

Making Real-Time Corrected Parametric Measurements using a Digital Oscilloscope

While accurate rise time measurements have become easier to make, it remains, nonetheless, quite easy to overlook error contributions due to not only the oscilloscope but also the probe. And, while the error contributed by a scope's finite step-response (rise time) is often accounted for, that contributed by the probe is often overlooked. The probe contributes its own source of error due to its own characteristic rise time. In this article, we will examine rise time measurements made while using a Gaussian scope and a probe, each of a known BW. Furthermore, we will look at how to make a systematic *on-the-fly corrected rise time measurement* using the DL9000 oscilloscope.

For a test system with a low-pass Gaussian frequency response, every element between the test point and the display of an oscilloscope contributes to the measured rise time (1). In the case of a DUT's rise time, a probe's rise time, and an oscilloscope's rise time, these three rise times may be summed by:

$$T_{rise_sum} = \sqrt{T_{DUT}^2 + T_{probe}^2 + T_{scope}^2}$$

Please realize that T_{rise_sum} is the measurement indicated by the oscilloscope.

In the case of an un-published rise-time, for a Gaussian system, such as a scope or probe:

$$T_{RISE} = \frac{0.338}{BW}$$

and so, logically, it follows that,

$$T_{measured} = \sqrt{T_{dut}^2 + T_{probe}^2 + T_{scope}^2}$$

and, with those two equations, we can easily correct the rise time measurement of any given DUT using:

$$T_{dut} = \sqrt{T_{measured}^2 - T_{probe}^2 - T_{scope}^2}$$

At this time, it is prudent to recall a rule of thumb for rise-time measurements: For accurate rise time measurements, the combined rise time of the scope and probe together should be at least three times the signal rise time. Four to six times is advisable.(1) At 3X, you can expect an error of approx 5%; at 5X, you may expect an error of approx 2%.

An example of rise time correction would be the following scenario. We wish to measure a waveform which has an edge with a rise time which we know to be in the neighborhood of approximately 1 ns. Using a Yokogawa DL9240L oscilloscope with a BW of 1.5 GHz and a Yokogawa PBA2500 probe with a BW of 2.5 GHz, we realize a test system rise time of:

$$T_{test_system} = \sqrt{T_{probe}^2 + T_{scope}^2} = 262 ps$$

This is equivalent to having a measurement system with 1.3 GHz of bandwidth. Is this sufficient?

$$T_{DUT} / T_{test_system} = 1000 ps / 262 ps = 3.8$$

Yes. With a test system rise time of nearly 4X that of the DUT, we can expect an error of less than 5%. (1) The rule of thumb requirement of 3X to 6X has been met.

Taking the measurement, using this system, and using proximal / distal points of 10% and 90% (traditional) we find that the probe/scope test system indicates a rise time of 1 ns. Please see Figure 2. Is this the actual rise time? No, we must correct for the error introduced by the rise time of the test system as follows:

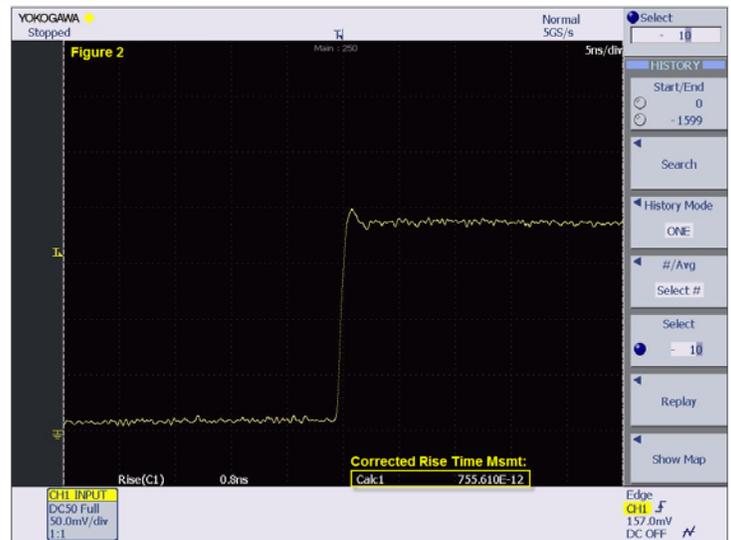
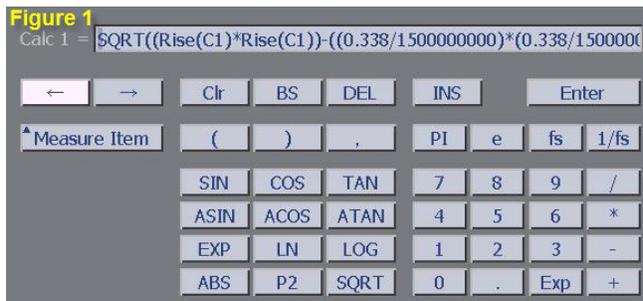
$$T_{DUT} = \sqrt{(1ns)^2 - (135ps)^2 - (225ps)^2} = 965ps$$

Thus, the 1 ns indication on our test system includes an error of only 3.6%; this is less than 5%, as predicted.

Using this formula within Yokogawa's parametric calculator, you may define a custom equation to correct your measurements on the fly. Figure 1 shows the parametric calculator, while Figure 2 shows the DL9240L display including the apparent rise time as well as the corrected rise time calculation result.

To further ensure accurate rise time measurements, keep your probe's ground lead as short as possible. Long ground leads in the presences of high-speed edges produce ringing / overshoot / undershoot – and can affect the oscilloscopes automatic parametric rise time measurement. Each of Yokogawa's oscilloscopes is compliant to IEEE 181-2003, the standard for waveform measurements; however, precautions such as good probing techniques must be made by the prudent engineer.

Yokogawa oscilloscopes offer statistical features to further enhance your measurements. Since most oscilloscopes typically measure only one edge per acquisition, the Yokogawa DL9000 models allow higher confidence in the measurement by making multiple measurements and calculating statistical data on the rise time measurement.



1. High Speed Digital Design - A Handbook of Black Magic, Howard Johnson, Martin Graham, 1993, Prentice Hall PTR, Prentice-Hall, Inc
2. Further Reading: Analog Circuit Design: Art, Science, and Personalities, Jim Williams, Editor, Butterworth-Heinemann, 1991.

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