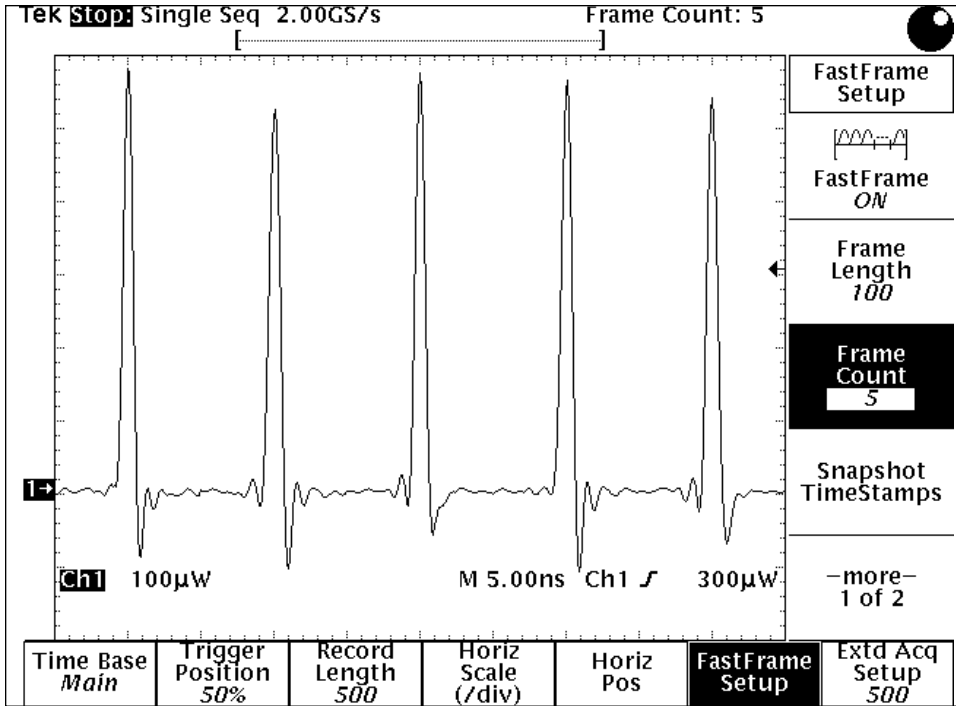


Using FastFrame Segmented Memory



Many of the problems faced in high-speed digital design and debug are characterized by infrequent or intermittent events. Laser pulses and metastable events in digital logic are two examples. To capture these events with the required resolution, both high sample rate and data capture over a long time duration are necessary.

This places extreme demands on oscilloscope performance. Even the most advanced

oscilloscopes have limited memory depth. Using higher sample rates means the acquisition memory fills faster and, therefore, decreases the total time window of data that is acquired. Conversely, capturing data over long periods of time usually means that the horizontal resolution (sample rate) is sacrificed.

With the high sample rates and bandwidths of today's oscilloscopes, the critical

issue is to optimize the quality of information captured by the oscilloscope. This includes:

- How to capture multiple events at the required horizontal resolution
- How to store and display only the necessary data

These and other topics are discussed in this application note.

Using Record Length to Your Advantage

Consider the single laser pulse shown in Figure 1. It was acquired in a 500-point waveform at a sample rate of 2 GS/s. At this sample rate, much of the waveform detail can be seen.

If, however, you want to view several consecutive pulses, you have to increase the time window you are capturing. This can be done by decreasing the sample rate or by increasing the record length. Decreasing the sample rate can be easily accomplished by turning the horizontal scale knob counter-clockwise, which increases the time/div but also may sacrifice horizontal resolution.

Alternatively, you can increase the record length, allowing you to increase the time window acquired without sacrificing sample rate. But this method also has its limitations. Even with the advances in memory technology, high-speed acquisition memory is still a precious resource. First of all, how much is enough? Even with what you might consider to be a long record length, you may still not be able to capture that last, and perhaps most critical, event.

As you can see in Figure 2, the time window was increased by 5000 times to capture three consecutive pulses. This was done by increasing the record length and holding the sample rate constant. This larger acquisition comes with some disadvantages:

- Larger acquisitions increase the storage requirements in NVRAM and on disk drives
- Larger acquisitions affect I/O transfer rate; i.e., GPIB throughput
- Faster memory and more processing power translate into a higher price to the user
- Because the oscilloscope has more

information to process, the period of inactivity (dead time) between acquisitions increases, resulting in a decrease in the update rate

With these trade-offs in mind, you must continually balance the need for high sampling rates with the available memory length per channel.

Segmented Memory Architecture

Many strategies have been formulated to solve this problem. One popular method is the “Segmented Memory” scheme. Oscilloscopes equipped with segmented memory allow you to divide the available memory into a series of segments. Each segment is then filled with a triggered acquisition at the desired sample rate.

By carefully defining trigger conditions, this technique allows you to capture only the waveform, or waveform segment, you’re interested in. Each captured event is then stored in its own numbered memory segment or frame. Multiple memory segments, or frames, can then be concatenated and displayed in the order they were captured. This feature essentially allows you to remove unwanted sections of the waveform so you can focus on the signal of interest.

Figure 3 illustrates this approach. Using the Fast-

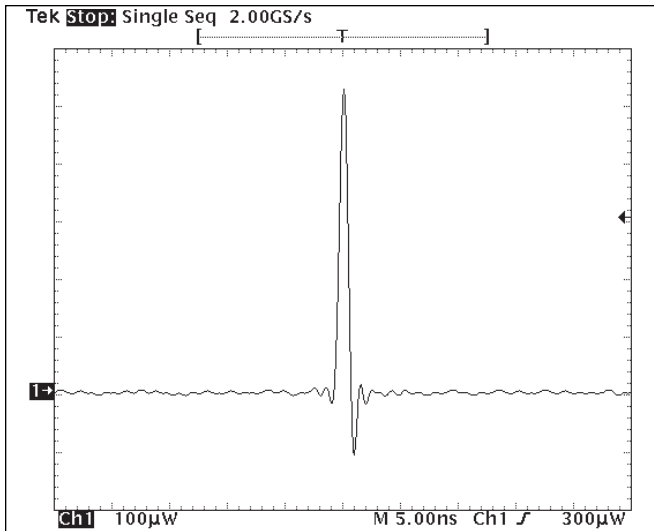


Figure 1. A single laser pulse captured at high resolution.

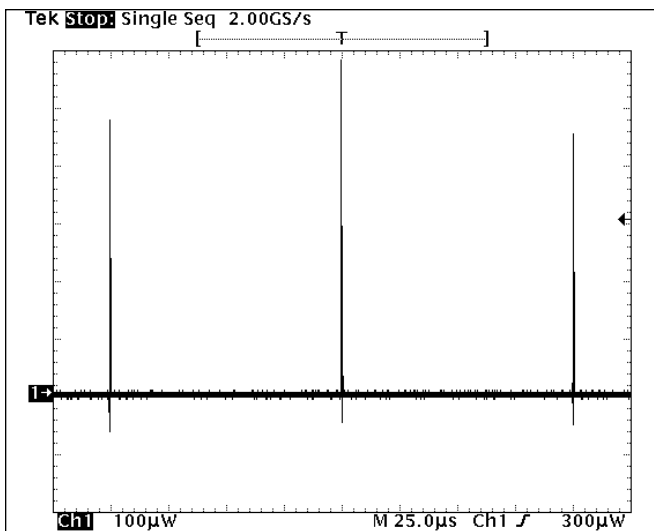


Figure 2. Multiple laser pulses captured at high resolution with long record length.

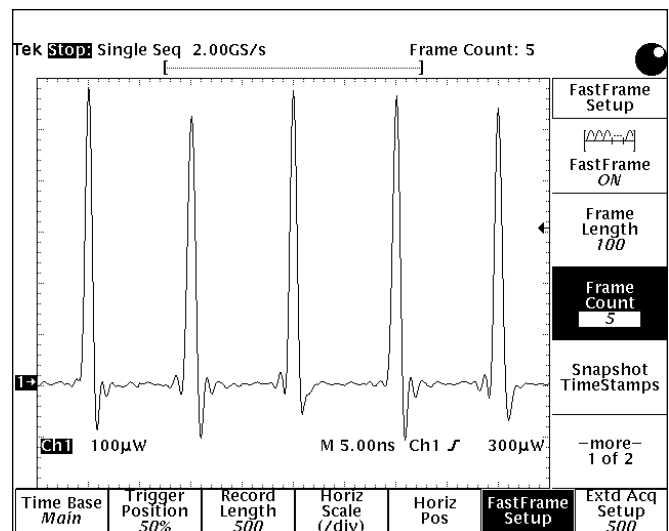


Figure 3. Using the TDS FastFrame segmented memory, multiple laser pulses can be captured at full resolution.

Frame segmented acquisition memory in the TDS 784D scope, the same laser pulses are captured at a sample rate of 2 GS/s with the same small record length as shown in Figure 1. The segmented memory has been concatenated so that all of the pulses appear on the screen simultaneously. The waveform detail has been preserved by using high sample rates and all of the pulses were captured because the available memory was segmented.

Frames and Frame Sizes vs. Record Length

The TDS FastFrame lets you partition the available acquisition memory into frames (memory segments) of 50 to 50,000 samples each, and acquire as many as 372 frames (1,489 frames with Option 2M) of data. This capability, coupled with the high processing speed of Tektronix' proprietary Tristar™ (DSP) processor, gives FastFrame a burst trigger rate of 80,000 frames/sec (acquisitions/sec), which equates to a maximum dead time of 12.5 microseconds – a significantly faster trigger rate than available on many other oscilloscopes.

The TDS automatically computes and selects the required record length when you set the number of frames and the number of points per frame (frame length). It computes the product of the number of frames and the frame length, and selects the nearest record length that is greater than or equal to the product. If the product exceeds the maximum available record length, the TDS automatically reduces the frame length or number of frames such that the product will fit the record length.

The display is concatenated; i.e., the frames are linked together in succession to form a normal waveform record. This allows you to use the ZOOM function to see the details of each frame, and scroll through the indi-

vidual frames using the horizontal position control. The position frame control in the FastFrame menu can also be used to step through the frames, automatically placing the trigger point of the selected frame in the center of the screen.

Averaging/Enveloping of Frames

FastFrame supports all TDS acquisition enhancement modes (Average, Hi-Res, etc.) except the equivalent-time sampling mode. When FastFrame is used with the Envelope or Average modes, the TDS adds an extra frame at the end of the concatenated record. This extra frame is the computed envelope (maximum and minimum values) or average of the previous frames.

For example, when the Average mode is used with FastFrame and the frame count is 10, the TDS calculates the average of the 10 frames and displays the averaged waveform as the 11th frame. If the Envelope mode is used with FastFrame, the TDS computes the maximum and minimum values of all waveforms in the 10 frames and displays these values as an enveloped waveform in the 11th frame. (If the acquired waveform data for a selected frame fills the selected record length, the last frame is deleted and replaced with the averaged or enveloped frame.)

In the Sample, Peak Detect, and HiRes modes, the concatenated frames contain the triggered acquisitions of the respective modes – no additional frame is attached at the end of the record.

Time Stamping of Acquisitions

The waveforms in each of the frames tell only part of the story. There is also important information embedded in the timing of each of the frames. Each of the trigger points carries along its timing information which is called a time stamp. By analyzing the time stamps, you can determine

when each event occurred, as well as the relative time between events.

Time Resolution

The timing of the trigger is determined and displayed with very high resolution. By a process of time interpolation, the trigger timing is resolved to a small fraction of the sample interval. At high sample rates, this can be less than a nanosecond. Although this resolution may not be interesting for time stamping an individual event, it's a very powerful tool when measuring time intervals between events.

FastFrame User Interface

When FastFrame is on, the first menu page gives the basic controls to define and navigate through an acquisition. This menu allows you to select the frame length and the number of frames. It also allows you to select which frame (the position frame) to display at the center of the screen.

The second page of the menu contains the time stamp on/off control and two frame selection controls. The reference frame can be any frame, but is often the first frame in the acquisition. The position frame is the frame that is always displayed at center screen. The reference frame is the starting frame and the position frame is the ending frame for relative measurements.

The time stamp readouts (which displace the measurement readouts in the upper right corner of the graticule) display the time stamps for the reference frame, the position frame, and the time difference between the reference and position frames. The time stamps are displayed in a format which shows date (day, month, year), clock time (hours, minutes, seconds), and fractions of a seconds (milliseconds, microseconds, nanoseconds, picoseconds).

Applications

Evaluating Start-up Phenomena in a Switching Power Supply

The start-up interval in a power electronics circuit generally places the most electrical stress on switching transistor components. To verify that power transistors are operating within specified limits during the start-up interval, the transistor's voltage and current waveforms must be captured simultaneously. The relationship between the two signals can then be analyzed for compliance with specifications.

Traditionally, a storage oscilloscope is used to capture the entire start-up interval. This method, however, sacrifices timing resolution for recording time. Even with a record length long enough to capture the entire interval, the oscilloscope may not provide the resolution needed to see transition dynamics. In other words, the oscilloscope spends the bulk of its time capturing the time between transitions rather than the transitions themselves.

Figure 4 shows the start-up waveforms in a switching power supply circuit. The upper waveform is the transistor's collector-to-emitter

voltage (V_{ce}). This floating voltage was captured using a P5205 high-voltage differential probe. The lower waveform is the collector current (I_c). It was captured with a TCP202 current probe.

The most dramatic transition dynamics appear in the first few cycles, where the power supply is charging up the storage capacitors. To capture this 1 millisecond sequence with a 5,000-point record length means that the sampling rate is limited to 5 MS/s, or 200 ns per sample. And even though you could zoom in on the transitions after the waveform is captured, the results would not accurately show transition dynamics with sufficient horizontal resolution because the risetime of the signal may be less than the sample interval. FastFrame offers a unique solution to this problem. It allows you to trigger on and display only the switching transitions. In this example, we're not interested in how I_c ramps up after the transistor has saturated (where V_{ce} is near zero). What we are interested in is the power dissipated in the device while the transistor voltage is falling.

Using FastFrame, you only capture the part of the waveform that is of interest.

Figure 5 shows the start-up interval captured using FastFrame. A frame event is defined as the falling edge of V_{ce} , in order to examine the turn-on dynamics. Five frames are selected at 1000 points per frame to use the same overall record length of 5000 points. The time interval of each frame is set to 1 microsecond to adequately capture a turn-on transition. But more importantly, each transition is captured at 1 GS/s, or 1 ns between points. For the same record length (5000 points), the sampling resolution using FastFrame is improved by a factor of 200. With the relevant information captured in much greater detail, post-acquisition analysis is not only more accurate; it's greatly simplified.

Also notice that in Figure 5, the math waveform of dissipated power ($V_{ce} * I_c$) was calculated. The peak power, measured with gating on the third pulse shows a peak power of 11 W. All of these advanced features are available with FastFrame.

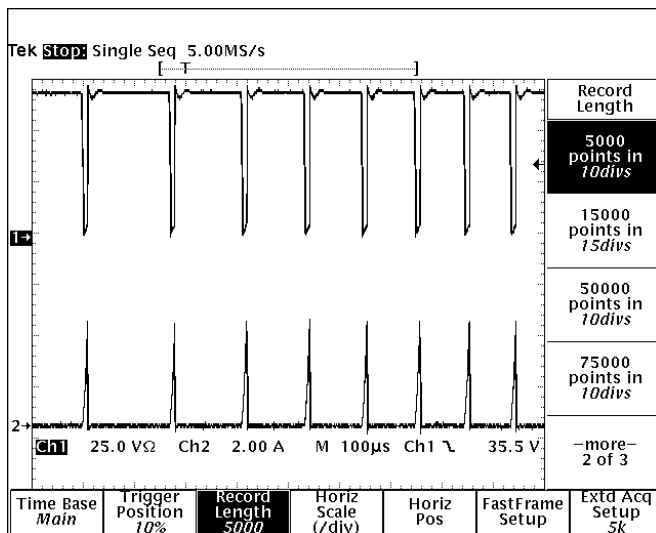


Figure 4. A switching transistor's V_{ce} and I_c waveforms during power supply start-up.

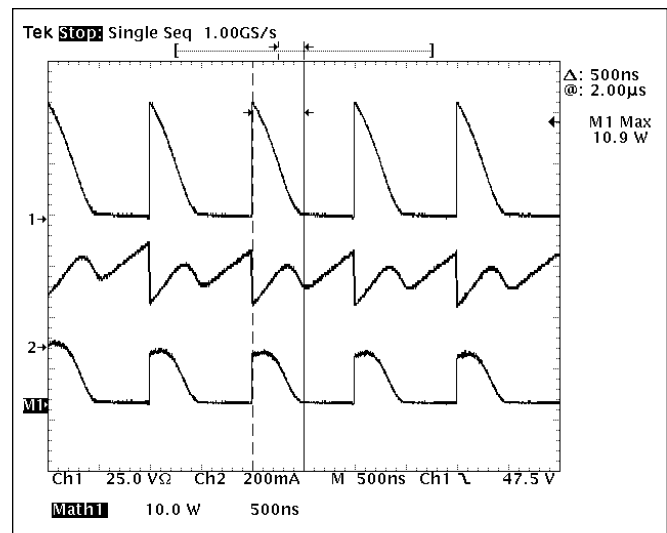


Figure 5. A FastFrame acquisition of the transistor's V_{ce} and I_c waveforms during power supply start-up. Automatic parametric measurements can be made on individual frames using measurements with measurement gating.

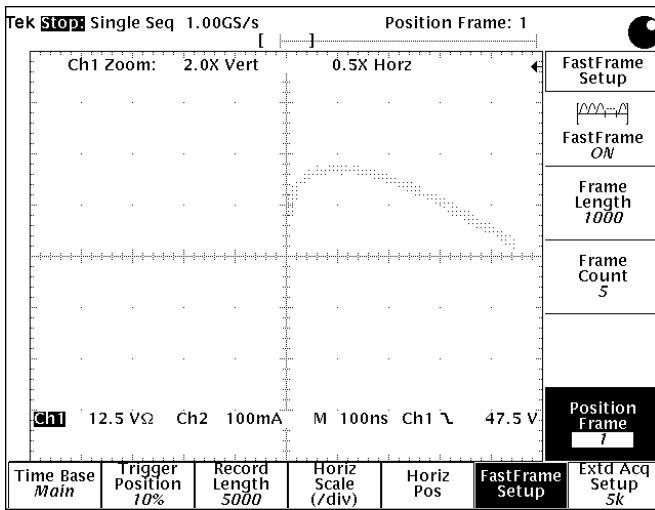


Figure 6. A safe-operating-area display of a switching transistor's V_{ce} vs. I_c .

Now that V_{ce} and I_c have been simultaneously captured, the two waveforms can be parametrically related to verify that transitions occur within safe operating area (SOA) limits. Recall that without FastFrame, the low sampling rate provided only 200 ns between samples – giving questionable parametric resolution for transition times of a few hundred nanoseconds. Figure 6 shows I_c vs. V_{ce} for the first turn-on transition, of the first frame. Fast Frame allows you to display the I_c vs. V_{ce} trajectory on a frame-by-frame basis. Plus, you can zoom in on each waveform pair in the normal XY display mode as you step through each transition.

Comparing Infrequent Phenomena – Laser Pulse Characteristics

FastFrame is ideally suited for testing in the pulsed laser environment. In this example, the circuit generates infrequent optical impulses. We are primarily interested in the shape of the waveform in this case. We want to capture each of the infrequent pulses at high horizontal resolution. The signal is connected to channel 1 via a P6703B optical-to-electrical converter.

We've elected to use the Envelope acquisition mode to capture the maximum and minimum values of the laser pulses over a series of acquisitions. Select FastFrame

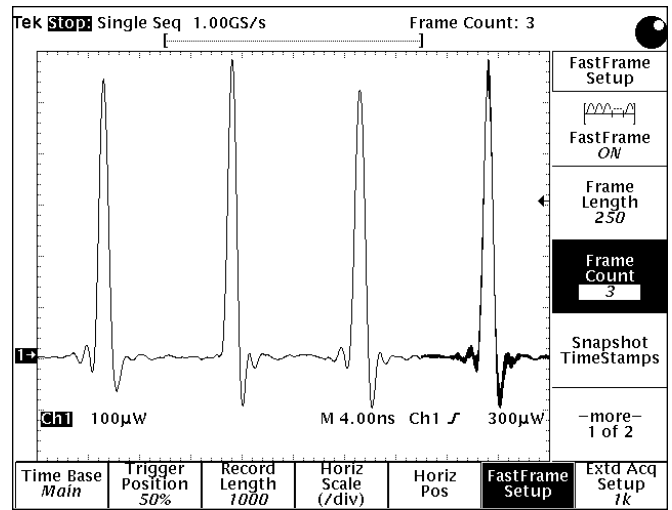


Figure 7. A FastFrame capture of a series of laser pulses. The final frame contains an envelope (min/max) display of all of the acquired frames.

Setup from the Horizontal Menu and set the frame length at 250 points with a frame count of three. The TDS automatically adjusts the Record Length to at least the product of the frame length and the number of frames; in this case, 1000 points.

Next, turn FastFrame ON. The screen goes blank momentarily as the TDS acquires three pulses and concatenates them for display. Since we are using the Envelope acquisition mode, the TDS concatenates and displays four frames (Figure 7). The fourth frame is the envelope (maximum and minimum values) of the previous three frames.

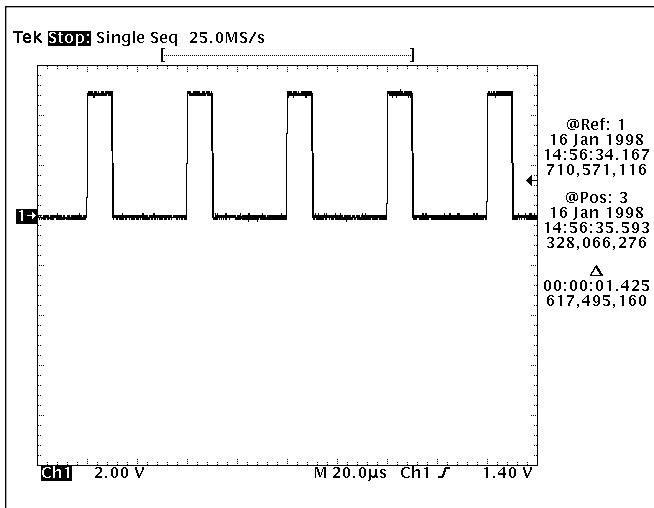


Figure 8. Timing measurements between microprocessor interrupts can be easily made in FastFrame mode.

Debugging Errors with Time Stamps – Intermittent Microprocessor Interrupts

FastFrame can provide a different type of functionality for digital designers. For example, if your processor 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 scope in normal acquisition mode and be at all sure of acquiring the information you need.

However, FastFrame can do this easily. In this example,

the active-high interrupt strobe is measured to be about 10 microseconds wide, so we set up the scope to capture 5 frames of 1000 points, with each frame 40 microseconds long. In this application, the shape of the pulse is not of particular interest, but rather we're interested in the time of the pulses' rising edges.

The trigger point in each frame has a time stamp associated with it. These time stamps can be displayed on the screen in the measurement readout area at the right side of the screen as shown

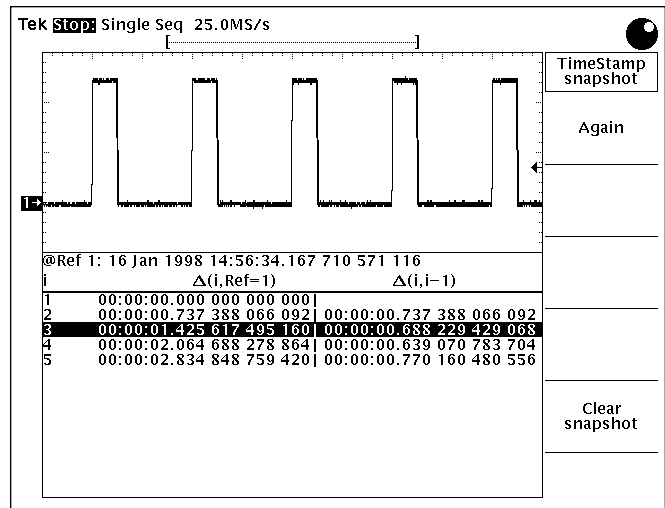


Figure 9. FastFrame Time Stamp Snapshot display shows the relative time between microprocessor interrupts.

in Figure 8. The reference frame was chosen to be the first interrupt pulse and the position frame (at the center of the screen) is the third pulse. The absolute times of these pulses are shown, as well as the relative timing offset between them.

The time stamps of all of the frames can also be displayed, as shown in Figure 9. In the time-stamp snapshot display, the left-hand snapshot shows the times relative to the reference frame (frame 1 in this case) and the right-hand column shows the times relative to the preceding frame.

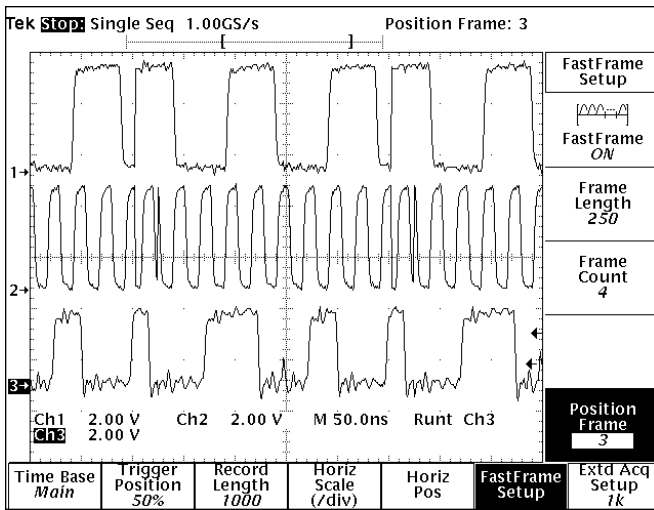


Figure 10. A cause/effect analysis using FastFrame in multi-channel mode. Channel 1 is a data signal, channel 2 is the clock, and channel 3 is the resulting signal with runt pulses caused by a setup/hold time violation.

Comparing Intermittent Events – Metastability

In digital design and test applications, intermittent timing differences between a data signal and its clock can be difficult to detect. Since the set-up and hold violations often occur infrequently, capturing a series of these events, with the high sample rates needed to see them, normally requires very long memory. However with FastFrame, you can isolate a number of these events from the rest of the signal at the desired high sample rate.

In this example, we'll examine the operation of a flip-flop in a circuit. We've connected a data input signal to Channel 1 of a TDS scope, the clock to Channel 2, and the data output to Channel 3.

Since we want to capture the anomalies caused by set-up and hold violations, we define the trigger parameters to catch runt pulses in the output signal. Set the trigger Type to Pulse, the trigger Class to Runt, the trigger Source to Ch3, the Polarity to either, and the Thresholds to TTL threshold levels.

Now, set the FastFrame parameters. Set the Frame Length to 250 samples and the Frame Count to 4. This selects a record length of 1000 points. Turn FastFrame ON and then enable single sequence acquisition mode by selecting Stop After Single Acquisition Sequence in the Acquire Menu. Using the Position Frame control in the FastFrame Setup menu, you can examine the input and

output signals at the trigger time in all of the frames. By using the multi-channel acquisition capability of FastFrame, we're able to quickly compare the causes and effects of several suspected setup and hold violations. In this example (see Figure 10), we can determine that the problem is a set-up violation, where the data signal is going low too close to the rising edge of the clock. In each case, the result is a positive runt pulse.

We can also zoom in and examine each frame in detail. For example, to compare the second and fourth runt pulses on Channel 3, dual-window zoom can be used as shown in Figure 11 to overlay the pulses for visual comparison.

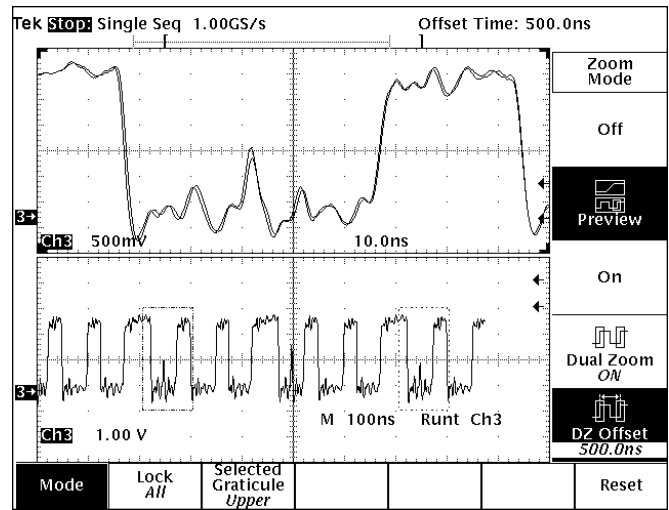


Figure 11. A comparison of intermittent anomalies using zoom with FastFrame acquisition. Notice the dual-window zoom selection boxes in the lower graticule and the overlaid runt pulse waveforms in the upper graticule.

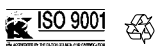
Conclusion

In applications requiring both high sample rates and long record lengths, adding more memory is not always the answer. In situations where a series of infrequent or intermittent events are to be captured, the TDS FastFrame function provides an ideal means to capture only the necessary events. By seg-

menting the acquisition memory and providing a trigger for each memory segment, FastFrame optimizes information content and offers smarter usage of a limited resource. With time stamps, the timing information for each frame retains the required timing information without storing the entire waveform.

For further information, contact Tektronix:

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