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Improve Delta Time Accuracies in Semiconductor Device Modeling and Characterization with the HP 71500A

Product Note 70820-5

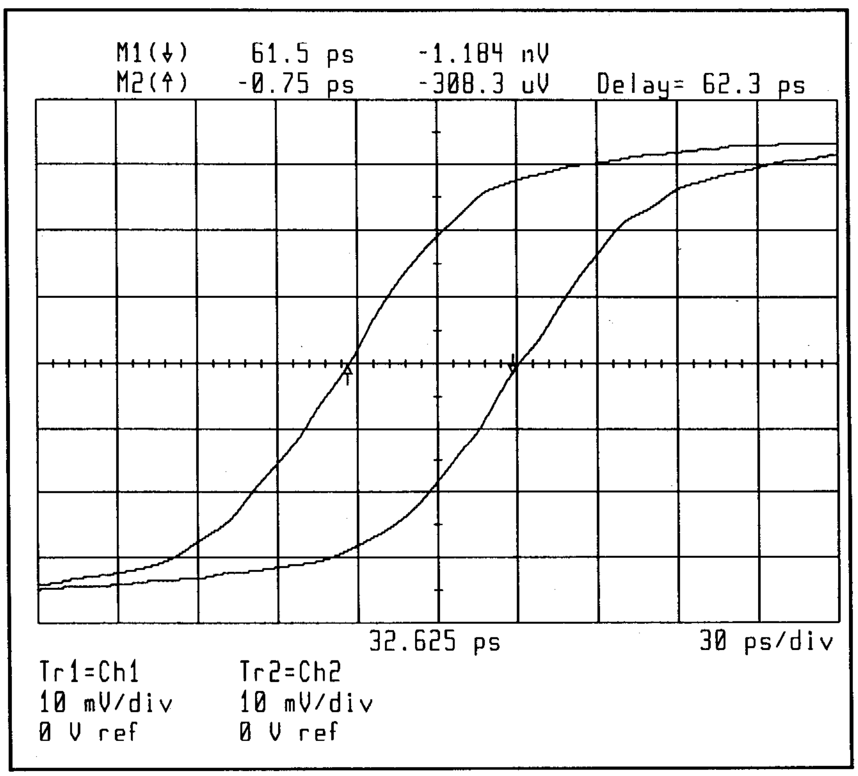

Figure 1. The HP 71500A improves the accuracy of delta time measurements, such as this delay measurement of 62 picoseconds.

Bringing new products to market faster requires getting designs right the first time. Accurate device modeling and characterization are key to understanding your fabrication process and obtaining accurate simulations for optimal designs. The time-scale accuracy of the measuring instrument, resolution and trace noise, and the fidelity of the measurement configuration all affect the accuracy of the measurement. Each of these factors is improved using the HP 71500A's:

- ***1 ps time-scale accuracy to provide a solid foundation for timing measurements***
- ***Noise filter to improve resolution, quickly***
- ***Frequency response correction to remove loss due to connecting cables***

1 ps Time-scale Accuracy, a Solid Foundation for Timing Measurements

Time-scale accuracy provides the foundation on which timing measurements are based. For time-domain measurements, the HP 71500A can be thought of as a phase-locked oscilloscope. This phase-locking ability allows time-scale accuracies to 1 ps.

The sampler frequency of the HP 71500A is locked to a 10 MHz frequency reference (time base). This reference should be tied to the reference for the source that is used to stimulate your device under test. If the source you are using is a pulse generator, it may not be synthesized and may not have a 10 MHz frequency reference (time base). You can lock references by driving the trigger input of the pulse generator with a synthesizer that shares a common frequency reference with the HP 71500A.

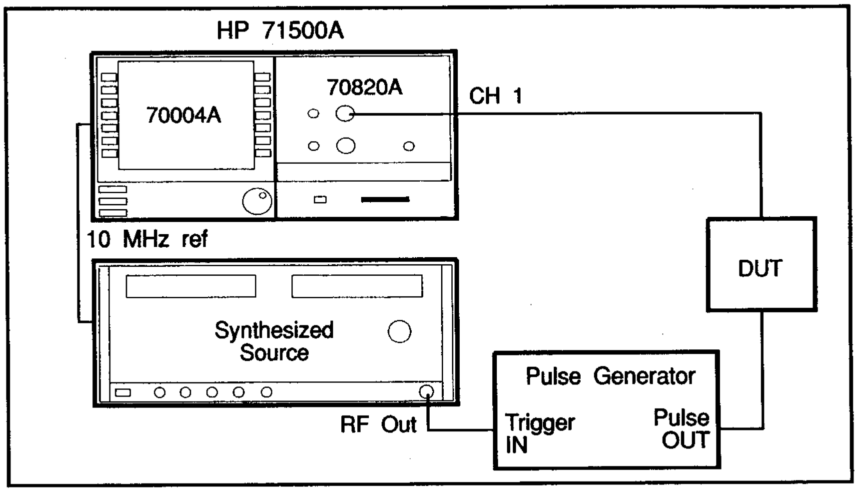

Figure 2. Using a synthesized source, the time base of the HP 71500A and the time base of a pulse generator can share references giving time scale accuracies to 1 ps.

The timing-accuracy equation in the HP 71500A includes a term, E_{diff}[1], that can be forced to zero by sharing references. E_{diff} is proportional to the difference between what the source considers to be its output frequency and what the HP 71500A considers to be the source output frequency. This discrepancy is due to the use of two different frequency references, one for each instrument. By sharing references, E_{diff} can be forced to zero. Then, the accuracy equation is dominated by a resolution term: either 1 ps or 0.1% of the time span, whichever is greater, plus noise effects.

Delta T accuracy = (E_{diff} + E_R)(reading) + resolution
With shared frequency references (time bases), $E_{diff} = 0$
and E_R = error of reference ≈ 1 ppm << resolution ≈ 1000 ppm
Delta T accuracy ≈ resolution

Noise Filter Quickly Improves Resolution

Improving time-scale accuracy to 1 ps is only part of the accuracy improvement, over traditional sampling oscilloscopes, made possible using the HP 71500A. Reducing noise to improve the resolution, which lets you take advantage of the time-scale accuracy, is the next contribution.

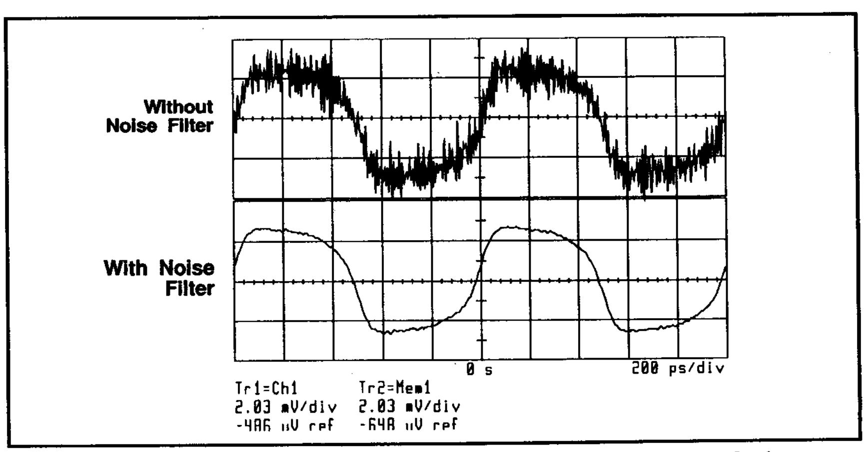

Figure 3. The noise filter improves accuracy by improving the resolution or repeatability of your measurement.

[1] In the HP 70820A specifications, E_{diff} is seen as $(F_{aa} + F_{drift})/F_{IF}$

With its unique noise-filter function, the HP 71500A improves resolution when viewing periodic signals. Periodic signals are composed of a fundamental signal and its harmonics. The noise filter preserves the fundamental and harmonics but filters out the noise between these spectral components. This provides a very clean signal on every trace update. The measurement is performed much faster than using averaging, which also cleans up the signal but is time consuming.

Noise Filter and Amplification Improve Sensitivity and Let You Reduce Errors

Impedance mismatches in your test setup are another major source of measurement error at high frequencies. Inserting a well-matched attenuator (padding your signal) as close as possible to your device under test improves accuracy by reducing mismatch, but it also attenuates the signal. The improved resolution of the noise filter and the 60 dB of variable step gain inside the HP 71500A provide the sensitivity needed to view these attenuated signals.

The sensitivity of the HP 71500A also lets higher-impedance resistive divider probes be used. Resistive divider probes can be designed to fairly low input capacitances, preventing loading at high frequencies. But the probes are usually limited to 500Ω or 1 kΩ input impedance, which may load the circuit at lower frequencies. As the input impedance of the probe increases, so does the divider ratio (500Ω = 10:1, 1 kΩ = 20:1). Most oscilloscopes don't have the sensitivity to allow practical use of more than a 1 kΩ probe. But the sensitivity of the HP 71500A allows 5 kΩ resistive divider probes (5 kΩ = 100:1) to be used. This higher impedance prevents the circuit from being loaded down while probing, even in 100Ω to 200Ω environments.

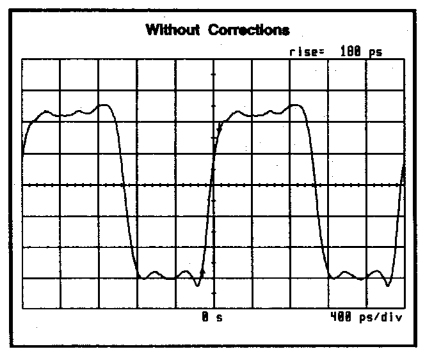

Figure 4A. Without frequency response corrections for the connecting cable, the rise time of the DUT measures 180 ps.

Frequency Response Corrections Remove Errors Due to Cable Loss

Significant measurement accuracy can be lost due to the cables connecting the measurement tool and the device. User-corrections in the HP 71500A let you correct for the frequency response of connecting cables. You can enter up to 128 magnitude and phase points (versus frequency) that characterize the connecting cable system. Your waveform is then captured in the time domain, an FFT is performed, the data is multiplied by corrections for your cables, an inverse FFT is performed, and your corrected waveform is displayed onscreen.

The HP 71500A can also help you determine the magnitude and phase response of your cables. The magnitude and phase points can be determined by doing a frequency sweep of the cables and storing the results of the frequency characterization to the user-corrections of the desired channel.

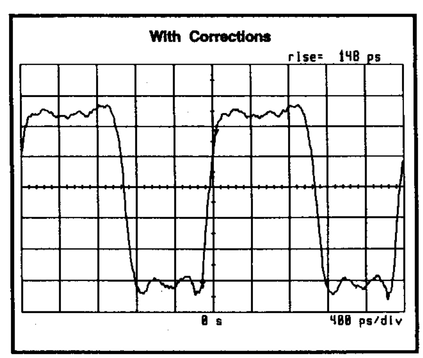

Figure 4B. After correcting for the loss of the connecting cable, the rise time reads 148 ps.

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About the HP 71500A

The HP 71500A is part of the HP 70000 Modular Measurement System (MMS). The HP 71500A consists of the HP 70820A microwave transition analyzer module and the HP 70004A color display. The microwave transition analyzer has two channels and covers the frequency range from dc to 40 GHz.

There's even more to find out about than these accuracy advantages. The HP 71500A includes an FFT to see the frequency content of your signal, extensive waveform math for manipulating data (such as measuring the energy in a pulse), and simplified triggering. Whether you are characterizing a faster process or trying for more density, or whether you want better yields or better reliability, the HP 71500A can help you characterize your process more accurately.

Contact your HP sales representative and see how the HP 71500A gives you the measurement edge.

Color Brochure:

"HP 71500A Microwave Transition Analyzer"	5091-0791E

Product Notes:

"The Microwave Transition Analyzer: Picosecond Delta Time Accuracy"	5952-2545E
"Simplified Triggering of the HP 71500A Improves Accuracy When Characterizing Lightwave Components"	5952-2549E

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