High-precision Time-domain Reflectometry with the Agilent 86100 Digital Communications Analyzer and Picosecond Pulse Labs 4020 Source Enhancement Module

Sub-millimeter two-event resolution

9 picosecond TDR, 5 picosecond TDT step speed

Minimal pulse aberrations through calibration

Time-domain reflectometry (TDR) and time-domain transmission (TDT) are the most common tools for verification and analysis of the transmission properties of high-speed systems and components. Signal path discontinuities that cause reflections can be precisely located and quantified through TDR. Transmission parameters such as attenuation, pulse degradation and propagation times are determined through TDT. There are three key elements that determine the precision of any TDR/TDT measurement system:

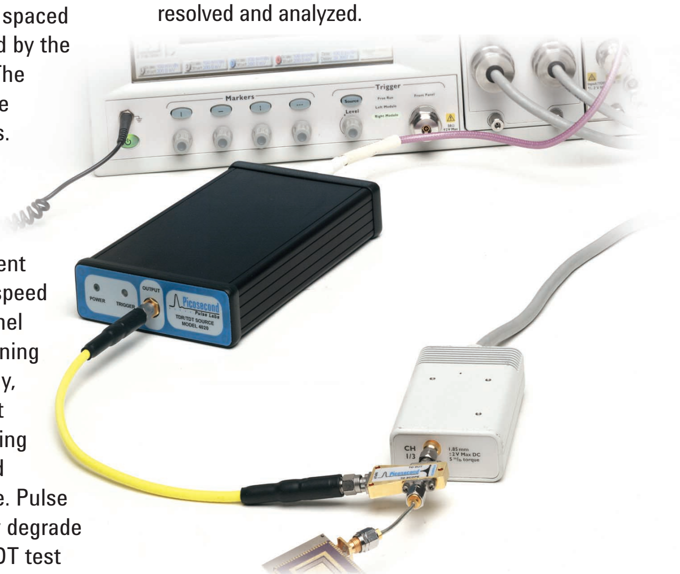
- The edge speed of the stimulus pulse produced by the TDR
- The bandwidth of the channel used to receive the pulses from the device under test (DUT)
- The maintenance of pulse fidelity through minimizing cabling lengths to and from the DUT

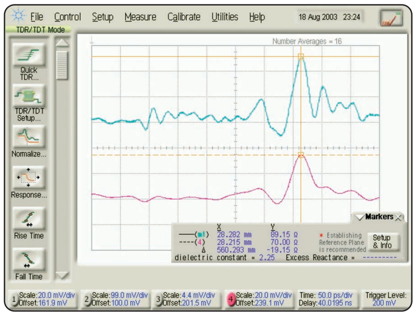
Edge speed is critical for two important reasons. First, reflection characteristics change with signal spectrum, and spectral content is dependent upon edge speed. To accurately determine how high-speed digital signals propagate, the TDR/TDT system should produce a test pulse with similar characteristics to the signals that will exist in actual usage. Digital signals with rise and fall times under 20 picoseconds are becoming common. Second, when there are multiple discontinuities in a circuit, multiple reflections occur. The ability to independently resolve closely spaced reflections is highly influenced by the speed of the stimulus pulse. The faster the pulse, the higher the two-event resolution becomes.

Reflected signals in a TDR test, and transmitted signals in a TDT test must be received by the measurement system. The higher the edge speed produced, the wider the channel bandwidth necessary for retaining measurement precision. Finally, system cabling should be kept at a minimum to avoid degrading both transmitted and reflected pulses in speed and amplitude. Pulse degradation will subsequently degrade the precision of any TDR or TDT test results, as it can be difficult to differentiate whether the features of the monitored waveform are due to the DUT or the test system setup.

Building a high-precision TDR/TDT measurement system

When the 86100 Digital Communications Analyzer (DCA) is configured as a TDR and combined with the Picosecond Pulse Labs 4020 TDR/TDT source enhancement module, TDR edge speeds are increased from 35 ps to as fast as 9 picoseconds. TDT edge speed can be as fast as 5 picoseconds. Thus even the fastest signal rates can be directly simulated. Two-event reflection resolution is improved by a factor of 4. Reflections separated by a millimeter or less can be resolved and analyzed.





Measurement results

The dramatic improvement in accuracy obtained with the 86100/PSPL 4020 system can be seen in the above measurement of a connector assembly. The lower trace is obtained using the standard 35 ps TDR. The upper is from the 86100/PSPL 4020 system. Two critical aspects are observed. First, in the standard TDR measurement, the many reflections from the complex connector assembly are blurred together indicating that there are only one or two reflections in the assembly. In the upper trace the reflections from the multiple interfaces within the connector are easily observed, even those that are separated by only one or two millimeters. Second, the magnitude of the reflections and subsequent impedance values are dependent upon the TDR speed. The largest discontinuity is measured at 70 Ω with the 35 ps TDR, but is 89 Ω when measured at 9 ps. (Each measurement is an accurate assessment of the reflection magnitude, as the amount of energy reflected is dependent upon the speed of the stimulus. Thus, devices intended for very high-speed systems should be characterized with a very high-speed TDR that has minimal spurious responses.)

System operation

The Picosecond Pulse Labs 4020 module receives the 35 picosecond, 200 mV step from the Agilent 86100 DCA configured with a 54754A TDR plug-in module. The 35 picosecond step is amplified to 4 V and sent to a nonlinear transmission line (NLTL). The output edge is now below 5 picoseconds, but at the original 200 mV amplitude.

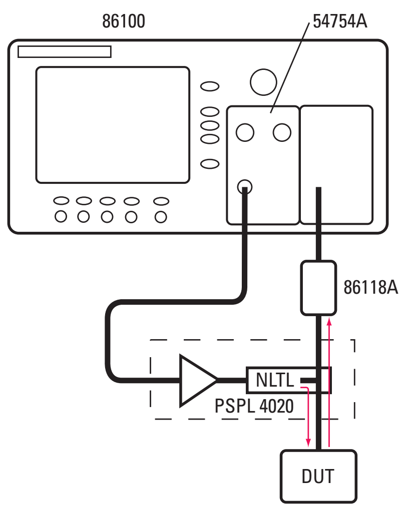
This signal is then routed to the DUT. Any reflections from the DUT are monitored by a receiver channel in the 86100. For highest bandwidth and minimal cable lengths, the Agilent 86118A 70+ GHz remote sampling modules are used. These can be mounted directly to the Picosecond Pulse Labs 4020 module. (Other 86100 series plug-ins may also be used at reduced performance.)

The high-speed pulse produced by the 4020 module will have some overshoot and ringing. Pulse aberrations can be misinterpreted as small reflections, severely reducing the improvements achieved from a faster step. This effect can be mitigated through a unique calibration capability within the 86100 (commonly known as normalization).

Configuring a system

The high-speed TDR system is composed of:

86100 oscilloscope mainframe
54754A TDR/TDT plug-in module
High-speed receiver channel:
86118A (~75 GHz, remote head)
or 86117A (50 GHz, non remote)
Picosecond Pulse Labs 4020 TDR/TDT source enhancement module (TDR, TDT, or TDR/TDT configurations are available)



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