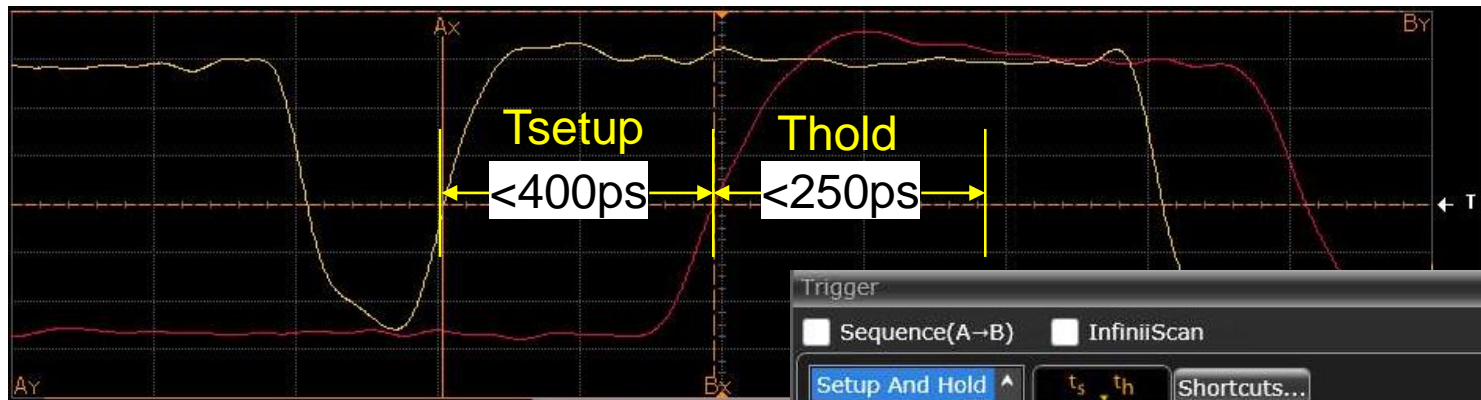
- You can have Infiniium trigger on violations of Setup time, Hold time, or both Setup and Hold time.

- To use Setup Violation Type, Infiniium needs a clock waveform, used as the reference and a data waveform for the trigger sources.
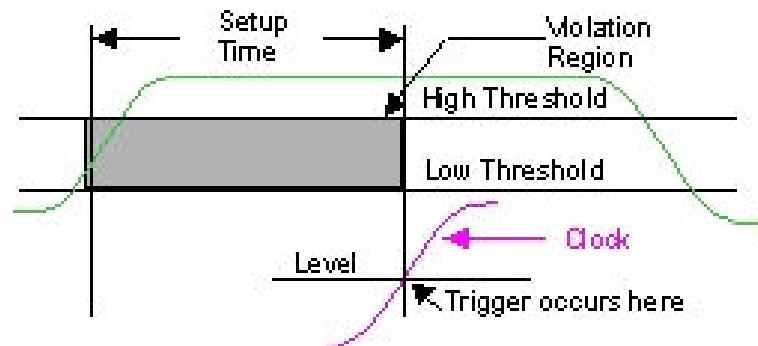
Window Trigger

Entering Voltage Range		A voltage range is specified and the oscilloscope triggers when the waveform enters this range.
Exiting Voltage Range		A voltage range is specified and the oscilloscope triggers when the waveform exits this range.
Inside Voltage Range > Time Inside Voltage Range < Time		A voltage range is specified and the oscilloscope triggers on a waveform that has been inside the range for either too long (> Time) or too short (< Time). See the Trigger Point section below for more information on when exactly the oscilloscope triggers.
Outside Voltage Range > Time Outside Voltage Range < Time		A voltage range is specified and the oscilloscope triggers on a waveform that has been outside the range for either too long (> Time) or too short (< Time). See the Trigger Point section below for more information on when exactly the oscilloscope triggers.
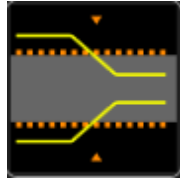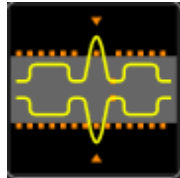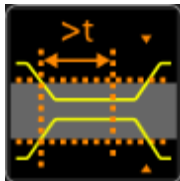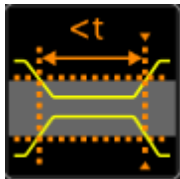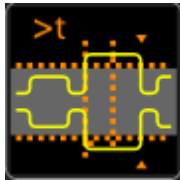
KEYSIGHT
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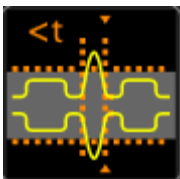
Window Trigger Outside Voltage Range Example

Trigger event occurs due to window level and time criteria exception exceeding the lower threshold

Video Trigger
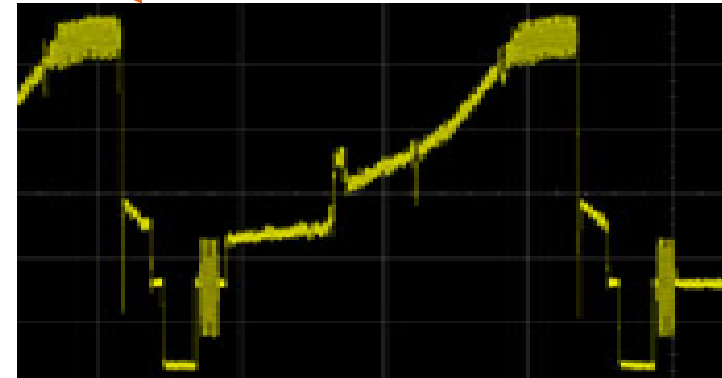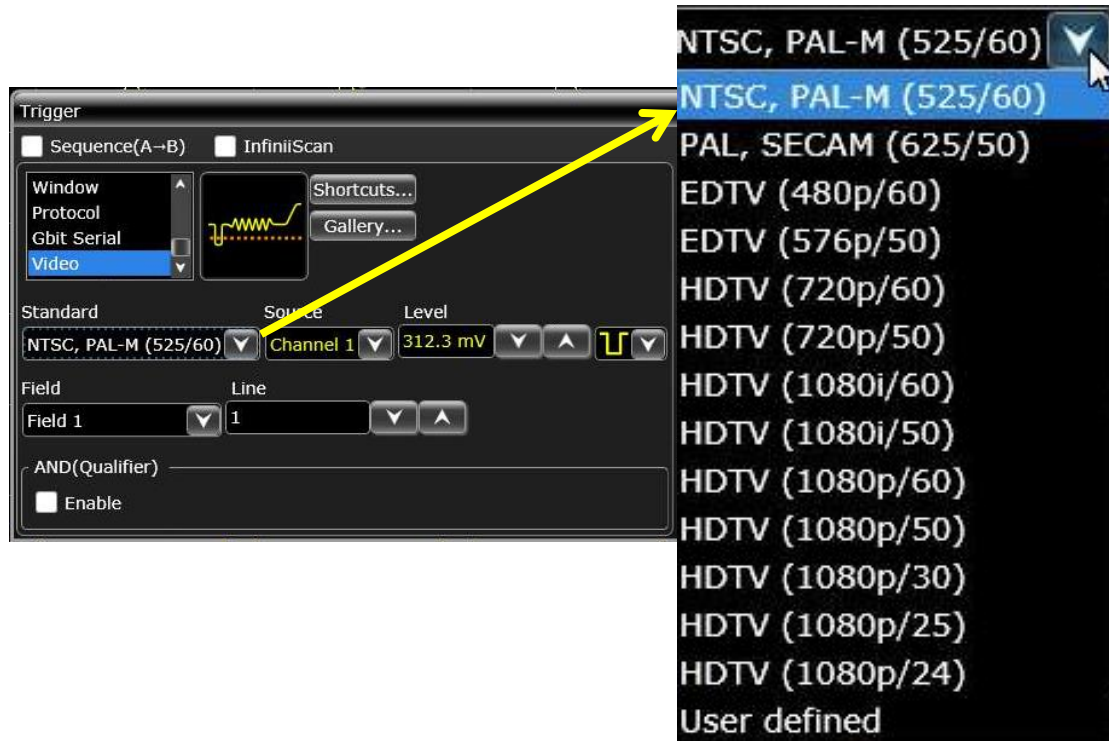
- Triggering on complex video signals is easy with video triggering capabilities built into the trigger systems
- Polarity allows you to choose positive or negative Sync

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2-Stage Sequence Hardware Trigger
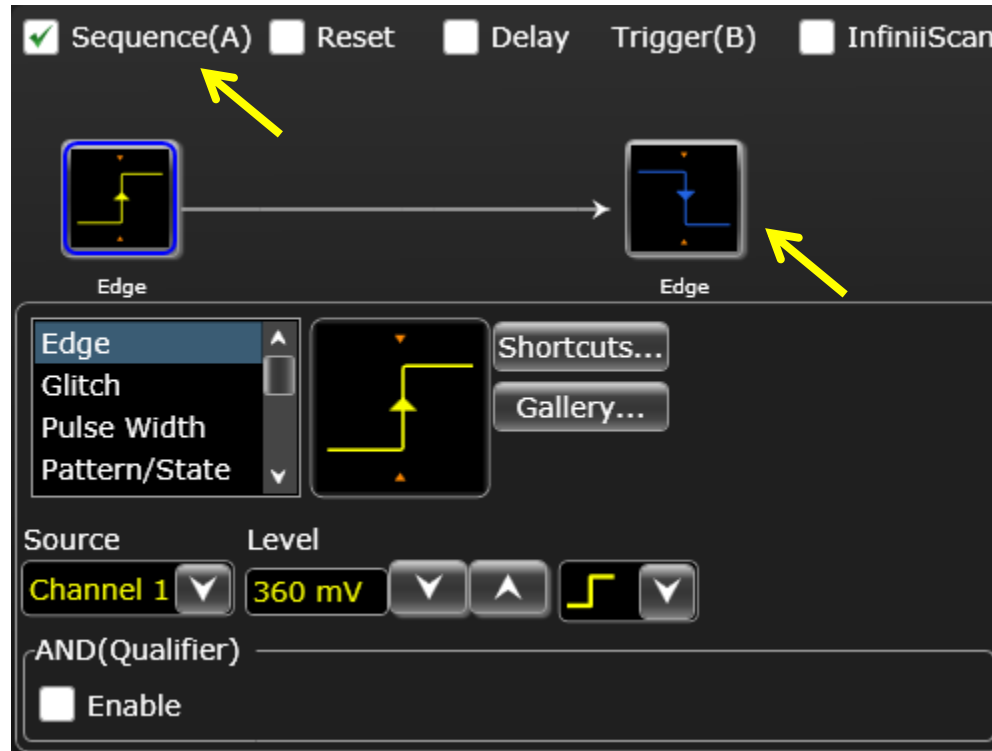
- Sequential triggers let you trigger on an event that follows another event.
- The first event is called the Find(A) event. The second event is called the Trigger(B) event.

Reset Condition in 2-Stage Sequence Hardware Trigger

Check Reset. Click the box under Reset. Select one of the options below.

- Time — Use the Reset Time field to specify the time to wait before resetting the sequence.
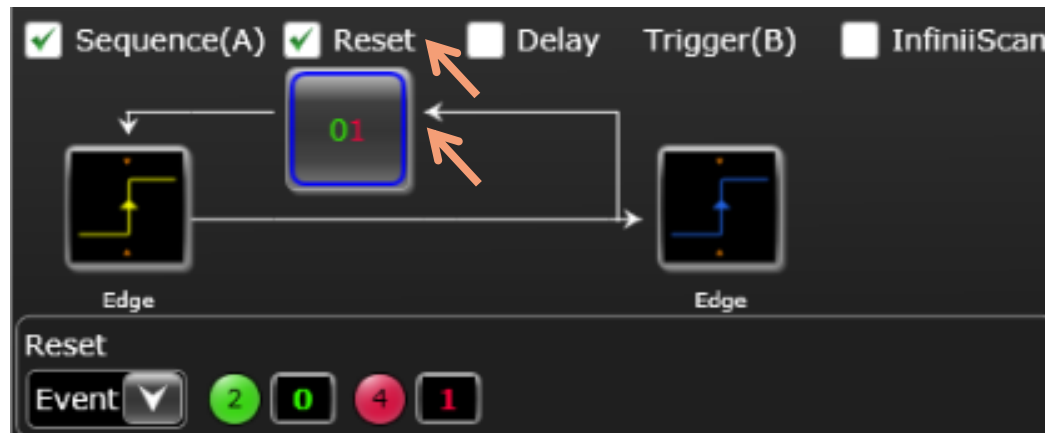
- Event — Use the analog channel buttons to specify the logic levels that will reset the sequence.

Time Delay in 2-Stage Sequence Hardware Trigger

Check Delay. Specify the time after the Find(A) event occurs to wait before searching for the Trigger(B) event.
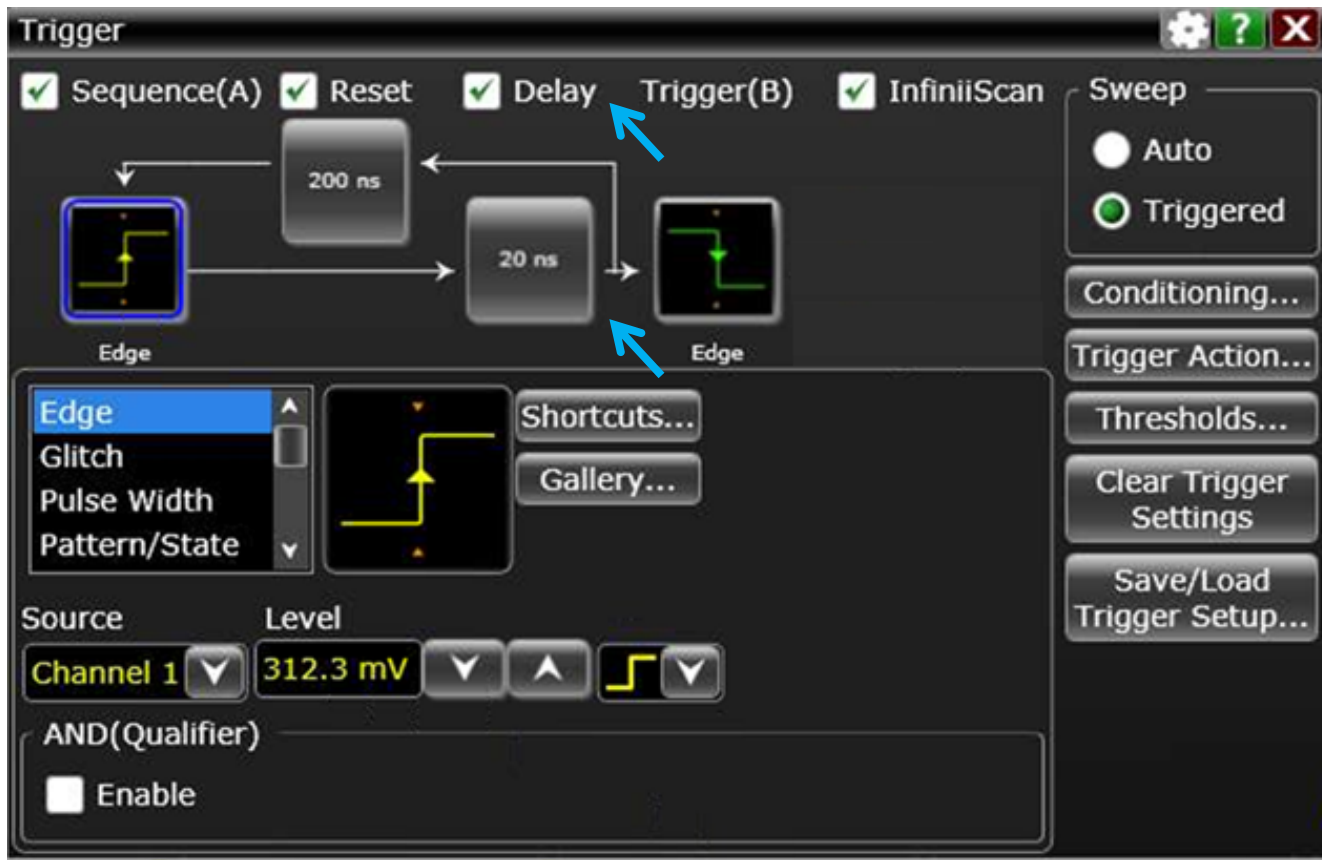
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3-Stage Trigger with InfiniiScan Software Trigger
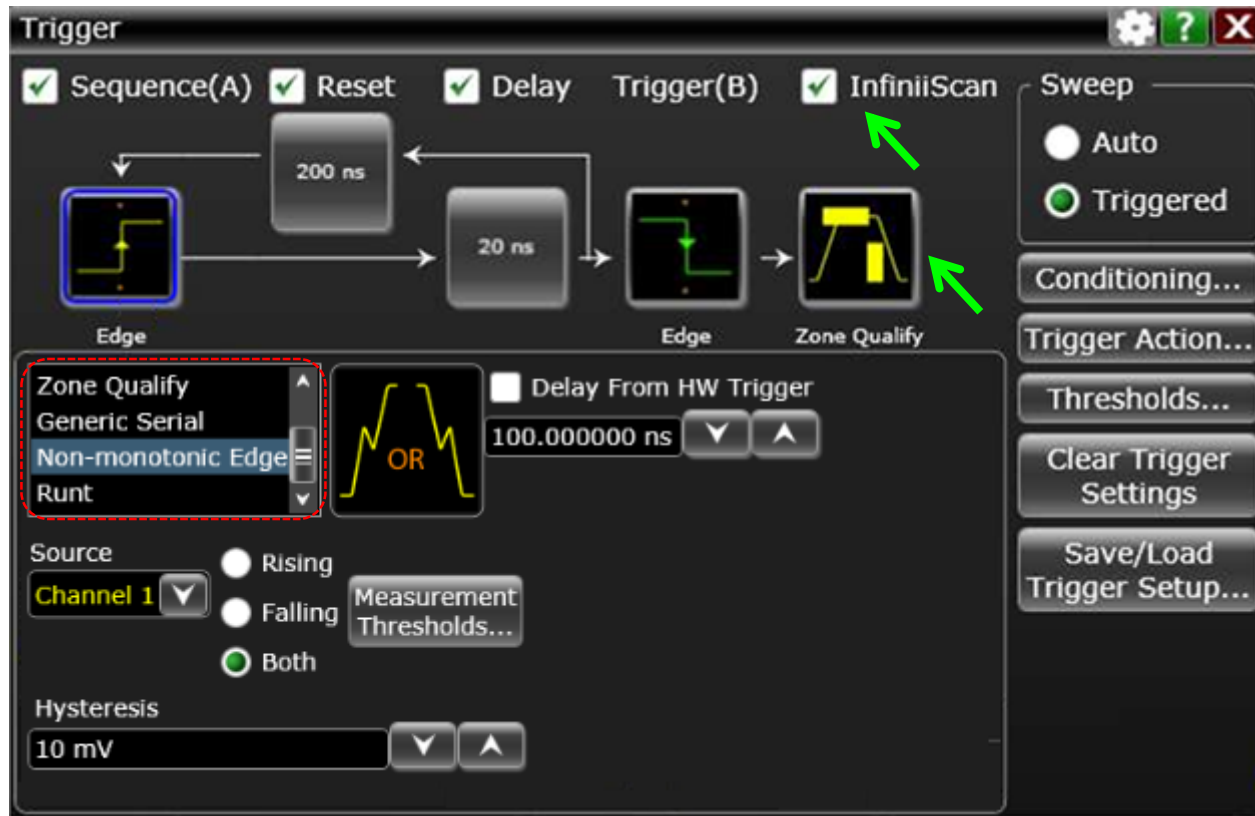
- InfiniiScan works in conjunction with the hardware trigger to further qualify a waveform event you are interested in capturing.

- As a software trigger, InfiniiScan should not be used to trigger on rare events.

- InfiniiScan is used here to further qualify the pulse width to < 100 ps.

InfiniiScan Zone Qualify Graphical Trigger

If you can see it, you can trigger it by drawing up to a combination of 8 zones on multiple channel waveforms.
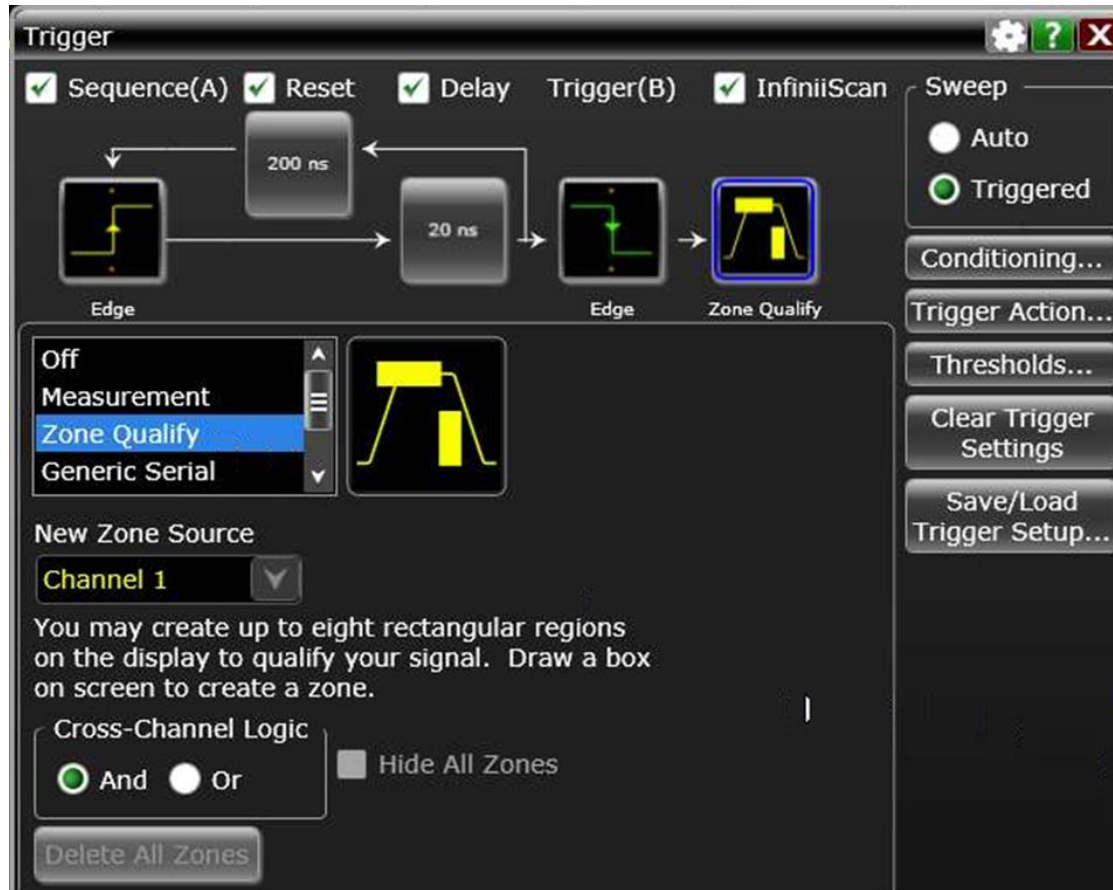
InfiniiScan Zone Qualify – How does it work?

- DDR test example - Complex Read/Write conditions are a triggering challenge
- Trigger on glitches or anomalies

DQS

Horizontal Waveform Zoom
Waveform Zoom
Horizontal Gating (Channel 1) ▶
Zones ▶
Cancel

Zone 1 ▶
Zone 2 ▶
Zone 3 ▶
Zone 4 ▶

AND Must Intersect
AND Must Not Intersect
OR Must Intersect
OR Must Not Intersect

DQS-Write Only

DQ-Write Only

KEYSIGHT
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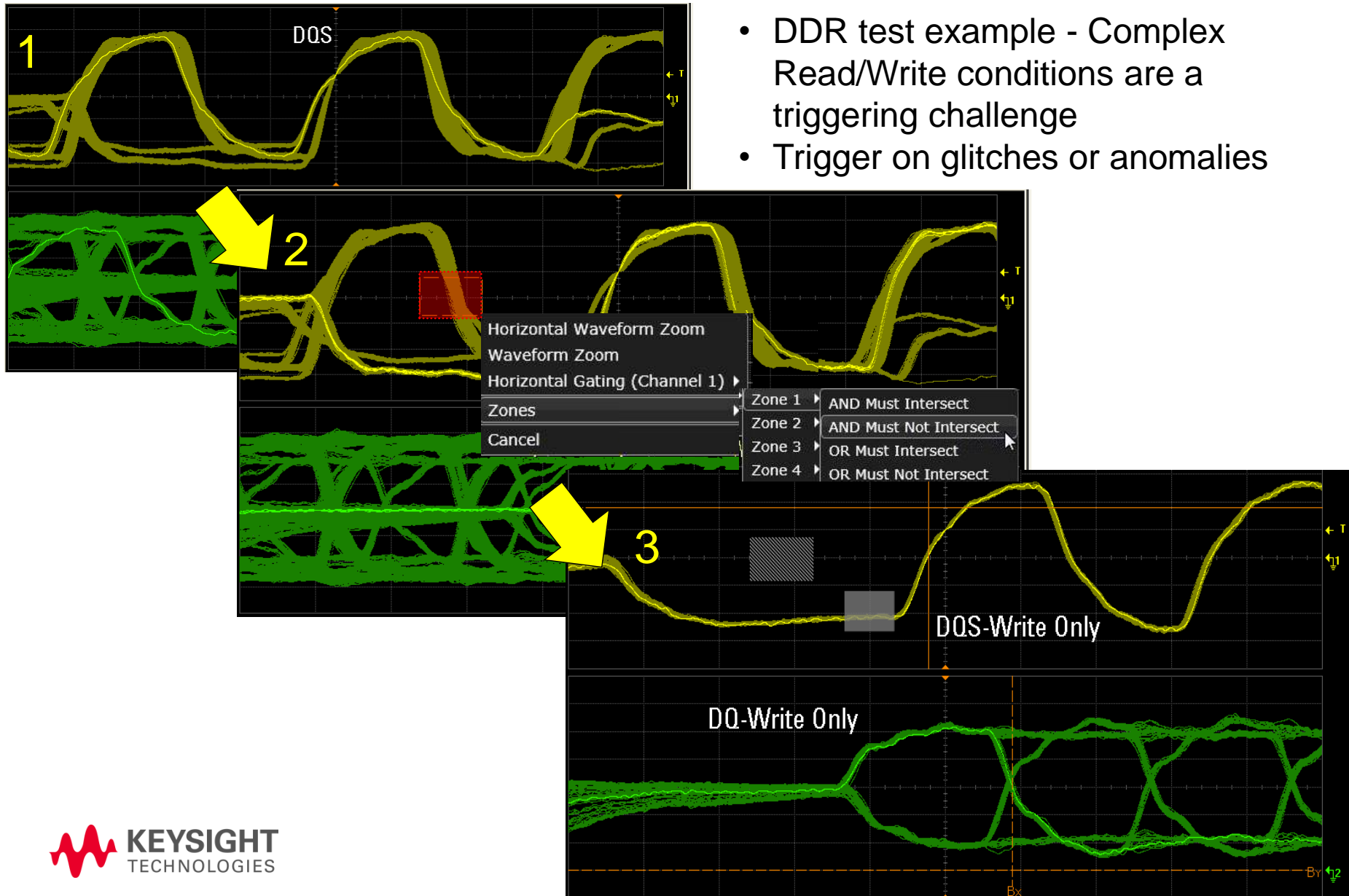
Complex Triggering with InfiniiScan Zone Qualify
Qualify complex bus waveforms for analysis with flexible logic triggering
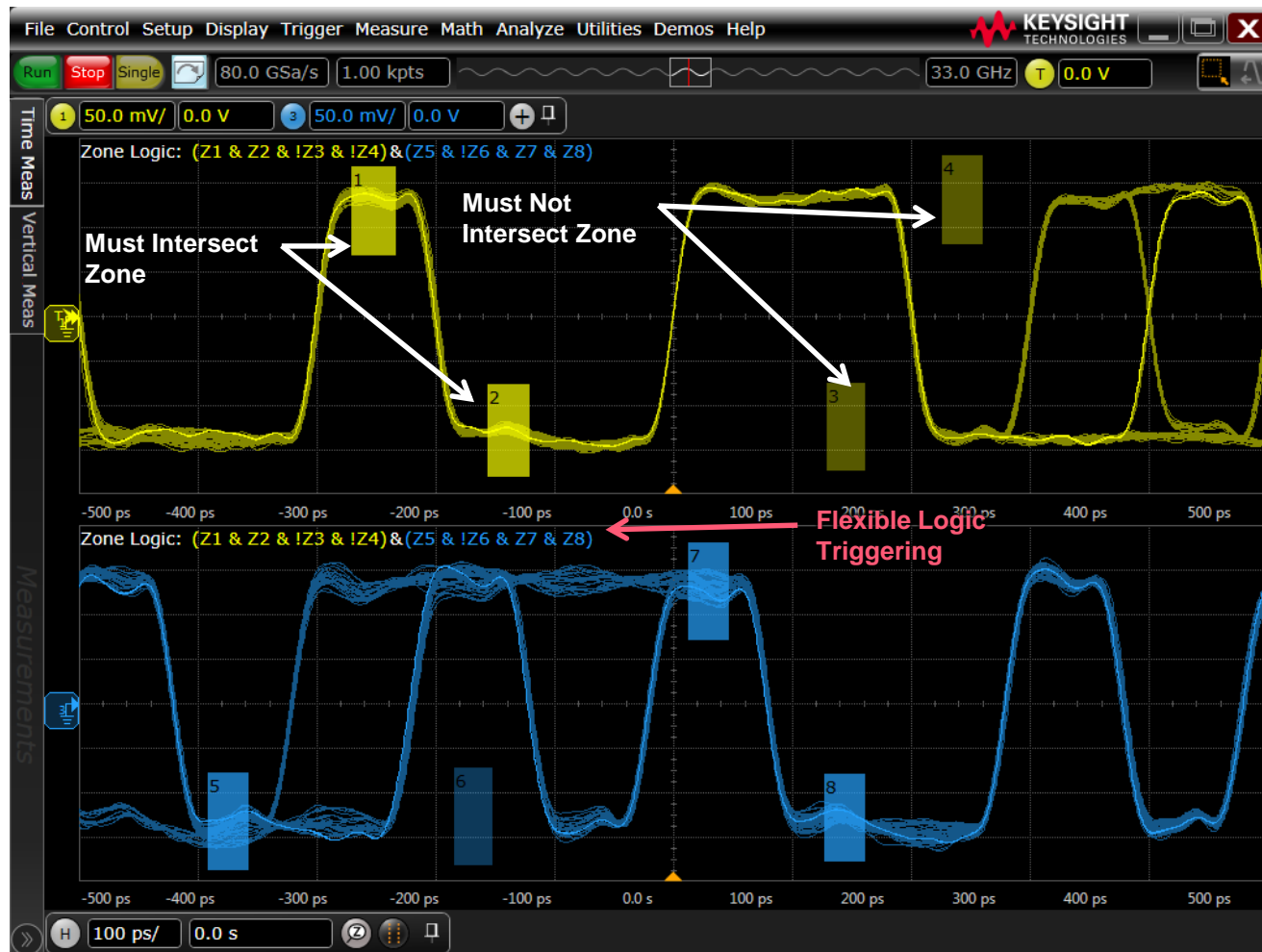
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TECHNOLOGIES

Triggering Case Study for USB 2.0 Link Problem

USB 2.0 bus link with occasional link failures

Problem:

- Bus errors are causing performance problems due to corrupt packets with occasional link failures

Activities during the bus transaction:

- Problem happens at the start of a new bus transaction on the data signal (DP) initiated from the USB Host.

- The USB Device draws power from the USB Host through Vbus.

- A high-frequency power switching supply on the USB Host is turned during high speed transmission.

How Advanced Triggering is Used to Solve Real World Problems

1. Use rising edge trigger and hold off to trigger at the beginning of transaction of the data signal (DP).

2. Use window trigger to find any voltage droop that exceeds the Vbus tolerance.
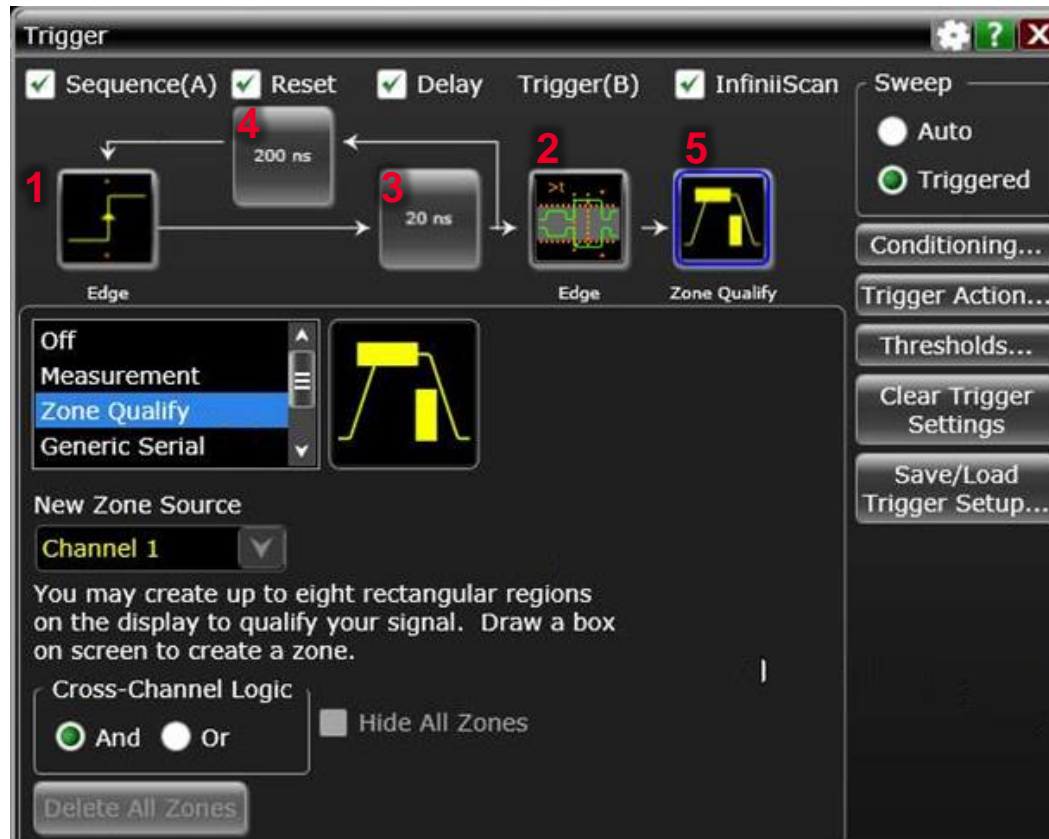
3. Add 20ns delay to the A → B event trigger when searching for the voltage droop.

4. Reset the trigger if no voltage droop is found in 200ns

5. Use zone qualify to further check for any power supply switching coupling into the data signal (DP).

Advanced Trigger Pinpoints Coupling Issue Corrupting the USB 2.0 Data Signal

1. Use rising edge trigger and hold off to trigger at the beginning of transaction of the data signal (DP).

2. Use window trigger to find any voltage droop that exceeds the Vbus tolerance.

3. Add 20 ns delay to the A → B event trigger when searching for the voltage droop.

4. Reset the trigger if no voltage droop is found in 200 ns.

5. Use zone qualify to further check for any power supply switching coupling into the data signal (DP).

20 ns delay

Crosstalk

200 ns reset
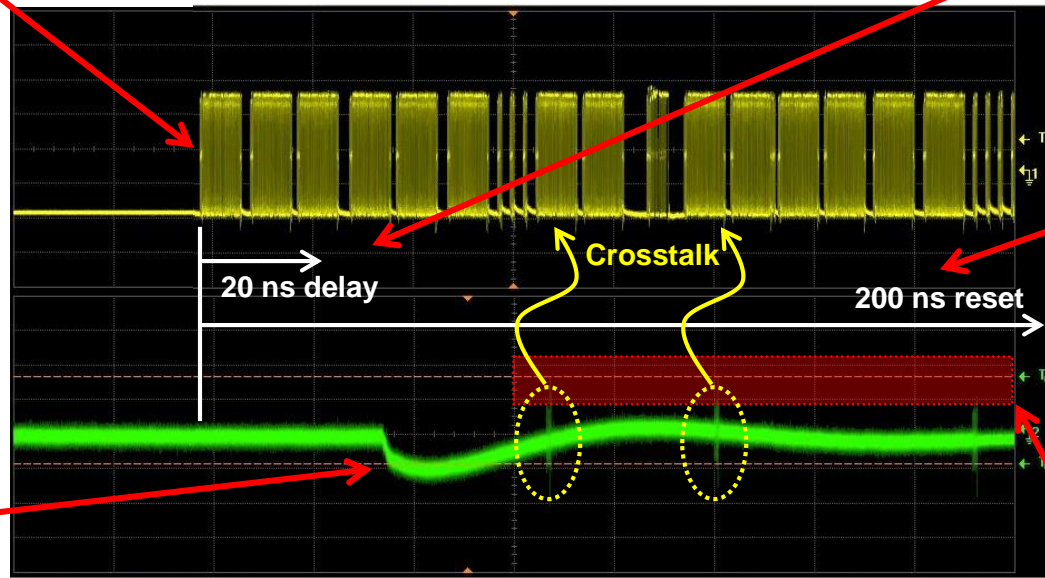
The trigger found the issue. The combination of Vbus voltage droop and power supply switching is coupled to the DP signal corrupting the signal.

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Advanced Protocol Software Triggering and Decode

- Example of scope decoding USB 3.0 protocol and CRC packets
- Software triggers can't be used for low occurrence event but hardware trigger can help improve the probability

USB 3.0 packet decode

Shows whether the bits are correctly received with the CRC verification.

CRC-32 = 97A6 B281 (GOOD)
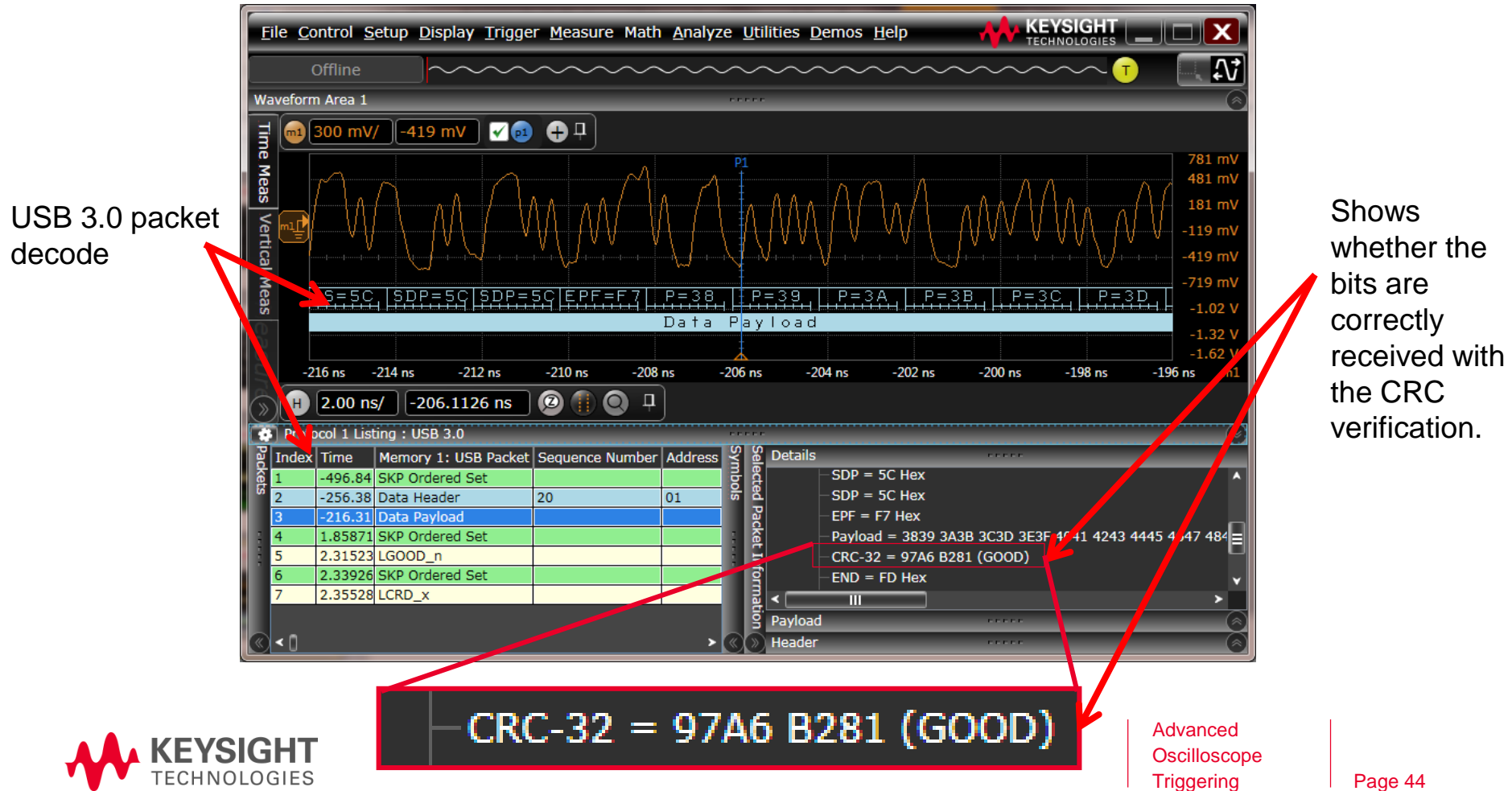
Trigger on Protocol Packet Type and Error
Example list of USB 3.0 protocol packet and errors

USB 3.0 protocol packets:
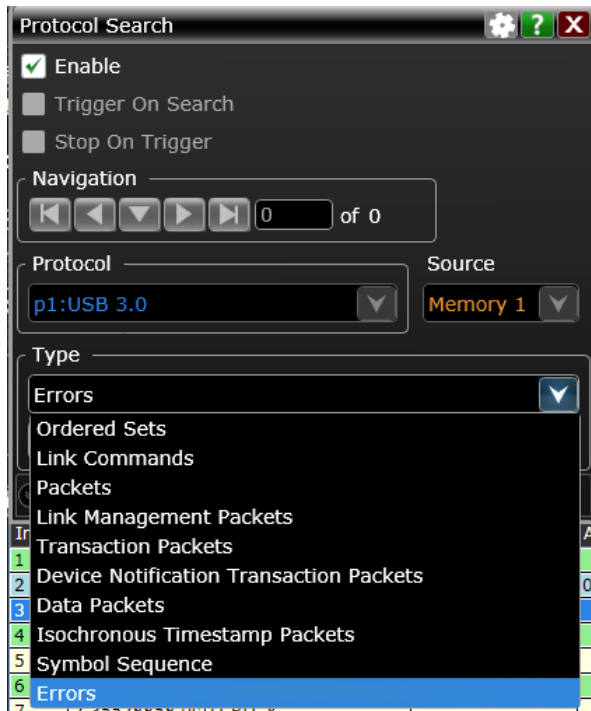
USB 3.0 errors:
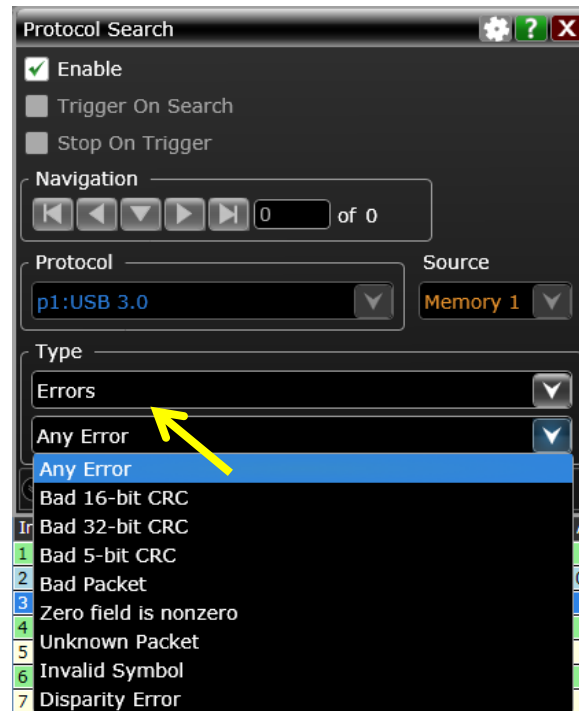
- Trigger on any packets, error or error specific to the protocol.

- Correlate between physical and protocol layer issues.

- Supported protocols:
  - USB 3.1, 3.0
  - PCIe Gen 3
  - SATA Gen 3
  - SAS-3
  - MIPI D-PHY
  - MIPI M-PHY
  - I2C, SPI
  - Others

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Scope dead time could miss specific events or pattern
Could be challenging with debugging the issue

- Scope has long dead time to trigger on specific high speed pattern.
- Re-arm and waveform processing time between acquisition cycles may be many orders of magnitude larger than the acquisition time.
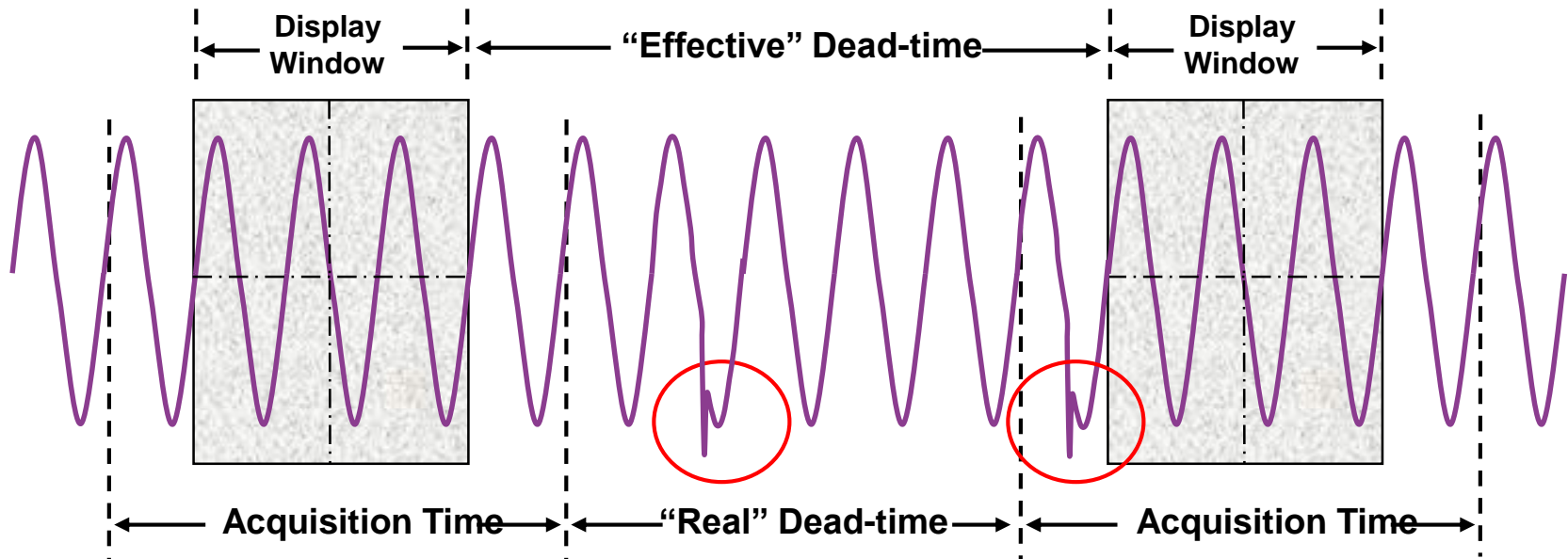
Advanced Trigger with Gbit Serial Trigger

Tracks high-speed serial pattern without dead time

- Gbit Serial can lock to the bit stream and trigger on the specified pattern.

- Long pattern trigger is required to trigger on USB 3.1 (132-bit) and PCIe Gen3 (130-bit) symbols

Supported high-speed protocols by V-Series hardware serial trigger

V-Series with 12.5 Gb/s and 160b pattern length is the only scope that can trigger at the USB 3.1 and PCI Gen3 symbols.

Trigger on 130-bit symbols in PCIe Gen3
Trigger on the 130-bit compliance pattern defined in the PCIe spec

PCIe Gen3 Base Spec:

4.2.10. Compliance Pattern in 128b/130b Encoding

The compliance pattern consists of the following repeating sequence of 36 Blocks

1. One block with a Sync Header of 01b followed by a 128-bit unscrambled payload of 64 1's followed by 64 0's
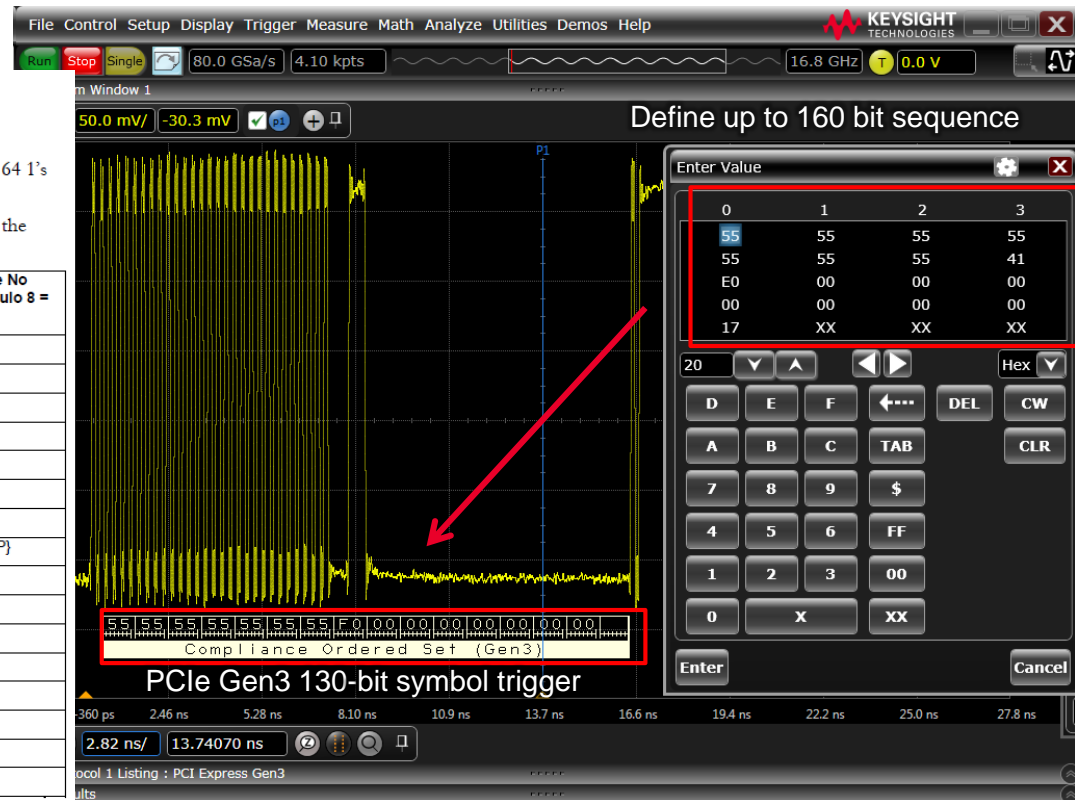2. One block with a Sync Header of 01b followed by a 128-bit unscrambled payload of the following:

	Lane No modulo 8 = 0	Lane No modulo 8 = 1	Lane No modulo 8 = 2	Lane No modulo 8 = 3	Lane No modulo 8 = 4	Lane No modulo 8 = 5	Lane No modulo 8 = 6	Lane No modulo 8 = 7
Symbol 0	55h	FFh	FFh	FFh	55h	FFh	FFh	FFh
Symbol 1	55h	FFh	FFh	FFh	55h	FFh	FFh	FFh
Symbol 2	55h	00h	FFh	FFh	55h	FFh	FFh	FFh
Symbol 3	55h	00h	FFh	FFh	55h	FFh	F0h	F0h
Symbol 4	55h	00h	FFh	C0h	55h	FFh	00h	00h
Symbol 5	55h	00h	C0h	00h	55h	E0h	00h	00h
Symbol 6	55h	00h	00h	00h	55h	00h	00h	00h
Symbol 7	{P,~P}	{P,~P}	{P,~P}	{P,~P}	{P,~P}	{P,~P}	{P,~P}	{P,~P}
Symbol 8	00h	1Eh	2Dh	3Ch	4Bh	5Ah	69h	78h
Symbol 9	00h	55h	00h	00h	00h	55h	00h	F0h
Symbol 10	00h	55h	00h	00h	00h	55h	00h	00h
Symbol 11	00h	55h	00h	00h	00h	55h	00h	00h
Symbol 12	00h	55h	0Fh	0Fh	00h	55h	07h	00h
Symbol 13	00h	55h	FFh	FFh	00h	55h	FFh	00h
Symbol 14	00h	55h	FFh	FFh	7Fh	55h	FFh	00h
Symbol 15	00h	55h	FFh	FFh	FFh	55h	FFh	00h

Define up to 160 bit sequence

0	1	2	3
55	55	55	55
55	55	55	41
E0	00	00	00
00	00	00	00
17	XX	XX	XX

PCIe Gen3 130-bit symbol trigger

55 55 55 55 55 55 55 F0 00 00 00 00 00 00 00
Compliance Ordered Set (Gen3)

PRBS Bit Error Trigger

Find corrupted PRBS bit error

- Triggers on PRBS bit error (PRBS 7, 15, 23 and 31).

- Check error at different location on the circuit. Use this method to debug issue related to ISI where a bit (data dependent) is corrupted by a lossy channel.

PRBS7 bit error found
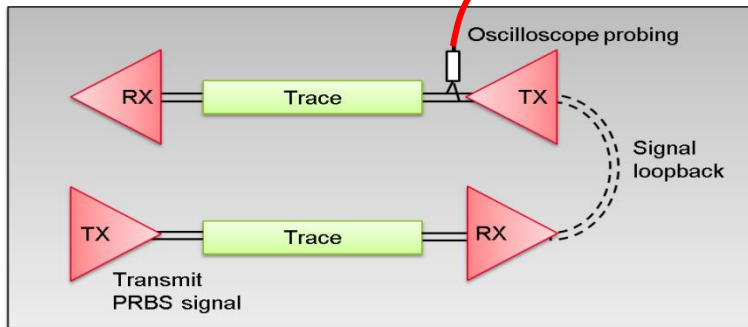
V-Series the only scope with PRBS bit error trigger

KEYSIGHT
TECHNOLOGIES

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16-ch Digital Logic Trigger with 20 GSa/s Sample Rate

Available with Mixed Signal Oscilloscope (MSO)

4 analog channels

16 digital channels
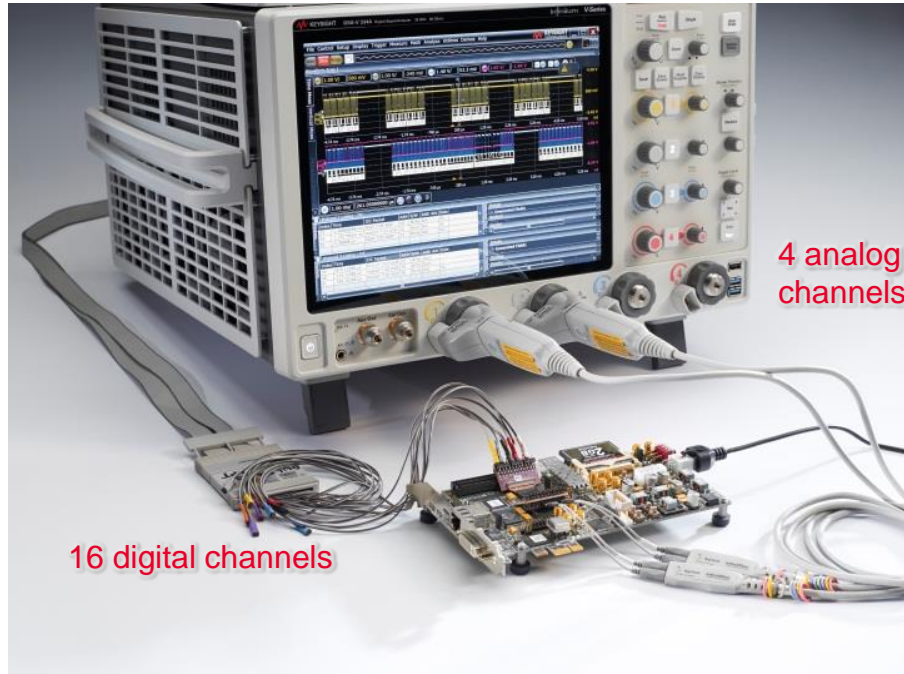
Performance	Specification
Digital Channels	16
Sample Rate	20 GSa/s (8 ch) or 10 GSa/s (16 ch)
Connection	Fully Differential
Compatibility	Any 90 pin Logic Analyzer Probe
Analog Bandwidth	3 GHz
Memory Depth	500 Mpts (2 µs)

- Today's designs require access to complex triggers and multiple instruments.

- MSO integrates traditional 4 analog channels with 16 digital channels, providing up to 20 channels you can use at once.

- Trigger across any combination of analog and digital channels, as well as decode the acquired data.

- Supports real-time DDR protocol triggering.

KEYSIGHT TECHNOLOGIES

Parallel bus trigger and decode
Use MSO for your cutting-edge DDR memory bus validation

DDR3 write trigger

DDR3 decode

DDR3 write cycle eye-diagram
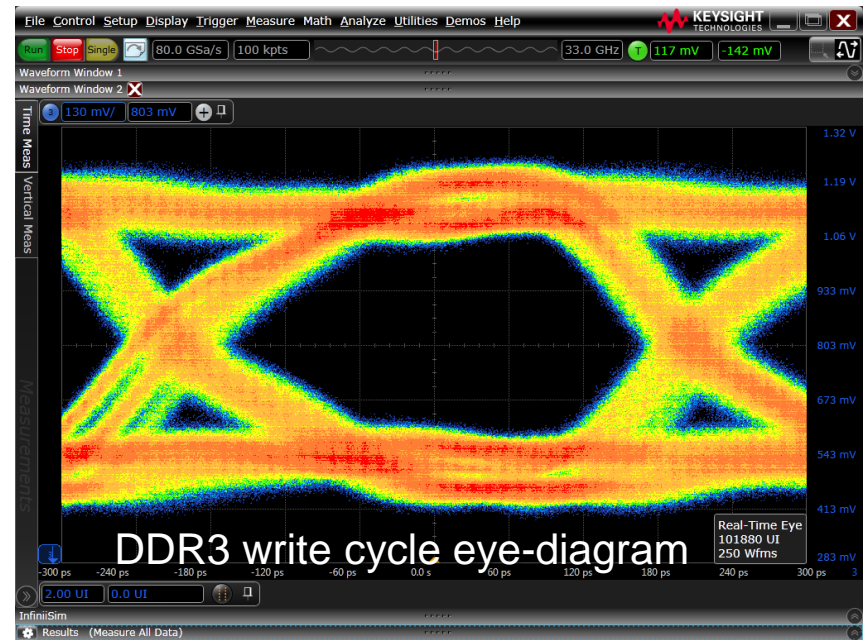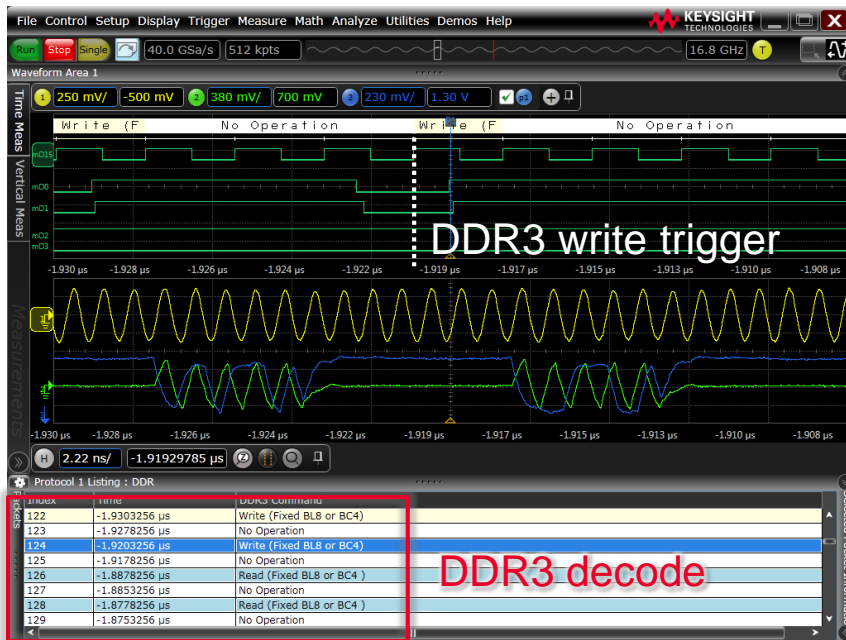
- Use digital channels to trigger on the different DDR commands such as read, write, activate, precharge, etc.

- DDR protocol decoder can decipher the DDR packets and provide time-aligned listing window to search for specific packet information.

- Command trigger makes reads and write separation easy, providing fast electrical characterization, eye-diagram and timing measurements.

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Summary of Advanced Trigger Options

What's unique / invented by Keysight?

- **Huge variety of basic and advanced** hardware trigger options
- **InfiniiScan software trigger** provides additional qualifier
- **3 stage sequence** trigger with integrated HW and InfiniiScan SW trigger
- **A → B Sequence** Trigger with "**delay**" &"**reset**" condition setting
- **Advanced protocol packet trigger** to find error and any packet specific to protocol
- **Hardware Gbit serial trigger with longest 160b, 12.5 Gb/s** to find pattern in high speed bit stream
- **PRBS bit error trigger** to find corrupted bits
- **Fastest 20 GSa/s logic trigger** to trigger on a combination of 16 digital and 4 analog channels for fast parallel signals

KEYSIGHT TECHNOLOGIES
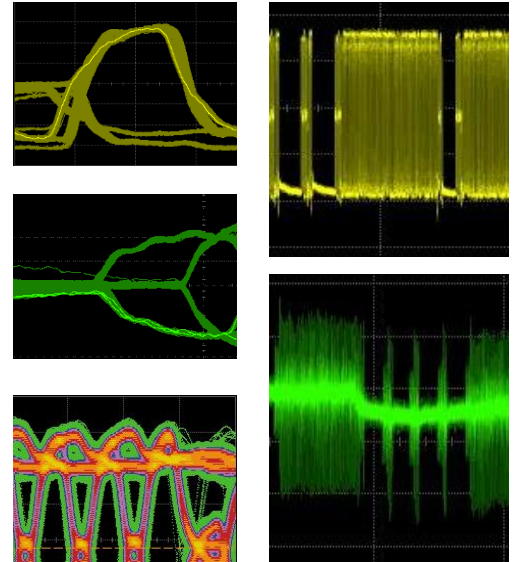
Summary

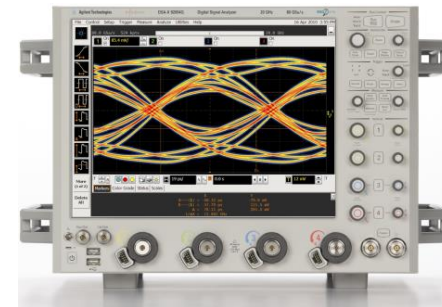## Keysight Real-Time Oscilloscope with Advanced Scope Triggers

- Basic scope triggers are great tools for capturing important events for analysis.

- Advanced Oscilloscope Triggering is essential to solving complex problems.

- Keysight real-time scope has a variety of unique hardware and software triggers to help you find and debug problems faster.

- This allows shorter time to market and more insight into your designs.
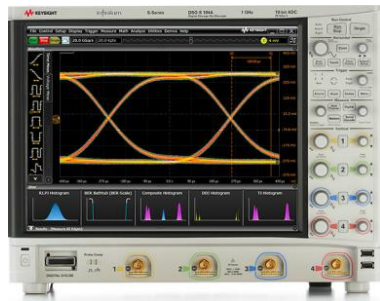
S-Series
500 MHz – 8 GHz

V-Series
8 GHz – 33 GHz

Z-Series
20 GHz – 63 GHz

KEYSIGHT
TECHNOLOGIES

Thanks for joining us!

Questions?

Advanced
Oscilloscope
Triggering

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