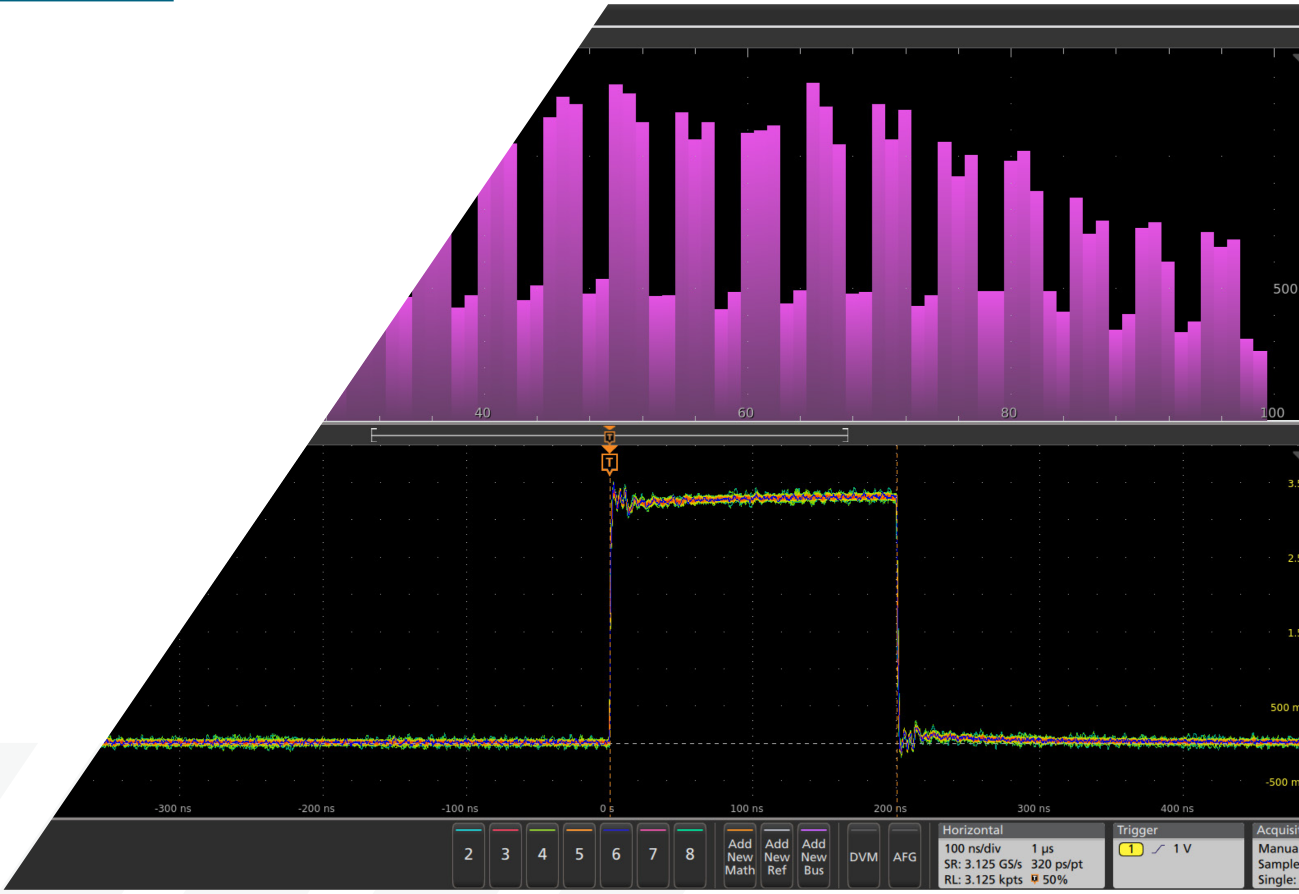
Using FastFrame™ Segmented Memory on the 4/5/6 Series MSOs and 7 Series DPO

TECHNICAL BRIEF



Introduction

Debug and verification of complex systems present many technical challenges, including capturing and visualizing multiple infrequent or intermittent events, such as serial data packets, laser pulses, and glitches. To accurately measure and characterize these signals, they must be acquired at high sample rate over an extended time period. Sometimes these are repetitive, bursty signals against a background with random noise which require averaging to improve the signal-to-noise ratio (SNR) to perform more precise measurements.

The oscilloscope's default acquisition mode forces a compromise between timing resolution and capture time due to the finite acquisition memory depth. Using higher sample rates fills the instrument's memory more rapidly and decreases the time window of data acquisition. Conversely, capturing data over long periods of time has typically come at the expense of horizontal timing resolution (sample rate).

What you will learn:

This technical brief discusses the challenges of capturing infrequent signal events and how to improve the efficiency of memory usage and quality of data acquisition, especially the SNR of the signal, using FastFrame™ segmented memory acquisition mode, including:

- How to capture multiple events at a sufficiently high horizontal resolution for effective analysis
- How to optimize the use of acquisition memory by storing and displaying only the necessary data
- How to improve the signal-to-noise ratio (SNR) by averaging waveforms using Summary Frame Averaging or Orthogonal Frame Averaging

Then FastFrame acquisitions are used in a few typical applications: characterizing intermittent events, measuring infrequent events, acquiring bursty serial packets, comparing infrequent events with "golden" references, and improving the SNR of signals using averaging.

The examples in this brief were captured on a 5 Series MSO and 7 Series DPO, but operation of FastFrame segmented memory is practically identical on the 4 and 6 Series MSOs.

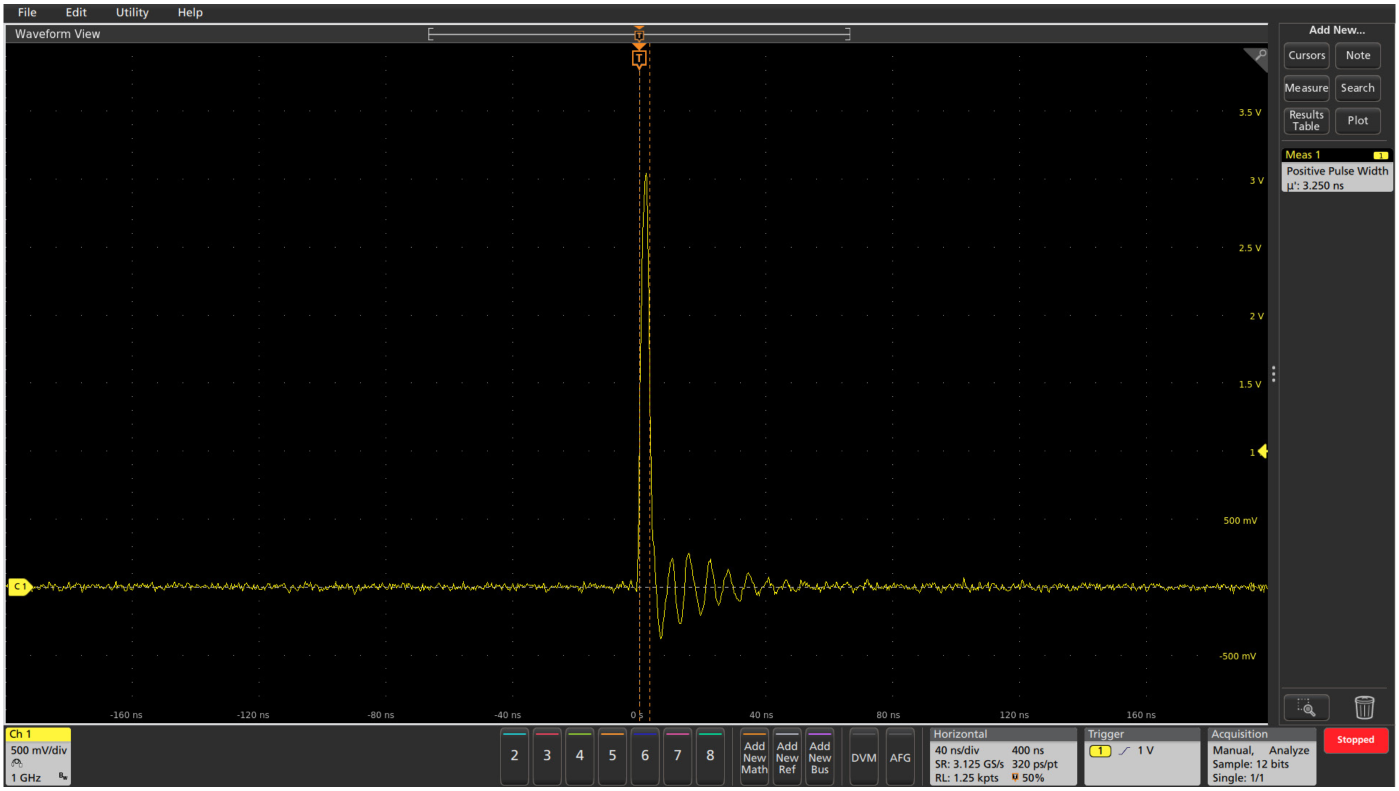


Figure 1. A single pulse captured at high resolution.

Using Record Length to Your Advantage

Consider the single 3.25 ns pulse shown in **Figure 1**. It was acquired with the 5 Series MSO in a 1250-point waveform at a sample rate of 3.125 GS/s and 12-bit vertical resolution. At this sample rate and resolution, much of the waveform detail can be seen.

If, however, you want to view several consecutive pulses, the time window of acquisition must be increased and compromises must be made. Either the sample rate must be decreased or the record length must be increased. Of course, lowering the sample rate inherently sacrifices horizontal timing resolution.

Alternatively, you can extend the record length, up to the hardware limit of the oscilloscope. But record length is a limited resource, and even using the maximum record length, you may still not be able to capture that last and perhaps most critical event.

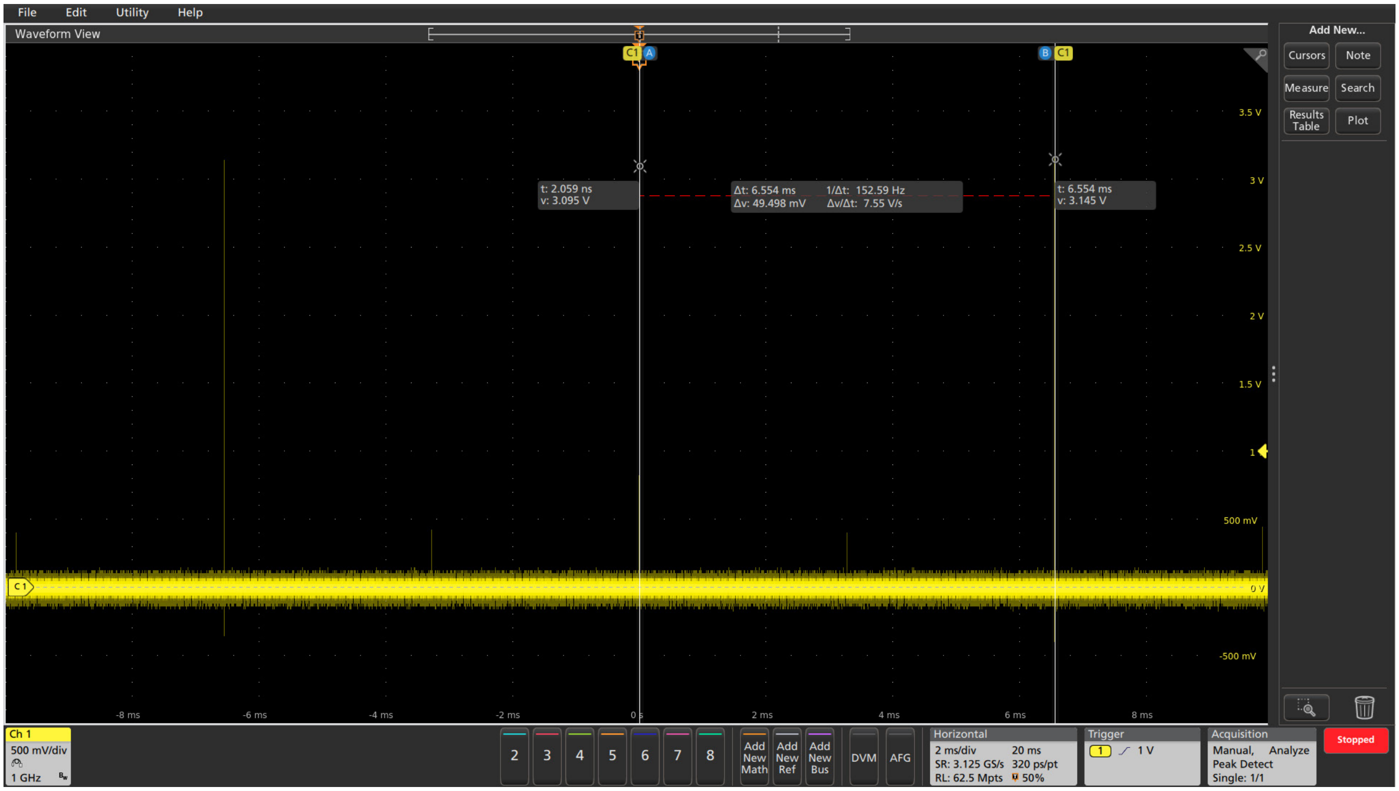


Figure 2. Multiple pulses captured with Peak Detect and long record length.

In the case of this signal, the pulses are over 6.5 ms apart. To acquire the signal at the same sample rate as in **Figure 1**, the time window was extended by 50,000X to capture more consecutive pulses by increasing the time/division and the record length. (Peak Detect acquisition was also used to make the narrow pulses more visible.)

As you can see in **Figure 2**, this consumes the entire standard record length of the product. Yet only three 3.25 ns pulses were captured in the 20 ms acquisition. In this case, only 0.00005% of the acquisition is of interest!

Long acquisitions come with some significant disadvantages:

- Increased data processing is required, which reduces the maximum trigger rate and limits the waveform capture rate
- Increased data storage requirements
- Reduced I/O transfer rates
- Additional optional record length can be expensive

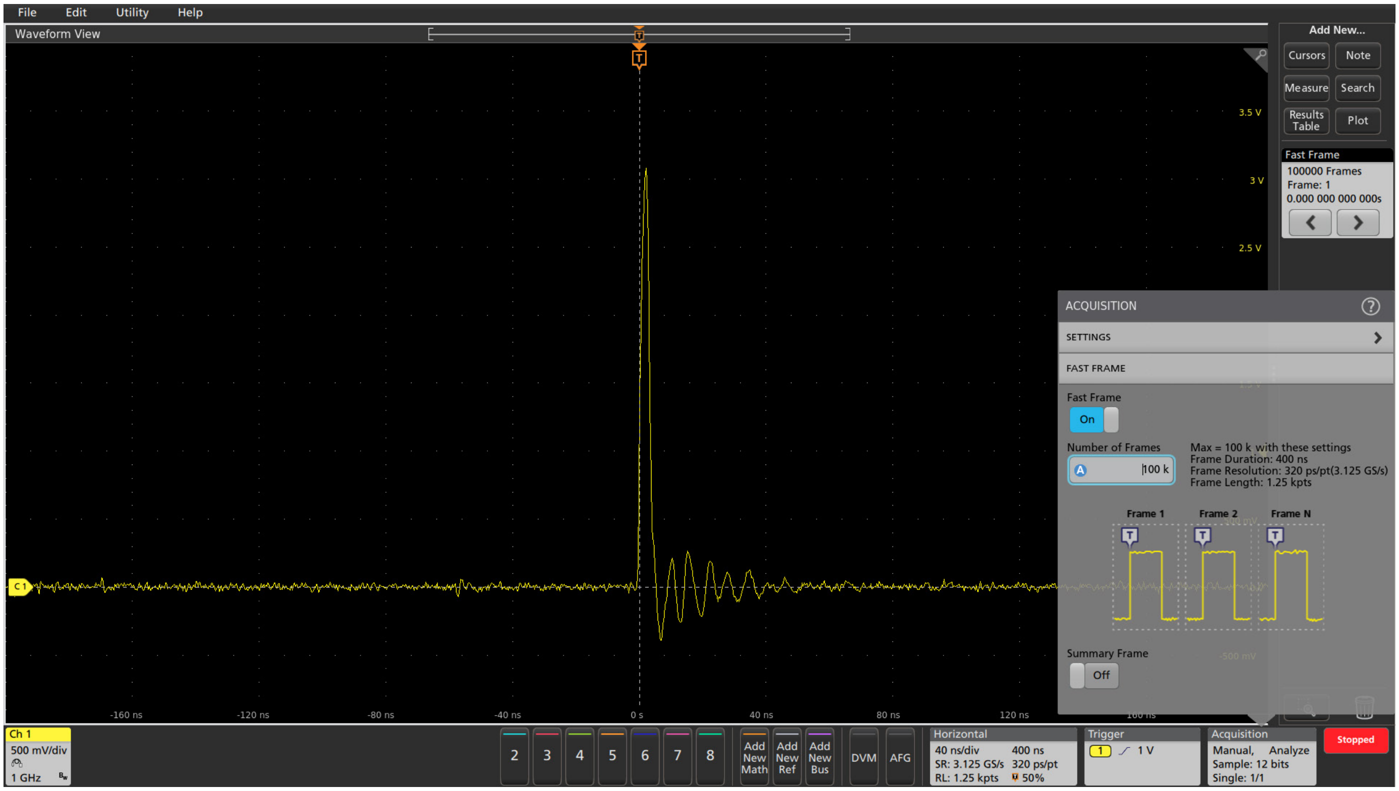


Figure 3. Using the 5 Series MSO FastFrame Segmented Memory multiple pulses can be captured at high resolution.

Segmented Memory Architecture

FastFrame™ Segmented Memory allows you to partition the acquisition memory into a series of frames. The record length of each frame is the same as before FastFrame mode was enabled, and the maximum number of frames is calculated as the instrument's maximum record length divided by the record length of a frame plus some overhead which varies by oscilloscope model.

Each frame is then filled with a triggered acquisition at the specified sample rate, capturing only the portions of the waveforms of interest. The frames can then be viewed individually in the order they were captured, or overlaid to show their similarities and differences, allowing you to easily scan through the waveforms so you can focus on the signal of interest.

Figure 3 illustrates this approach, capturing 100,000 frames. Using FastFrame Segmented Memory in the 5 Series MSO, the pulses are captured at a sample rate of 3.125 GS/s with the same small record length as shown in **Figure 1**.

FastFrame acquisition mode is capable of a burst trigger rate of >5,000,000 frames per second (acquisitions/sec) for the 4/5/6 Series MSOs or >30,000,000 frames per second (acquisitions/sec) for the 7 Series DPO — a significantly faster trigger rate than that of any other oscilloscope.

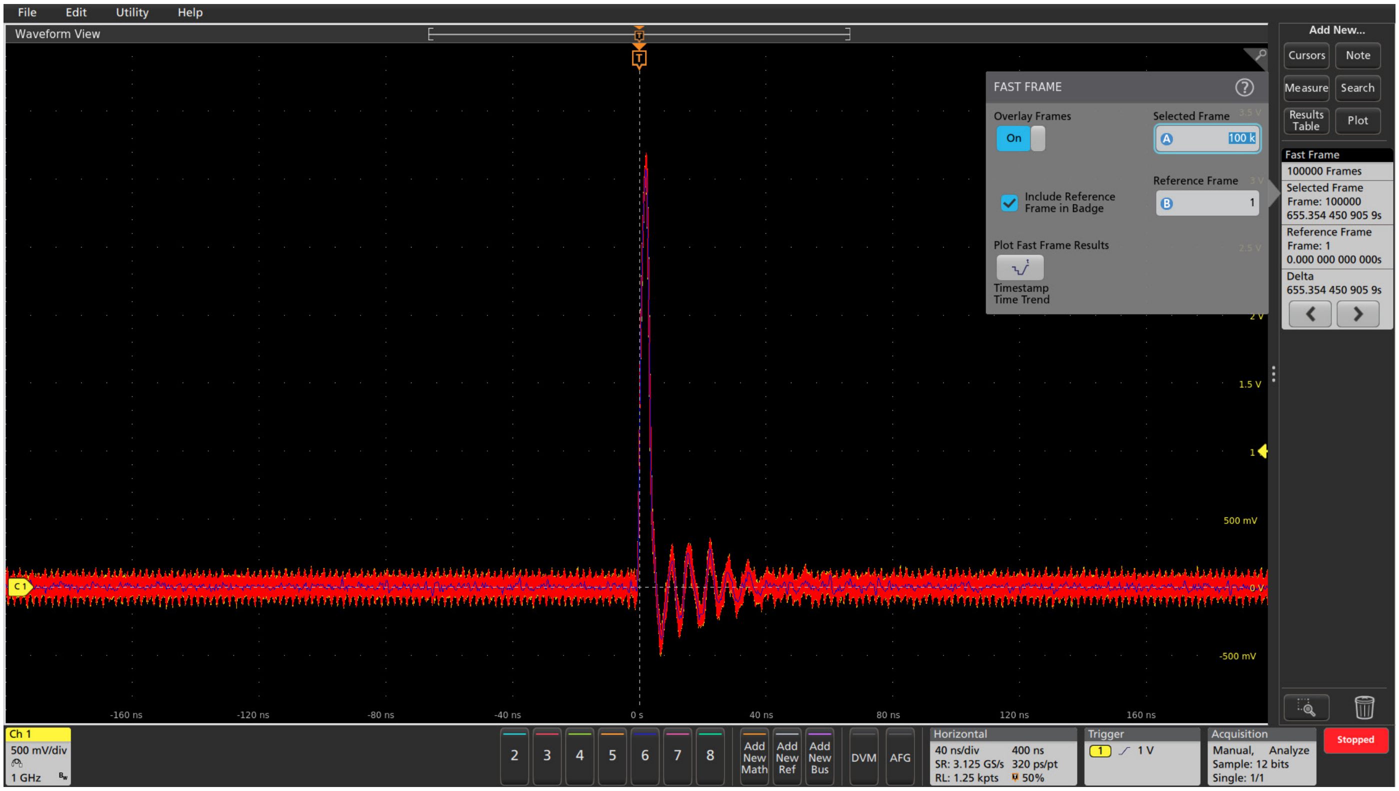


Figure 4. **Overlaid FastFrame display of all acquired frames allows quick visual comparison.**

The segmented memory frames have been overlaid in **Figure 4** so all of the pulses appear stacked on top of one another on the screen. This allows quick visual comparison of all acquired frames.

The Selected Frame has been set to 100,000 and the waveform is displayed in blue on top of the overlaid frames. The time difference (Delta) between the Reference Frame and the Selected Frame is shown in the results badge at the right side of the display.

Advantages of the FastFrame segmented memory approach include:

- The high FastFrame waveform capture rate increases the probability of capturing infrequent events
- The horizontal waveform detail has been preserved by using high sample rates
- The pulses were captured with minimum dead-time between them, ensuring efficient use of the record length
- The segments can be quickly and visually compared to determine if an anomaly appears in the overlaid display

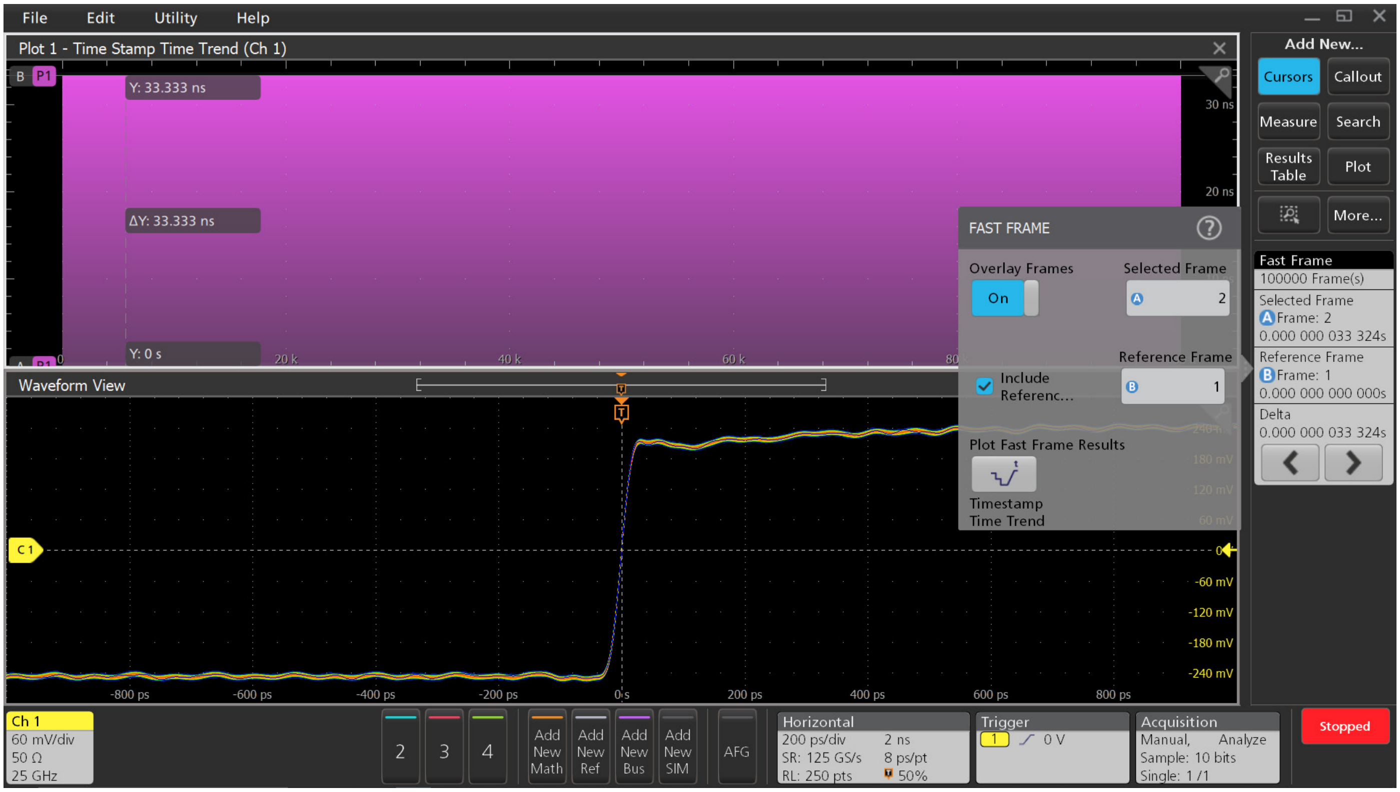


Figure 5. FastFrame Timestamp displays, showing the time delta between frames 1 and 2 in the results badge at the right side of the display. The pink time trend column chart at the top of the display shows that the time deltas between all 100,000 pulses are very consistent at approximately 33 ns between pulses or 30,000,000 pulses/second (>30,000,000 frames/second rate on 7 Series DPO only. >5,000,000 frames/second on 4/5/6 Series MSO.).

FastFrame Time Stamps

The waveforms in each of the frames tell only part of the story. There is also important information embedded in the absolute and relative timing of each of the frames. The timing of each of the trigger points is characterized with a time stamp. For example, **Figure 5** shows a rising edge captured with high resolution, but the FastFrame Time Stamps show that this edge occurs very regularly, with 33 ns between edges, a rate of 30,000,000 edges per second.

Trigger time interpolation provides very high timing resolution for each trigger timestamp, down to a small fraction of the sample interval. Timestamps are displayed with picosecond resolution. Although this resolution may not be applicable for absolute time-stamping of individual events, it can be very powerful when measuring time intervals between events (shown in **Figures 5 and 6**).

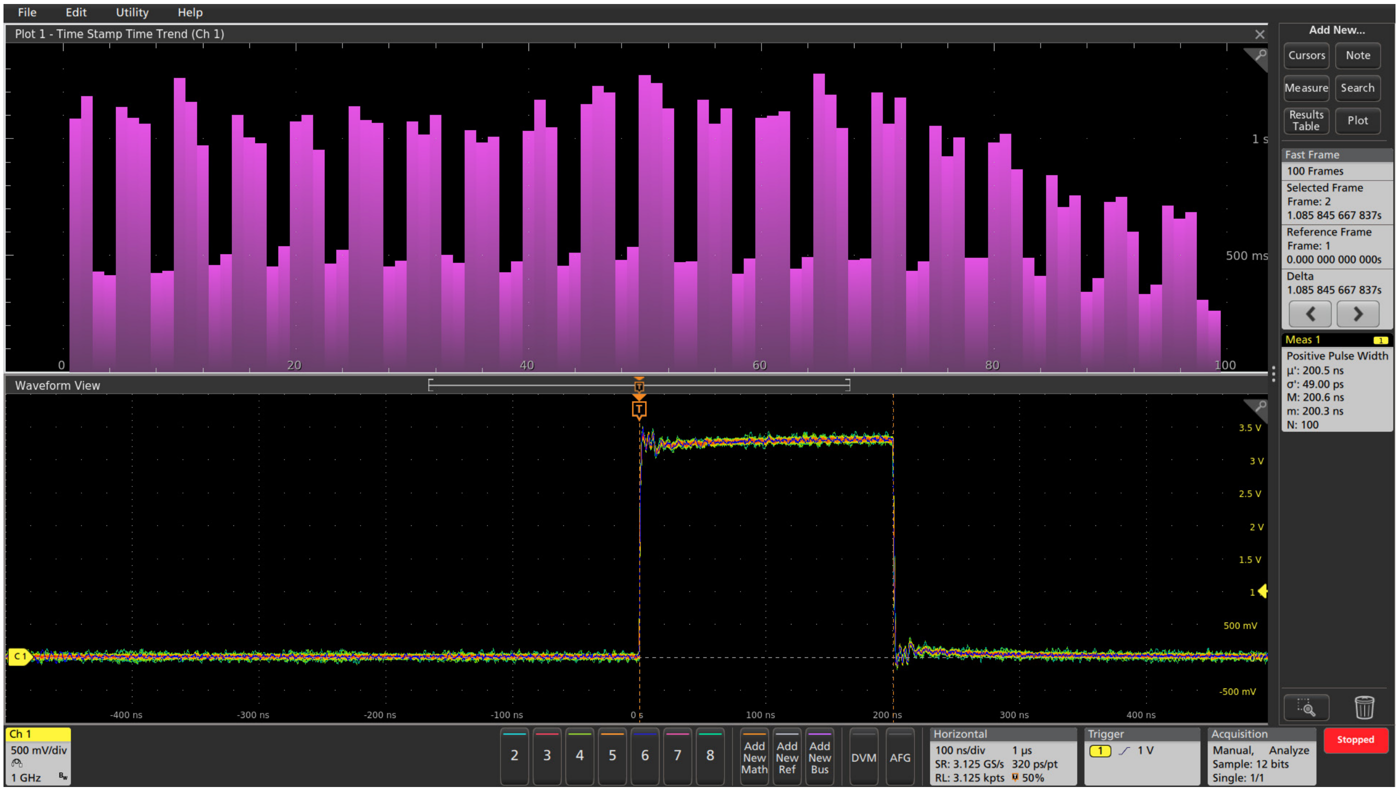


Figure 6. FastFrame timing characterization of intermittent pulses.

With FastFrame we are able to capture these intermittent pulses with high timing resolution while simultaneously making efficient use of record length by not capturing the time in between pulses.

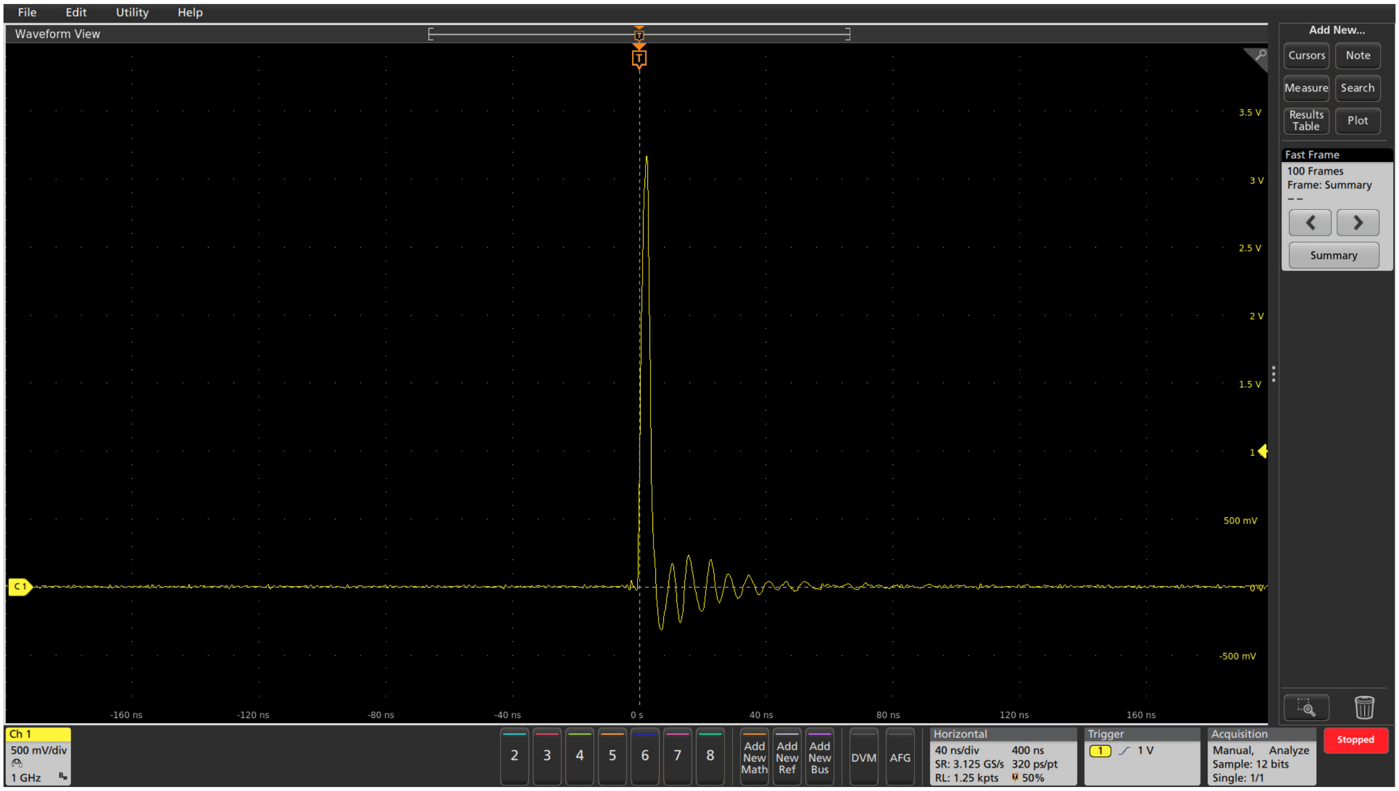


Figure 7. FastFrame display showing the Average Summary Frame on the right side of the the display (captured on 5 Series MSO).

Summary Frames

FastFrame segmented memory supports the standard Sample acquisition mode, as well as Peak Detect and High Res. FastFrame can provide an extra "Summary" frame at the end of the record. For Sample and High Res acquisition modes, an Average Summary frame can be added to show the average of the waveforms in all of the frames. For Peak Detect acquisition mode, an Envelope Summary can be added to show the maximum and minimum values of the waveforms in all of the frames.

FastFrame Averaging

The FastFrame acquisition function can be used to quickly acquire large sets of waveforms and create highly averaged waveform data. The kind of average waveform data that FastFrame produces depends on how the FastFrame acquisition is configured.

Average Summary Frame

When the Acquisition Mode is set to Sample, and both FastFrame and the corresponding Summary Frame are enabled, the Summary Frame will contain a waveform that is the average across all frames in the acquired Frame Set. In this configuration frames will be averaged together horizontally from Frame 1 through Frame N to produce a Summary Frame at the end of the Frame Set, as illustrated in **Figure 8** below.

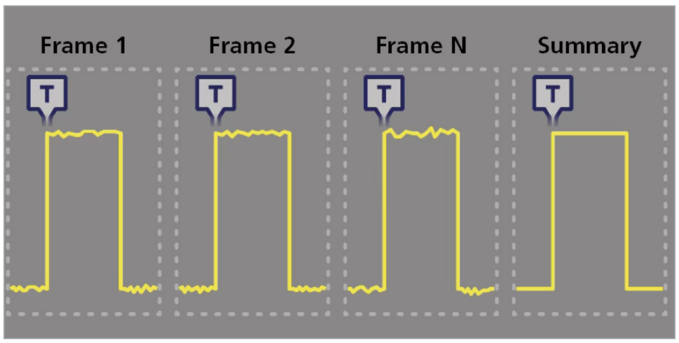


Figure 8. Average Summary Frame is calculated from averaging Frames 1 through Frame N.

The Average Summary Frame is useful for quickly acquiring many waveforms and producing an average waveform. It is especially useful when the trigger events happen very rapidly and would normally be missed without the use of FastFrame.

Orthogonal FastFrame Averaging (7 Series DPO)

When the Acquisition Mode is set to Average and FastFrame is enabled, averaging will be performed between frame sets rather than between frames contained in the same set. This is known as Orthogonal FastFrame Averaging. In this mode, frame averaging is performed vertically with Frame 1 of the Frame Set being averaged with Frame 1 of the next Frame set, Frame 2 with Frame 2 continuing all the way to Frame N as seen in **Figure 9** below.

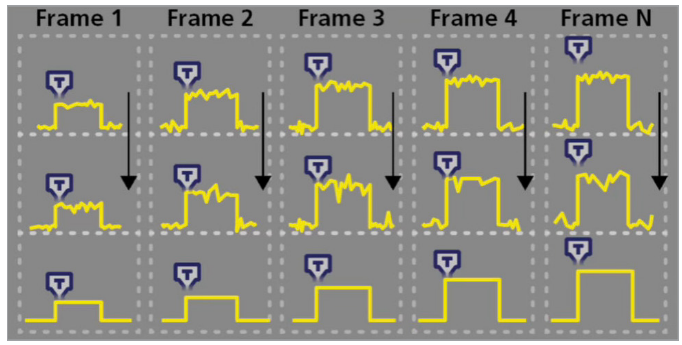


Figure 9. Orthogonal Summary Frame.

As each Frame Set is acquired, the acquisition count that makes up the average waveform contained within each frame increases by one. This results in a final Frame Set where each frame contains averaged waveform data. This differs from the Average Summary Frame, where only the Summary Frame contains average waveform data.

Orthogonal FastFrame Averaging is useful for acquiring repeatable, multi-step processes where averaging is required to get a higher signal to noise ratio. It is available on the 7 Series DPO and also available on the MSO/DPO70000DX and DPO70000SX Series.

Applications

Characterizing Intermittent Events - Pulse Waveform Characteristics

FastFrame Segmented Memory can provide a different type of functionality for digital designers. For example, if your microprocessor system is being infrequently interrupted, it can be difficult to gather timing information with an oscilloscope. If you don't know when or how frequently the event will occur, you can't set up the instrument in normal acquisition mode and be assured of capturing the information you need.

FastFrame Segmented Memory is ideally suited for testing intermittent waveforms such as microprocessor interrupts. In the example in **Figure 10**, the narrow digital pulses are spaced seconds apart. Using normal acquisition methods, the timing resolution of such pulse measurements would be very low, even when the oscilloscope's full record length is used.

FastFrame segmented memory captures the specified number of pulses to complete an analysis, while eliminating the "dead time" intervals between them. This saves memory, yet enables you to capture each of the pulses at high horizontal resolution. The measurement results badge at the right side of **Figure 10** shows that the pulse widths are measured, with a mean value of 200.5 ns and a standard deviation of about 49 ps. And the time trend column chart at the top of the display shows that some of the pulses are over 1 second apart.

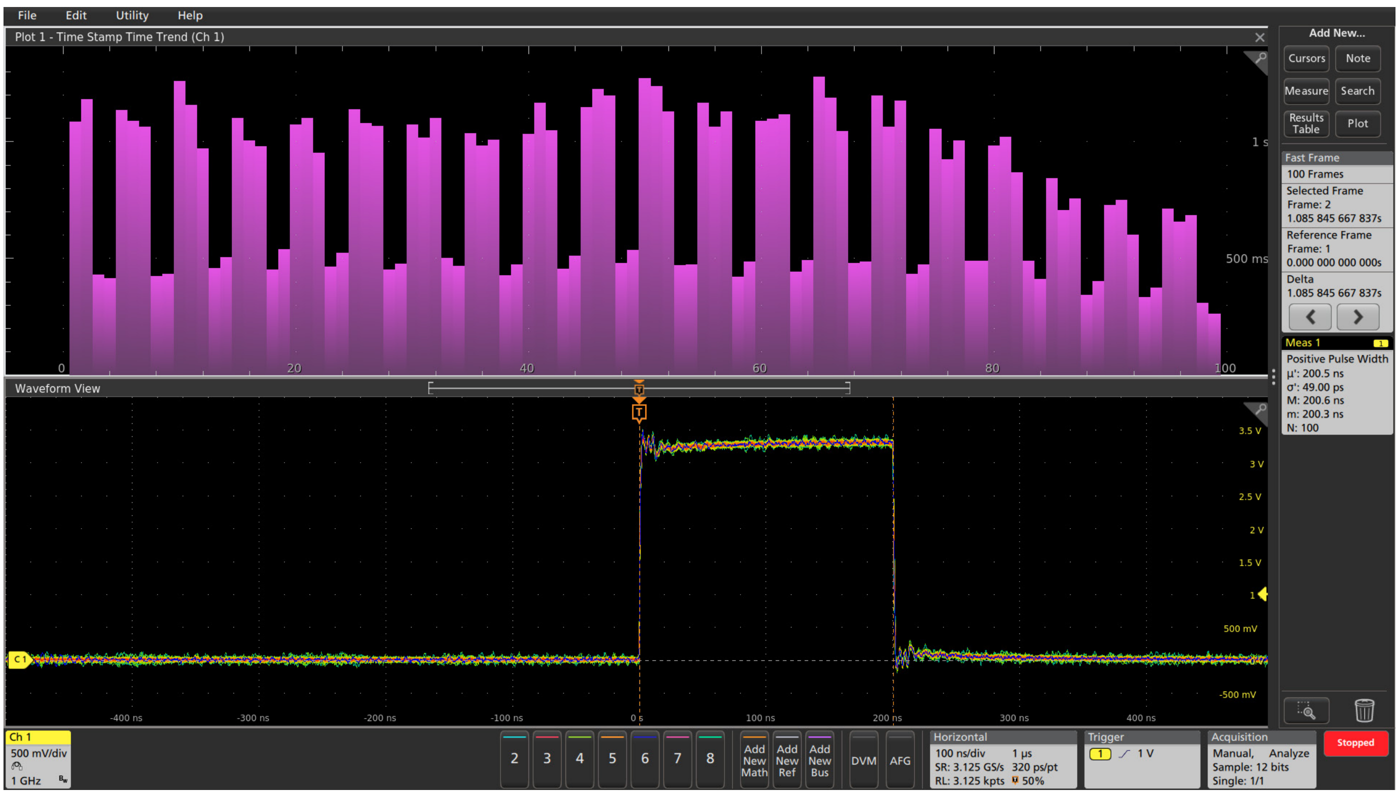


Figure 10. FastFrame timing characterization of intermittent pulses.

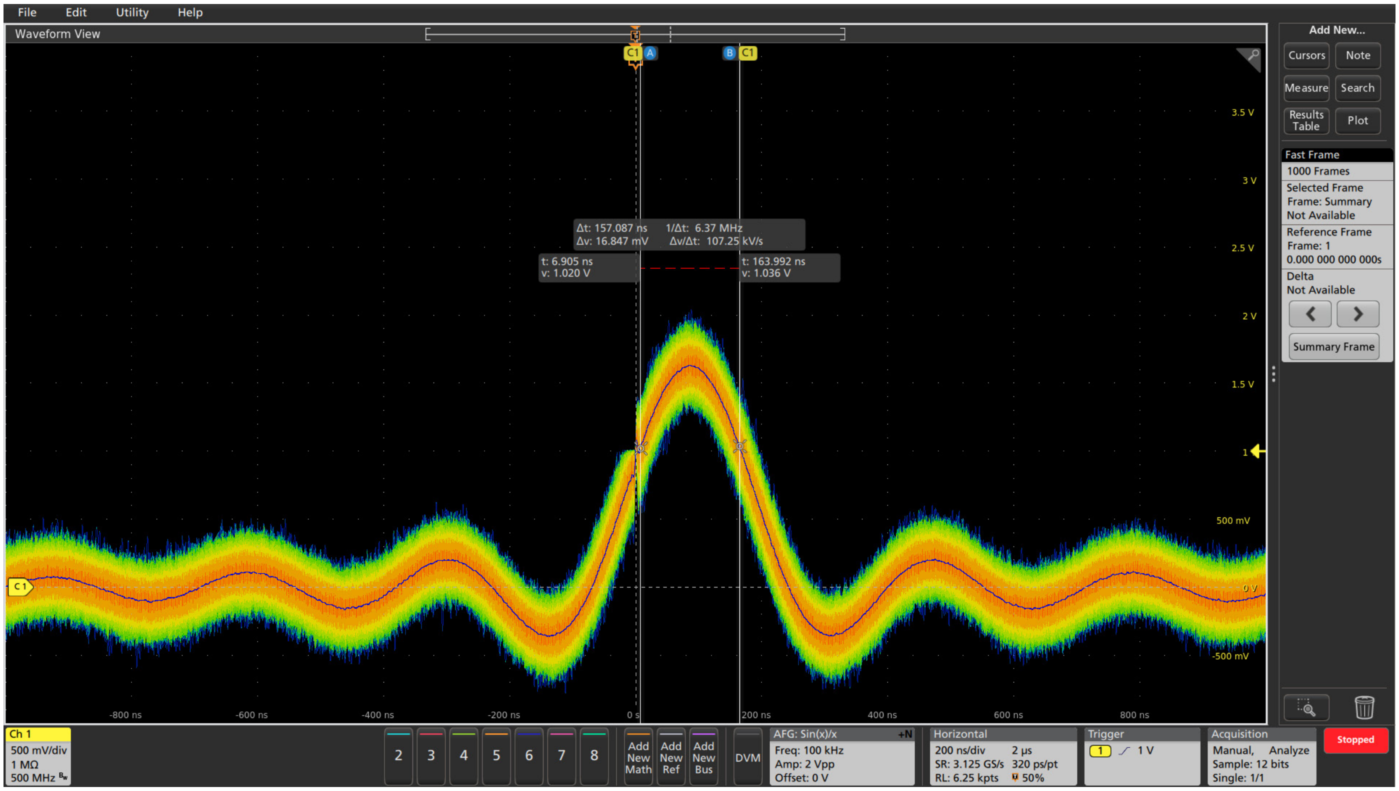


Figure 11. FastFrame average summary frame, represented by the thin trace in the overlaid frames, provides a way to make high-resolution measurements on repetitive and, in this case, noisy signals.

Improving the Signal-to-Noise Ratio (SNR) for a Repetitive Signal

FastFrame summary frames provide stable waveforms that can be used for making measurements on repetitive, noisy signals. As shown in **Figure 11**, 1000 noisy pulses are captured, overlaid and averaged. The resulting waveform can then be measured providing very high timing resolution pulse width measurement of the noisy signal.

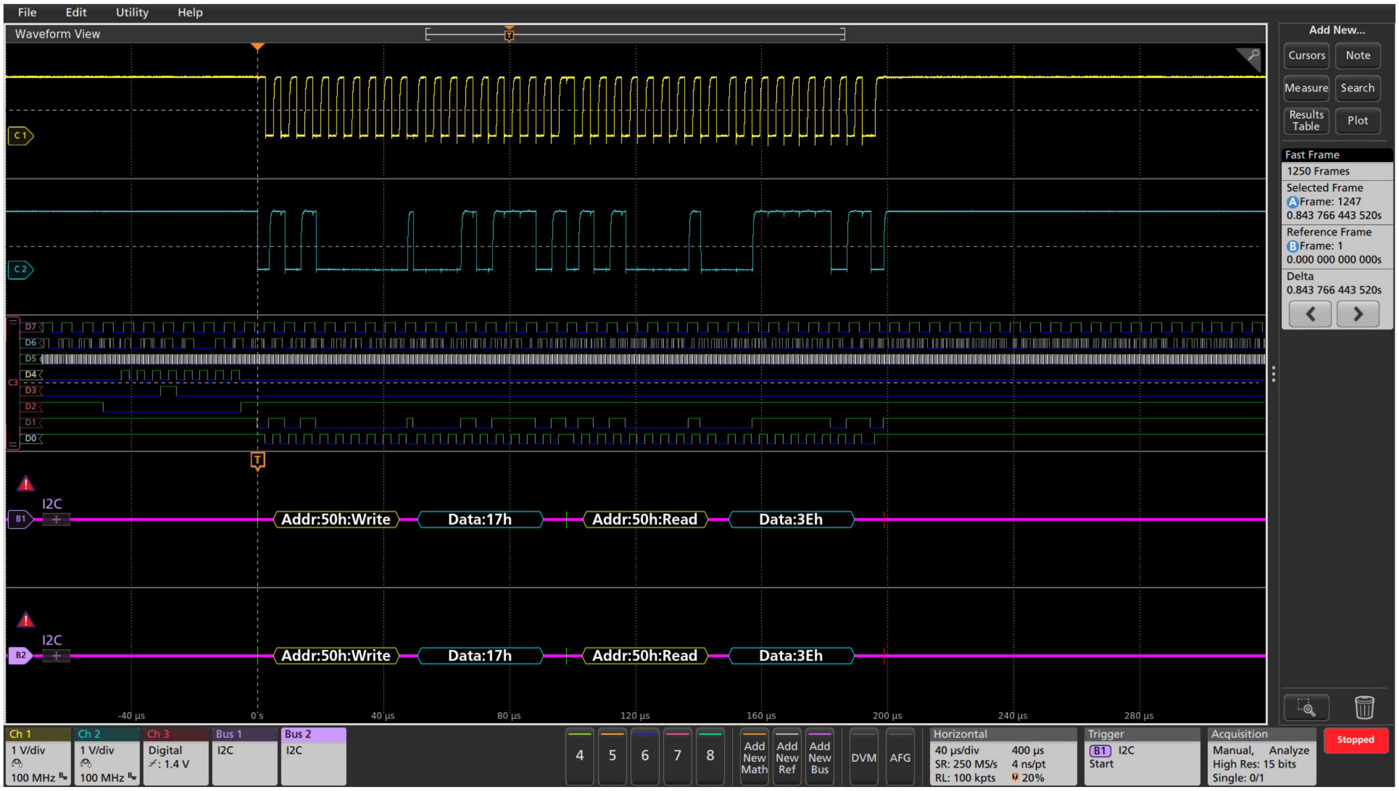


Figure 12. FastFrame acquisition of analog and digital serial bus signals, along with the decoded bus waveforms from each, capturing the bus activity and ignoring the dead-time between packets.

Decoding Bursty Serial Signals

FastFrame segmented memory allows more efficient use of the oscilloscope's record length. In the example shown in **Figure 12**, the I²C serial buses are inactive about half of the time. Using FastFrame effectively doubles the available record length. In this test setup, one bus is acquired using analog channels and the other is acquired using digital channels. The decoded bus waveforms from both buses can be easily compared.

In addition to displaying the decoded bus waveforms for the selected frame on the display, the time-stamped data can be presented in tabular format in a Results Table. For further off-line analysis and documentation, the decoded bus information for the entire acquisition can be exported to a .CSV file.

Figure 13. FastFrame can also be used to visually compare specific details between an acquired signal and a "golden" reference waveform.

Comparing infrequent events with "golden" references

The example in **Figure 13** shows a manual comparison between a stored FastFrame "golden" waveform reference and a FastFrame capture. The reference signal was captured from a known-good device under test and is loaded into a reference waveform. Using the reference waveform controls, a specific frame of interest is selected.

The same acquisition setup is then used to capture a similar signal on another device under test. The frame selection control can then be used to time-align the acquired frame with the reference frame for comparison.

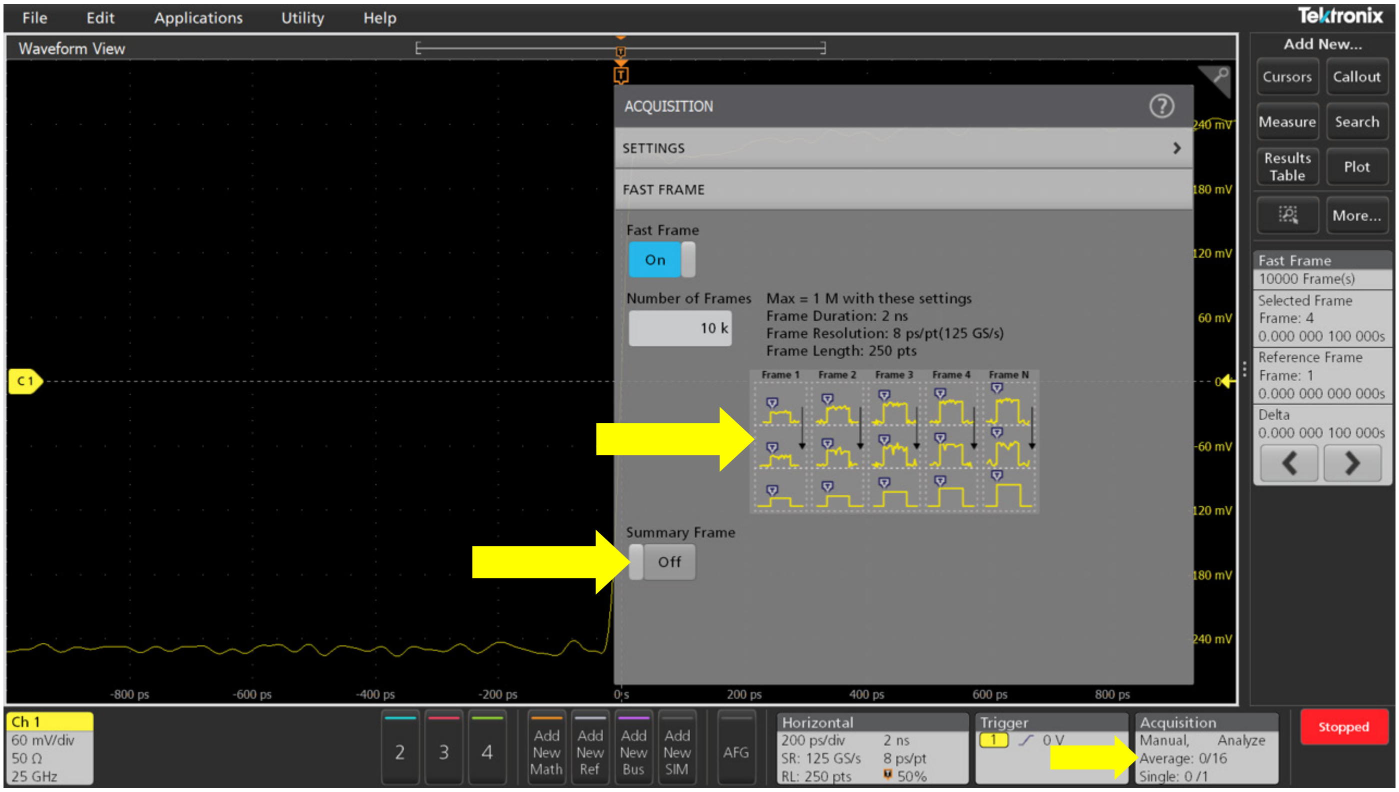
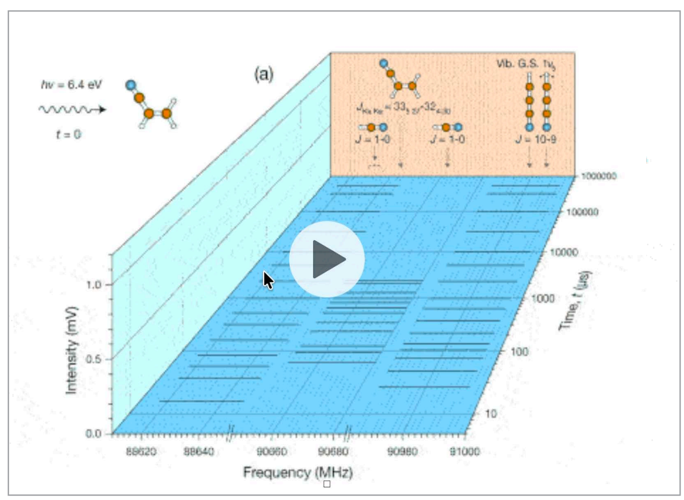


Figure 14. FastFrame's Orthogonal Frame Averaging (available on 7 Series DPO and DPO70000 Series only) used to produce a frame set that is the average across all of the acquired Frame Sets which is useful for acquiring repeatable, multi-step processes, (e.g., rotational spectroscopy), where averaging is required to get a higher signal to noise ratio.

Improving the Signal-to-Noise Ratio (SNR) for Rotational Spectroscopy

Rotational spectroscopy provides accurate identification of the constituent molecules in a gas mixture, as well as the ability to study moment-by-moment chemical reactions within the test chamber. One of the challenges of this application is the requirement for very high dynamic range on the acquisition system, due to the very wide range of amplitude of the spectral lines. Researchers make use of averaging to extend the dynamic range of the oscilloscope, which then places performance demands on the oscilloscope to perform hundreds of thousands to millions of acquisitions in the shortest time possible. The oscilloscope creates a set of average frames, which is taken from the acquisition of multiple frame sets, dramatically reducing acquisition time. Once the averaging is complete, what remains is the Average Frame Set, which can then be rapidly transferred to an external computer for further analysis.

For more information on Tektronix solutions for Rotational Spectroscopy visit: https://www.tek.com/en/solutions/application/research/rotational-spectroscopy



Hover over the image above and click to see the signal move over time.

Figure 15. Animated example showing the time evolution of a repeatable multi-step chemical process. Using FastFrame orthogonal averaging you can capture the process multiple times to improve the signal to noise ratio.

Above is the time evolution of the CP-FTmmW signals of HCN, HNC, and HCCCN following photodissociation at t = 0 of CH2CHCN obtained in the fine time resolution mode of the spectrometer. Reprinted (adapted) with permission from "Time-Resolved Kinetic Chirped- Pulse Rotational Spectroscopy in a Room-Temperature Flow Reactor" published in the Journal of Physical Chemistry Letters. Copyright 2018 American Chemical Society.

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Rev. 02.2022

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