Signal Integrity eSeminar Series Q&A: Using a High-Speed Scope for Digital Jitter Measurements

The following Questions and Answers were created from the live eSeminar broadcast of October 22, 2003. You can view the archived eSeminar by going to **www.agilent.com/find/sigint** and selecting it from the list of Signal Integrity Series eSeminars.

The following questions pertain to jitter generation sources:

Q: Is the peak jitter different for sinusoidal signal versus pulsed waveforms?

A: No. The difference in these is how they may affect bit errors. A signal that causes jitter that dwells at its extreme for a long period of time will have a greater chance of negatively affecting the link than one that doesn't. They may still have the same peak-to-peak value. An issue that may be considered is comparing a square wave jittered signal and a sinusoidal one at the same frequency. If the frequency is within the receiver loop bandwidth, the sinusoidal signal may be accommodated well, however the harmonics of the square wave may fall outside the loop bandwidth and cause a greater peak-to-peak value in jitter.

Q: You imply that there is an interaction between Duty Cycle Distortion (DCD) and Inter-Symbol Interference (ISI). Can you explain this?

A: If DCD is not zero, or the Duty Cycle is not precisely 50%, the energy in a 1 will be different than the energy in a 0. If we think of ISI being caused by a filter construct such as a cable and a connector, then the time response to a rising edge or a falling edge will be a function of the driving waveform and the filter response. If the responses are not totally settled before one unit interval (UI), then an accumulation of previous responses occurs. This is your typical ISI. Further, if the driving energies for highs and lows are different (DCD), the response trajectories will be altered as well.

Q: Can you talk a bit about your random noise source that you used in the jitter generation system you put together?

A: We used 3 RF amplifiers. To the input of the first we connected a 50 ohm load and then we amplified the output with the other two, taking care that we didn't get into limiting anywhere. It functions as a good thermal noise source. This was verified as Gaussian down to 10^{-12} BER using Q measurements.

Q: What is the bandwidth of the phase modulation port of the 81134A pulse generator?

A: It has a 1 dB bandwidth of 200 MHz and a 3 dB bandwidth of 500 MHz.

Q: Why did you use the 86100 DCA for your testing or your calibration?

A: First of all, we wanted to have the lowest residual jitter possible, and the 86100 DCA allows this with the 86107A high-precision time base. Another key consideration is that it allows for independence in results when evaluating jitter measurements.

Q: Does Agilent have instruments that specifically generate jitter? Do you have anything for jitter sources?

A: The 81134 Pulse Generator, N4900 Series Serial BERTs, and 81250 ParBERT can be modulated for RJ, PJ, and can be adjusted for specific duty cycle distortion levels. The remaining jitter component is Inter-Symbol Interference (ISI), which is very difficult to create except through the addition of filters, cables, backplanes, etc. You can find more information about jitter at **www.agilent.com/find/jitter_info**

Q: What different kind of techniques do you use to create jitter; that is, for the jitter transmitter?

A: Using the delay port of the 81134A pulse generator one can create the random and periodic jitter very easily. If you needed to have multiple sources of PJ or bounded uncorrelated this will work; it will be a matter of the summing network that needs to be devised. But there are mechanisms that really can't be modeled that way, such as Duty Cycle Distortion (DCD) and Inter-Symbol Interference (ISI). DCD can be accomplished through a independent control of a threshold level in a limiting amp. Then there is ISI, which is a tougher thing. We recommend a medium with characteristics that you will likely encounter in your design such as a backplane. The ISI for this can be evaluated using the step response of the source being used and convolving with time response of the backplane (which can be derived from S-parameter measurement).

Q: Is ISI always from the media; i.e., the transmission line or the PC board, or can it come from other places?

A: No. It can be in the receiver and it can be in the transmitter as well. I modeled it as part of the media because that is where the dominant ISI contributors are often found.

Q: Do you have a recommended method for adding a known amount of ISI to a given signal?

A: I think the best choice is to use a cable of prescribed length, and to evaluate its ISI using its S-Parameters and the expected time response of the transmitter to be used.

Q: How close is the real jitter distribution to a perfect Gaussian distribution?

A: For the jitter transmitter discussed we made baseline measurements and found that it comes close to a true Gaussian. However, using a double delta approach (fitting the tails of the distribution to a Gaussian) we find that the means of the Gaussians thus derived are about 4.8 ps apart. This gives a measure of how close it is to a Gaussian. Another way to view this question is to address whether there is even such a thing as true Gaussian noise. This is a philosophical question we desired to avoid for the time being.

The following questions pertain to real-time scope jitter measurements:

Q: Why does your Time Interval and Jitter Analysis software offer ten different methods for separating RJ and DJ, and which of these do you recommend?

A: There are ten different methods allowed by the MJSQ standard, as we mentioned. However, we would recommend using the edge jitter method, which is equivalent to the time interval error jitter measurement method, which just simply measures each edge crossing point relative to a perfect edge crossing point. This jitter measurement method is going to be the best at measuring both RJ and DJ and separating those out accurately, providing the most accurate measurement for you. That is the default standard setup for the E2960 Time Interval and Jitter Analysis tool. When you set up your threshold specifications and the DJ or data jitter separation technique, it's going to automatically default to the edge jitter method (TIE method).

Q: Can I use the Time Interval and Jitter Analysis software with more than one oscilloscope?

A: There are two different versions of the software. One version works with just one oscilloscope and another version that will work with up to four different oscilloscopes, one at any one time but up to four. The four-scope license is a nice alternative for large labs with multiple scopes, where the jitter software needs to be used on different scopes occasionally. It eliminates the hassle of having to re-install software each time the license key is moved from one scope to the next.

Q: Could you describe the difference between edge jitter or TIE and the pulse-width jitter measurement?

A: Edge jitter is measuring each edge in the pattern or in the acquisition relative to where that edge should have landed if you had an ideal clock and no jitter in the signal. Pulse-width jitter is just measuring the width of each pulse in the acquisition, so from one edge to the very next edge, and comparing that length to an ideal pulse the same number of unit intervals long.

Q: Could you explain the model for calculating total jitter and where does the 14σ come from when converting RMS random jitter into peak-to-peak random jitter?

A: The 14 comes from multiplying seven by two! The seven comes from the ratio of the peak-to-sigma value that gives you a bit error ratio number of 10^{-12}. The relationship can be derived from the

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Gaussian curve. As you integrate one of the tails to that 7σ value, the area under that curve, that portion of a curve is 1×10^{-12}. From the mean of the distribution to that point is 7σ. Since we have two edges, we have two distributions (one on either side of the left and the right crossing point), we have two of these 7σ segments, and that's where the 14 comes from. Total Jitter for a 10^{-12} BER on a signal that has purely Gaussian jitter is then 14*σ (where σ = standard deviation of Gaussian).

Q: If I got RMS jitter from random jitter, ± 6σ, is that an overestimate for peak-to-peak jitter? As for the measurement, the peak-to-peak jitter indicated for the histogram is a few sigmas smaller than ± 6σ?

A: That's because the 6σ is a number that pops up in clock distribution measurements or their specification. As mentioned above, the peak-to-peak jitter estimate requires two things: desired BER level (commonly10^{-12}) and a knowledge of the sigma of the Gaussian. When you evaluate a histogram, be prepared to see a lesser value for peak-to-peak because by definition we are talking about relatively rare events. To truly measure total jitter (peak-to-peak) to a level of 10^{-12} BER you need about $4*10^{12}$ bits with no errors. At 1Gb/s this is 4000 seconds, or 1.1 hours. In reality, nothing is Gaussian. It's pretty simple to prove that because Gaussian implies infinity, which would mean if you have infinite jitter on an edge it would mean that an edge could happen before the previous edge. Basically the ±6σ comes from the clock world back in the old days where ±6σ is about what realistically you would see on a clock.

Q: If the total jitter equals DJ + 12 x RMS random jitter sufficient for product validation data?

A: The specs that I've seen always seem to specify 10^{-12} BER. Since they rely on the idea of Gaussians existing, that means you have to use the multiplier 14. If you use a lower multiplier, then you're underestimating total jitter at 10^{-12} and could potentially be at risk of shipping something that doesn't actually meet the spec.

Q: Can I get a copy of the presentation?

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