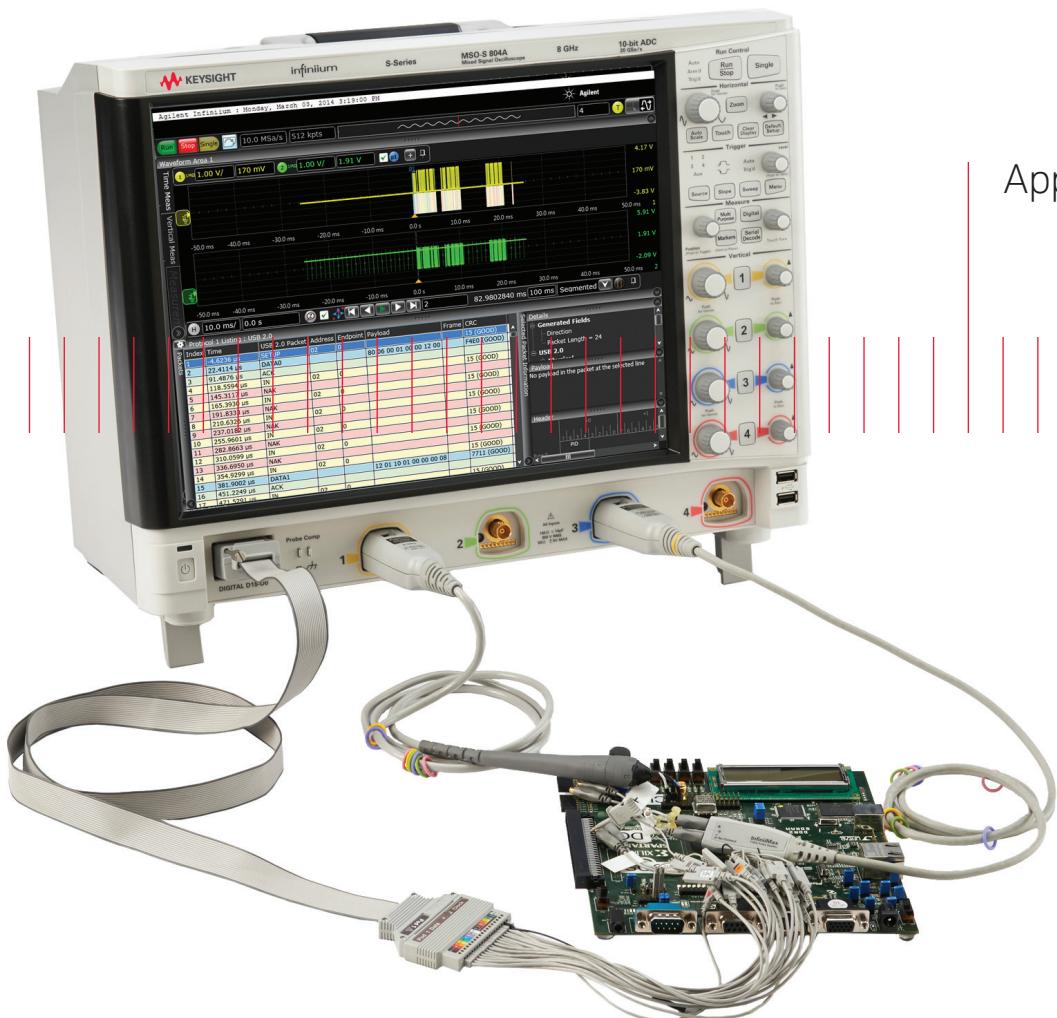


# Keysight Technologies

## Selecting the Right Oscilloscope for Protocol Analysis Applications

Application Note



## Introduction

Serial buses are pervasive in today's electronic designs to provide critical communication between ICs, subsystems, boards and systems. I<sup>2</sup>C and SPI have found their way into a broad array of chips and peripherals including FPGAs, a variety of I/O, ADCs, sensors, ASICs and processors. JTAG serial buses, test chips and boards also provide debug ports for microprocessors and other integrated circuits. CAN, LIN and FlexRay enable noise-immune communication networks for automotive and industrial products. USB ports have become pervasive on mobile and other consumer products, and PCIe has gained a foothold by passing large amounts of data quickly. Even legacy serial buses like RS-232/485/485 and MIL-STD 1553 continue to prosper despite their age. Low cost, minimal pin usage and a protocol layer that eases software implementation make serial buses ideal for a wide variety of applications across a range of industries.

All major oscilloscope vendors now offer scope-based protocol applications that enable you to gain faster and better insight when debugging systems with serial buses. These applications let oscilloscopes trigger on and display packets in addition to parametric signal detail. They help you answer questions, including "How are the devices on each end of the bus negotiating the link?" and "What values are being passed on the bus?"

With the right combination of oscilloscope and protocol application, you can resolve issues quickly, saving days to weeks of time. Although all major scope vendors offer protocol decode and triggering applications, the applications vary in capability and quality. When evaluating a new oscilloscope that will include protocol applications, you should consider the following six questions.

## 1. What protocols are supported and to what degree?

Make sure the oscilloscope vendor has support for protocols that you currently use or are likely to use in the near future. It's easy to check a Web page to see if the protocol you are interested in is supported on a particular scope. Getting a trial license is a great way to make a determination. You need to pull up the application on an oscilloscope or look through detail in the datasheet, to determine how well the particular protocol is supported.

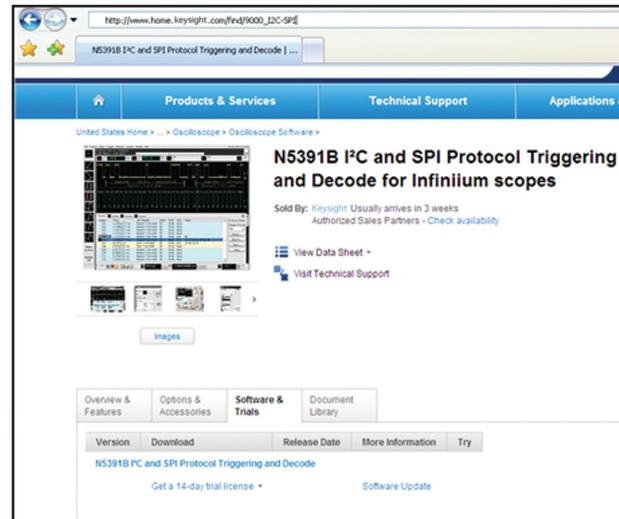


Figure 1. View product web pages to see if the protocol you are interested in is supported on a particular scope.

For example, if you are using SPI, what is the fastest data rate that is supported? Does the application support 2-, 3- and 4-wire SPI or only a subset? If you are using USB 2.0, does the application support the low-, full- and high-speed versions of the specification as well as HSIC? If using I<sup>2</sup>C, how well does the application support I<sup>2</sup>C where the read/write bit is included in the address field?

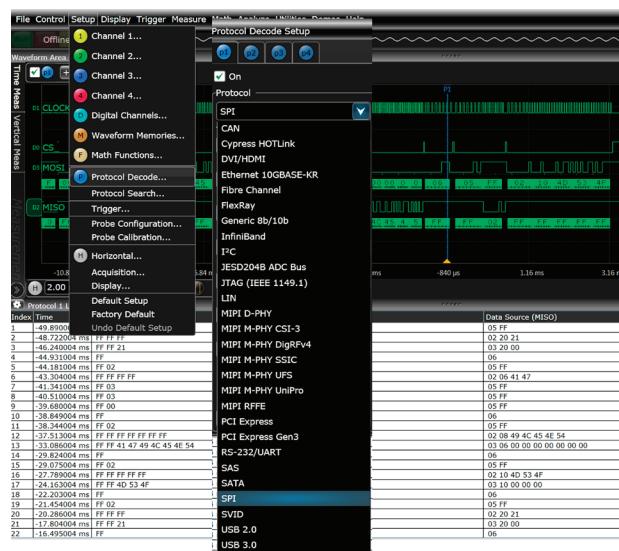


Figure 2. Try out a protocol application on your oscilloscope to better determine its capabilities.

## 1. What protocols are supported and to what degree? (Cont.)

Do you need to look at simultaneous decode of more than one serial bus (Figure 3)? How easy is it to set up decode of multiple buses, navigate between buses or change which bus is being used as the trigger source?

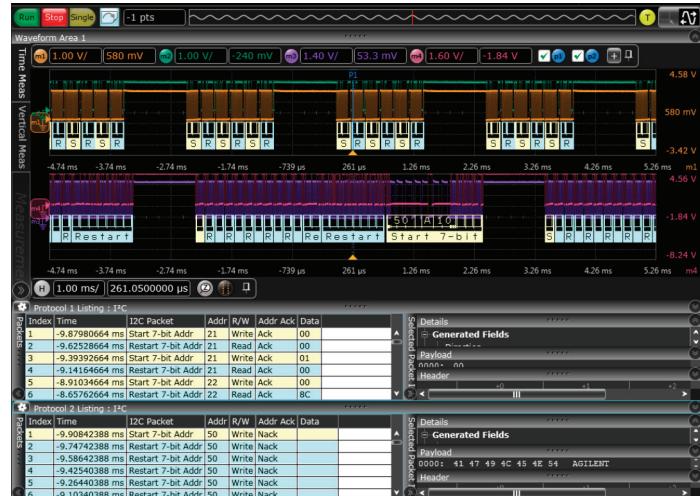


Figure 3. Keysight Infinium scopes support simultaneous, time-correlated decode of up to 4 serial buses.

Check with your oscilloscope vendor to determine which serial buses they support with a protocol application. You will need the information to meet current needs and plan for future needs.

Table 1. Infinium scopes support a wide array of serial protocols.

Serial Bus Protocol	Infinium Oscilloscope Family		
	S-Series	90000 Series	90000 X-Series
CAN and CAN .dbc symbols	✓	✓	✓
Ethernet 10GBase-KR		✓	✓
FlexRay	✓	✓	✓
HDMI	Up to 740 Mbps	✓	✓
I <sup>2</sup> C	✓	✓	✓
JTAG	✓	✓	✓
LIN	✓	✓	✓
MIPI	✓	✓	✓
PCIe	✓	✓	✓
RS-232/485/488	✓	✓	✓
SAS	✓	✓	✓
SATA	Up to 1.5 Gbs	✓	✓
SPI	✓	✓	✓
SVID	✓	✓	✓
USB	✓	✓	✓
XauI		✓	✓
8B/10B	✓	✓	✓

## 2. How easy is it to set up protocol decode?

Engineers excel at problem solving. Anytime too much brain power or time is required for a task, engineers will find another less taxing method of attacking a problem. Setting up a oscilloscope to take a protocol measurement should take you a minute or less.

To configure the scope for protocol decode, select which channels are probing specific serial signals and set the threshold value to determine when the signal is high and when it is low.

Although the concept seems simple enough, when you set up protocol decode for a serial bus with 3, 4 or 5 signals, the task becomes more complex than originally anticipated. If decode is set up for multiple simultaneous serial buses, the task becomes even trickier.

Keysight Technologies, Inc. offers “Auto Setup” for decode (Figure 4). After you assign channels, Auto Setup works a bit like autoscale. Auto Setup determines the correct threshold level for each signal and scales the timebase appropriately. This feature is particularly effective for users who don’t often make decode measurements or set up of multiple decodes simultaneously.

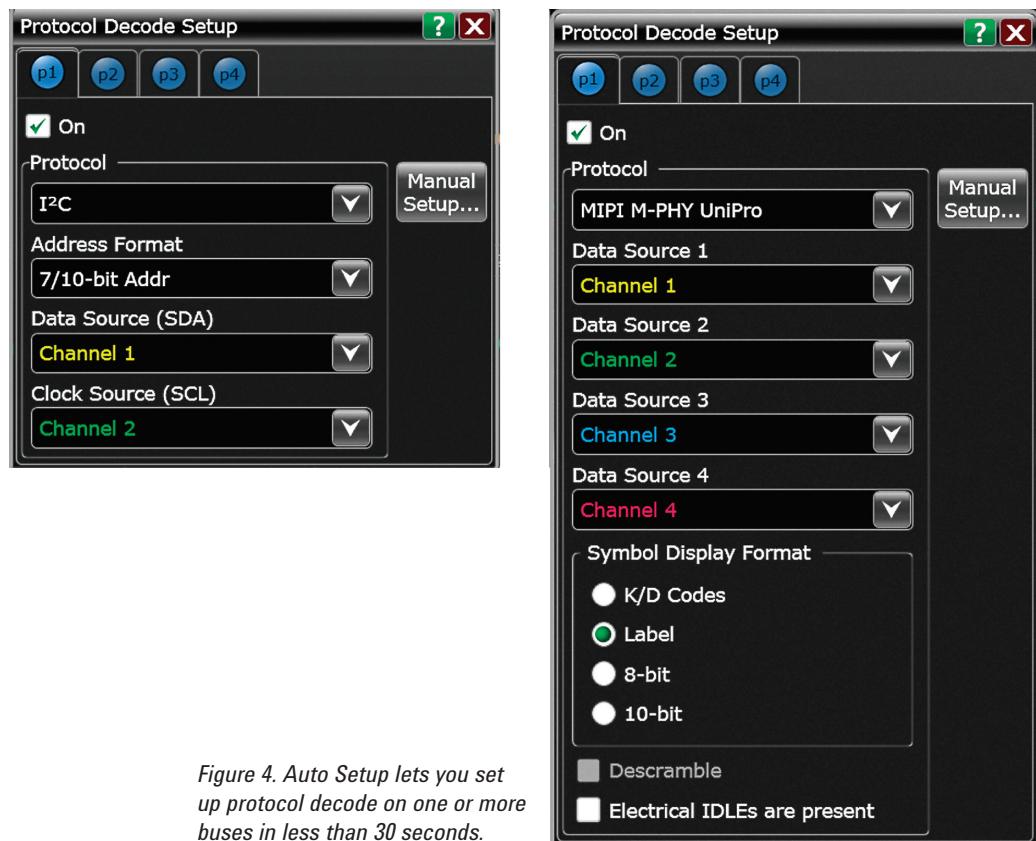


Figure 4. Auto Setup lets you set up protocol decode on one or more buses in less than 30 seconds.

### 3. How is the protocol decode displayed?

Although all vendors provide some level of decode, decode quality varies dramatically. Start by displaying protocol decode for the bus you are interested in on the oscilloscope you are considering.

Decode on waveforms is the most common method of displaying protocol packets (Figure 5). Packet content is aligned in time with parametric signal detail.

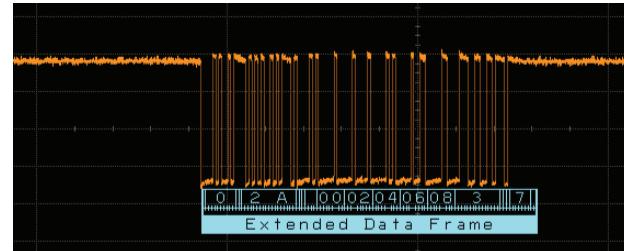


Figure 5. Decode on waveforms enables you to see time-aligned packets with the serial signal sources, but requires you to zoom in to see packet detail.

Keysight colorizes packets to make it easier to determine packet sequence even with larger timebase settings when packet detail is too compressed to see detail.

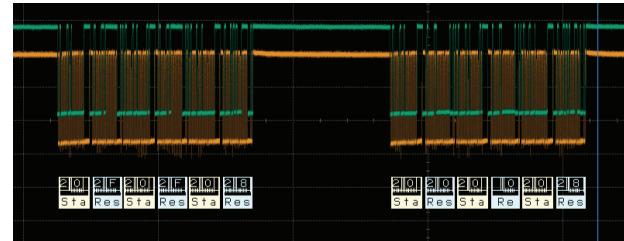


Figure 6. Keysight colorizes packets to make it easier to determine packet sequence.

Some vendors decode the entire acquisition memory, while others decode only what is on screen. Decoding only on-screen information can cause problems. If the entire packet isn't displayed on-screen, the oscilloscope won't decode any of the packet, or worse, decode it incorrectly. To correct the problem, users are forced to create a main display with all acquisition memory and a second zoom window to show decode detail, as shown in Figure 7.



Figure 7. Zoom in on detail in the waveform area while protocol packets from off-screen capture is still shown in the listing area.

### 3. How is the protocol decode displayed? (Cont.)

Most vendors also offer a lister that will display decode of sequential packets. Listings let users see the flow of packets in a more condensed format (Figure 8).

Unlike decode in waveform areas, listings show packet detail independent of timebase settings. But be aware that listing detail can vary greatly from vendor to vendor and scope to scope. Are lister rows colorized to match waveform decode color for rapid transition between physical and protocol layers?

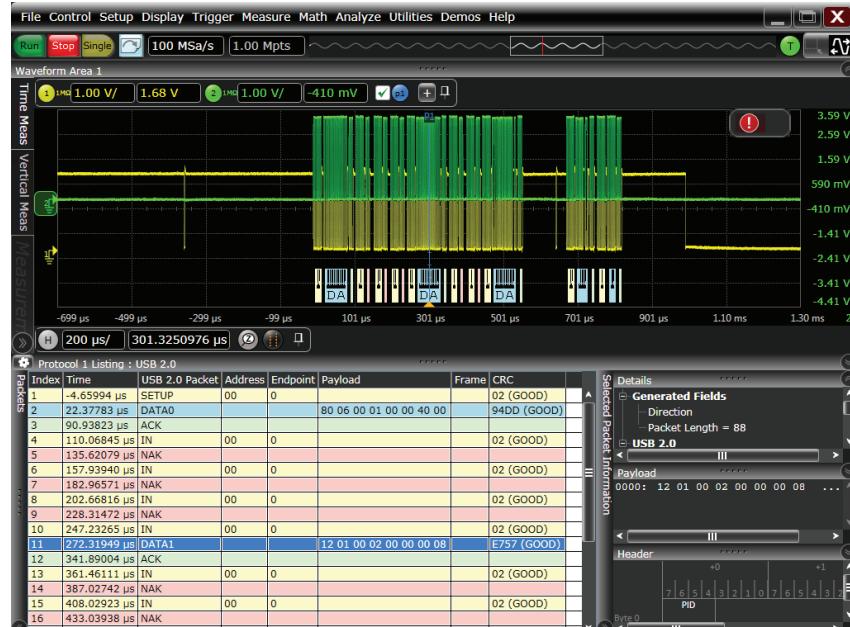


Figure 8. Infiniium protocol listers let you move quickly between physical and protocol layer with the advantage of seeing packet detail in the lister while zoomed out, as shown in this USB example.

When evaluating protocol decode on oscilloscopes that incorporate a lister, ensure that your vendor provides time alignment between each row in the lister and signals in the waveform display. With time alignment, users can move between physical layer and packet layer quickly and with confidence (Figure 9).

Some vendors provide listers with minimal or no time alignment with signal detail.

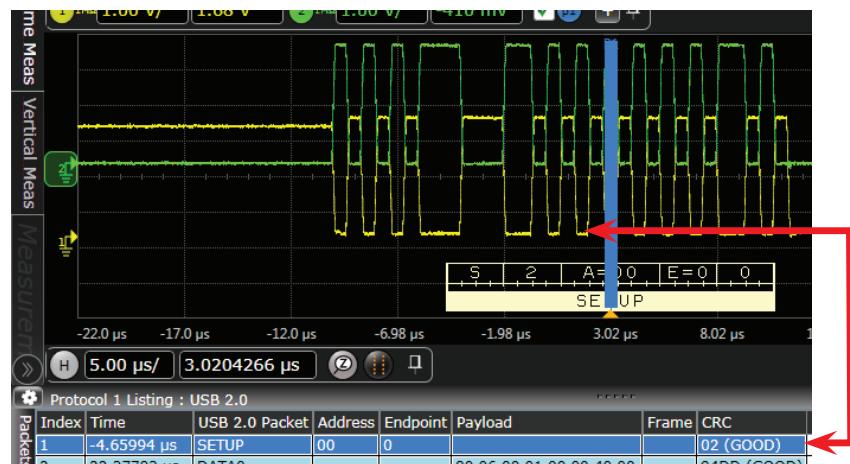
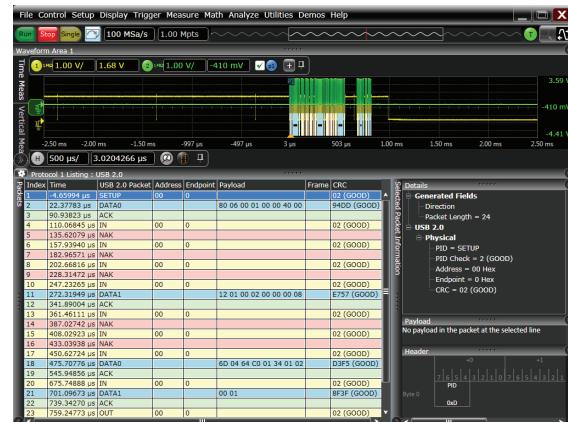


Figure 9. Time-aligned markers on Infiniium oscilloscopes track in the listing when moved in the waveform area or track in the waveform area when a new row of the lister is highlighted, as shown in this SPI example.

### 3. How is the protocol decode displayed? (Cont.)

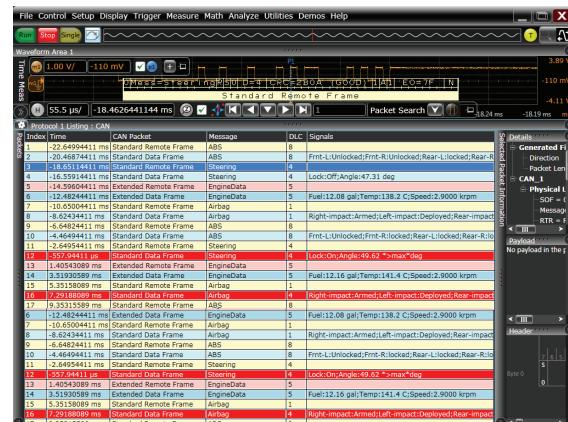
Does your oscilloscope allow different views of packet content?

Here's an example of Keysight's Infinium protocol viewer. In addition to seeing packet detail, users can see specified packet content in different formats. For example, see data packet payloads and packet detail in the header section as it would appear in a databook.



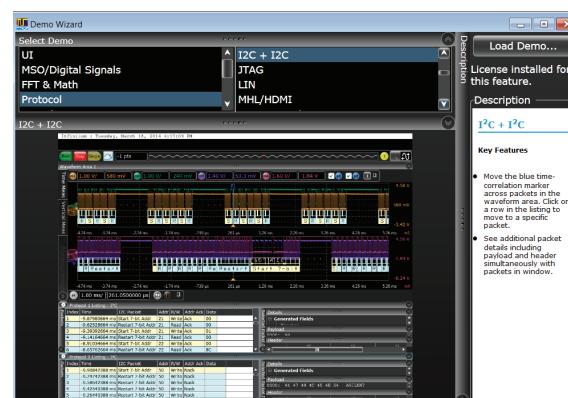
**Figure 10.** Packet details, payload, and header show additional info for the packet highlighted by the blue alignment bar.

Does your oscilloscope allow the listers to go full screen to display a greater number of packets at once? Infinium oscilloscopes allow users to determine how much of the display to dedicate to the lister versus the waveform area.



**Figure 11.** Infinium oscilloscope with full screen lister.

On Infinium oscilloscopes, a Demo Center stores saved files that can be quickly loaded into the scope for all supported protocol decodes. You can rapidly evaluate how decode is displayed for your particular protocol.



**Figure 12.** Connect to a live target or use built-in previously captured signals to evaluate decode and trigger capability for a specific protocol application.

#### 4. What type of packet triggering and searching is standard or incorporated in the protocol application?

Determining when to have the oscilloscope trigger and begin acquiring packets is critical for debug. Traditional edge, width and pattern trigger are not sufficient for packet triggering. Oscilloscope vendors typically bundle packet-based triggers with each decode application. These packet-based triggers can be implemented in software or hardware, and knowing this level of detail is important if you plan to trigger on infrequent events.

Hardware-based serial packet triggers are implemented in hardware—typically an FPGA—and run in real time. The vendor implements a real-time state machine that tracks incoming packet content. When a specified condition is met, this hardware interacts with the scope's trigger circuitry. For single-shot protocol acquisitions that require a trigger, hardware-based triggering is a requirement (Figure 13).

Software-based serial packet triggers are implemented in software. After each acquisition, the software analyzes the acquired packets and determines if any meet the trigger condition. If so, the oscilloscope displays the acquired signals. Alternatively, if the software searches the decoded packets and doesn't find the specified trigger condition, the oscilloscope discards the acquisition without display and acquires a new acquisition, starting the process again.

Software-based triggering has significant dead time between acquisitions, which makes it likely it will miss trigger conditions that occur infrequently. As memory depth increases, so does processing time, making dead time between acquisitions for software-based triggering even larger.

Given the superiority of hardware-based protocol triggering, why would a protocol app offer only software-based triggering? It's likely that hardware-based triggering for that specific protocol wasn't developed.

Pull up a serial trigger on your vendor's oscilloscope for the protocol you are working with. See what types of packet-based triggering are available and whether the trigger is implemented in hardware or software.

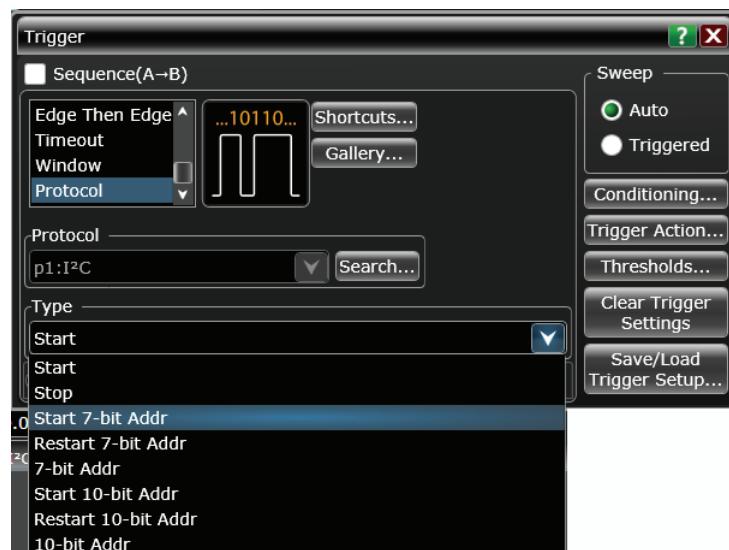


Figure 13. Hardware-based protocol triggers will absolutely enable the oscilloscope to trigger on a specified condition no matter how infrequent or brief the specified event is, with minimal latency between successive triggers. Shown is an USB enumeration trigger example.

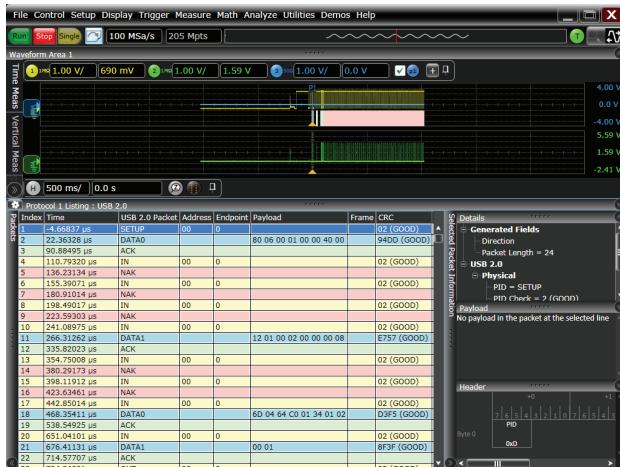
5. How much memory does your scope support for packet capture?

Capturing a sufficient number of protocol packets is critical for effective debug. Oscilloscopes acquire asynchronously and therefore use memory more quickly than dedicated protocol analyzers or state-based logic analyzers. For this reason, scope users with protocol analysis needs benefit greatly from deep-memory oscilloscopes. To maximize memory and display utilization, check to see if your scope vendor allows you to set memory depth, sample rate and timebase independently. This capability makes it dramatically easier to capture and view protocol signals with full memory depth.

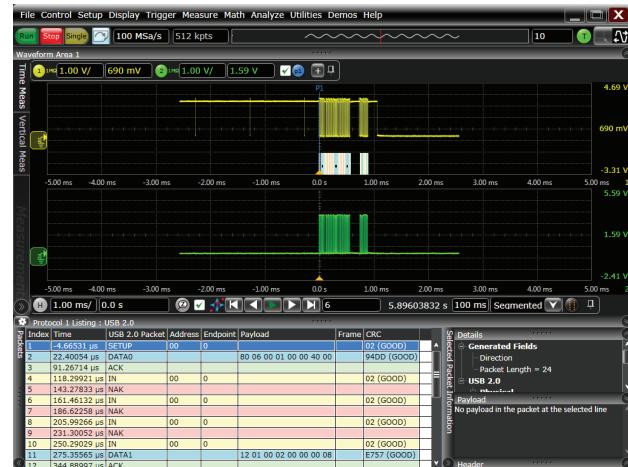
Oscilloscopes ship with a fixed amount of standard memory and users enable optional acquisition memory. To get a first order approximation of how many packets you can acquire in a single run, you can do a quick calculation by using the required sample rate for a specific bus coupled with the oscilloscope's time-base and optional memory. Most oscilloscope vendors have channel interleaving, which doubles memory depth only when 2 of the 4 analog channels are used. For example, Keysight Infiniium oscilloscopes ship with 50 Mpts memory standard on 4 channels or 100 Mpts standard on 2 channels. Users can enable optional memory to 400 Mpts on 4 channels and 800 Mpts on 2 channels (Figure 14).

Serial traffic often incorporates periods of dense activity followed by relatively long periods of dead time. Using the oscilloscope's segmented memory mode enables you to capture significantly longer periods with the same amount of memory. Each segment is started when the oscilloscope sees a specified trigger condition. For example, the trigger might be when a USB device enumerates a number of packets are sent, each with a SETUP packet. Using segmented memory, this sequence of events can be captured using 100 times less memory (Figure 15).

Check to make sure your oscilloscope vendor supports decode in segmented memory mode.



**Figure 14. How much memory does your scope have? In this example, Infiniium S-Series used 100 Mpts memory sampling at 100 MSa/s to capture over 2 full seconds of USB traffic, including a USB enumeration sequence in its entirety.**



**Figure 15.** Infiniium's segmented memory mode supports protocol decode. Using segmented memory mode, the required acquisition memory was reduced by 100 times, from 50 Mpts to 500 Kpts, to capture 6 seconds of time including the USB enumeration sequence.

## 6. If using mixed-signal oscilloscope for protocol analysis, what else should you consider?

Mixed Signal Oscilloscopes (MSOs) are a great choice for protocol analysis for several reasons. First, they free up analog channels for viewing other system activity. Second, if you are viewing more than one serial bus, MSOs offer additional channels, unlike digital storage oscilloscopes with only four channels. Third, some vendors have more standard MSO acquisition memory than is available on the analog channels, enabling capture of additional packets when the MSO digital channels are used rather than the scope's analog channels (Figure 16).

This may be surprising, but many vendors do not support segmented memory with MSO digital channels. This means that the MSO channels cannot provide protocol decode when you use segmented memory mode. Be sure to see if your oscilloscope vendor supports segmented memory on the MSO channels.

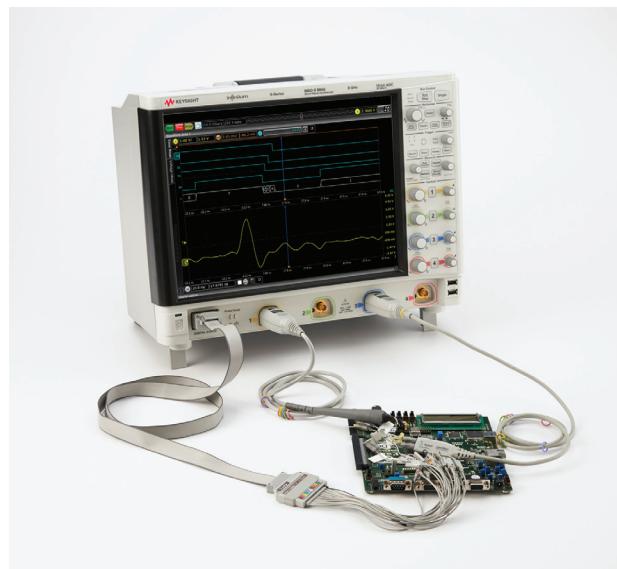


Figure 16. Check with your oscilloscope vendor to see if acquisition memory is shared between analog and digital channels or if each has separate acquisition memory. If separate, see how much memory is available for MSO channels. For example, Keysight Infiniium MSO digital channels offer separate acquisition memory, with 128 Mpts of memory on digital channels versus 20 Mpts standard on analog channels.

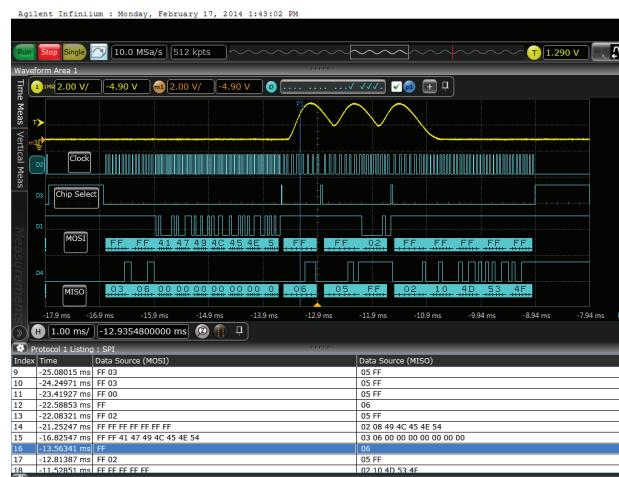


Figure 17. MSO channels are a great choice for protocol triggering and decode, as shown in this SPI example.

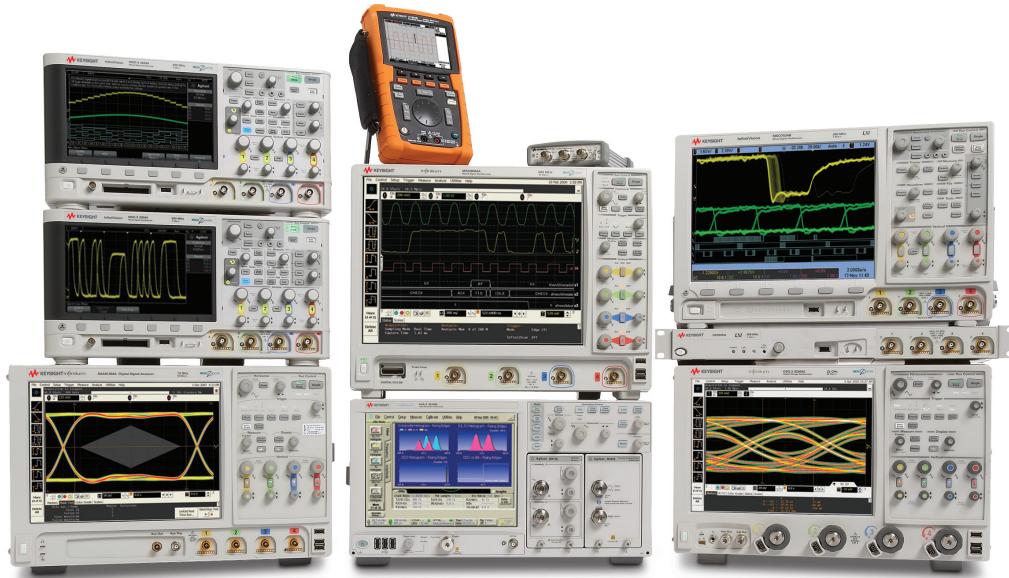
## Conclusion

Adding protocol analysis capabilities to a oscilloscope enables you to debug a wider range of issues faster. Evaluating both specific protocol applications and the scope's underlying ability to effectively perform packet-based triggering and decode will help you select the scope that best meets your needs.

Keysight encourages oscilloscope users to compare Infinium protocol trigger and decode capabilities and performance with any other oscilloscope on the market.

Only Keysight Infinium offers the following combination of protocol features:

- Auto setup
- Time-alignment marker between waveforms and lister
- Color-coded lister rows
- Multi-tab protocol viewer
- Decode of off-screen acquisition
- Independent setting of sample rate, timebase, and memory depth
- Deepest memory for capturing more packets up to 1 Gpt/ch)
- Full screen lister
- Demo center with pre-saved waveforms for rapid evaluation
- Free 14-day trial license
- Decode of up to 4 serial buses with lister selection
- Fast update rate with decode
- Extensive packet searching
- Decode support with segmented memory (including MSO channels)
- Standard MSO memory (128 Mpts)



Keysight Technologies Oscilloscopes

Multiple form factors from 20 MHz to >90 GHz | Industry leading specs | Powerful applications

## Related literature

*Keysight Infiniium S-Series Oscilloscopes (500 MHz to 8 GHz)*, Data sheet  
5991-3904EN

*Keysight Infiniium 90000A Series Oscilloscopes (2.5 GHz to 13 GHz)*, Data sheet  
5989-7819EN

*Keysight Infiniium 90000 X-Series Oscilloscopes (13 GHz to 33 GHz)*, Data sheet  
5990-5271EN

*Evaluating Oscilloscope Fundamentals*, Application note 5989-8064EN

To download these documents, insert the publication number in the URL:  
<http://cp.literature.keysight.com/litweb/pdf/xxxx-xxxxEN.pdf>

## Product web site

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