Finding Intermittent Signal Faults Using Replay Mode

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Summary

Intermittent signal aberrations are some of the most difficult and frustrating problems to identify and troubleshoot in electronic circuits. They are expensive in costs of engineering time and time to market delays. In the worst case, a rare intermittent circuit fault may not be noticed until mass production has started and the customers notice the problem.

For these reasons, oscilloscope vendors have incorporated a variety of tools in modern digital oscilloscopes to help design and test engineers locate intermittent signal faults. These tools range from those which are simple and very easy to use, perhaps with less ability to find circuit failures, to very advanced analysis which can spot difficult problems but require very advanced training in oscilloscope use (and it may only be available on expensive oscilloscopes). This paper gives advice on using Replay mode, a unique tool in the WaveJet series of oscilloscopes from LeCroy Corporation. Replay is very easy for the user to invoke and offers a fast method to clearly view, and make measurements on, intermittent signal behavior.

Perhaps the simplest tool in digital scopes for spotting occasional aberrations in signal shape is the use of persistence mode. For the last 15 years, just about every brand/model of oscilloscope has offered this mode. When persistence is turned on, the sample points of many acquisitions are placed on the screen (as opposed to "normal" mode which shows one signal capture at a time). The problem with persistence mode is that it often has too much information. With dots from many acquisitions on the screen, the image can become very cluttered and it becomes difficult to view/understand what is happening with the signal. The important acquisition, the one with unusual signal shape, might be masked by the dots from sample points of many uninteresting acquisitions. Or you might see a piece of an unusual signal, but the remainder of the signal is hidden in the forest of noise from the other acquisitions. Another drawback of persistence mode is that it is often difficult to make measurements on persistence display data. Most oscilloscopes cannot make parameter measurements on persistence mode waveforms nor can they do an FFT or other types of math.

Using Replay Mode

Replay mode on the WaveJet series of oscilloscopes allows the user to let the oscilloscope trigger many times and overlay the sample points of those acquisitions on the display. At any point the user can stop the acquisitions (if something "interesting" has happened) by pressing "stop" trigger and then view recent acquisitions by turning the Replay knob (Figure 1).

Figure 1: The front panel of a WaveJet. When something interesting appears on the screen the user can press "stop" trigger and then rotate the Replay knob (upper right) to view or measure up to 1024 recent individual waveform acquisitions.

The user starts with a view of multiple acquisitions with all the sample points on the screen (persistence mode), but can then view each waveform one at a time (like a "normal" oscilloscope display) with the Replay knob. This allows the user to clearly see each waveform and also to make cursor, parameter or math measurements on the individual waveforms. The most common method of troubleshooting an intermittent signal fault is to somehow observe one occurrence of the fault. Then set up a trigger which will watch for only the aberrant shape signal. This allows the user to consistently trigger on the fault, measure its rate of occurrence, make measurements/math that lead to insights and also to probe around the circuit to see what other signal might be associated with the failure (maybe power supply noise is associated with the intermittent fault). Replay mode can capture up to 1024 separately saved signal waveforms so it is also possible to see a history of waveforms that occurred before and after the "interesting" one. And by getting a clean view/measurement of the aberrant waveform, Replay often enables the user to figure out how to set up a trigger for that type of event.

Examples of Real Troubleshooting

Figure 2 shows an example in which many acquisitions of a signal have been acquired. Displays like this occur in all brands/models of scopes when they are in persistence display mode. In this figure we are viewing all of the sample points from all of the acquisitions. There are at least two types of waveforms in the display that might catch your attention. The first is a fairly small number of waveforms that are occurring much earlier in time than the main concentration of data. And at least one of those "early" waveforms looks like a double humped pulse rather than a simple single pulse. The other types of waveforms that might be interesting are a fairly large number of lower amplitude "runt" pulses which show up toward the right hand side of the display (i.e. they are coming somewhat later in time than the average pulse position). Overall this is a pretty complicated display and we might benefit from being able to see the interesting waveforms without the rest of the clutter. For example, one guess of what is happening in the circuit might be that there is an intermittent reflection problem which might cause some pulses to have a double peaked shape followed later by a small runt pulse. Figure 3 shows a single waveform (number 487 of the 1024 waveforms in Figure 2) which came early and has a double hump shape, but it does not

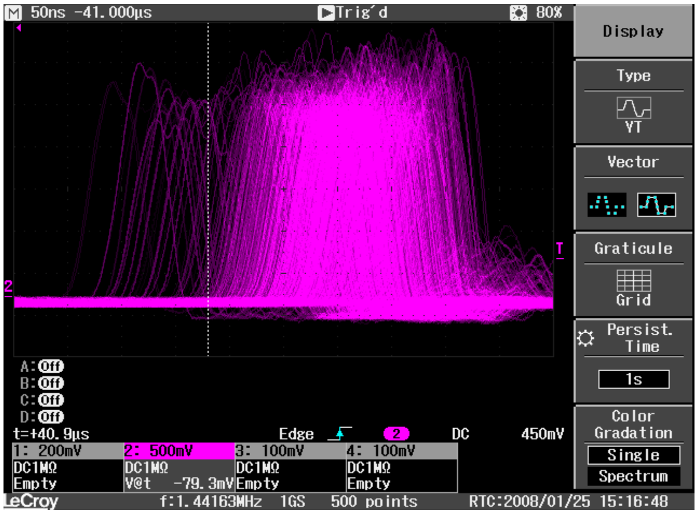

Figure 2: Many waveforms have been acquired by a WaveJet. The user could get a better view of the "early" waveforms (some with double hump) or "late" waveforms (with small amplitude) without the rest of the clutter on the screen by using Replay mode.

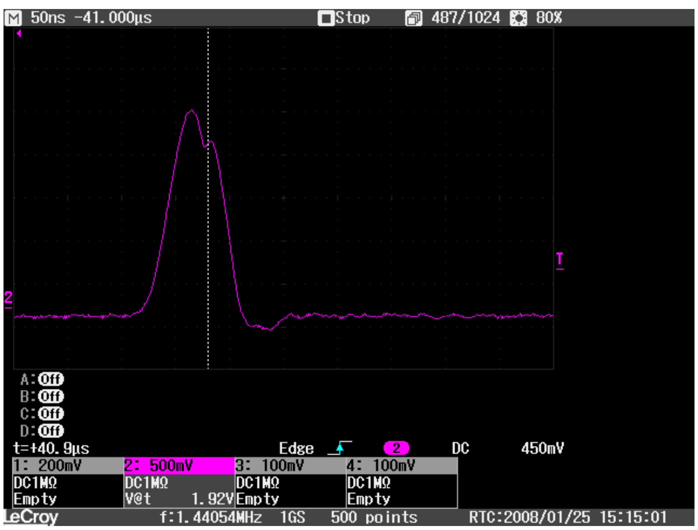

Figure 3: Note in the upper right this is the 487th waveform in a set of 1024 waveforms that are available for viewing using Replay. In this case the user can cleanly see what one of the "early" waveforms looks like.

have a small runt pulse later in the display. A cursor shows the voltage level where the waveform pauses on the falling edge (about 1.92 volts). You could make a measurement of the delay time between the top peak in this waveform and the secondary peak. That might give you insight into the cause (maybe there is a reflection from an intermittent impedance mismatch). You could also measure the width of the pulse at the time of the "pause" in the falling edge. Then your next step might be to set up a trigger condition to look for pulse widths that are wider than usual at a voltage level of 1.85 volts. That might give a stable trigger on this type of rare signal shape.

In our first troubleshooting example we looked at pulse shaped signals. Another very common type of circuit problem is when signal edges do not have the correct shape. Figure 4 shows a persistent display in which most of the edges have the correct rise time but there is clear indication of a few edges that have a too slow rise time. Note the statistics on the parameter measurement shows the slowest rise time is 3.067 nsec while the fastest is 2.256 nsec. If you make parameter measurements it is a good idea to activate statistics in order to know the worst case values of key signal characteristics. In Figure 5 you can see the slowest rise time was acquisition number 964 in the Replay of 1024 acquired waveforms.

As a contrast, Figure 6 shows the very next acquisition – number 965 – which is one of the normal, faster rise times (2.427 nsec). The user might have a theory that the rise time slows down temporarily and several consecutive rise times are slow, giving the picture in Figure 4 which shows several slow rise times. But this theory is not correct. The slow rise times occur occasionally, one at a time, with many normal rise times before and after each aberrant event. This is information the user can get via Replay mode that is not available from a traditional persistence display.

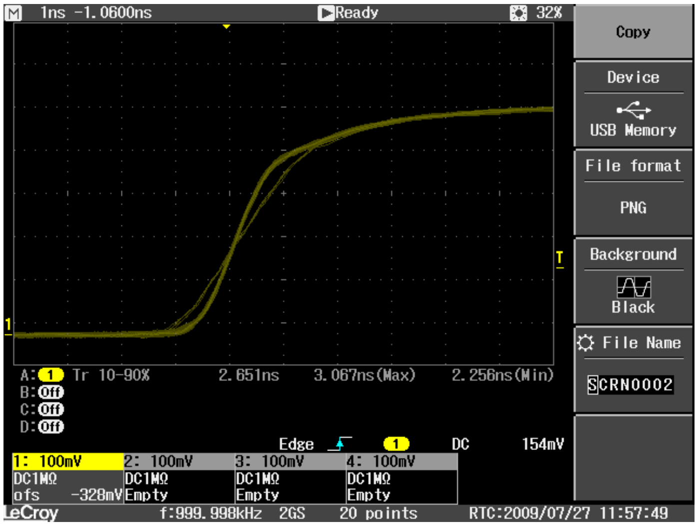

Figure 4: Many edges are captured. Most have a fast edge but several have a rise time that is clearly slower. Note the use of statistics to determine the fastest and slowest edge rates.

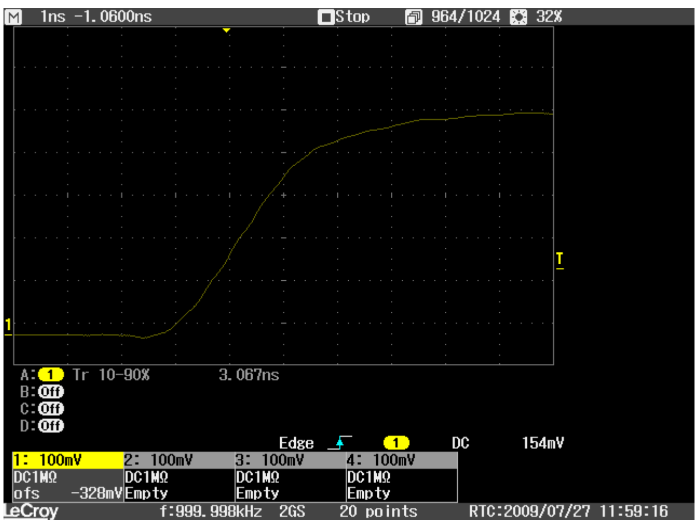

Figure 5: Replay is used to look at single edges that are contained in the display shown in Figure 4. This is the slowest edge (acquisition 964 in the sequence of 1024 triggers).

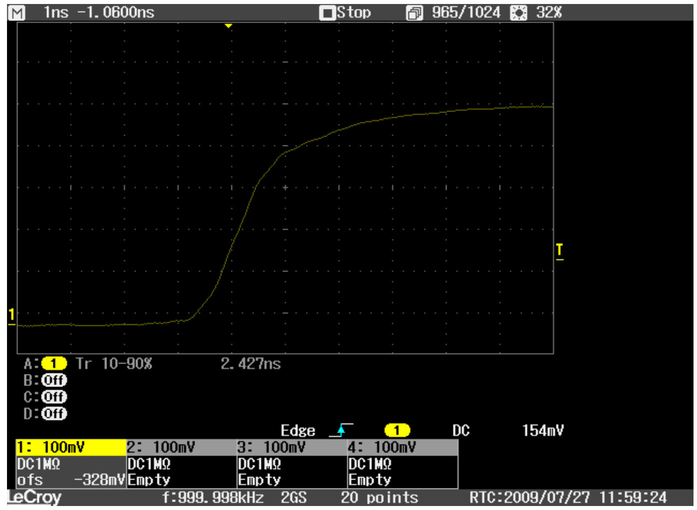

Figure 6: If the user turns the Replay knob by a small increment from the display in Figure 5, acquisition 965 (or 963) can be seen. Number 965, shown here, has a normally fast rise time of 2.427 nsec.

Conclusion

Modern digital oscilloscopes have a wide variety of tools to help the user test, verify performance and troubleshoot electronic circuits. Replay mode in the WaveJet series is an innovative tool that is easy to activate and gives the user more insight into device behavior than is available from a persistence display. It can be used to clearly view aberrant shaped signals, confirm (or deny) guesses as to the time order of intermittents, and to find the right parameter values to set up advanced triggers for stable capture of rare but interesting signal events.