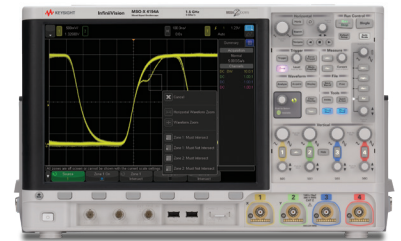


# Triggering on Infrequent Anomalies and Complex Signals using Zone Trigger



## Introduction

When debugging digital designs, it is often difficult-to-impossible to set up an oscilloscope to trigger on specific and unique signal problems. The Keysight Technologies, Inc. Zone Trigger, which is available as a standard feature in all InfiniiVision 3000T, 4000 and 6000 X-Series oscilloscopes, can be used in conjunction with conventional oscilloscope triggering to help zero-in on problem signals. If you can see the problem signal, then you can trigger on it using Zone Trigger.

The best way to understand what Zone Trigger can do for you is to see some examples. This application note will show the following four measurement applications:

- Triggering on Non-monotonic Edges
- Triggering on Setup & Hold Time Violations
- Triggering on Isolated “Ones” and “Zeros”
- Triggering on Serial Bus Arbitration

## Triggering on Non-monotonic Edges

A digital signal with a non-monotonic edge is one that either reverses direction or momentarily “stalls” while ramping up or ramping down. Figure 1 shows an example of a non-monotonic edge that occurs randomly and very infrequently. With an InfiniiVision X-Series oscilloscope that updates waveforms as fast as 1,000,000 waveforms per second, we can clearly see the problem signal while triggering on any rising edge of this digital pulse train. The problem now is figuring out how to trigger on and display just the problem signal with the odd anomaly and not display the normal signals that have clean edges. If we can trigger the scope’s display to show just the problem signals, then perhaps we can probe other signals in our system to look for correlation to help solve our signal integrity problem.

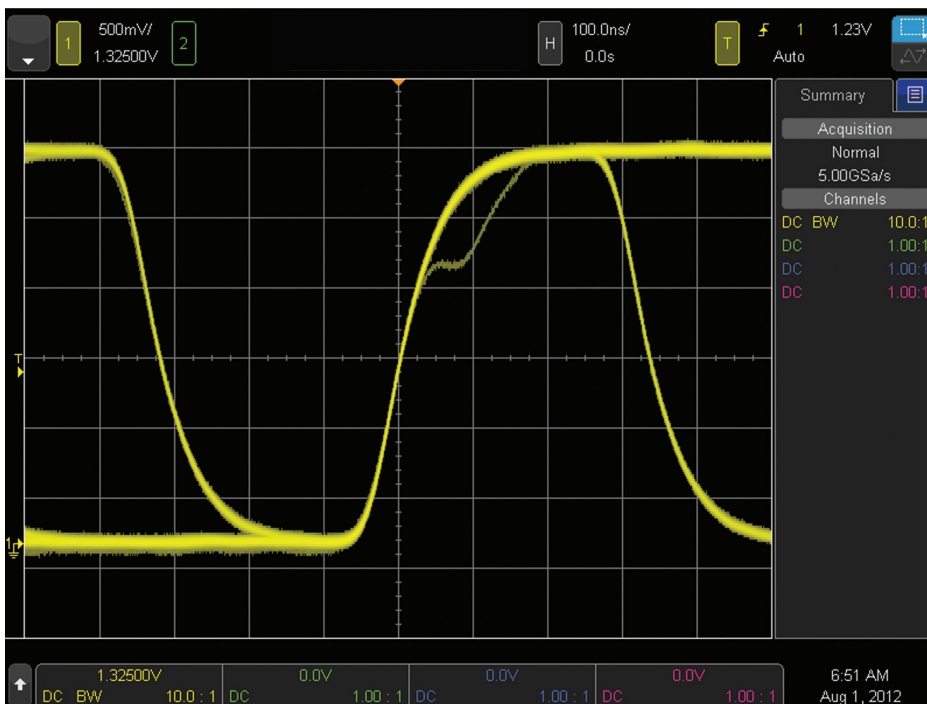


Figure 1. Capturing a signal with an infrequent non-monotonic edge using standard edge triggering.

Some scopes have the ability to trigger on edges based on “greater than” or “less than” rise or fall times, including Keysight’s 3000T, 4000 and 6000 X-Series oscilloscopes. This might solve our triggering problem, but setting up the scope to establish a unique trigger condition such as this can be time consuming. With Zone Trigger, we can simply draw a box (zone) on the scope’s capacitive touch screen display in the area of the signal anomaly and then specify that the waveform “must intersect” the hand-drawn zone (or down-loaded zone based on XY coordinates) in order to be uniquely captured and displayed. The scope then displays just waveforms that meet this qualification as shown in Figure 2.

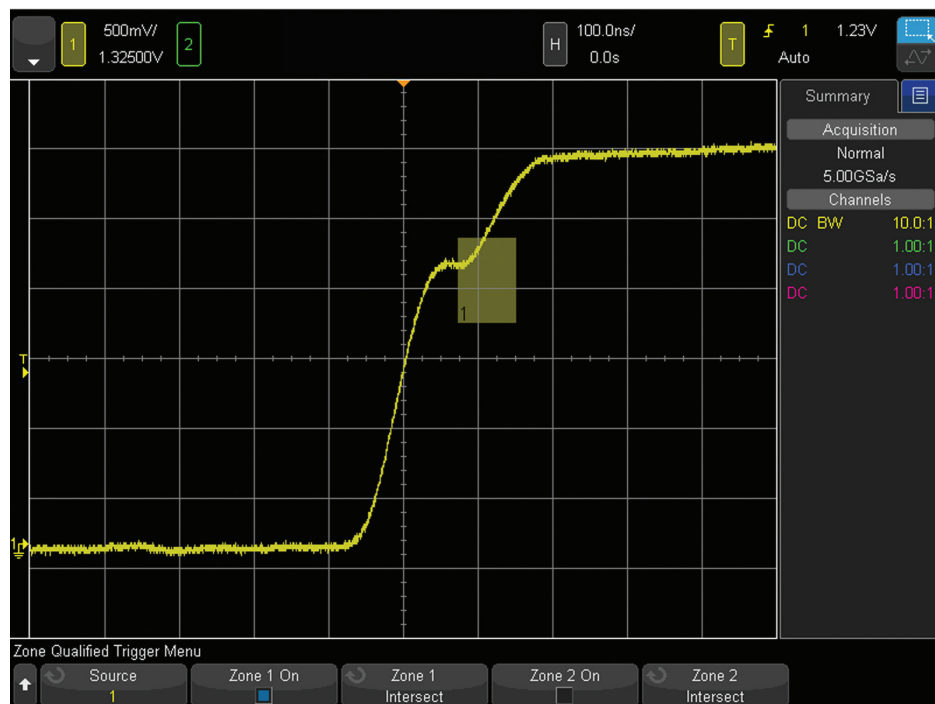
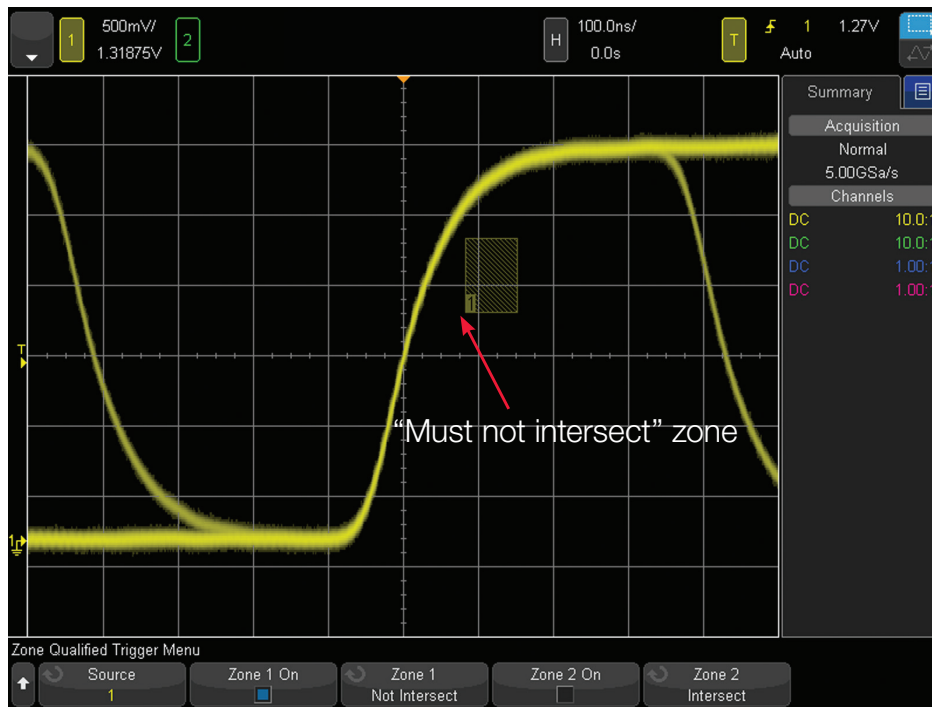


Figure 2. Capturing and displaying just waveforms with an anomaly (non-monotonic edge) using Zone Trigger.

Note that we can also change the qualification to “must not intersect,” in which case the scope would only display waveforms with normal rising edges as shown in Figure 3. Or, we could simply slide the original “must intersect” zone box to the adjacent waveform area of signal normalcy using the scope’s touch screen.



**Figure 3. Capturing and displaying just waveforms with “normal” edges using Zone Trigger.**

How does Zone Trigger actually work? When Zone Qualify Trigger is turned on, the oscilloscope first captures all waveforms that meet the specified conventional scope trigger condition at a capture rate of up to 200,000 waveforms per second (assuming that the input trigger rate meets or exceeds this rate). Although simple rising or falling edge triggering is used most often, any conventional trigger condition can be used as a pre-qualifier, including serial triggering. The scope then compares each captured waveform against the pre-defined “zones” (up to 2 qualification zones) to see if the waveform crossed through the “must intersect” zones and did not cross through the “must not intersect” zones.

With hardware-based scanning of captured waveforms at a rate of up to 200,000 compares per second, Keysight’s Zone Trigger capability provides a very easy and reliable method of capturing random and infrequent signal anomalies.

Basically, if you can see the anomaly on the scope’s display when the scope is updating at 1,000,000 waveforms per second (450,000 waveforms per second if using a 6000 X-Series oscilloscope) with Zone Trigger turned off, then the scope has a high probability of being able to uniquely display the signal anomaly when Zone Trigger is turned on.

## Triggering on Setup and Hold Time Violations

When digital data is transferred from one device to another, it is often synchronously clocked into the device. However, the data signal must be stable (high or low) for a minimum amount of time before the occurrence of the clock edge to insure that data is reliably clocked in. This is called the device's minimum required "setup time." In addition, data signals must remain stable (high or low) for a minimum amount of time after the occurrence of the clock edge. This is called the minimum required "hold time."

Figure 4 shows an example of the scope triggering on and capturing a clocking signal on channel-1 (yellow trace), while also capturing the data signal on channel-2 (green trace) as an eye-diagram pattern. Using the scope's timing cursors, we determine that the rising and falling edges of the data signal typically occur 40 ns prior to the rising edge of the clock. However, we also observe infrequent shifts in the data signal — both rising and falling edges — that result in a violation of the storage device's minimum setup time specification of 30 ns.

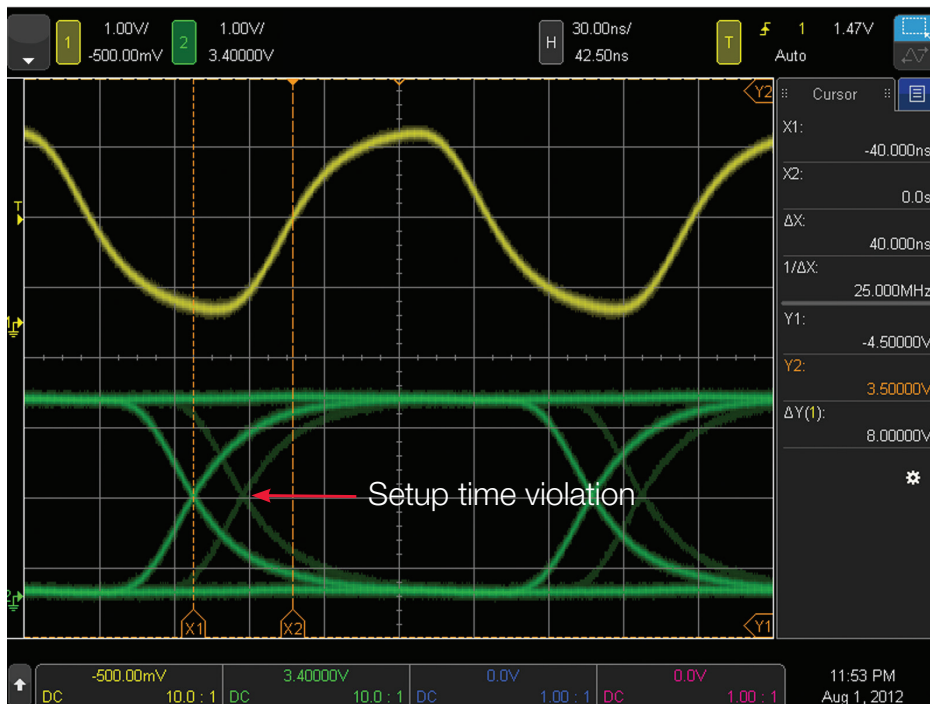


Figure 4. Observing an eye-diagram display of a data signal (green trace) with an occasional setup time violation while triggering on the rising edge of the clock signal (yellow trace).

To synchronize the scope's triggering and display of waveforms only when violations occur, we could use the scope's advanced Setup & Hold Time triggering mode. But this is another case where it is simply much easier to draw a "must intersect" zone box in the area of the violation signals as shown in Figure 5. With the X1 timing cursor repositioned to the cross-over point of the data signal, we now measure a setup time of approximately 20 ns, which violates the 30 ns specification of this device. At this point we could probe other signals in our system using channel-3 and channel-4 of the scope in an attempt to correlate the cause of this violation.



Figure 5. Using Zone Trigger to isolate setup time violations.

Triggering on just non-violation signals can be achieved by simply sliding the zone box (using the scope's capacitive touch screen) over to the region of the waveform where edges normally occur as shown in Figure 6.

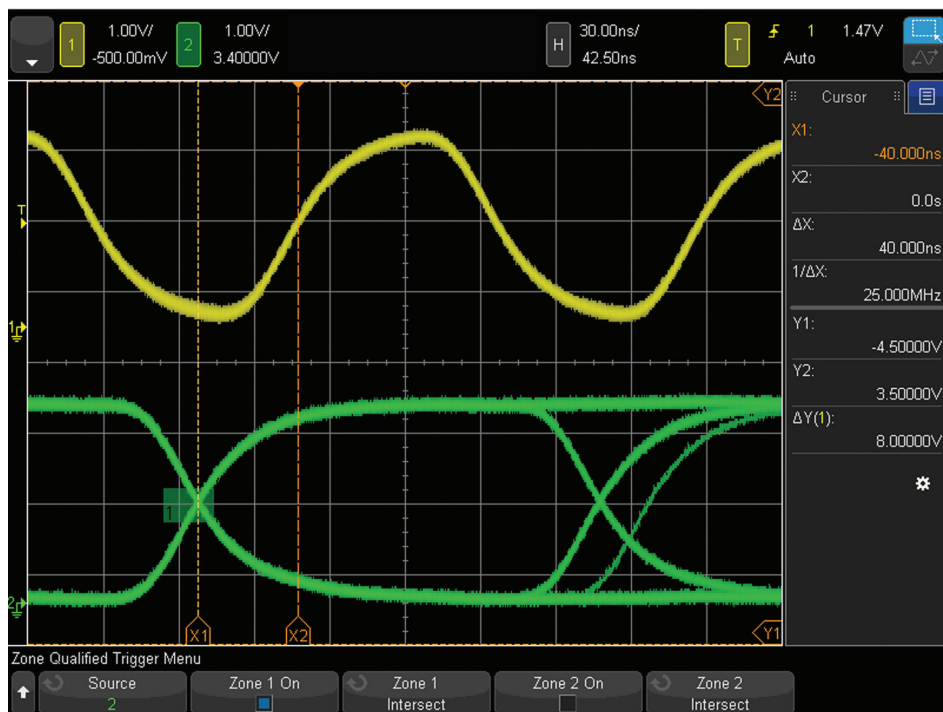


Figure 6. Using Zone Trigger to isolate valid setup times.

## Triggering on Isolated “Ones” and “Zeros”

Characterizing the quality of serial bus signals often requires performing measurements on isolated “ones” and/or isolated “zeros.” For NRZ type signals, an isolated “one” is defined as a single high bit that is both preceded and followed by a specified number of “zeros.” An isolated “zero” is defined as a single low bit that is preceded and followed by a specified number of “ones.”

The purpose of performing measurements on isolated bits is often to characterize an output driver’s ability to produce a valid bit without the influence of other nearby pulses that can introduce inter-symbol interference/distortion. Very few scopes on the market today have the ability to trigger on isolated bits that are preceded and/or followed by more than one bit of the opposite polarity. Let’s now set up the Keysight InfiniiVision X-Series scope to trigger on an isolated “one” that is preceded by at least three zeros and then followed by at least two zeros.

Figure 7 shows an example of the scope triggering on rising edges of a 10 Mbps FlexRay serial bus signal. At this point, nothing more than a rising edge of this signal is isolated on the scope’s display at center-screen. Since the serial baud rate of this signal is 10 Mbps, a single bit should be 100 ns wide. Setting the scope’s timebase at 100 ns/div will make it easy for us to establish the approximate widths of our zone boxes.



Figure 7. Triggering on a rising edge of a 10 Mbps serial bus signal with the timebase set at 100 ns/div.



Figure 8 shows where we have drawn two “must not intersect” zone boxes in order to meet the requirements of isolating a single high bit that is preceded by three or more zeros and then followed by two or more zeros. You can think of these zones as waveform “keep-out boxes.” Now that we have isolated the “ones” pulses, we can perform the required waveform characterization measurements such as rise time, fall time, pulse width, etc.

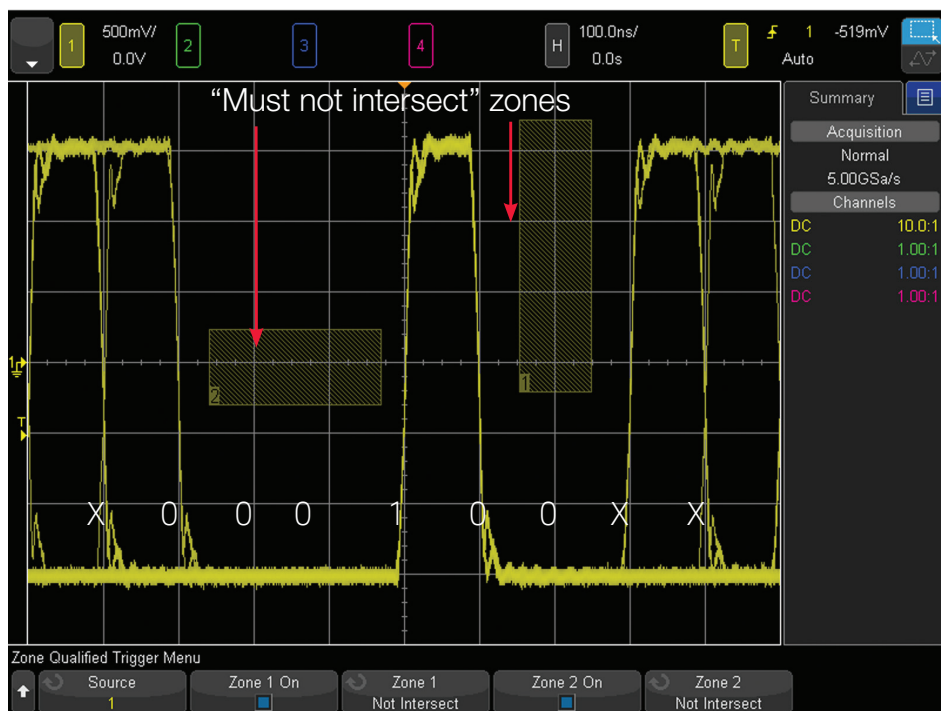


Figure 8. Triggering on isolated “ones” using two “must not intersect” zones along with a rising edge trigger.

Figure 9 shows an example of displaying just isolated zeros based on similar criteria: preceded by three or more ones and followed by two or more ones. This time we have set up the scope to trigger on falling edges and then established appropriate “must not intersect” zone boxes.

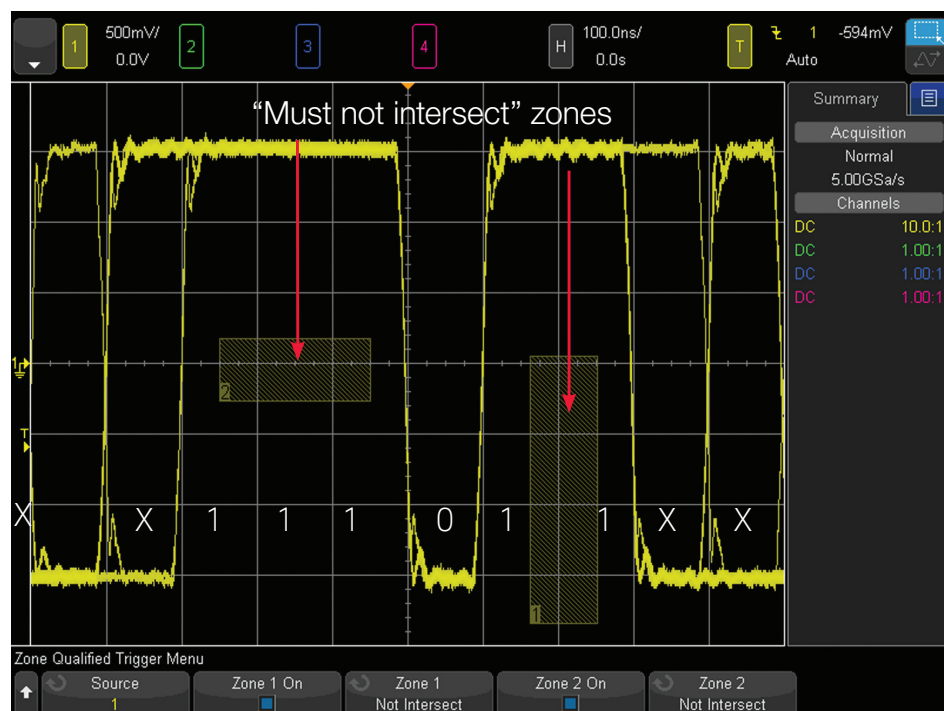


Figure 9. Triggering on isolated “zeros” using two “must not intersect” zones along with a falling edge trigger.

In addition to using Zone Trigger to trigger on isolated “ones” and “zeros,” it can also be used to synchronize on other unique serial patterns.

## Triggering on Serial Bus Arbitration

As mentioned earlier, Zone Trigger can be used in conjunction with more complex triggering, including serial bus triggering. Figure 10 shows an example of the scope triggering on a Controller Area Network (CAN) bus data frame with an ID equal to 025<sub>HEX</sub>. Note that you can observe the time-correlated decode trace near the bottom of the scope's display, which begins with the frame ID (025).

The CAN bus is based on asynchronous transmission of data from multiple nodes in a system, such as an automobile. With asynchronous transmission, multiple nodes may attempt to transmit data at or near the same time. When this happens, there is an arbitration process that determines which node has highest priority and can continue transmitting data. Lower priority nodes in the system must then halt transmission of data.

In Figure 10 we can see that the first pulse in frame 025<sub>HEX</sub> exhibits two different low-level amplitudes; sometimes it's low — and sometimes it's lower. When the signal goes to the lowest level, this is evidence that two nodes are attempting to transmit data at the same time and arbitration begins. When this pulse pops back up, this indicates that the arbitration process has finished and frame 025<sub>HEX</sub> won the priority battle.

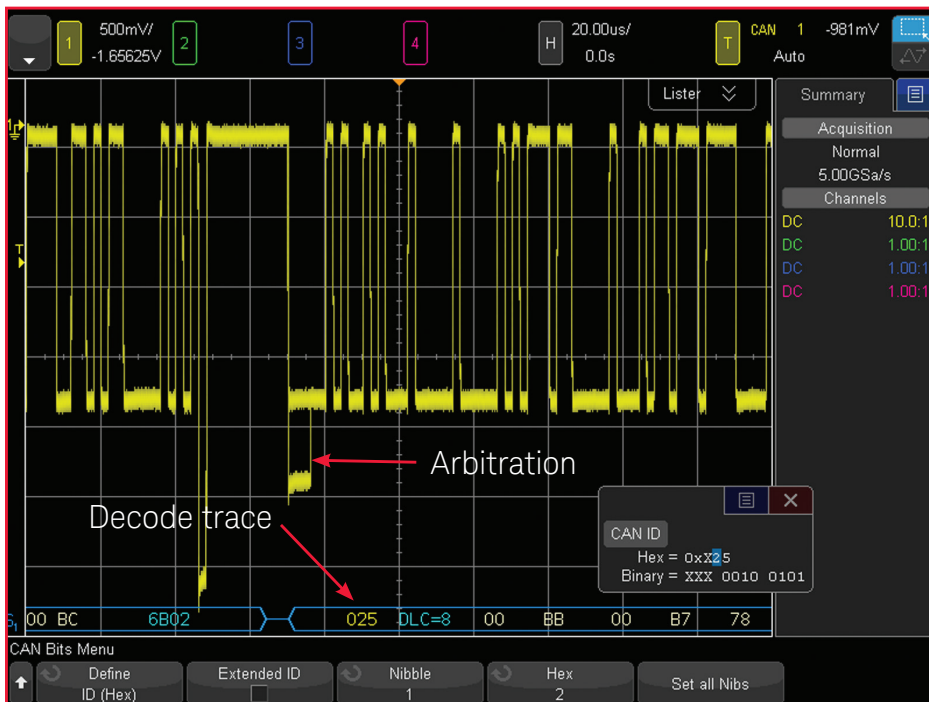


Figure 10. Triggering on a serial CAN frame that sometimes includes arbitration.

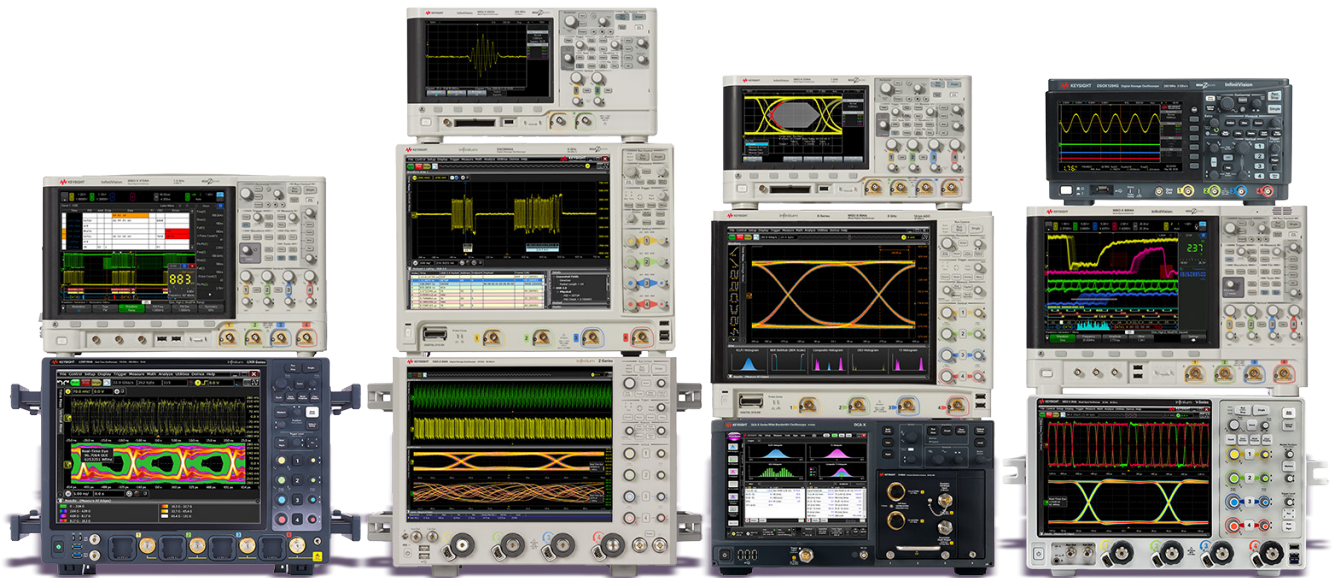
So, how do we synchronize the scope's display only on those frames that include arbitration? There isn't an advanced oscilloscope trigger condition that will do this for us, but serial bus triggering in conjunction with Zone Trigger will solve our problem. Figure 11 shows an example of using zone trigger to synchronize on just CAN frame 025<sub>HEX</sub> when arbitration occurs. In this case, we have first set up the scope to serially trigger on frame ID:025<sub>HEX</sub>. We then set up a "must intersect" qualification zone around the lower level pulse. Alternatively, if we had set up a "must not intersect" zone in the same location, the scope would have triggered on only those frames with an ID equal to 025<sub>HEX</sub> that didn't include arbitration.



Figure 11. Using Zone Trigger to synchronize on just frames that include arbitration.

## Related Literature

Publication title	Publication number
InfiniiVision Oscilloscope Probes and Accessories - Selection Guide Data Sheet	5968-8153EN
Oscilloscope Display Quality Impacts Ability to View Subtle Signal Details - Application Note	5989-2003EN
Oscilloscope Waveform Update Rate Determines Probability of Capturing Elusive Events - Application Note	5989-7885EN
InfiniiVision 3000T X-Series Oscilloscopes - Data Sheet	5992-0140EN
InfiniiVision 4000 X-Series Oscilloscopes - Data Sheet	5991-1103EN
InfiniiVision 6000 X-Series Oscilloscopes - Data Sheet	5991-4087EN
Characterizing CAN Bus Arbitration Using InfiniiVision 4000/6000 X-Series Oscilloscope - Application Note	5991-4166EN



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## Summary

In this application note we covered just a few examples of how Zone Trigger in Keysight's InfiniiVision 3000T, 4000 and 6000 X-Series oscilloscopes can be used to trigger on signals that include infrequent anomalies (or weird shapes). In addition, we have also shown how Zone Trigger can be used to trigger on signals that may be valid (non-problem signals), but may be so complex that using standard triggering may be difficult or even impossible with today's oscilloscope technology.

Many of today's newer digital storage oscilloscopes (DSOs) offer features that allow for more advanced triggering and analysis on complex and higher speed signals. But, using advanced oscilloscope features can often be more trouble than it is worth. That isn't the case with Keysight's Zone Trigger in the InfiniiVision 3000T, 4000 and 6000 X-Series DSOs and MSOs.

This new tool is both a powerful and simple-to-use tool that allows you to isolate measurements on specific signal shapes. When coupled with the oscilloscope's 1,000,000-waveforms-per-second update rate (450,000 waveforms per second if using a 6000 X-Series scope), if you see it, you can trigger on it.

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