Tektronix 4 Series MSO vs. Keysight 4000A X-Series Oscilloscopes

Blog post

In this post I will talk about the operational similarities and differences between the Tektronix 4 Series MSO and the Keysight 4000A X-Series oscilloscopes. I will be looking at not only datasheets, but instrument user guides as well. User guides can be lengthy to explore, but they provide a wealth of information on instrument settings and limitations that you may not be aware of after reading datasheets, white papers or blog posts.

Waveform Capture Rate

Let's get this one out of the way right up front. The waveform capture rate of the Tektronix 4 Series MSO is typically greater than 500,000 waveforms per second. With the Keysight 4000A X-series oscilloscope, they claim a one million waveforms per second update rate. Right away you are probably saying, "That's twice as fast. Where are they going with this?" Let's take a deeper look at waveform capture rate.

In an article published by Keysight's predecessor, Agilent Technologies, entitled "Measuring and Understanding Oscilloscope Update Rate", they make the following statement:

> "While one-million-waveforms per second is impressive, it is important to understand what the specification really means, as well as the settings required to achieve an ultra-fast update rate such as this."

We couldn't agree more. For instance, did you know that you can only achieve one million waveforms per second on the 4000A X-series at just four of the horizontal time/div settings? There is an entire page in the Keysight datasheet dedicated to waveform update rate, but no mention of it being limited by the horizontal settings. In fact, if you perform an apples-to-apples comparison beyond those four horizontal settings, you will find that the waveform capture rate of the Tektronix 4 Series MSO is equivalent to that of the 4000A X-series.

So why would you need such a fast update rate? The biggest use is for finding glitches or anomalies in your signals. In the 4000A X-series datasheet, it states:

> "As oscilloscopes acquire data, process it, and plot it to the screen, there is inevitable "dead time," or the time oscilloscopes miss signals completely. In general, the faster the waveform update rate, the shorter the dead time. The shorter the dead time, the more likely an oscilloscope is to capture anomalies and infrequent events. This is why it is critical to select an oscilloscope with a fast waveform update rate."

There is a bit more to it than that. Memory depth also plays a part in the ability of an oscilloscope to detect elusive problems. It is memory depth and timing resolution that determine how much signal detail can be captured. We will go into the details later, but it is important to note at this point that the Keysight 4000A X-series has a 4 Mpts record length compared to the 32.5 Mpts of the Tektronix 4 Series MSO.

Keysight also claims in the 4000A X-series datasheet that their update rate "gives you the highest probability of capturing random and infrequent events that you would miss on an oscilloscope with a lower waveform update rate." The probability of finding a glitch is not the same as never finding the glitch. In fact, utilizing FastAcq on the 4 Series MSO will enable you to find most glitches and anomalies. Even at one million waveforms per second, Keysight cannot claim they will find all glitches and anomalies.

Going back to the Agilent article it states:

> "To make an informed decision, understand how the oscilloscope will be used and measure the update rate based on this. In other words, do not purchase an oscilloscope based off a one million waveforms per second specification when in your use model, the oscilloscope is updating at less than one update per second."

Again, we couldn't agree more. Ultimately, no one knows how you will use an oscilloscope better than you. In fact, the Tektronix 4 Series MSO was built for engineers like you.

User Interface – Display resolution; gesture control, easily navigated menu system

Scopes have included touch screens for years, but the touch interface has been an afterthought. The touch interactions that you use with phones and tablets, and expect in a touch enabled device, are supported in the 4 Series MSO.

- Drag waveforms left/right or up/down to adjust horizontal and vertical position or to pan a zoomed view
- Pinch and expand to change scale or zoom in/out in either horizontal or vertical directions
- Drag items to the trash can to delete them
- Swipe in from the right to reveal the Results Bar or down from the top to access the menus in the upper left corner of the display

Smooth, responsive front panel controls allow you to make adjustments with familiar knobs and buttons, and you can add a mouse or keyboard as a third interaction method.

With the 4 Series MSO, waveform and scope operating parameters are displayed in a series of "badges" in the Settings Bar that runs along the bottom of the display. The Settings Bar provides Immediate access for the most common waveform management tasks. With a single tap, you can:

- Turn on channels
- Add math waveforms
- Add reference waveforms
- Add bus waveforms
- Enable the optional integrated Arbitrary/Function generator (AFG)
- Enable the optional integrated digital voltmeter (DVM)

The Results Bar on the right side of the 4 Series MSO display includes immediate, one-tap access to the most common analytical tools such as cursors, measurements, searches, measurement and bus decode results tables, plots, and notes. DVM, measurement and search results badges are displayed in the Results Bar without sacrificing any waveform viewing area. For additional waveform viewing area, the Results Bar can be dismissed and brought back at any time.

An exceptionally easy-to-use user interface lets you focus on the task at hand. This means a user interface with not only a touch screen, but also one with gesture control. The Keysight 4000A X-series offers touch screen capability, but only to drive an on-screen menu system. With the Tektronix 4 Series MSO, you get a touch screen, gesture controls and a user interface that doesn't require you to click your way through a bunch of nested menus.

Display Modes – Stacked or Overlay

The 13.1-inch display of the Tektronix 4 Series MSO has the highest resolution display in the industry, with full HD resolution (1,920 x 1,080). This enables you to see many signals at once with ample room for critical readouts and analysis. The viewing area is optimized to ensure that the maximum vertical space is available for waveforms. The Results Bar on the right can even be hidden; enabling the waveform view to use the full width of the display.
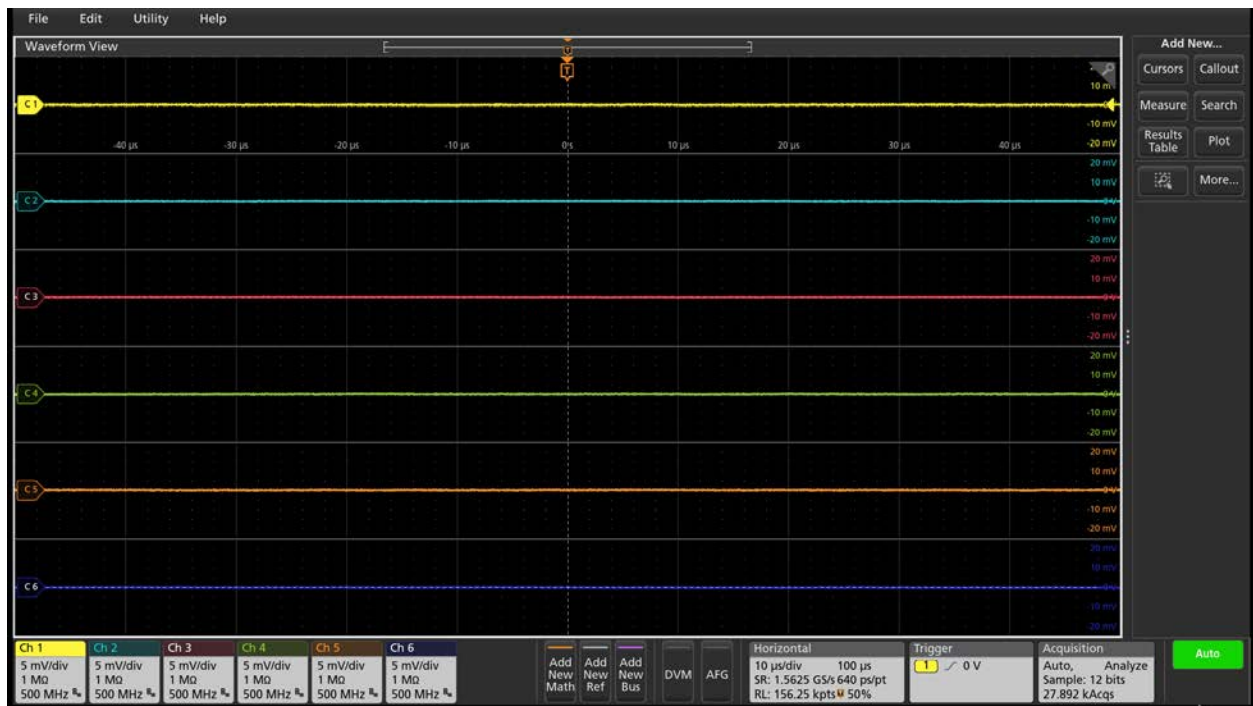
Figure 1. Stacked display mode of the 4 Series MSO enables different vertical settings for each channel

Beyond the key specs of the display, the 4 Series MSO also offers a revolutionary new stacked display mode (Figure 1). Historically, oscilloscopes (such as the Keysight 4000A X-Series) must overlay all waveforms in the same graticule, forcing difficult tradeoffs:

- To make each waveform visible, you vertically scale and position each waveform so that they don't overlap. Each waveform then uses a small percentage of the available ADC range, leading to less accurate measurements.

- For measurement accuracy, you vertically scale and position each waveform to cover the entire display. The waveforms overlap each other, making it hard to distinguish signal details on individual waveforms

The new stacked display on the 4 Series MSO eliminates this tradeoff. It automatically adds and removes additional horizontal waveform 'slices' (additional graticules) as waveforms are created and removed. Each slice represents the full ADC range for the waveform. All waveforms are visually separated from each other while still using the full ADC range, enabling maximum visibility and accuracy. And it's all done automatically as waveforms are added or removed! Channels can easily be reordered in stacked display mode by dragging and dropping the channel and waveform badges in the Settings bar at the bottom of the display. Groups of channels can also be overlaid within a slice to simplify visual comparison of signals. This can be extremely helpful when performing power measurements and you need to group current and voltage measurements.
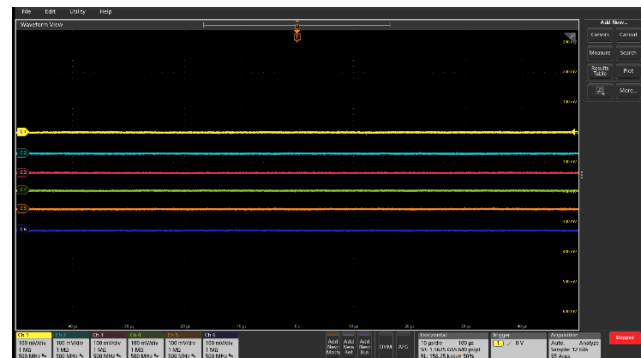

Figure 2. Overlay mode on the 4000A X-Series (left) and 4 Series MSO (right)

Compared to the Keysight 4000A X-Series display (12.1-inch, 800 x 600 resolution), the larger, higher resolution display of the 4 Series MSO provides more viewing area not only for signals, but also for plots, measurement results tables, bus decode tables and more. And, compared with the fixed view from Keysight, the Tektronix 4 Series MSO is simply more flexible as you can easily resize and relocate the various views to suit your application.

Acquisition Time – Record Length & Sample Rate

When looking at scope specifications, it is important to understand Record Length, Sample Rate and the relationship between the two. Record Length is the number of data points that are stored during an acquisition. Sample Rate is how often a waveform is sampled. When you divide the Record Length by the Sample Rate, you get the Acquisition Time for an oscilloscope. Maximizing the Acquisition Time yields a more accurate waveform and thus more accurate measurements.

Record Length

With the Keysight 4000A X-Series, per the datasheet you get a maximum Record Length of 4 Mpts. I say, "per the datasheet", because the Record Length is not displayed on the instrument itself. This means that while performing measurements, you have no idea how many data points are being stored. You can calculate this value, but wouldn't you rather see it displayed on the screen? The Tektronix 4 Series MSO offers a standard maximum record length of 31.25 Mpts with an option to double that to 62.5 Mpts. If you want to know your record length at any time, this information is displayed in the Horizontal settings badge at the bottom of the screen (Figure 3).
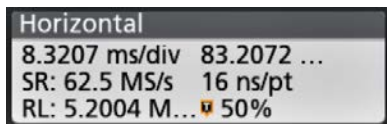

Figure 3. The Horizontal settings badge on the 4 Series MSO shows sample rate (SR) and record length (RL)

The Keysight 4000A X-Series datasheet also states that the 4 Mpts is with half channels interleaved but is 2 Mpts for all channels. What exactly does this mean? (This is where the User Guide information comes in handy.) This means the record length is split across the channel pairs; meaning you get 2 Mpts available for channels 1 & 2 and 2 Mpts for channels 3 & 4. Even if you are acquiring a simple, analog waveform this memory can be reduced even more. A Single acquisition with Ch 1 and Ch 2 active has a maximum record length of 2 Mpts. A Running acquisition with that same channel pair has a maximum record length of 1 Mpts. Then, if you start adding reference waveforms, digital channels or even use segmented memory, the record length gets smaller and smaller. This means even fewer data points being stored for the acquisition which will impact accuracy.

Unlike the Keysight 4000A X-Series, the maximum record length of 31.25 Mpts (62.5 Mpts optional) on the Tektronix 4 Series MSO is per channel. So, whether you have one or six channels active, the record length remains the same. This means more data points stored per acquisition which enables more accurate waveforms being displayed. With the Tektronix 4 Series MSO, you also have more control over the record length by switching from Automatic Horizontal Mode to Manual Horizontal Mode. This gives users more control over their test environment by allowing them to determine the combination of sample, record length and horizontal scale that best meets their needs.

Sample Rate

Besides record length, another banner specification for oscilloscopes is sample rate. The sample rate of an oscilloscope is a function of the sample interval. The sample interval is simply how often the analog-to-digital converter in the oscilloscope samples the input signal. To properly reconstruct the signals, Nyquist sampling requires that the sample rate be at least twice the highest frequency being measured. That's the theoretical minimum. In practice, sampling at least 5 times as fast is generally desirable.

The Keysight 4000A X-series datasheet states that the maximum sample rate is 5 GSamples per second on half channels and 2.5 GSamples per second on all channels. This is a similar situation to the record length where the sample rate is also split across the channel pairs. This means you get 2.5 GSamples per second for channels 1 & 2 and 2.5 GSamples per second for channels 3 & 4.

With the Tektronix 4 Series MSO, the maximum sample rate of each channel is 6.25 GSamples per second. Whether you use a single channel, four channels or even six channels the maximum sample rate available to you does not change. This overall faster sample rate with the 4 Series MSO means that you can measure higher frequencies and capture more signal detail than with the 4000A X-series.

Acquisition Time

Acquisition time is a function of record length in points or samples, divided by the sample rate in samples per second. Acquisition time is important for two reasons:

1. More acquisition time means more signal detail
2. Acquiring more samples increases the chance of capturing an error was well as the fault that caused it.

This is why there is more to capturing glitches and anomalies than a fast waveform update rate.

Calculating the maximum acquisition time for the Keysight 4000A X-series, we find the maximum acquisition time is 0.8 ms.

$$Keysight\ Acquisition\ Time = \frac{Max.\,Record\,Length}{Max.\,Sample\,Rate} = \frac{4\ Mpts}{5,000\ MS/s} = 0.8\ ms$$

$$Tektronix\ Acquisition\ Time = \frac{Max.\,Record\,Length}{Max.\,Sample\,Rate} = \frac{31.25\ Mpts}{6,125\ MS/s} = 5.1\ ms$$

With the Tektronix 4 Series MSO, the maximum acquisition time is 5.1 ms. If you upgrade to the optional 62.5 Mpts record length, the acquisition time doubles to 10 ms. That means the 4 Series MSO has more than 6X the acquisition time of the 4000A X-series!

Passive Probes – Impact of Capacitance

If you are making measurements with passive probes, then understanding the impact of probe loading is critical. When using the passive probes shipped with the Keysight 4000A X-series, they have a 9.5 pF input capacitance. The Tektronix 4 Series MSO ships with passive probes that have a 3.9 pF input capacitance. The higher the input capacitance, the more impact it can have on your measurements. It is possible for large probe loading to make good signals look bad or make bad signals look good. You can spend time accounting for large probe loadings in your measurements with the 4000A X-series, but why bother when you can minimize the impact of probe loading with the passive probes included with the 4 Series MSO.

Zone Triggering – Two zone triggers vs how many do you need? Cannot resize or change interact/don't interact

Oscilloscopes contain a specialized hardware circuit called a trigger which allows predictable acquisition and display of time-correlated signals. The trigger makes repetitive waveforms appear stationary by displaying the same portion of the input signal at the same horizontal position on the oscilloscope display. Because capturing and finding the right characteristic of a complex signal can require hours of collecting and sorting through thousands of acquisitions for the event of interest. Defining a trigger that isolates the desired event and shows data only when the event occurs is extremely helpful. Once such trigger is called a visual or zone trigger.

A visual trigger makes the identification of the desired waveform events quick and easy by scanning through all acquired analog waveforms and graphically comparing them to geometric shapes on the display. By discarding acquired waveforms which do not meet the graphical definition, visual triggering

extends the oscilloscope's trigger capabilities beyond the traditional hardware trigger system. Although Visual Trigger is similar in appearance to mask testing, where acquired waveforms are graphically compared to mask regions on the display, there is an important difference. Visual Trigger actually discards waveforms which do not conform to the specified shape, so only conforming
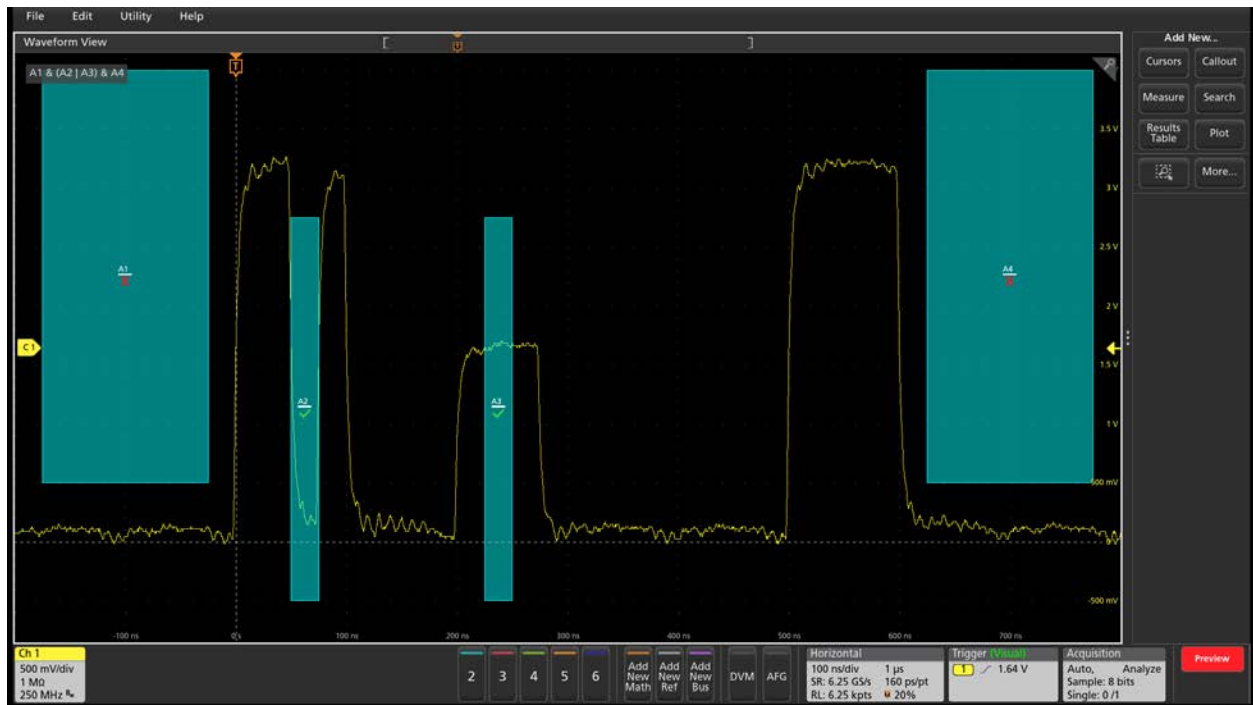waveforms can be displayed, measured, and saved to a reference.

Figure 4. Visual triggering on the 4 Series MSO provides multiple, customizable zones.

The Tektronix 4 Series MSO offers visual triggering (Figure 4); as does the Keysight 4000A X-Series (although they refer to it as zone triggering). The 4000A X-Series "zone qualified trigger" give the user the ability to set a maximum of two rectangular areas where a waveform must either intersect or not intersect these areas to activate the trigger. Per the User Guide, besides being limited to two trigger areas, you are also limited to triggering on a single analog channel and the update rate is >200,000 wfms/sec. (That's right, it isn't 1,000,000 wfms/sec.)

InfiniiScan Zone (HW zone qualifier)   Trigger on user-defined zones drawn on the display. Applies to one analog channel at a time. Specify zones as either "must intersect" or "must not intersect." Up to two zones. > 200,000 wfm/sec update rate.
Supported modes: normal, peak detect, high resolution.

From Keysight 4000A X-Series User Guide

With the Tektronix 4 Series MSO, you have more precise control of each visual trigger area. The configuration menu (Fig. 1) allows you to edit the shape, size, and position of each area. Exact coordinates for the vertices for each area can be specified in amplitude and time values. In addition, visual triggers can be set across multiple analog channels. These are important when you only want to capture the most important signal events.

Mixed Signal Oscilloscope

It used to be that most testing was done using only one or two analog channels of an oscilloscope, and possibly even 8 or 16 digital channels. With testing requirements becoming more complex, there is now a need for more than four analog channels. But, using a second scope involves significant effort to align trigger points, difficulty in determining timing relationships across the two displays, and then there are the documentation challenges.

The Keysight 4000A X-Series has a maximum of 4 analog channels and 16 digital channels (if you buy the MSO version). The challenge is that many applications, such as embedded systems, three-phase power electronics, automotive electronics, power supply design, and DC-to-DC power converters, require the observation of more than four analog signals to verify and characterize device performance, and to debug challenging system issues. The 4 Series MSO redefines what a mixed signal oscilloscope should be.

The 4 Series MSO offers better visibility into these complex systems by offering four and six FlexChannel™ models. FlexChannel™ technology enables each channel input to be used as a single analog channel or eight digital logic inputs (with the TLP058 logic probe). This means with a six channel 4 Series MSO, you can have up to 48 digital channels. With this level of flexibility and configurability, the Tektronix 4 Series MSO is the one instrument that can be used across multiple labs for multiple requirements.

Gated FFT vs Spectrum View

Mixed domain analysis is especially useful for answering questions such as:

- What's going on with my power rail voltage when I'm transmitting wireless data?
- Where are the emissions coming from each time I access memory?
- How long does it take for my PLL to stabilize after power-on?

The Keysight 4000A X-Series uses a gated FFT and zoom window to "time correlate" multiple domains. This locks the signals together with no independent domain control, and it is limited to a single analog channel. Even with this multi-domain analysis, you cannot get past the fact that FFTs are notoriously difficult to use. The 4000A X-Series offers some spectrum analyzer style controls (i.e. Start, Stop, Span & Center Frequency, but because traditional scope FFTs are driven by the same acquisition system that delivers the analog time-domain view, it is virtually impossible to get optimized views in both domains at once. Changing the center frequency or span will change the scope's horizontal scale, sample rate and record length in unanticipated and undesired ways. Once the desired frequency domain view is achieved, the time domain view of other signals is no longer usable. When adjustments are made to horizontal scale, sample rate, or record length to again achieve the desired time domain view, the FFT view is no longer usable.
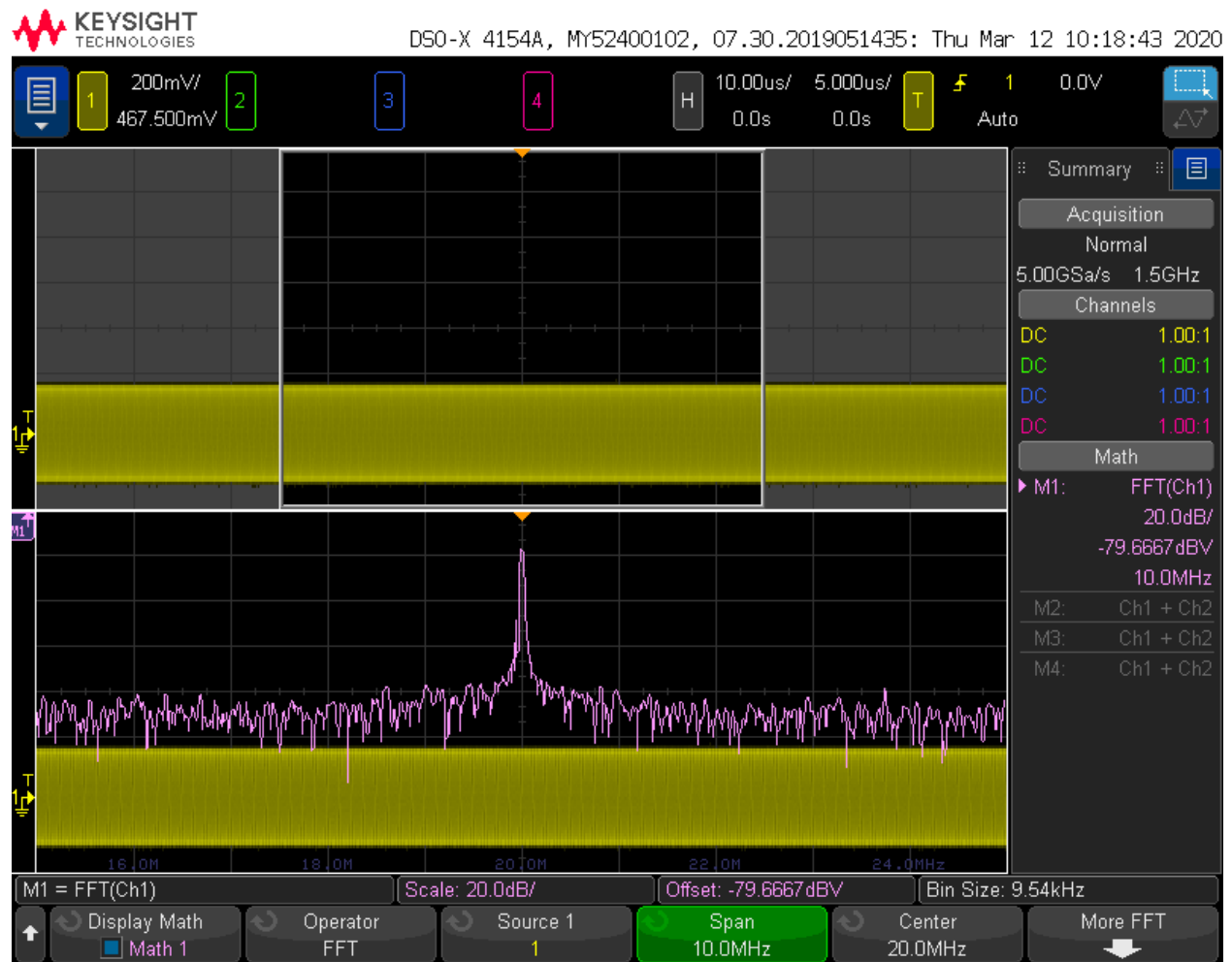
Figure 5. A gated FFT shown on the Keysight 4000A X-Series.

The Tektronix 4 Series MSO with Spectrum View is different. It lets you independently adjust time- and frequency-domain views, by using patented technology behind each FlexChannel™ input. You can turn on Spectrum View for any analog channel, enabling multi-channel mixed domain analysis. Intuitive spectrum analyzer controls like center frequency, span, resolution bandwidth (RBW), and peak markers make setups and time-correlated analysis easy. In addition, Spectrum View on the 4 Series MSO:

- Allows optimization of both time domain and frequency domain displays independently.
- Enables a signal to be viewed in both a waveform view and a spectrum view without splitting the signal into different inputs.
- Enables accurate correlation of time domain events and frequency domain measurements (and vice versa).
- Significantly improves achievable frequency resolution in the frequency domain.
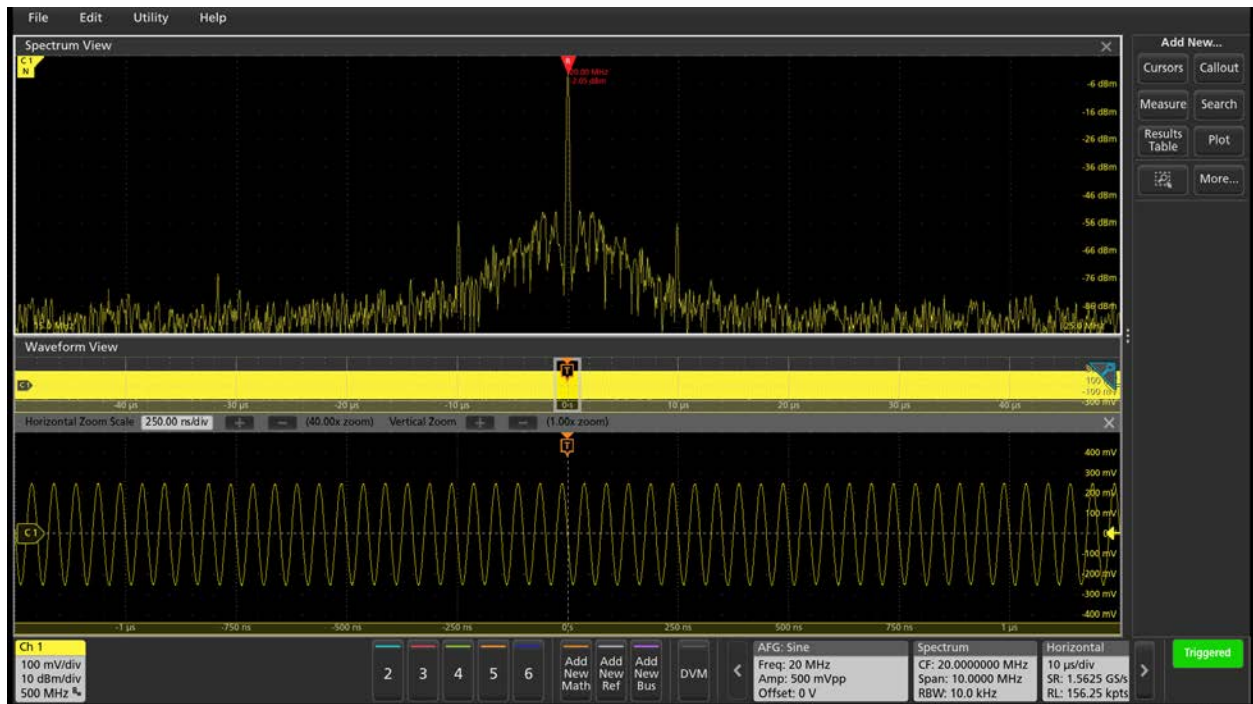- Improves the update rate of the spectrum display

Figure 6. Spectrum View enabled on the 4 Series MSO provides a spectrum analyzer type display.

Want to learn more about Spectrum View? Check out this application note:
https://www.tek.com/document/application-note/spectrum-view-new-approach-frequency-domain-analysis-oscilloscopes

Serial Decode & Analysis

When it comes to serial protocol analysis, most manufacturers support the major standards. This is true of both the Tektronix 4 Series MSO and Keysight 4000A X-Series; although you will find that the Keysight 4000A X-Series lacks support for the Ethernet, I3C and SPMI protocols. Ultimately though, it is about seeing accurately decoded results.

Most designs today use I^{2}C, SPI or both. With the Keysight 4000A X-Series, you can set up two bus decodes (only one if it is SPI), but can only examine one bus at a time because the instrument only displays a single decoded signal. The Tektronix 4 Series MSO won't limit you to a single displayed decode. In fact, with a 6-channel, 4 Series MSO, you can display a decoded I^{2}C and SPI bus on the same screen. The ability to see multiple bus decodes on a single screen is a big time-saver when debugging today's sensor-laden designs.
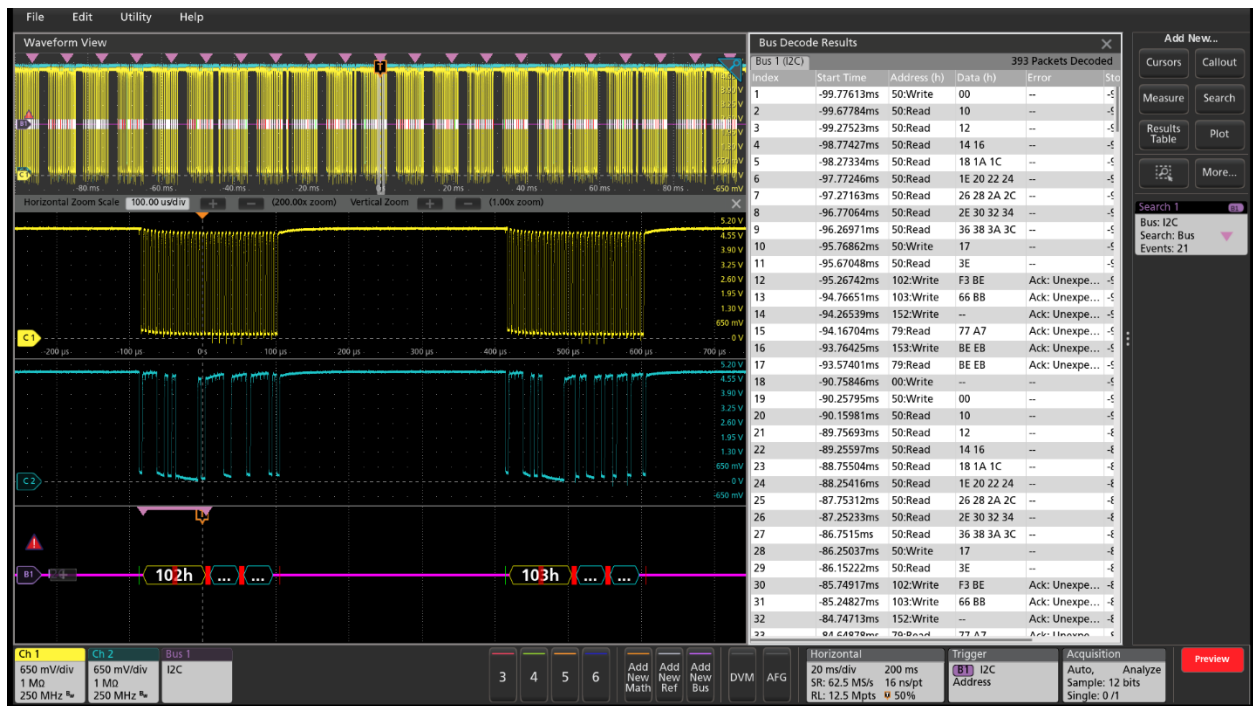
Figure 7. Example of serial decode and analysis of an I²C bus on the 4 Series MSO.

Bandwidth Upgrades

While you always try to anticipate your bandwidth needs when purchasing a new oscilloscope, sometimes planning for future requirements conflicts with the budget available today. The Tektronix 4 Series MSO has you covered with software license-enabled bandwidth upgrades. Even if you are using 200 MHz today, you can purchase a bandwidth upgrade up to 1.5 GHz in the future. And, the best part is you don't need to send the instrument anywhere to get the upgrade. You simply install the upgrade license on your scope, and you are ready to test in a short amount of time.

Unfortunately, the only software-enabled bandwidth upgrades available on the Keysight 4000A X-series allow you to go from 350 MHz to 500 MHz. Any other bandwidth upgrade must be sent to a Keysight Service Center to be completed, and from the description in the datasheet it sounds like it can be very time consuming. There are also additional costs for shipping the unit to the Service Center. You don't need to experience either of these with the Tektronix 4 Series MSO.

	Process description
1	Place order for a return-to-Keysight service center bandwidth upgrade product to a Keysight sales partner. Serivce Center installation, calibration, shipment costs are in addition to bandwidth upgrade product price.
2	Keysight Business Center will contact you regarding process and timing of the service center installation. Continue to use oscilloscope until contacted again later when parts are available at service center.
3	Ship the oscilloscope per provided instructions to service center.
4	Service center ships back upgraded oscilloscope with stick-on labels applied to front and rear panels indicating upgraded bandwidth specification. Model number and serial number of the oscilloscope do not change.

Table from p. 36 of Keysight 4000A X-Series Datasheet

Conclusion

We covered a lot of information in this blog to demonstrate why the Tektronix 4 Series MSO is a much more capable oscilloscope compared to the Keysight 4000A X-Series.

- ✓ Higher sample rate
- ✓ Deeper record length
- ✓ True mixed domain analysis
- ✓ Modern user interface made for touch

✓ Flexchannel™ technology

Experience the 4 Series MSO for yourself. Call your local Tektronix Account Manager or Distribution Partner to arrange for a demo. Learn more about the Tektronix 4 Series MSO on our website.

Tek.com