Glitch Hunting Techniques

APPLICATION NOTE

October 22, 2010

Summary

Intermittent transient events and glitches are among the most frustrating problems to solve. This is especially true if you have no idea about the nature of the transient. LeCroy oscilloscopes include tools to help capture and locate these pesky transients. This paper will focus on techniques for glitch hunting.

WaveStream and WaveScan

WaveStream™ is a fast update acquisition mode and WaveScan™ is an advanced search and analysis capability that allows the user to find waveform conditions rapidly. Both are available in LeCroy's WaveMaster 8Zi, WavePro 7Zi, WaveRunner-Xi series and WaveSurfer-Xs oscilloscopes.

WaveScan provides the ability to use over 20 search modes, different from hardware triggers, to do a simple search and find for an event on a single acquisition. It also allows a user to perform a continuous "scan" for data in many acquisitions, with the scope set to stop, save data, save images, etc. when the condition is found. In addition, "found" events can be overlaid or histogrammed with advanced tools.

WaveStream provides a vibrant, intensity graded (256 levels) display with a fast update to closely simulate the look and feel of an analog oscilloscope. WaveStream is most helpful in viewing signals that have signal jitter or signal anomalies. Timing jitter is often visually assessed to understand approximate behavior. WaveStream makes it easy to understand jitter on edges or in eye diagrams. WaveStream also excels in allowing you to relate composite (WaveStream) to single-event (real-time sampled) behaviors. This last function is even more powerfully evident when used with WaveScan a waveform search function that offers 20 different search criteria.

Consider the example shown in Figure 1. This is a WaveStream history of a timing synchronizer. The bottom trace (C4) is the input signal. The upper trace (C3) is the output of the synchronizer. The synchronizer uses a 400 MHz clock and it is expected that the edge of the output signal would have a timing uncertainty of 2.5 ns which is uniformly distributed. The WaveStream history shows multiple acquisitions overlaid in a persistence display. Most of the output signals are clearly within the expected 2.5 ns range. WaveStream has caught a single output waveform that is late by at least a full clock period. The Delta Time at Level (dt@lv) parameter has been used to quantify the measurement. It shows a range (max-min) of delay values between the input and output that spans a range of 5 ns or 2 clock periods.

Figure 1: 1 A WaveStream history showing a timing anomaly in a timing synchronizer

At this point we can use LeCroy's WaveScan tool, to record a long acquisition with a large number of events and search for the anomaly. WaveScan lets the user search for non-monotonic edges, specific measurement conditions and common trigger related conditions like runts and glitches. WaveScan finds events that triggers alone can't find. Also, it searches in a single acquisition, or scans multiple acquisitions until an event is found. It is standard in most LeCroy XStream™ oscilloscopes and in the WaveRunner Xi, WavePro 7Zi, and WaveMaster 8 Zi scopes it offers additional advanced analysis features.

In this case, we will search a long acquisition using a measurement. The ability to search on a measurement is unique in the test and measurement industry. In our example we will search based on a dual input skew parameter. The WaveScan setup is shown in Figure 2. It is searching for delay measurements greater than 55 ns, a value we have learned from the WaveStream measurement. Filter methods include greater than, less than, within limits, outside of limits, and rarest events.

The scope is setup to acquire 5 ms of data. This is shown in Figure 3. The skew parameter statistics readout for the number of measurements indicates that almost 12,500 events are contained in the acquisition. WaveScan automatically indicates all instances of the measurement meeting the search

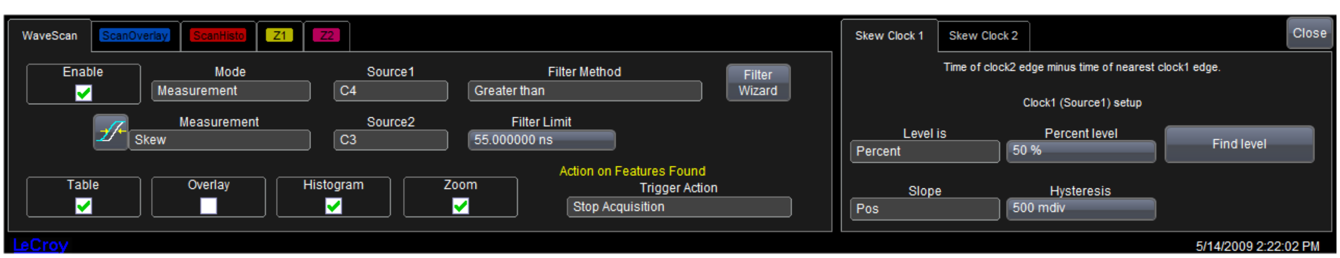

Figure 2: The WaveScan Setup using a dual channel measurement parameter

criteria. These can be seen as red lines extending through the upper traces. The lower trace (Z1 and Z2) are a zoom expansion of a user selected anomaly. In this case we have shown both the input and output trace. These traces are time locked using LeCroy's Multi-Zoom feature so that timing information is maintained. Touching any entry in the table will cause the zoom traces to pan to the location on the waveform corresponding to the entry meeting the search criteria.

As you can see these two great features of LeCroy oscilloscopes complement each other providing the ability to detect and analyze timing and other problems in great detail.

The WaveScan search feature is available on all LeCroy XStream oscilloscopes but the scan overlay and histogram analysis functions are only found in the WaveRunner-Xi, WavePro, and WaveMaster product lines. WaveSurfer-Xs only incorporates

Figure 3: The WaveScan overlay, histogram, and zoom displays

The center traces shown the scan overlay of all detected anomalies, and a histogram of the measured parameter values of the selected events. In this case the histogram includes all events listed in a table in the upper left hand corner of the figure. ScanHistogram accumulates over multiple acquisitions (it will have more information over time than just the table will). ScanOverlay and Table are always 100% correlated – they are both on a single shot of data.

The search function. does not contain this advanced analysis capability. The WaveStream fast update display is contained in the WaveMaster 8 Zi, WavePro 7 Zi, WaveRunner-Xi and WaveSurfer-Xs oscilloscopes.

Exclusion Triggering

Exclusion triggering can be applied to periodic waveforms such as clock signals. These waveforms have a nominal shape that does not change with any regularity. Most transients manifest themselves by abnormal timing. The idea behind exclusion triggering is to measure the signal's nominal timing and to trigger the scope whenever the signal is outside the nominal range of values. In effect, exclusion trigger is really 'lying in wait' for the event. You can combine exclusion trigger with the fast update rate achievable using sequence mode acquisition to capture intermittent abnormal signals at rates as high as 1,000,000 times per second. This can give much more insight into signal faults than older technologies, which trigger fast, but which capture mostly the "normal" shape signal.

Figure 4: Using parameter measurements to determine the exclusion trigger limits.

The square wave clock shown in Figure 4 is a typical example of a periodic clock waveform. We can use measurement parameters such as period, width, frequency, or duty cycle as the basis of an exclusion trigger. In this example we have chosen pulse width. Measure the pulse width using parameter statistics to determine the minimum and maximum values for a typical waveform. In the example in Figure 4 the nominal pulse width is 0.996 µs with a minimum value of 0.995 µs and a maximum value of 0.998 µs. From this data you can set up an exclusion trigger based on the pulse width. The scope will trigger if the input pulse width is outside the range of 990ns ± 10ns.

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In Figure 5, the trigger setup using SMART Trigger® based on pulse width:

The scope will trigger if a pulse has a width of less than 980 ns or more than 1.00 µs. Pulses with widths in the nominal range are excluded from scope acquisitions. An example of a step shaped pulse with an abnormal width is shown in the acquired channel 2 trace in the figure.

Figure 5: The setup of a SMART Trigger exclusion trigger using pulse width

Sequence mode acquisition breaks the scope's acquisition memory up into as many as 20,000 segments. Each segment acquires a single sweep, and the scope holds off all non-acquisition related functions until all the segments are filled. This means the scope operates with minimum dead time between acquisitions. The update rate in sequence mode can be as high as 1,000,000 sweeps per second even when using all four channels of the scope. So the total acquisition rate of signals can be over 1,000,000/sec. This rate of acquisition is maintained beginning from the time that the acquisition is started until the sequence mode buffers are filled. In addition to fast update rate, the scope time stamps each acquisition. This tells the user the time interval between trigger events. When exclusion trigger is used the sequence mode time stamps tell the time between glitches. This information can be invaluable because it provides additional information about phenomena causing the glitches. Figure 6 shows a sequence mode setup controlled from the Timebase dialog box. The user can set the number of segments to be acquired.

In this example there are 20 segments in each sequence acquisition. The sequence mode acquisition in Figure 6 is displayed as adjacent segments. This is one of five sequence mode display types that can be selected from the Display dialog box. Figure 7 shows the same data displayed in mosaic display format. Here the 20 segments are displayed in an array of up to 80 segments.

Sequence mode time stamps, found under the Channel Status selection under the Vertical pull down menu provide both the absolute time of each trigger event as well as the relative time between events. This can be seen in Figure 8. In this figure the time between transient events is from 0.52 to 1.6 seconds. Exclusion triggering based on signal timing such as width, period, frequency, or duty cycle is a quick way to spot glitches and other signal anomalies. As mentioned earlier it can only be applied to periodic waveform like clocks. For more general types of waveforms, the use of the Track math function, combined with long memory, allows users to capture, locate, and isolate waveform glitches.

Figure 6: The sequence mode setup in the Timebase dialog box

Figure 7: Displaying the sequence waveforms in the mosaic type display

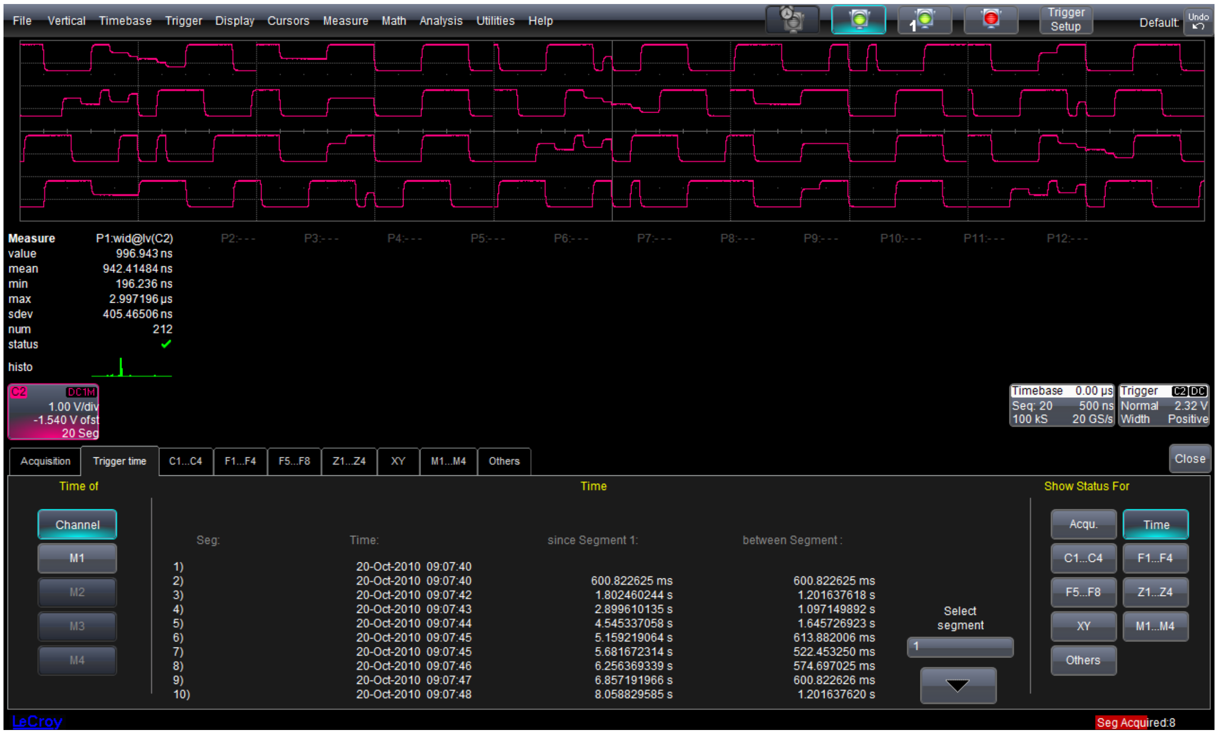

Figure 8: The display of the trigger time stamps showing the time between transient events

TriggerScan

Exclusion trigger is a very useful tool; but, in order to make the best use of SmartTrigger LeCroy has developed TriggerScan™

TriggerScan is a function, incorporated in the WaveMaster 8 Zi and WavePro 7Zi oscilloscope families, that automates the two key processes in the use of the trigger system to find rare events. It automatically trains by looking at normal acquired waveforms and generates a list of smart trigger settings to trigger on abnormal situations. It then automatically loads trigger setups from the list generated and cycles through these settings. As triggers occur, they are overlaid on the screen.

Figure 9 shows the TriggerScan tab on the Trigger dialog box.

Selecting a trigger source and pressing the Trainer button brings up the TriggerScan Trainer setup. This allows the user to select which types of trigger events to search for. The default setting is to search for all. The users can elect to reduce the number of searches based on their experience.

After training the Trigger Scan dialog box will list all the possible trigger types and appropriate parametric settings as shown in Figure 10. These settings can be modified and/or archived for future use. When the training is complete pressing the Start Scan button will initiate the search for glitches.

Figure 9: The TriggerScan tab shown just prior to "training" TriggerScan

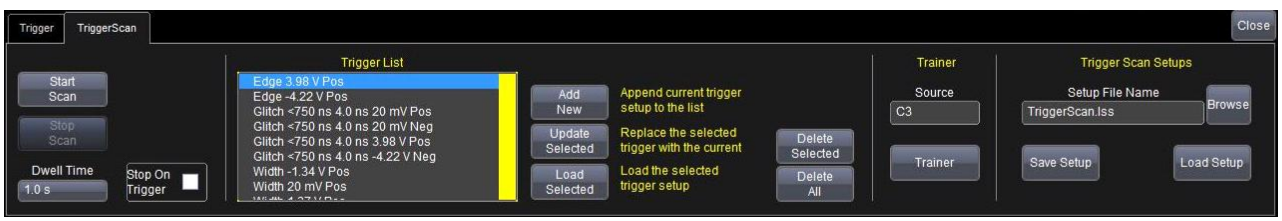

Figure 10: The TriggerScan scroll list after TriggerScan training

TriggerScan can run continuously, with a user settable dwell time for each search, or it can be set to stop on a trigger event as shown in Figure 11. The highlighted entry in the Trigger List shows that the trigger setting used to capture this anomaly was a Glitch trigger with a width< 750 ns. TriggerScan trigger setup lists can be edited manually and stored for future use.

TriggerScan is a unique feature of LeCroy oscilloscopes and brings the following advantages:

For rare events and for high edge rates, it will find anomalies faster than the fast update modes on competitive scopes.

It does not just show a picture of the anomalies – waveforms (even long waveforms) are available for further processing just like always.

Since TriggerScan uses the trigger system, it can find a trigger setup that will trigger on the anomaly therefore solving the isolation problem (with fast update, the scope user is left with a picture of the error and must figure out himself how to set up the smart trigger)

Figure 11: The result of a TriggerScan capture of a glitch. The highlighted entry in the TriggerList shows that the trigger setting used to capture this anomaly was a Glitch trigger with a width <750 ns

Parameter Track Functions

The math track function creates a waveform showing the history of parameter values that is time synchronous with the source waveform. Figure 12 shows the track function of pulse width (lower trace) displayed along with the source waveform. The vertical scale of the track waveform is pulse width in ns. Note that the changes in track amplitude are time synchronous with the changes in the source waveform. The track function can be created from any of the scopes over 140 parameters.

The best way to use the track function is to apply it to a long record and use the track function to point at waveform anomalies or glitches.

In Figure 13, the trace F1 is the track of width. The vertical spike represents a high width value. The location of the spike is time correlated with the occurrence of the narrow glitch in the data record. Since there are 2,500 pulses in the record, the ability to locate a single anomaly is a clear advantage. If we create a zoom trace of channel 3 and expand it about the spike in the track using Multi-Zoom, we can see the transient. This process is shown in the lower two traces in Figure 13.

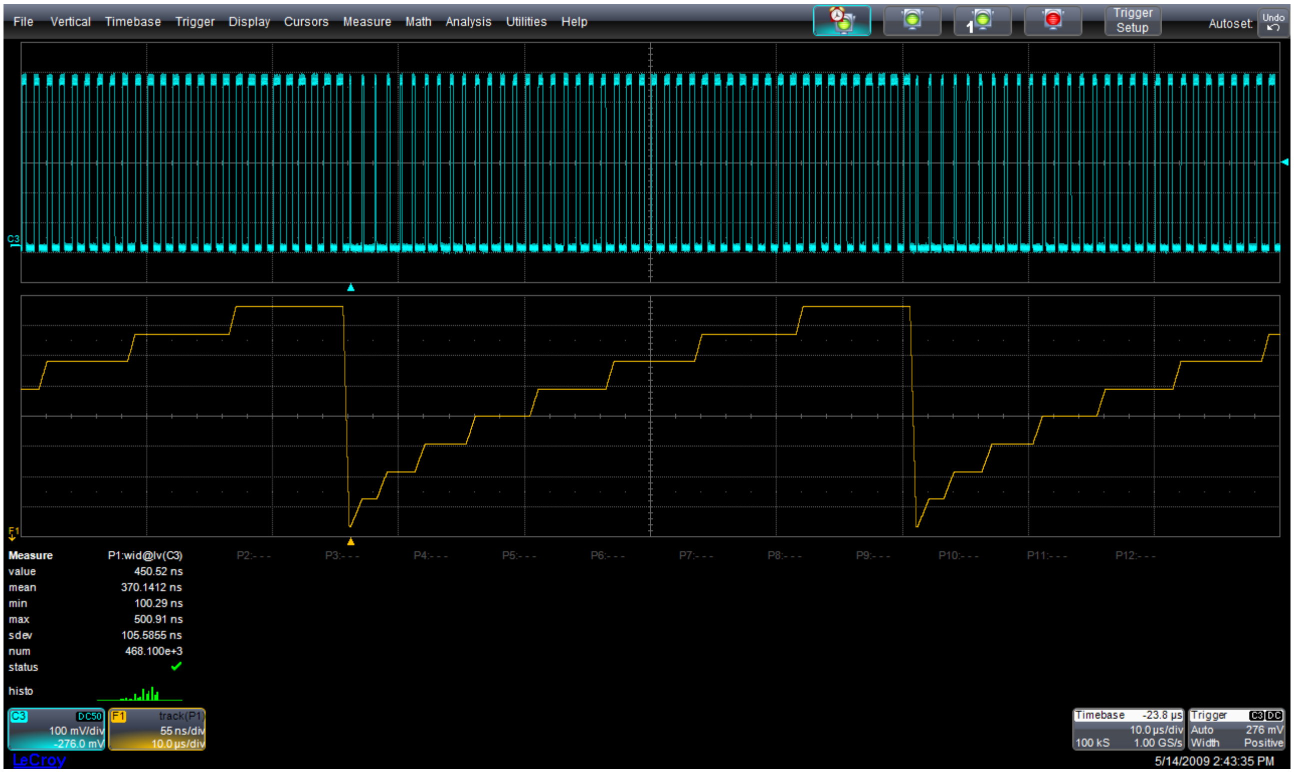

Figure 12: An example of the track function of pulse width along with its source waveform

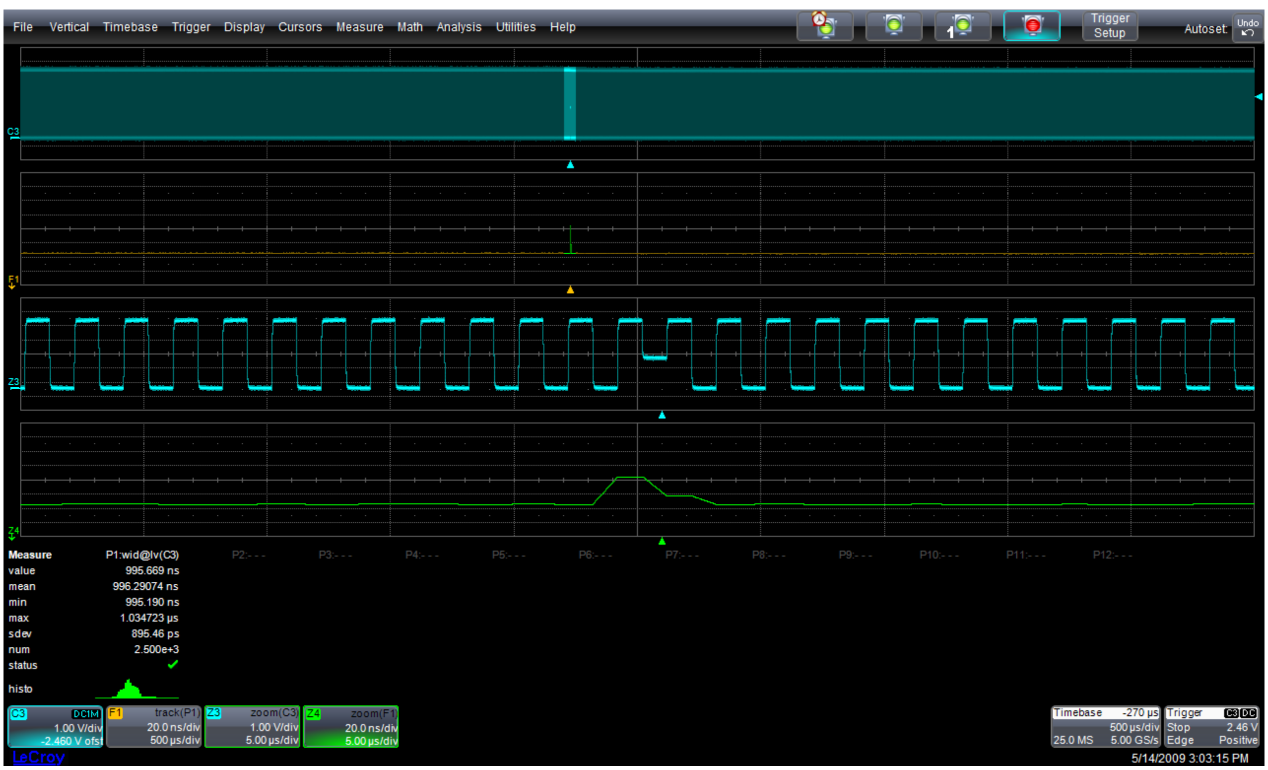

Figure 13: Capturing a glitch in a long record and using Multi-Zoom to see it in detail

Histograms

Histograms of measured parameters provide a statistical view of the "glitch" phenomena. The histogram can provide information about the number, size, and frequency of occurrence of glitches. In Figure 14 a histogram of pulse width has been used to analyze the width of all pulses acquired. The same Pass/Fail criteria is still being used (980 ns<width<1 µs). Histogram specific parameters have been set up to read the mean, standard deviation, range, and width value with the highest frequency of occurrence (X@Peak).

Sequence mode acquisition is also being used to improve the measurement update rate. Because sequence mode holds off all non-essential operations during acquisition, it can greatly increase the scopes update rate. Longer acquisition (sweep) times and higher number of segments generally yield faster update rate. The principal trade-off is shorter memory length (since each sequence mode acquisition uses only a fraction of the total memory), which in some cases can cause a lower sampling rate. These settings require some trade-offs that each user has to evaluate while making the measurements. The key thing to remember is that, through the use of Pass/Fail testing the glitch catching process is automated and the user can set it up and do something else while the scope fully documents the glitches it captures.

The results of making 16 million measurements are that, in addition to the nominal pulse width (996 ns), there are glitches with widths of 196 ns, 396 ns, 1.58 µs and 2.99 µs. There were 14 of these anomalous pulses during the measurement.

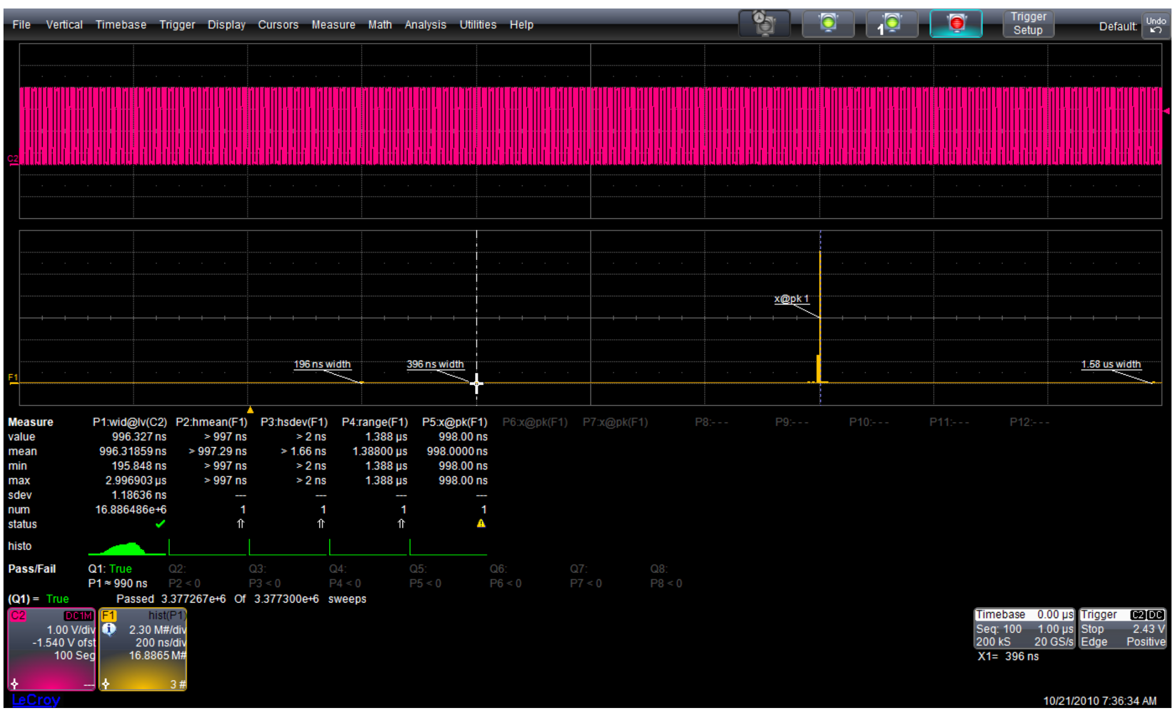

Figure 14: Combining histograms, Pass/Fail testing, and sequence mode

Eye Diagrams

When serial data waveforms are measured, the traditional glitch catcher is the eye diagram. Whether triggered directly from a symbol clock or a clock derived from the data stream, the eye diagram represents a very simple way to look at multiple data transitions using a persistence display. Signal fidelity can be evaluated using Pass/Fail testing based on masks and/or parameters. Figure 15 shows a typical mask- based test of an eye diagram from a LeCroy Serial Data Analyzer model SDA816 Zi. This type of mask testing automatically locates and shows bits that violate the mask. All LeCroy digital scopes can create eye diagrams and test them. Options, such as SDM Serial Data Mask test make the setup and operation of eye testing available in most LeCroy Scopes.

We have seen several approaches that use LeCroy oscilloscopes to detect, locate, and isolate glitches and other transient events. If you have any problems, contact your local LeCroy sales office and ask to speak to one of our applications engineers concerning your glitch detection needs.

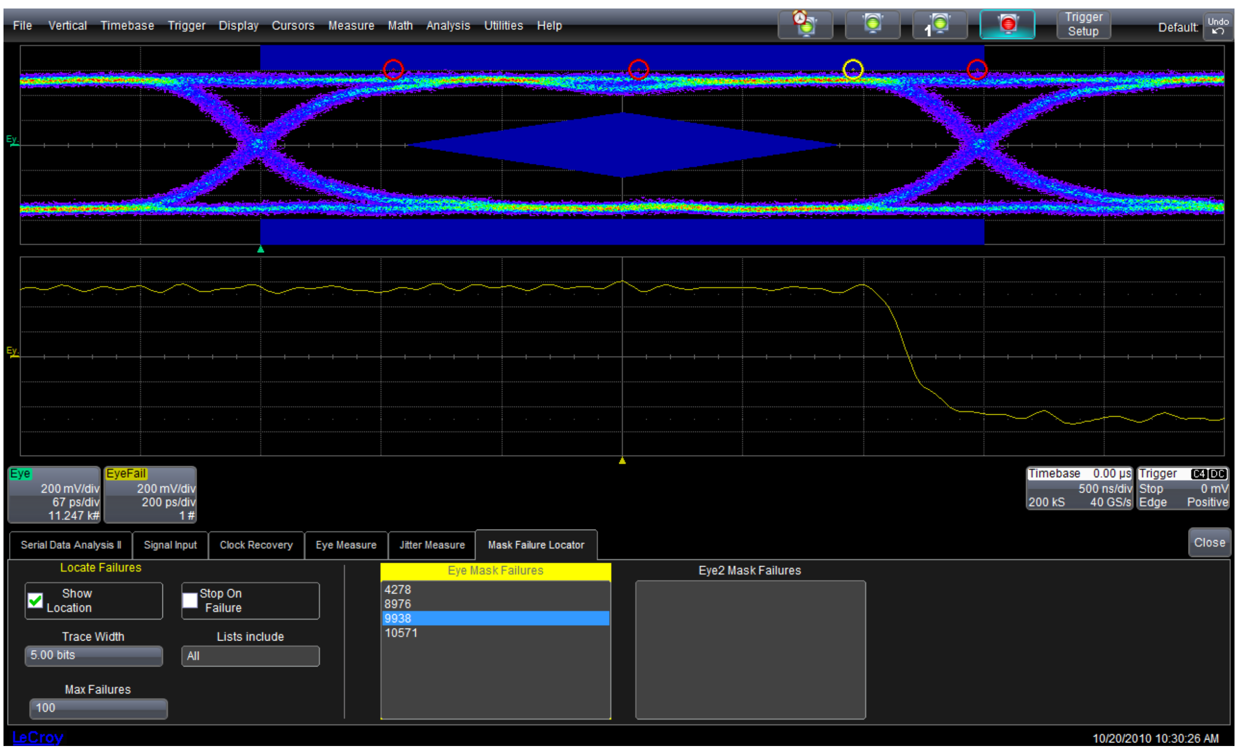

Figure 15: A mask test on a 2.5 GB/s serial data stream showing a mask violation error and the serial bit that caused it