



# Wave Inspector® Navigation and Search: Simplifying Waveform Analysis

## Application Note

### Introduction

As Moore's Law pushes electronic technology faster, system designs continue to become more complex, and subsequently harder to design, build, troubleshoot, and fix when they break. So what does this mean to modern oscilloscopes?

As designs become faster and more complex, the need for long records, more bandwidth, and higher sampling rate will also increase. Record length is the number of samples an oscilloscope can digitize and store in a single acquisition. The longer the record length, the longer the time window the oscilloscope can capture with high timing resolution (high sample rate). The record length required for a specific application is directly affected by the bandwidth and sample rate. As bandwidth goes up, the sampling rate must be approximately five times higher to accurately capture the signal's high frequency content. As the sampling rate goes up, a given time window of signal acquisition requires more samples.

For example, to capture 2 milliseconds of a 100 MHz signal at 5 GS/s requires a 10 million point record. (Divide 2 milliseconds by the 200 picosecond sample interval.) Even at lower frequencies, there are many applications that require long records. Just capturing a single frame of NTSC video (two fields in a 1/30th of a second interval, at 100 MS/s to resolve all the luminance information) requires over 3 million points (33 milliseconds divided by 10 nanoseconds). Capturing several seconds of bus traffic on a 1 Mb/s CAN bus to diagnose problems in an electro-mechanical system may require 10 million points for adequate resolution. These and a variety of other applications have driven and continue to drive the need for longer and more detailed data capture windows.

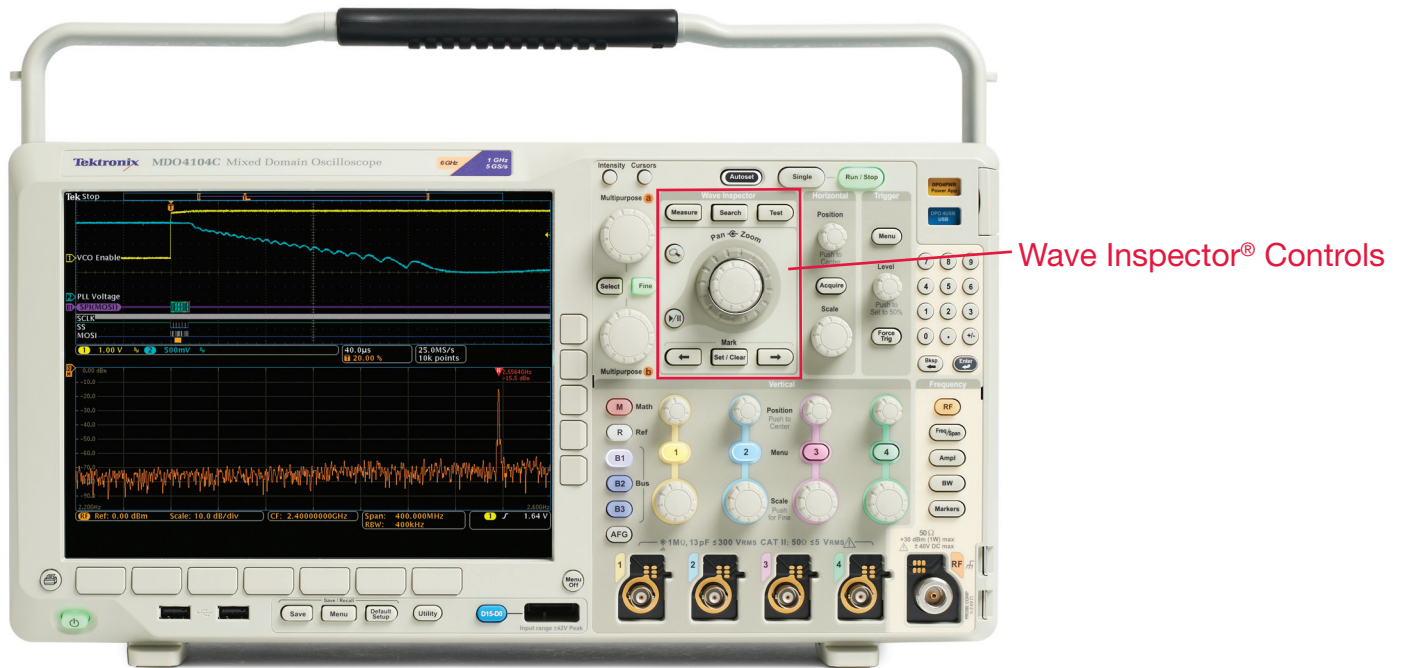


Figure 1. Wave Inspector® provides dedicated front-panel controls for efficient waveform analysis.

## Analyzing all that Data

The first digital oscilloscopes had very short record length. As such, it was easy to see everything the oscilloscope captured because it was all on the screen at one time. As oscilloscopes evolved and records got longer, horizontal scrolling was used to see all the data. This was not a big issue as you move from one screen's worth of information to two, then up to four, eight, twenty, etc. However, as records became longer and longer with each generation of oscilloscope, the time required to look through all the data captured in a single acquisition grew longer and longer.

We are now dealing with record lengths in the millions of points that represent thousands of screens worth of signal activity. By way of comparison, imagine trying to find what you're looking for on the Internet without the assistance of your favorite search engine, web browser, or bookmarks. It would be like searching for a needle in a haystack. Until recently, this is what oscilloscope users faced with their long record length oscilloscopes. Clearly, the old solutions will no longer work.

## Wave Inspector® Navigation and Search

Available on the MSO/DPO5000, MDO4000, MDO3000, and MSO/DPO2000 Series oscilloscopes, Wave Inspector® controls make working with long records and extracting the answers you need from your waveforms a simple and efficient process.

## Zoom / Pan

Most digital oscilloscopes on the market today offer some form of zoom capability. However, the controls associated with the zoom view (zoom factor and position) are often buried in menus or multiplexed with other front-panel controls. For example, the zoom window's horizontal position is typically controlled by the horizontal position knob on the front panel. Once you've zoomed in on an event of interest, if you want to move the zoom window to another location in the acquisition it typically means either turning the horizontal position knob countless times to slowly move the window to the new location, or zooming back out, adjusting the window's location and then zooming back in. Neither approach is efficient nor intuitive. It becomes even less efficient when you have to navigate through menus just to access these basic zoom controls.

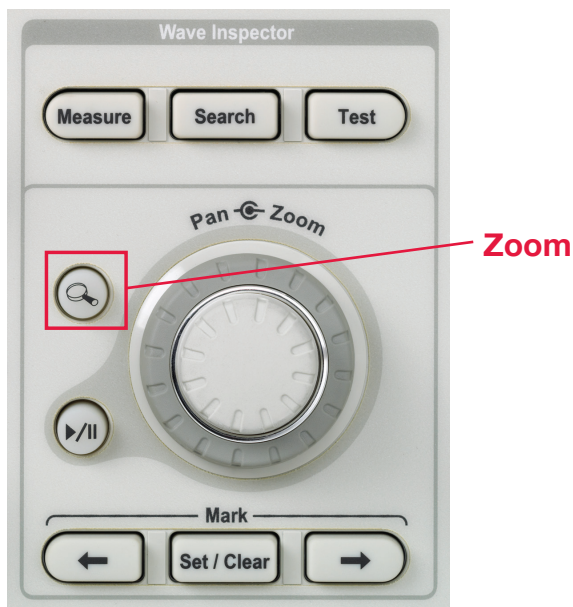


Figure 1A. Wave Inspector® provides dedicated front-panel zoom and pan controls.

As shown in Figure 1A, Wave Inspector provides a dedicated two-tier front-panel Zoom / Pan knob for efficient waveform navigation. The inner knob controls the zoom factor. The farther clockwise you turn it, the farther you zoom in. Turning it counter-clockwise zooms back out and ultimately turns zoom off.

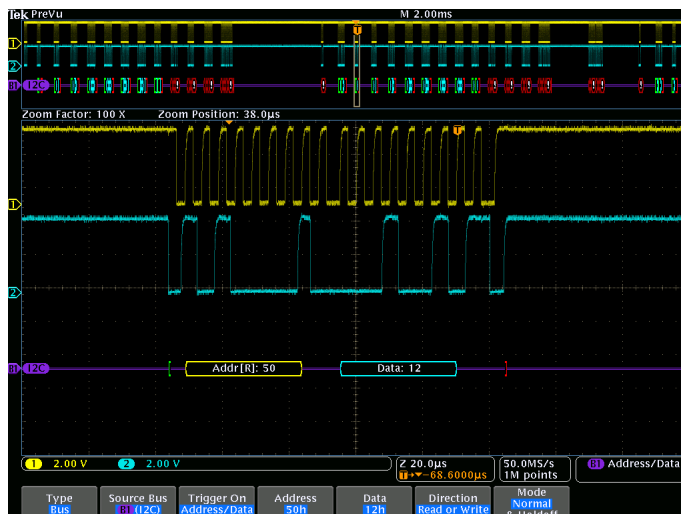


Figure 2. Navigating through a long acquisition of an I<sup>2</sup>C bus.

The outer ring is a force/rate sensitive pan control. Turning it clockwise pans the zoom window right on the waveform, counterclockwise pans it left. The farther you turn it, the faster the zoom window moves across the waveform. In Figure 2, we can quickly navigate from one packet to the next by simply turning the pan control in the desired direction. Even with a 10 million point acquisition, you can rapidly move the zoom window from one end of the record to the other in a few seconds, without ever having to change your zoom factor.

In Figure 2 we're probing an I<sup>2</sup>C bus. The complete acquisition is shown in the upper window and the zoomed portion is in the lower, larger window. In this case, we've zoomed in to view the decoded address and data values for one particular packet.

## Play / Pause

Many times when debugging a problem, you don't know what's causing the problem so you're not sure what to look for in the waveform you've acquired. However, you know you've captured the time window that contained the problem and you now need to look through the data you've captured to see if you can find the issue. Again, on most modern oscilloscopes this is done by manually turning the horizontal position knob countless times to inspect the acquired waveforms for any suspicious activity. Wave Inspector® controls help in this area as well. You can simply press the Play button on the front panel to have your zoom window automatically pan across the waveform. Play speed and direction are adjusted using the intuitive pan control. The farther you turn the pan control the faster the waveform plays by. This allows hands-free playback so you can concentrate on what's important – the waveform itself. In the I<sup>2</sup>C example (Figure 2), you could play the waveform while watching the decoded address and data values to monitor activity on the bus. When you spot the event you're looking for simply press the Play/Pause button again to stop the waveform.

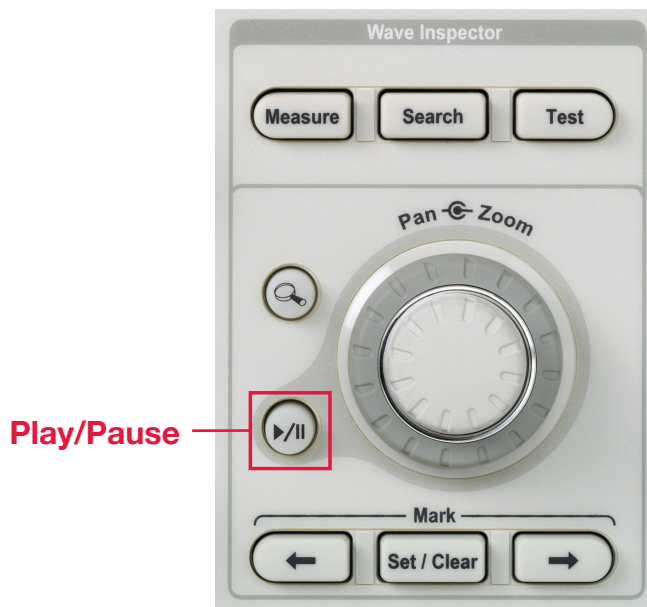


Figure 2A. Dedicated front-panel control for automated waveform playback.

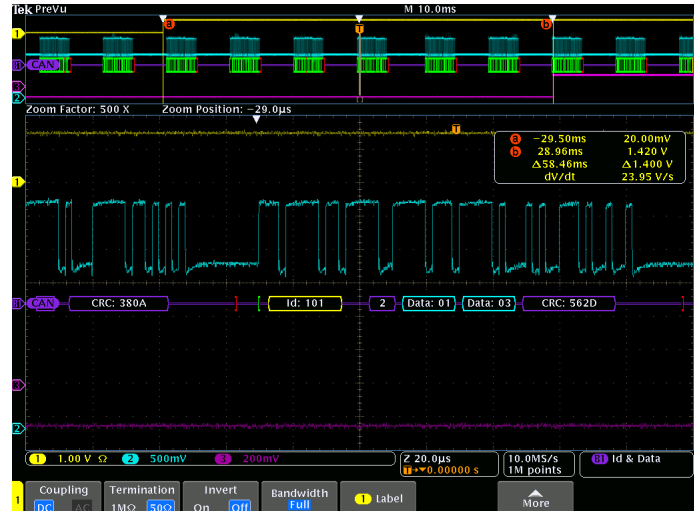




**Figure 2B.** Dedicated front-panel controls for setting/clearing marks and navigating between them.

## Marks

While looking for the source of the problem, you may find numerous areas of the waveform that either warrant further investigation or are indicative of something happening in the device under test that you want to use as a reference point during the rest of your analysis. For example, assume you need to make timing measurements associated with the latency from when a driver presses the Passenger Window Down switch on the driver's door panel to when the passenger window actually starts to move. The first event you'll want to find in the acquisition is when the switch was pressed. The next may be when the CAN module in the driver's side door issues the command to the CAN module in the passenger door. The last event may be when the motor engaged in the passenger door and the window started to move. Wouldn't it be nice to mark each of these locations on the waveform so you can quickly jump back and forth between the areas of interest for timing measurements? With the Tektronix Wave Inspector® Navigation Series you can.



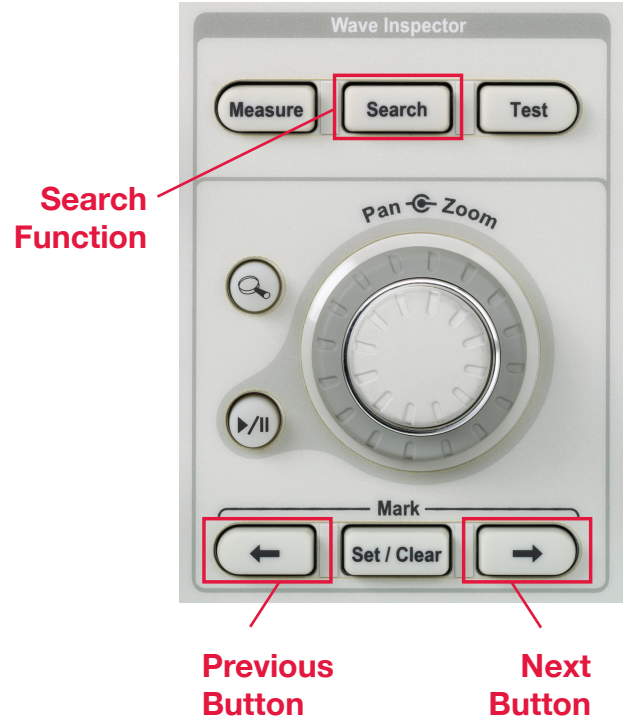
**Figure 3.** Placing marks on the waveform to assist in latency measurements on a CAN bus.

In Figure 3, Channel 1 is the output of the switch in the driver's door, Channel 2 is the CAN bus, and Channel 3 is monitoring the motor drive in the passenger door.

We've set the oscilloscope up to trigger on the packet of interest by specifying the appropriate Identifier and Data. Next, we've used the front-panel Set / Clear Mark button to mark each of the events of interest on the waveform. These user marks are shown as solid white triangles along the top edge in both the upper and lower windows. The rising edge on Channel 1 indicates when the switch was pressed. The trigger event is the CAN module in the driver's door issuing the command and the window beginning to move is the transition on Channel 3. Using the front-panel Previous and Next buttons we can instantly jump between marks to place cursors for quick and easy latency measurements. In Figure 3, we find that the total time from the press of the switch to window movement is 58.46 ms, well within the amount of acceptable delay.

## Search & Mark

In addition to placing marks on waveforms manually, Wave Inspector® has the power to search through the entire acquisition and automatically mark every occurrence of a user-specified event. For example, imagine you are capturing laser pulses. The laser fires approximately every 20  $\mu$ s, with each pulse being only 15 ns wide. You want to look at multiple pulses to characterize their shape and to make precise timing measurements between them, but to navigate from one to the next you need to sift through close to 20  $\mu$ s of dead time. Then you need to repeat this for every other pulse in the acquisition. Clearly, it would be desirable to be able to move from pulse to pulse instantly without having to waste time “twiddling” a position knob.



**Figure 3A.** Wave Inspector's® powerful Search capability allows you to find every occurrence of a user-specified event in the acquisition.

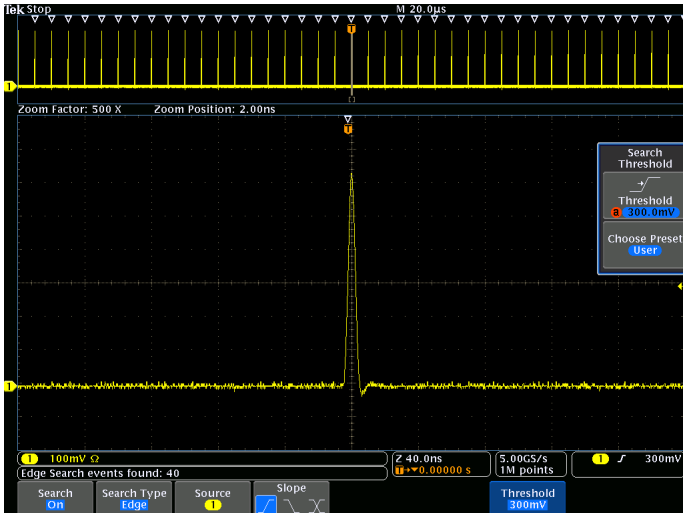


Figure 4. Wave Inspector® marking every pulse that crosses 300mV in a long acquisition.

A very simple search setup that looks for rising edges that cross a threshold of 300mV is illustrated in Figure 4. Marks generated by the search are shown as hollow white triangles along the top edge in both the upper and lower windows. This search resulted in 40 marks being placed throughout the record. Now all you have to do is press the front-panel previous and next buttons to jump from one pulse to the next, no adjustment of zoom scale or position is required!

Wave Inspector's® Search goes well beyond simple edge searches. Imagine the chip you're working with has an indeterminate output every so often that's causing the overall system to crash. You suspect that it's a metastability issue caused by Setup & Hold violations. In a matter of seconds, you can specify search criteria to have the oscilloscope automatically find every occurrence in the acquisition where setup and hold times you specify were violated. In this case, the part we're using has published setup and hold times of 12 ns and 4 ns, respectively. To have the oscilloscope automatically find violations of these limits, we simply need to tell it Clock is on Channel 1, Data is on Channel 2, set the thresholds, and enter the desired setup and hold times. The oscilloscope then checks the timing relative to every clock edge throughout the entire acquisition and marks the



Figure 5. Setup & Hold violation search results in six occurrences found.

occurrences that violate the specified setup and hold times. In Figure 5, our search resulted in 13 violations. The 13 events are marked with hollow white triangles in the upper window. The lower window is showing a zoomed-in view of one of the violations. It's clear that the data line is transitioning within 4 ns of the positive clock edge.

We've found the metastability source without having to manually scroll through the waveform and without having to use cursors to measure anything. You can even perform worst case checks by adjusting the setup and hold times and seeing how many events Wave Inspector® finds. For example, you can set the hold time to zero and then reduce the setup time until only one event is found.<sup>1</sup>

Another powerful search capability provided by Wave Inspector is searching for data in a bus. You can use the front-panel bus buttons to define your signals as an I<sup>2</sup>C, SPI, USB, CAN, LIN, FlexRay, RS-232/422/485/UART, I<sup>2</sup>S/LJ/RJ/TDM, Ethernet, MIL-STD-1553, or parallel bus. Then the oscilloscope will decode the bus into packets, displaying the information in a meaningful form. You can trigger on or search for data in the packets. (Requires optional applications or application modules.)

<sup>1</sup>The MSO/DPO5000 Series supports search of setup & hold violations between clock and data on one other input channel.

To further simplify waveform analysis, the MDO4000, MDO3000, and MSO/DPO2000 Series oscilloscope support simultaneous search for setup & hold violations on all analog and digital input channels in the oscilloscope.

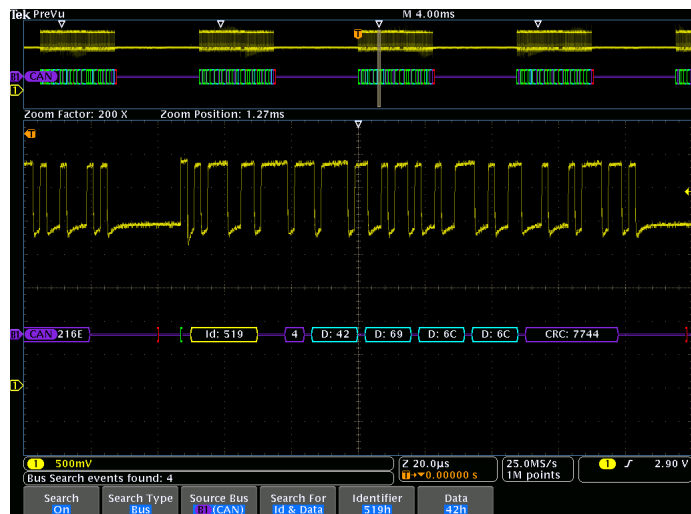


Figure 6. Searching for specific Identifier and Data values in CAN messages.

While this triggering is critical to isolate the time window that contains the problem, it's highly likely that you'll need to view bus activity over many packets to understand what's going on at a system level. The bus search feature enables you to specify packet level criteria and mark every occurrence of it in the record for quick viewing, navigation and analysis. Continuing the earlier CAN example, in Figure 6 we've searched for every message in a long acquisition of a CAN bus with the specific Identifier (519) and Data (42) values we're interested in.

Wave Inspector® found four messages in the acquisition that met the criteria. Again, moving the zoom window from one occurrence to the next is as simple as pressing the previous and next buttons on the front panel. And because the oscilloscope is decoding the packets for you, you can instantly see all the relevant information without having to manually decode from analog waveforms.

In addition to the examples provided above, Wave Inspector® can search for many other types of events. The full list of search capabilities is shown in Table 1.



Search Type	Description
<b>Edge</b>	Searches for edges (rising, falling, or either) with a user-specified threshold level.
<b>Pulse Width</b>	Searches for positive or negative pulse widths that are $>$ , $<$ , $=$ , or $\neq$ a user-specified pulse width.
<b>Timeout</b>	Timeout (MSO/DPO5000, MDO4000, and MDO3000 Series only): Search for an event which remains high, low, or either, for a specified time period.
<b>Runt</b>	Searches for positive or negative pulses that cross one amplitude threshold but fail to cross a second threshold before crossing the first again. Search for all runt pulses or only those with duration $>$ , $<$ , $=$ , or $\neq$ a user-specified time.
<b>Logic</b>	Search for a logic pattern (AND, OR, NAND, or NOR) across multiple waveforms with each input set to either High, Low, or Don't Care. Search for when the event goes true, goes false or stays valid for $>$ , $<$ , $=$ , or $\neq$ a user-specified time. Additionally, you can define one of the inputs as clock for synchronous (state) searches.
<b>Setup &amp; Hold</b>	Search for violations of user-specified Setup and Hold times.
<b>Rise / Fall Time</b>	Search for rising and/or falling edges that are $>$ , $<$ , $=$ , or $\neq$ a user-specified time.
<b>Bus</b>	<p>I<sup>2</sup>C: Search for Start, Repeated Start, Stop, Missing Ack, Address, Data or Address &amp; Data.</p> <p>SPI: Search for SS Active, MOSI, MISO, or MOSI &amp; MISO.</p> <p>USB (MSO/DPO5000, MDO4000, and MDO3000 Series only): Sync, Reset, Suspend, Resume, End of Packet, Token (Address) Packet, Data Packet Handshake Packet, Special Packet, or Error.</p> <p>RS-232/422/485/UART: Search for Tx Start Bit, Rx Start Bit, Tx End of Packet, Rx End of Packet, Tx Data, Rx Data, Tx Parity Error and Rx Parity Error.</p> <p>CAN: Search for Start of Frame, Type of Frame (Data, Remote, Error, Overload), Identifier (standard or extended), Data, Identifier &amp; Data, End of Frame, or Missing Ack.</p> <p>LIN: Search for Sync, Identifier, Data, Identifier and Data, Wakeup Frame, Sleep Frame or Errors such as Sync, Parity, or Checksum Errors.</p> <p>FlexRay (MSO/DPO5000, MDO4000, and MDO3000 Series only): Search for Start of Frame, Type of Frame (Normal, Payload, Null, Sync, Startup), Identifier, Cycle Count, Complete Header Field, Data, Identifier and Data, End of Frame or Errors such as Header CRC, Trailer CRC, Null Frame, Sync Frame, or Startup Frame Errors.</p> <p>I<sup>2</sup>S/LJ/RJ/TDM (MDO4000 and MDO3000 Series only ): Search for Word Select, Frame Sync, or Data.</p> <p>10BASE-T and 100BASE-TX Ethernet (MSO/DPO5000 and MDO4000 Series only): Search for Start Frame Delimiter, MAC Addresses, Q-Tag Control Information, MAC Length/Type, MAC Client Data, IP Header, TCP Header, TCP-IPv4 Client Data, End of Packet, Idle, or FCS (CRC) Error.</p> <p>MIL-STD-1553 (MSO/DPO5000, MDO4000, and MDO3000 Series only): Search for packet-level information.</p> <p>Parallel (MSO/DPO5000, MDO4000, MDO3000, and MSO2000 Series only): Search for data value.</p>

\* Additional search types available for MSO/DPO5000 Series.

**Table 1.** List of search events.

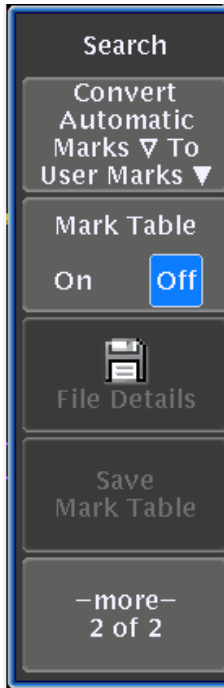


Figure 7. Search side menu.

## Multiple Searches

An obvious question at this point is, “What if I want to perform another search, but don’t want to lose the results (marks) from my first search?” Simply select the Convert Automatic Marks (hollow upside down triangle) to User Marks ▾ menu selection and you’ll see that the hollow white triangle search marks become filled in, appearing the same as marks placed with the front-panel Set Mark button. These marks are now saved on the waveform and a new search can be performed. You can do this as many times as you like, effectively creating unlimited searching ability. Of course, if you would like to start over with a clean slate you can press the Clear All Marks button to remove all marks from the waveform or you can remove any single mark using the Set/Clear Mark front-panel button.

## Search Interaction with Trigger

Two other powerful and time-saving capabilities are included in the Search menu: the ability to copy trigger settings to search and copy search settings to trigger. Copying the current trigger settings to the search menu is most useful when you want to search through the acquisition to see if there are any other occurrences of the trigger event in the captured data. Alternatively, copying search settings to the trigger menu is most useful when you’ve found an event in your data and you want to reacquire new data using that event as the trigger criteria.

## Wave Inspector with Advanced Search and Mark

The MSO/DPO5000 Series offers extended search and mark capabilities by combining Wave Inspector with Advanced Search and Mark. The MSO/DPO5000 can simultaneously search for up to 8 different events. These products can also stop acquisitions when an event is found in the acquired signals, extending the products’ hardware trigger capabilities with software triggering.

## Conclusion

Modern digital oscilloscopes can capture massive amounts of data. Until now, searching through that data has been a time-consuming and frustrating process. With Tektronix Wave Inspector® Navigation and Search, you can extract the answers you need with efficiency and precision and unlike any other oscilloscope.

Wave Inspector® Navigation and Search is available on the following oscilloscopes:

	<b>MSO/DPO5000B Series</b>	<b>MD04000C Series</b>	<b>MD03000 Series</b>	<b>MSO/DPO2000B Series</b>
<b>Bandwidth (analog)</b>	2 GHz, 1 GHz, 500 MHz, 350 MHz	1 GHz, 500 MHz, 350 MHz, 200 MHz	1 GHz, 500 MHz, 350 MHz, 200 MHz, 100 MHz	200 MHz, 100 MHz, 70 MHz
<b>Channels (analog)</b>	4 analog	4 analog	2 or 4 analog	2 or 4 analog
<b>Channels (RF)</b>	--	1 RF (optional)	1 RF	--
<b>Channels (digital)</b>	16 digital (MSO Series)	16 digital (optional)	16 digital (optional)	16 digital (MSO Series)
<b>Record Length (All Channels)</b>	25 M standard, Up to 125 M optional	20 M	10 M	1 M
<b>Sample Rate</b>	Up to 10 GS/s	Up to 5 GS/s	Up to 5 GS/s	1 GS/s
<b>Display</b>	10.4 in. XGA	10.4 in. XGA	9 in. WVGA	7 in. WQVGA
<b>Optional Serial Bus Triggering and Analysis</b>	I <sup>2</sup> C, SPI, USB, CAN, LIN, FlexRay, RS-232/422/485/UART, Ethernet, MIL-STD-1553, MIPI D-PHY	I <sup>2</sup> C, SPI, USB, CAN, LIN, FlexRay, RS-232/422/485/UART, I <sup>2</sup> S/LJ/RJ/TDM, Ethernet, MIL-STD-1553	I <sup>2</sup> C, SPI, CAN, LIN, FlexRay, RS-232/422/485/UART, I <sup>2</sup> S/LJ/RJ/TDM, MIL-STD-1553, USB	I <sup>2</sup> C, SPI, CAN, LIN, RS-232/422/485/UART

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**For Further Information**

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