Application Note

SELECTING YOUR NEXT OSCILLOSCOPE: WHY DEEP MEMORY MATTERS

Products:

- ► R&S®RTB2000 Oscilloscopes
- ► R&S®RTM3000 Oscilloscopes
- ► R&S®RTA4000 Oscilloscopes
- ► R&S®MXO 4 Oscilloscopes
- ► R&S®RTO2000 Oscilloscopes
- ► R&S®RTO6 Oscilloscopes
- ► R&S®RTP Oscilloscopes

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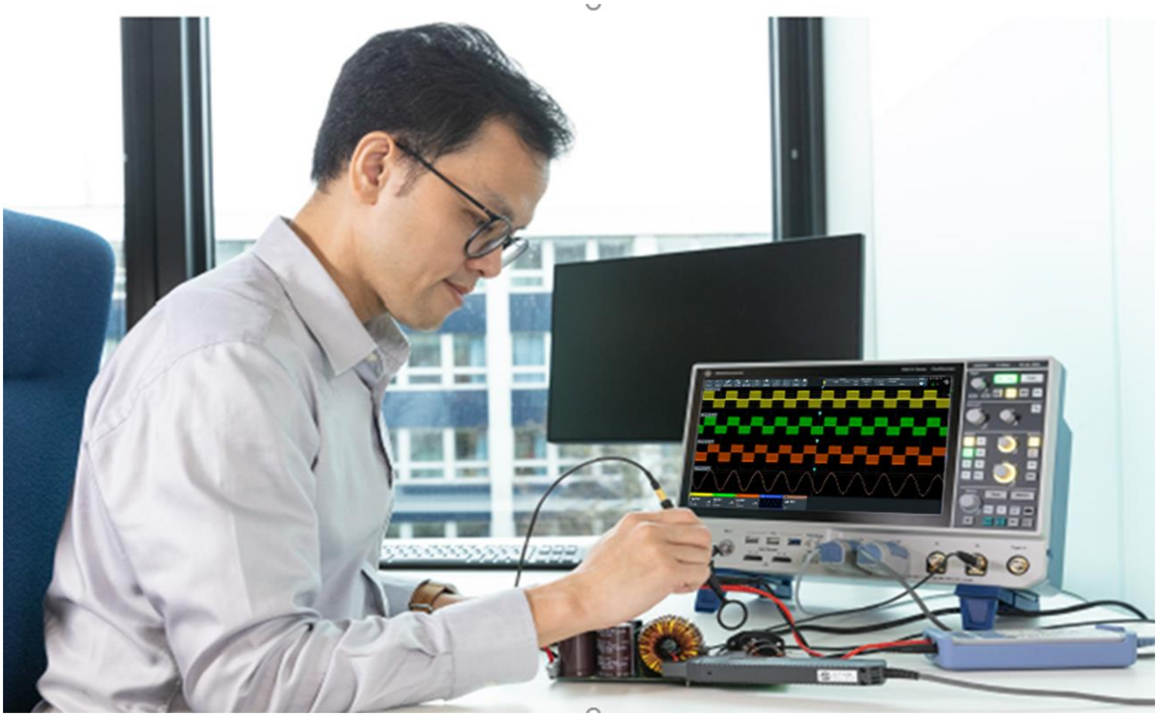
Contents

1 Overview

Oscilloscope users consistently rate bandwidth, sample rate, and memory depth as the three most important specifications. This application note will focus oscilloscope selection considerations associated with acquisition memory. Selecting an oscilloscope with deep memory can result in significant troubleshooting and debug time saving.

It's helpful to assess the goodness and quality of oscilloscope memory depth, versus just looking at a single figure. Understanding memory depth attributes and benefits ensures selection of a specific oscilloscope matches the desired needs and applications.

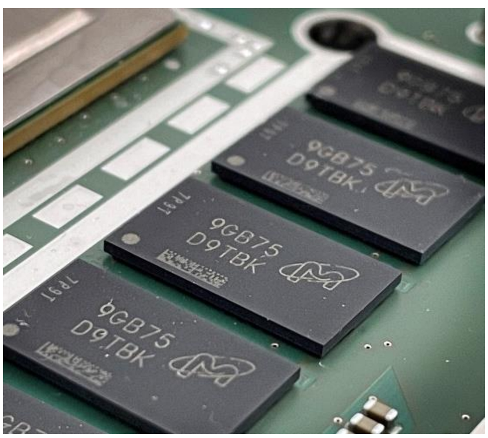


2 Acquisition Memory Definition

Acquisition memory, also referred to as memory (M) or record length (RL), describes the number of samples that can be stored with each oscilloscope acquisition. Acquisition memory unit specification is a sample, typically referred to as a point (i.e. Mpts), so that sample rate (MSa/s) and memory depth (Msa) don't get confused. Memory depth equals the instruments sample rate times the amount of time captured.

$$Memory = (Sample\ rate) * (time\ captured)$$

An oscilloscope that acquires a record length of one million samples in a single acquisition on one channel has acquisition memory of 1 Mpts of memory. If multiple channels each acquire 1 Mpts of memory at the same time, the record length is still defined as 1 Mpts. If a sample point comes from an 8-bit ADC, or has 16 times more vertical information from a 12-bit ADC, it's still a single memory point.



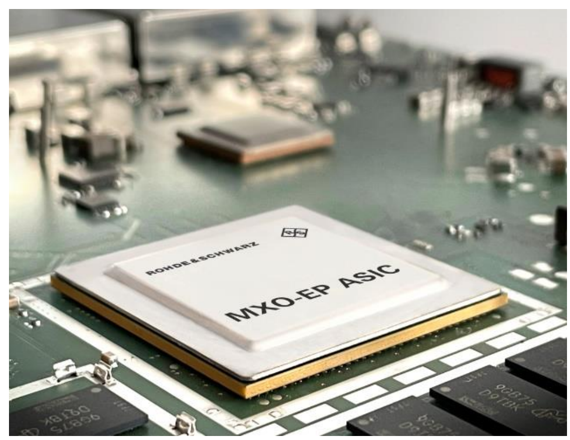


Figure 1. For R&S®MXO 4 Series oscilloscopes, the R&S®MXO-EP (Extreme Performance) ASIC contains an integrated memory controller that reads and writes to fast DDR memory. The 28 nm CMOS ASIC powering the industry's fastest deep memory update rate, has over 36M transistors and can process at 200 Gb/s.

2.1 Is More Better?

If all other attributes are equal, a scope with more memory depth will always be more valuable than a scope with less acquisition memory. More memory has a number of values. However, more memory also comes with a tradeoff when the additional memory is utilized. Oscilloscopes are processing-intensive instruments. As more memory is utilized, processing requirement increase, slowing down overall scope operation. Ideally, a scope would offer an infinite amount of acquisition memory, but only use just the amount needed, and no more, for a specific application to keep the scope as responsive as possible.

In practice most users don't know how much memory their current scope has and tend to figure out how to creatively debug and test using whatever memory is available. At the time a team selects a new scope, they often buy more memory as an insurance policy for potential future need. After the transition, they wonder how they ever got along with a smaller amount.

2.1.1 Standard or Pay Option

All oscilloscopes come with a defined amount of base acquisition memory that comes standard with the scope purchase. Historically oscilloscope manufacturers produced different versions of hardware, each with a specific amount of total acquisition memory. In the early 2000's manufacturers found it more economical to create a single hardware platform with the deepest memory that would be used. Instruments come standard with a portion of this acquisition memory enabled, then via a software license, users can enable more of the available acquisition memory. Many users also liked having a lower initial purchase price with less memory, with the flexibility to license more memory as their needs evolved. Oscilloscope manufacturers may have a specification that reference the base memory, or might communicate a memory depth specification associated with a larger acquisition memory depth that require a for-pay option to enable. Without looking at a datasheet, it’s often difficult to determine if a manufacture's memory value is the base memory value included with the instrument, or if the memory value is a maximum value associated with an additional for-pay option.

3 Memory Depth Isn't a Static Value

Ever purchase a product for a couple banner specifications, and then find out they were mutually exclusive? Not all oscilloscope manufacturers specify acquisition memory depth in the same way. Oscilloscope manufacturers typically provide a banner spec for memory depth, but this depth might not be available based on different scope settings. Most oscilloscope architectures have tradeoffs between memory depth and other scope settings. Let's take a look at a few common ones.

3.1.1 Number of channels

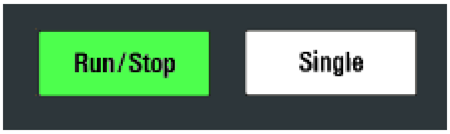
Internal to the oscilloscope architecture, there’s a memory controller and some fixed amount of acquisition memory, typically a fast in slow out (FISO) DDR memory architecture. The total available DDR memory in the system will be a much higher amount as it is shared across channels, reference waveforms, and other functionality.

Figure 2. Many oscilloscopes have a tradeoff between the number of channels that are enabled, and the maximum memory available per channel.

Many oscilloscope architectures provide a maximum memory specification that applies when up to half of the analog channels are turned on, but drops by a factor of two when analog channels that share the same processing and storage path are simultaneously enabled. For example, a scope may have memory depth of 4 Mpts when only channel 1 is enabled, but when channel 2 is additionally turned on the memory depth per channel drops to 2 Mpts.

For many scopes, the memory architecture is shared across both analog and digital channels. Digital channel samples consume less sample space as they are only 1 bit. However, digital channels are typically turned on in granularity of 8 or 16 channels at a time, so overall memory consumption can be high. For example, an oscilloscope that starts with 4 Mpts of acquisition memory on a single channel, drops to 2 Mpts memory when 2 channels are enabled, and drops again to 1 Mpts memory depth when MSO logic channels are turned on.

3.1.2 SINGLE vs RUN Mode



Depending on the oscilloscope architecture, the maximum memory depth specification may be different if the scope is running repetitively or if a single acquisition is taken. The maximum depth applies definitively to a single shot acquisition. However, it might be half the value when the oscilloscope is running repetitively. Oscilloscopes that have faster throughput architectures have two acquisition engines running sequentially and storing to acquisition memory sequentially. In RUN mode, they each have access to half memory while in SINGLE mode, as update rate is not important, just one engine runs and has access to double the amount of storage space. On other scopes, the memory depth is identical in SINGLE versus RUN mode. It depends on the oscilloscope architecture and the decisions made in the design of the scope.

For the example above of a scope with 4 Mpts of memory with one channel, that drops to 2 Mpts with 2 channels, and 1 Mpts with digital additionally added, the scope drops to 512 Kpts when in RUN mode.

4 Deep Memory

4.1 How much is deep?

The definition of deep memory varies from vendor to vendor, and has changed over time. Early digital oscilloscope acquisition memory was measured in hundreds of points and evolved to Kpts in the 1990s. Today's scopes have acquisition memory depth typically in the tens to hundreds of Mpts. Vendors will claim to have deep memory even though a competitor may offer up to 100 times more acquisition memory depth. This particularly is the case for oscilloscopes that have been on the market for a long period of time; when they were new their memory depth was considered deep, but relative to current competitors the memory depth is small. Many types of embedded hardware testing benefits from oscilloscope deep memory.

4.2 Application Examples

4.2.1 Need to capture long time

The boot time of a power supply is a classic example of something that occurs in “human" time. Power sequencing takes tens of milliseconds. While turning voltage rails on and off doesn’t require higher bandwidths, high-speed serial buses and other system components have signals that require higher bandwidth analysis in parallel with power sequencing events. For this, deep memory is extremely beneficial to capture sufficient time with sufficient bandwidth.

4.2.2 Root cause and symptom are separated in time

Sometimes the source of a problem is greatly distanced in time from a symptom that is observable. Having deep memory enables teams to isolate the symptom, then track back to the root cause.

4.2.3 Need to solve complex problems

Deep memory in an oscilloscope can unravel problems faster. Electromagnetic interference (EMI), crosstalk/cross-coupling, and related issues can plague many different parts of a design. Often, the device impacted is operating at full speed, but the source of the problem is occurring in milliseconds or seconds.

4.2.4 Serial buses

Low serial buses such as I2C, SPI, RS-232, CAN, or LIN are often used as the control elements for digital designs. In many cases, because these are the source of change or action on the system, they are used to troubleshoot and understand system behavior. While protocol triggers can help, visibility across many bursts or packets of data is often required to gain insight. Two commonly used methods to view multiple bursts — reducing sample rate on the scope or viewing multiple packets with segmented memory have tradeoffs. Reducing sample rate to capture more time runs the risk of under sampling the serial bus, and not being able to trigger or decode correctly. Using segmented memory eliminates the ability to see between trigger events, and often limits analysis capabilities as the scope may only be able to analyze packets in a given segment, but not across segments.

4.2.5 When further analysis is needed

Several applications require users to collect as much information as possible, then analyzer this data after collecting it. This "swallow and wallow" approach can involve further analysis using oscilloscope tools and analysis applications, or might involve offloading the instrument's capture to analyzer using MATLAB or a Python script.

5 Memory, Sample Rate, and BW Relationship

While many users think of memory depth, sample rate and bandwidth as independent specifications with constant value. However, all are closely related.

$$Memory = (Sample\ rate) * (Time\ captured)$$

5.1 Capture More Time at a Specified Sample Rate

$$Time\ captured = \frac{Memory}{(Sample\ rate)}$$

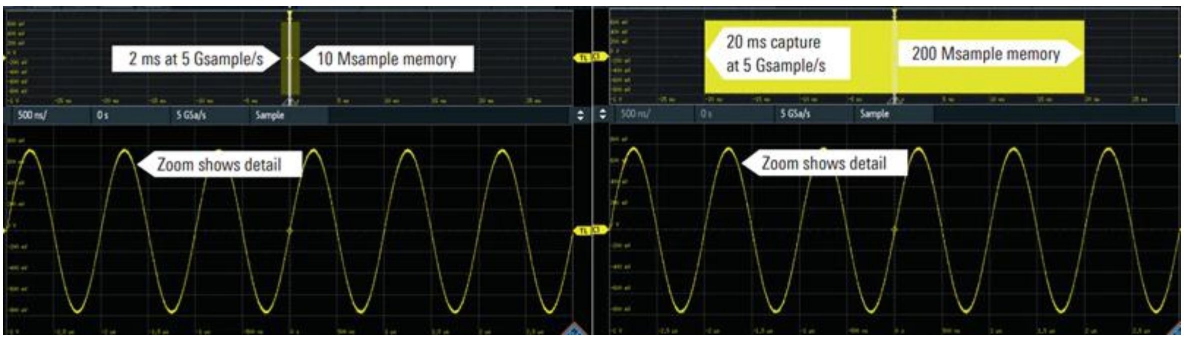


Figure 3. More memory means an oscilloscope can capture more time at a given sample rate.

Many users want to capture a specific amount of time, or as much time as they can.   For a given sample rate, having more memory allows the user to capture for longer periods of time. This benefit is obvious and appreciated. Additional memory depth allows users to retain a needed sample rate, or even a faster-than-needed sample rate which provides some degree of confidence, and also provides greater flexibility when acquiring a combination of slow and fast signals.

5.2 Retain Needed Sample Rate When More Time is Captured

$$(Sample\ rate) = \frac{(Time\ captured)}{Memory}$$

As a user changes the oscilloscope timebase to a slower setting to capture more time, the capture rate remains constant until a maximum memory depth is reached. Beyond this point, when more time is captured the instrument must reduce its sample rate. Turning the time base to capture even more time further reduces sample rate.

Often this results in a resulting sample rate that is insufficient for the rated oscilloscope bandwidth. Signals will be under sampled and aliasing can occur. This too can be frustrating as no measurement results will be valid. A user thinking that their oscilloscope bandwidth is 1 GHz may not realize that the sample rate is only sufficient for 1 MHz bandwidth.

There is no notification from the oscilloscope that the user might have a significant measurement problem. Oscilloscopes aren't designed to let users know when sample rate is not sufficient for the rated bandwidth and under sampling and/or aliasing is occurring. The challenge of identifying is more difficult on oscilloscopes that don't display the sample rate all the time on the main display. For designs that have a combination of fast and slow signals, more memory is extremely beneficial for longer time capture with sufficient sample rate for the fast signals.

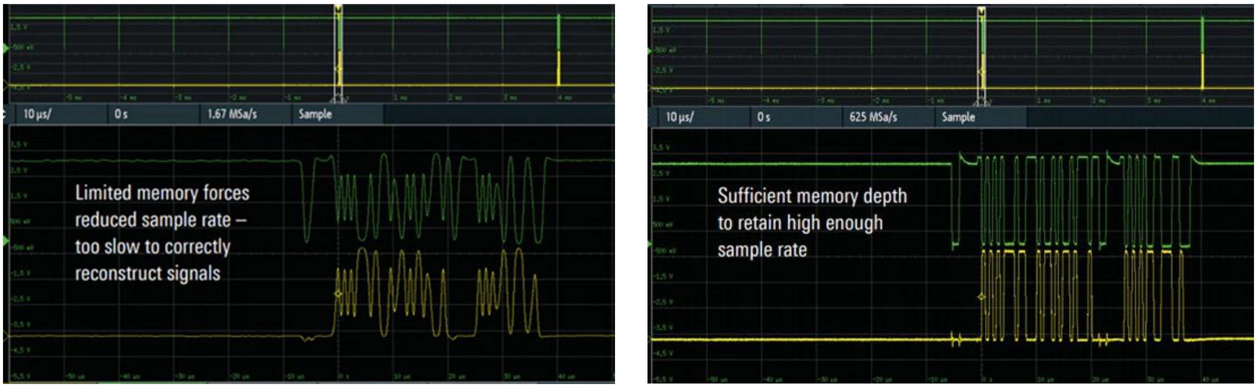


Figure 4. More memory means the instrument can capture more time without reducing sample rate.

5.3 Relationship Dependencies

By default, most oscilloscopes limit the amount of memory used. They do this to ensure the scope doesn't get sluggish when deep memory is enabled. For example, one vendor might have a default limit of 10 Kpts memory while another has a default limit of 10 Mpts, while both scopes have a maximum available memory that is greater than either of their default values.

Uses must manually change the scope settings to allow the instrument to use more than the artificial default limit. To change users either need to enter a manual acquisition setting dialog where they can control at least sample rate. Some oscilloscopes don't allow the user to independently control the sample rate, or the oscilloscope may not allow the user to independently control timebase, sample rate, and memory depth.

This can be a frustrating user experience as the dependencies are not expected and there is no workaround. Oscilloscopes that allow the user to independently control all three setting are able to capture off-screen acquisition, which can be useful in some instances.

6 Segmented Memory

Most oscilloscope provide a segmented memory mode as a standard function, or as a for-pay option. This mode provides a more effective way of capturing signals that are separated by periods when the signal is inactive. Example include serial buses, pulse analysis, and RF chirps.

Using segmented memory, users define a trigger condition and a certain amount of capture memory surrounding trigger events. Each new trigger event creates a small acquisition by the oscilloscope. The period of time between trigger events when the signal is inactive isn't captured, and hence doesn't consume memory. This technique allows for a single-shot capture across a longer time duration than would have been possible in a single monolithic acquisition.

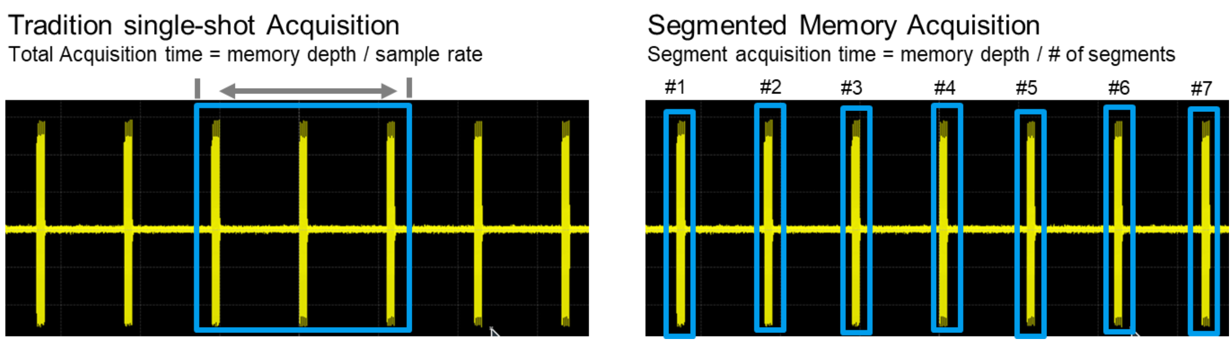


Figure 5. Segmented memory saves only a capture window around the trigger event for more efficient memory utilization for applications where a single shot acquisition is sufficient. More memory means the instrument can have more segments, more sample rate, or more time with each segment.

While segmented mode allows for more efficient utilization of acquisition memory, there are tradeoffs.

► It's a single shot acquisition, and doesn't work well in RUN repetitive mode.

► Viewing the measurement results involves moving through multiple acquisition screens.   Analysis across segments often has limitations, or at a minimum is more difficult.

Segmented mode doesn't compensate for shallow memory. The amount of memory available per segment equals maximum memory divided by the number of segments. A scope with more memory depth has more powerful segmented memory as it can capture more segments, or each segment can include more time, or the overall sample rate of the oscilloscope can be higher.

History mode is closely related to segmented mode. Segmented mode setup is done by a user. For history mode, the oscilloscope automatically saves sequential acquisitions in the background, and if the user presses STOP, they can go back and view the previous acquisitions.

7 Serial Bus Decode and Memory

Serial buses provide excellent points of visibility for debug and testing. Oscilloscopes can be equipped with serial bus triggering and decode applications providing testing at the protocol packet level. It's often very difficult to determine the correlation between deep memory and the number of packets that can be captured. For each protocol, the oscilloscope must maintain at certain sample rate for correct decode of that protocol, and each protocol has a physical layer structure that is unique.

Deep memory with protocol decode enabled is very taxing on oscilloscope processing resources. Oscilloscopes process significant amounts of information with protocol, and scopes can become sluggish with deep memory and protocol decode.

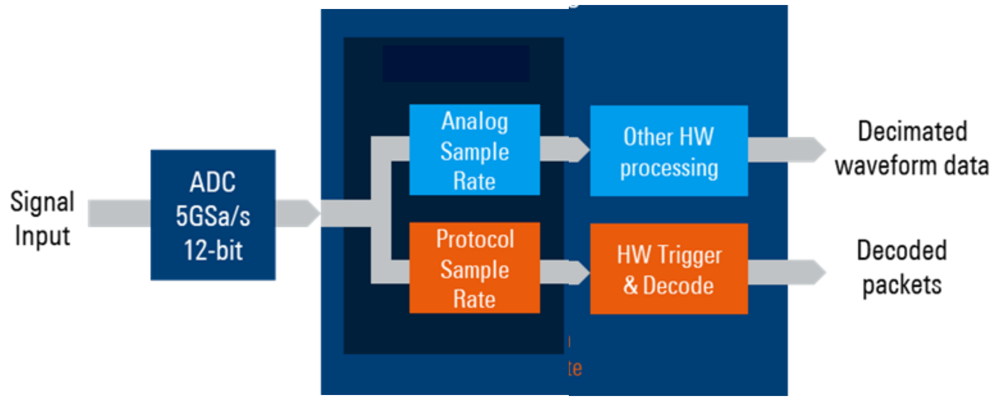


Figure 6. R&S®MXO 4 Series oscilloscopes are the first in the world that have a dual-path protocol analysis. This innovation solves problems with oscilloscope decode over long periods of time. A separate packet decode memory means a more responsive scope with a deterministic number of maximum packets that can be captured.

R&S introduces an innovative technique for packet decode when long time duration capture is needed. The instrument's architecture provides two key benefits that alleviates many problems.

1. Dual-path protocol analysis

   1.1. The instrument has a duplicate sample path for protocol decode that samples at a rate that is sufficient for popular serial buses like I2C, SPI, RS-232, CAN, LIN, and others. If the instrument has a slow time base and a slower analog sample rate, it still correctly triggers and decodes serial buses. This technique allows for a great number of packets to be decoded correctly, even with slower analog sample rate.

   1.2. Dual-path protocol analysis stores protocol packets as packets. This has multiple benefits. First, the database for the packet information is much smaller than the historical continual packet reconstruction method, meaning that the instrument will have faster update rate and be more responsive. Second, the instrument has a dedicated packet memory meaning that users have a deterministic value for how many packets can be stored.

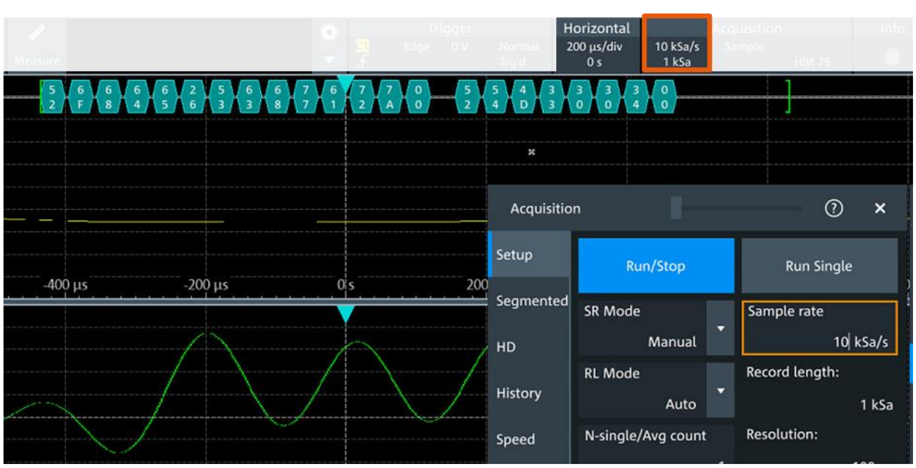


Figure 7. R&S®MXO 4 Series oscilloscope dual-path protocol analysis provides accurate packet triggering, and packet decode even if the original serial bus signals are severely under sampled. This allows users to capture longer time duration with serial decode.

8 Conclusion

Rohde and Schwarz oscilloscopes include multiple families with deep acquisition memory. R&S®MXO 4 Series oscilloscopes come equipped with 400 Mpts of acquisition memory. At 5 GSa/s they can capture 80 mS of real-time signal activity. The memory expansion options doubles memory enabling 160 mS of real-time signal activity capture at 5 GSa/s.

Acquisition memory deserves its key specification status next to bandwidth and sample rate. Oscilloscopes with more acquisition memory offer greater flexibility in capturing for longer periods of time, retaining higher sample rates with slower time bases, and offer insurance for both current and future application test and debug needs.

When selecting an oscilloscope, compare memory depth claims and understand the settings associated with the claim to make equivalent comparisons. An oscilloscope's ability to quickly process more memory ensures a responsive instrument and higher testing productivity.

Rohde & Schwarz

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