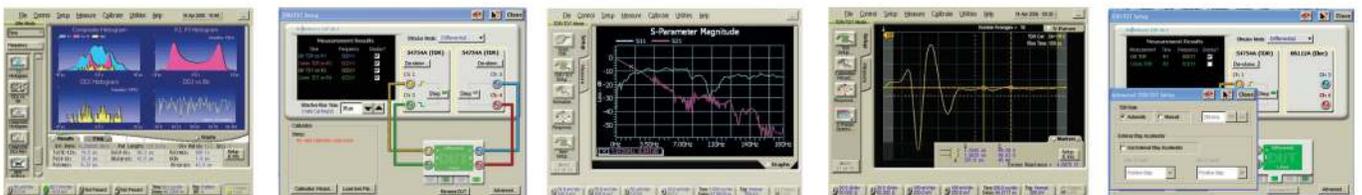


Keysight Technologies

SATA II Drive Tx/Rx Testing & Cable SI Test Using the 86100C DCA-J

Technical Overview



Overview:

Serial ATA (SATA) is the latest generation of the ATA internal storage interface. Due to the inherent limitations of parallel technology, SATA is expected to replace parallel ATA everywhere, and expand the use of ATA-based technology in the entry server and network storage market segments.¹

The “SATA 1.0” and “SATA II” terminology represent a family of specifications, while “SATA 1.5 Gb/s” and “SATA 3 Gb/s” references indicate products and their supported speeds that were developed under these respective specifications. All products developed under SATA 1.0 have a maximum speed of 1.5 Gb/s. Products developed under SATA II can either be 1.5 Gb/s or 3 Gb/s. In addition, the SATA II specifications are backward compatible with the SATA 1.0 specification.¹

Many devices are covered by the SATA standard and each device has its own test requirements. The SATA standard and the associated Interoperability Test Program Unified Test Document define the following testing requirements for internal drives and internal cables with additional devices and requirements being added regularly:

Drives:

PHY General, 1-4
PHY TX 1-6
PHY TSG 1-12
PHY RX 1-6
PHY OOB 1-7

Cables:

SI 1-9

This Product Note, based on SATA approved Methods of Implementation, explains how to use the Keysight Technologies, Inc. 86100C DCA-J (high bandwidth equivalent time sampling oscilloscope and Time Domain Reflectometer) to make the required Rx and Tx tests for internal drives and the required SI tests for internal cables.

Keysight’s SATA approved Method of Implementation explaining how to make the PHY General, TSG and OOB tests using Keysight’s DS081204A/B (12 GHz bandwidth, 40 Gb/s per channel) is available on Keysight’s web site www.keysight.com/find/n5411A.

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Procedure, Testing SATA II Internal Cables with the Keysight 86100C DCA-J:

Introduction

This procedure describes how to setup and use the 86100C DCA-J to make the following measurements on a SATA internal cable to determine if the cable meets the requirements of the standard:

- SI-01 Mated Connector Impedance
- SI-02 Cable Absolute Impedance
- SI-03 Cable Pair Matching
- SI-04 Common Mode Impedance
- SI-05 Differential Rise Time
- SI-06 Intra-Pair Skew
- SI-07 Insertion Loss
- SI-08 Differential to Differential Cross Talk: NEXT
- SI-09 Inter-Symbol Interference



Tests SI-01 through SI-08 use Time Domain Reflectometry (TDR) techniques to measure impedance in the time domain with test results reported in the time domain or frequency domain (S-Parameters) as required by the standard. The 86100C DCA-J with option 202 can easily translate between the time and frequency domains with a single button push.

Test SI-09 is performed by making an actual jitter measurement on the specified data pattern sent through the cable being tested. The 86100C DCA-J with option 200 performs complete jitter analysis at the touch of a button, reporting Total Jitter and all jitter subcomponents, including ISI (inter-symbol interference).

The SATA standard for testing the internal cable is quite complex:

- Some measurements require different TDR step rise times than others.
- Some measurements require the effects of the fixture's connector to be included while other measurements require removing the effects of the fixture's connector.
- The cable includes 2 differential pairs and 2 connectors for a total of 8 inter-connects. Some measurements are performed on both pairs for both connectors while others are performed on a subset



The Keysight 86100C DCA-J in combination with the recommended COMAX SATA test fixtures can handle those many different requirements quite easily:

- The test fixtures consist of short high-performance, low loss semi-rigid coaxial cables connected directly to SATA plugs or receptacles. The fixture's major impact to measurement results is due to the actual SATA connectors and in many cases that impact is a desired part of the measurement (per the standard).
- The Keysight 86100C DCA-J includes a built-in TDR calibration routine which, combined with a calibration kit, allows the user to calibrate out the effects of the test cables and fixtures, when required by the standard, with a process similar to one used with vector network analyzers.
- Once calibrated, the user can adjust the effective rise-time of the TDR step from the 86100C DCA-J to meet the various requirements outlined in the standard.

The test procedure is formatted to establish and save all the various instrument setups first. The rest of the procedure uses those established setups to make the required tests and groups tests with similar instrument setups together for efficiency. Further efficiency can be realized through automating the set-up and test processes.

Equipment Requirements

- 1 - Keysight 86100C DCA-J with options 001, 200 and 202
- 2 - Keysight 54754A TDR modules
- 7 - high quality SMA cables
- 2 - Coax style SATA Cable test fixtures, Plug side, COMAX P/N H303000104A
- 1 - Coax style SATA Cable test fixture, Receptacle side, COMAX P/N H303000204A
- 1 - 1/4 inch open end wrench
- 1 - Keysight N1024B Calibration Kit
- 1 - Low jitter 3 Gb/s Differential Pattern Generator such as the Keysight 81134A
- 4 - 50 ohm loads

I Instrument Setup and Calibration

A. Initialize the 86100C DCA-J

- 1 Ensure the 86100C DCA-J has been running for at least 1 hour for proper warm-up.
- 2 Remove all the cables from the 86100C DCA-J and press the Default Setup button
- 3 Perform a module calibration for each measurement module *This process accomplishes several things within the module to maximize measurement accuracy. The sampler gain and bandwidth are optimized for the different bandwidth settings, amplitude linearity correction is performed and TDR step voltage is calibrated.*
 - (a) Touch the calibrate drop-down menu
 - (b) Touch "all calibrations"
 - (c) Touch "calibrate left module" and follow prompts, using the 50 ohm loads from the calibration kit as required.
 - (d) Touch "calibrate right module" and follow prompts, using the 50 ohm loads from the calibration kit as required
- 4 Using the torque wrench, connect cables to channels 1, 2, 3 and 4.

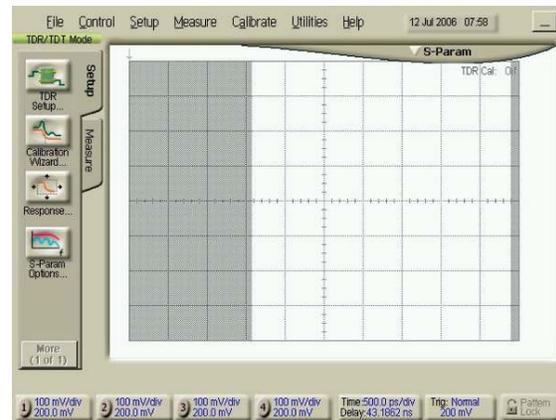


Figure 1. TDR Mode

B. Overview: Operating the Keysight 86100C DCA-J TDR:

- 1 Press the "TDR/TDT" button on the front panel to put the instrument in TDR mode. Figure 1 shows the instrument TDR screen.
- 2 Along the left side of the screen are four icons:
 - (a) Setup: click here to establish the TDR instrument configuration (stimulus and response) and response traces you want to see.
 - (b) Calibration Wizard: Clicking here is one of the ways you can initiate TDR calibration.
 - (c) Response: Click here to define and adjust the gain and offset of the TDR responses (Responses other than a raw channel trace such as differential/common mode responses or calibrated responses are controlled here).
 - (d) S-Parameter options: Click here to adjust S-Parameter graph details.

- 3 Along the bottom of the screen are seven icons:
 - (a) Channels 1-4: Click here to set the units for the channels and responses (ohms, volts, reflection coefficient) and adjust the gain and offset of the raw channel traces.
 - (b) Time/Delay: Click here to manually enter values for the time base and delay (or you can adjust the horizontal knobs)
 - (c) Trigger: Not used for TDR
 - (d) Pattern Lock: Not used for TDR

- (iii) The steps are launched from the module at different times so they will arrive at the end of the cables – at the DUT – at the same time.
- (iv) A trigger delay is added to one of the receivers so reflections that enter the cables from the DUT at the same time are sampled by the receivers at the “same” time.

(b) Deskew Process

- (i) Set averaging to 64:
 - (i) From the drop down menu choose “Setup” then “Averaging”
 - (ii) In the “Number of Averages” box enter 64
- (ii) Deskew both pairs of cables using the procedure for TDR deskew found in the 86100C DCA-J on-line help (Help-Contents-S-Skew-Differential TDR Skew) or refer to Appendix A.
- (iii) Set averaging back to 16

4 Calibration

(a) Why Calibrate?

This process, which is part of each measurement setup in this procedure, requires connecting known standards (a short, a 50 ohm load and, for TDT measurements, a thru) to the instrument at the measurement reference plane. The instrument then reads the value of the standards, establishes a “time 0” reference and develops a digital filter that compensates for the non-ideal frequency response of the test system (step, test cables/fixtures and receiver) in a manner similar to the calibration process used with a vector network analyzer. By compensating for the non-ideal response of the system, measurement results reflect the performance of the DUT alone and not the measurement system plus DUT.

(b) Calibration Process

- (i) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
- (ii) When setting the time base delay, ensure the rising edge (indicating the “open” at the end of the cable) is approximately between the first and second gratitudes on the left of the screen. Note that a 1 or 2 ns/div time base setting during the cal process allows for testing a wide range of cable lengths. Use the SHORTS and LOADS from the N1024B Cal Kit as needed.
- (iii) Close the setup dialog box.

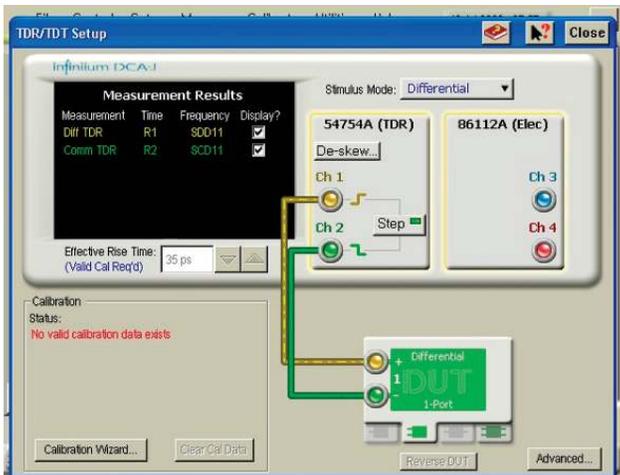


Figure 2. TDR Setup

C. Setup - Differential Impedance, Pair A (line 2 and 3), 70 ps rise time

- 1 Touch the TDR Setup icon on the left side of the screen to display the setup dialog box (Figure 2).
- 2 Setup the TDR for:
 - (a) A two port device (choose the 2-Port DUT from the bottom of the screen)
 - (b) Differential stimulus (choose “differential” as the stimulus mode from the top of the screen)
 - (c) Show the Differential Response (check “Diff TDR” in the Measurement Results window on the left of the screen).
- 3 Deskew for TDR
 - (a) Why Deskew?

This process corrects for the effects of using unequal length cables to connect to the device to be tested. If cables used in testing a differential line aren't identical in length, the “skew” induced by the different length cables results in 2 detrimental effects:

 - (i) The steps, launched from the TDR module at the same time, arrive at the DUT out of alignment (one arrives before the other).
 - (ii) Reflections from the DUT will also be skewed as those reflections travel along the non-equal length cables back to the receivers in the module. The deskew process does two things to correct for the effects of the unequal length cables.

- 5 Establish a differential stimulus rise time of 70 ps:
 - (a) Touch the “Measure” tab on the left side of the screen and choose “rise time” to measure the rise time of the differential stimulus.
 - (b) Touch the “setup/info” button to the right of the measurement results, choose “Configure Meas...” and choose 20%, 50%, 80% for the threshold.
 - (c) Go back to the TDR Setup screen and adjust the effective rise time until the measured rise time is 70 ps (set to $70 + 0 - 5$ ps).
 - (d) Change the units of channels 1 and 2 to ohms.

6 Save Configuration

- (a) Save the setup (File-Save-Instrument Setup) as “Pair A”
- (b) Save the calibration (File-Save-TDR/TDT Calibration) as “Pair A”

D. Setup - Differential Impedance Pair B (lines 5 & 6), 70 ps rise time

- 1 Touch the TDR Setup icon on the left side of the screen
- 2 Setup the TDR for a two port device with differential stimulus (channels 3 and 4) and display the differential TDR response.
- 3 Deskew for TDR
 - (c) Set averaging to 64:
 - (i) From the drop down menu choose “Setup” then “Averaging”
 - (ii) In the “Number of Averages” box enter 64
 - (d) Deskew both pairs of cables using the procedure for TDR deskew found in the 86100C DCA-J on-line help (Help-Contents-S-Skew-Differential TDR Skew) or refer to Appendix A.
 - (e) Set averaging back to 16
- 4 Calibration
 - (a) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
 - (b) When setting the time base delay, ensure the rising edge (indicating the “open” at the end of the cable) is approximately between the first and second gratitudes on the left of the screen. Note that a 1 or 2 ns/div time base setting during the cal process allows for testing a wide range of cable lengths. Use the SHORTS and LOADS from the N1024B Cal Kit as needed.
 - (c) Close the setup dialog box.
- 5 Establish a differential stimulus rise time of 70 ps:
 - (a) Touch the “Measure” tab on the left side of the screen and choose “rise time” to measure the rise time of the differential stimulus (should already be configured for a 20-80 measurement).
 - (b) Go back to the TDR Setup screen and adjust the effective rise time until the measured rise time is 70 ps (set to $70 + 0 - 5$ ps).
 - (c) Change the units of channels 3 and 4 to ohms.

6 Save Configuration

- (a) Save the setup (File-Save-Instrument Setup) as “Pair B”
- (b) Save the calibration (File-Save-TDR/TDT Calibration) as “Pair B”

E. Setup - Single-ended Impedance, 70 ps rise time 1 Z1 (line 1)

- (a) Touch the TDR setup icon on the left side of the screen
- (b) Set up the TDR for a 1 port device with single ended stimulus using channel 1 and display the SE TDR response.
- (c) Calibration
 - (i) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
 - (ii) When setting the time base delay, ensure the rising edge (indicating the “open” at the end of the cable) is approximately between the first and second gratitudes on the left of the screen. Note that a 1 or 2 ns/div time base setting during the cal process allows for testing a wide range of cable lengths. Use the SHORTS and LOADS from the N1024B Cal Kit as needed.
- (d) Close the setup dialog box.
- (e) Establish a stimulus rise time of 70 ps:
 - (i) Touch the “Measure” tab on the left side of the screen and choose “rise time” to measure the rise time of the stimulus (should already be configured for a 20-80 measurement).
 - (ii) Go back to the TDR Setup screen and adjust the effective rise time until the measured rise time is 70 ps (set to $70 + 0 - 5$ ps).
- (f) Change the units of channel 1 to ohms.
- (g) Save the setup (File-Save-Instrument Setup) as “Z1”
- (h) Save the calibration (File-Save-TDR/TDT Calibration) as “Z1”

2 Z2 (line 2)

- (a) Touch the TDR setup icon on the left side of the screen
- (b) Set up the TDR for a 1 port device with single ended stimulus using channel 2 and display the SE TDR response.
- (c) Calibration
 - (i) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
 - (ii) When setting the time base delay, ensure the rising edge (indicating the “open” at the end of the cable) is approximately between the first and second gratitudes on the left of the screen. Note that a 1 or 2 ns/div for time base setting during the cal process allows testing a wide range of cable lengths. Use the SHORTS and LOADS from the N1024B Cal Kit as needed.

- (d) Close the setup dialog box.
- (e) Establish a stimulus rise time of 70 ps:
 - (i) Touch the “Measure” tab on the left side of the screen and choose “rise time” to measure the rise time of the stimulus (should already be configured for a 20–80 measurement).
 - (ii) Go back to the TDR Setup screen and adjust the effective rise time until the measured rise time is 70 ps (set to $70 + 0 - 5$ ps).
- (f) Change the units of channel 2 to ohms.
- (g) Save the setup (File-Save-Instrument Setup) as “Z2”
- (h) Save the calibration (File-Save-TDR/TDT Calibration) as “Z2”

3Z3 (line 3)

- (a) Touch the TDR setup icon on the left side of the screen
- (b) Set up the TDR for a 1 port device with single ended stimulus using channel 3 and display the SE TDR response.
- (c) Calibration
 - (i) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
 - (ii) When setting the time base delay during the cal process, ensure the rising edge (indicating the “open” at the end of the cable) is approximately between the first and second graticules on the left of the screen. Note that a 1 or 2 ns/div time base setting during the cal process allows for testing a wide range of cable lengths. Use the SHORTS and LOADS from the N1024B Cal Kit as needed.
- (d) Close the setup dialog box.
- (e) Establish a stimulus rise time of 70 ps:
 - (i) Touch the “Measure” tab on the left side of the screen and choose “rise time” to measure the rise time of the stimulus (should already be configured for a 20–80 measurement).
 - (ii) Go back to the TDR Setup screen and adjust the effective rise time until the measured rise time is 70 ps (set to $70 + 0 - 5$ ps).
- (f) Change the units of channel 3 to ohms.
- (g) Save the setup (File-Save-Instrument Setup) as “Z3”
- (h) Save the calibration (File-Save-TDR/TDT Calibration) as “Z3”

4 Z4 (line 4)

- (a) Touch the TDR setup icon on the left side of the screen
- (b) Set up the TDR for a 1 port device with single ended stimulus using channel 4 and display the SE TDR response.
- (c) Calibration
 - (i) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
 - (ii) When setting the time base delay during the cal process, ensure the rising edge (indicating the “open” at the end of the cable) is approximately between the first and second graticules on the left of the screen. Note that a 1 or 2 ns/div time base setting during the cal process allows for testing a wide range of cable lengths. Use the SHORTS and LOADS from the N1024B Cal Kit as needed.
- (d) Close the setup dialog box.
- (e) Establish a stimulus rise time of 70 ps:
 - (i) Touch the “Measure” tab on the left side of the screen and choose “rise time” to measure the rise time of the stimulus (should already be configured for a 20–80 measurement).
 - (ii) Go back to the TDR Setup screen and adjust the effective rise time until the measured rise time is 70 ps (set to $70 + 0 - 5$ ps).
- (f) Change the units of channel 4 to ohms.
- (g) Save the setup (File-Save-Instrument Setup) as “Z4”
- (h) Save the calibration (File-Save-TDR/TDT Calibration) as “Z4”

F. Setup - Thru Measurements, 35 ps rise time:

- 1 Touch the TDR Setup icon on the left side of the screen
- 2 Setup the TDR for a four port device with differential stimulus (channels 1 and 2), and differential response (channels 3 and 4) and display the differential responses.
- 3 Deskew for TDT
 - (a) Set averaging to 64:
 - (i) From the drop down menu choose “Setup” then “Averaging”
 - (ii) In the “Number of Averages” box enter 64

- (b) Configure for a TDT skew measurement
 - (i) Connect channels 1 and 3 together using a barrel from the Cal Kit.
 - (ii) Connect channels 2 and 4 together using the other barrel from the Cal Kit.
- (c) Deskew following the procedures in 86100C on-line help (Help-Contests-S-Skew-Differential TDR Skew) or refer to Appendix B.
- (d) Disconnect the channels from each other and remove the barrels
- (e) Set averaging back to 16

4 Insertion Loss and Skew

- (a) From TDR setup dialog box, clear the calibration data
- (b) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
 - (i) When setting the time base delay during the cal process, ensure the rising edge (indicating the “open” at the end of the cable) is approximately between the first and second graticules on the left of the screen. Note that a 1 or 2 ns/div time base setting during the cal process allows for testing a wide range of cable lengths. Use the SHORTS and LOADS from the N1024B Cal Kit as needed.
 - (ii) When performing a “thru” calibration (connecting channel 1 to channel 3 and channel 2 to channel 4):
 - (i) Connect channels 1 and 2 to Pair A of a fixture with a plug (CH1 to line 2, CH2 to line 3).
 - (ii) Connect channels 3 and 4 to Pair A of a fixture with a receptacle (CH3 to line 2, CH4 to line 3).
 - (iii) Connect the fixtures together

See the note on calibration in section I.C.3 of this procedure for a general explanation of the TDR calibration process. The specific calibration procedure in this section includes the fixtures in the through path which means that the effect of the fixtures – including the SATA connector – will be removed from the measurement as required by the SATA standard. Note that a common, but safe, assumption is made – that the characteristics of the fixture with a receptacle (which is used in this calibration process to connect to the other fixture, one with a plug) are similar to the characteristics of the fixture with a plug (which is used, along with a second fixture with a plug, to connect to the DUT when making the measurement).

- (c) Close the setup dialog box.
- (d) Establish a stimulus rise time of 35 ps:
 - (i) Touch the “Measure” tab on the left side of the screen and choose “rise time” to measure the rise time of the differential stimulus (should already be configured for a 20-80 measurement).
 - (ii) Go back to the TDR Setup screen and adjust the effective rise time until the measured rise time is 25 to 35 ps.
 - (iii) Remove the fixtures.
- (e) Save Configuration
 - (i) Save the setup (File-Save-Instrument Setup) as “IL&SKEW”
 - (ii) Save the calibration (File-Save-TDR/TDT Calibration) as “IL&SKEW “

5 NEXT and Differential Rise Time

- (a) From the TDR setup dialog box touch the “Clear Cal Data” button to reset the TDR cal.
- (b) Set the time base for 3 ns/div
- (c) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
 - (i) When setting the time base delay during the cal process, ensure the rising edge (indicating the “open” at the end of the cable) is approximately between the first and second graticules on the left of the screen. Use the SHORTS and LOADS from the N1024B Cal Kit as needed.
 - (ii) When performing a “thru” calibration, connect channel 1 to channel 3 using a barrel from the cal kit and connect channel 2 to channel 4 using the second barrel from the cal kit.
 - (iii) Close the setup dialog box.
- (d) Establish a stimulus rise time of 35 ps:
 - (i) Touch the “Measure” tab on the left side of the screen and choose “rise time” to measure the rise time of the differential stimulus (should already be configured for a 20-80 measurement).
 - (ii) Go back to the TDR Setup screen and adjust the effective rise time until the measured rise time is 25 to 35 ps.
- (e) Save Configuration
 - (i) Save the setup (File-Save-Instrument Setup) as “NEXT&DRT”
 - (ii) Save the calibration (File-Save-TDR/TDT Calibration) as “NEXT&DRT “

- (f) Verify NEXT of the fixtures.
 - (i) Connect the 86100C DCA-J to one of the plug fixtures: CH1 to line 2, CH2 to line 3, CH3 to line 5, CH4 to line 6.
 - (ii) Plug the receptacle fixture into the plug fixture and terminate the 4 SMA lines from the receptacle fixture with 50 ohm loads
 - (iii) Measure NEXT per step VI of this procedure.
 - (iv) Adjust the time base to display frequencies up to 5 or 10 GHz. Ensure the maximum NEXT between 10 MHz and 4500 MHz is $< \text{or} = -36$ dB.
 - (v) Remove the first plug fixture, replace it with the second plug fixture and repeat the measurement.
 - (vi) Any fixture not meeting the requirement cannot be used to test cables for NEXT.

G. Setup - Pattern Generator for ISI

- 1 Configure the Pulse Pattern Generator for differential data, 500 mV p-p, 3 Gb/s, SATA "lone" bit pattern (20 bit repeating pattern - 0011 0110 1111 0100 0010; see 7.2.4.3.5 of SATA spec).
- 2 Turn off the outputs of the PG.
- 3 Save the setup (File-Save-Instrument Setup) as "SATA ISI"

H. Setup - 86100C DCA-J for ISI, Pair A

- 1 Press the Eye/Mask button
- 2 Setup a differential trace
 - (a) Touch the "Measure" drop down menu, then select "Math"
 - (b) Turn on function 3, choose "subtract" as the operator, "Channel 1" as Source 1 and "Channel 2" as source 2.
 - (c) Close the Math dialog box
- 3 On the front panel, turn off all channels so only the Math function is displayed on the screen.
- 4 Save the setup (File-Save-Instrument Setup) as "SATA ISI A"

I. Setup - 86100C DCA-J for ISI, Pair B

- 1 Press the Eye/Mask button
- 2 Setup a differential trace
 - (a) Touch the "Measure" drop down menu, then select "Math"
 - (b) Turn on function 1, choose "subtract" as the operator, "Channel 3" as Source 1 and "Channel 4" as source 2.
 - (c) Close the Math dialog box
- 3 On the front panel, turn off all channels so only the Math function is displayed on the screen.
- 4 Save the setup (File-Save-Instrument Setup) as "SATA ISI B"

II Measurements - Mated Connector Impedance (SI-01) Cable Absolute Impedance (SI-02) and Common Mode Impedance (SI-04), Pair A

A. Setup

- 1 Connect cables to the plug fixture (CH1 to line 2, CH2 to line 3, CH3 to line 5, CH4 to line 6).
- 2 Recall setup for Pair A
 - (a) Touch the file drop down menu
 - (b) Choose "open" then "Instrument Setup" then "Pair A .set"
 - (c) Choose "open" then "TDR/TDT Calibration" then "Pair A.tdr"

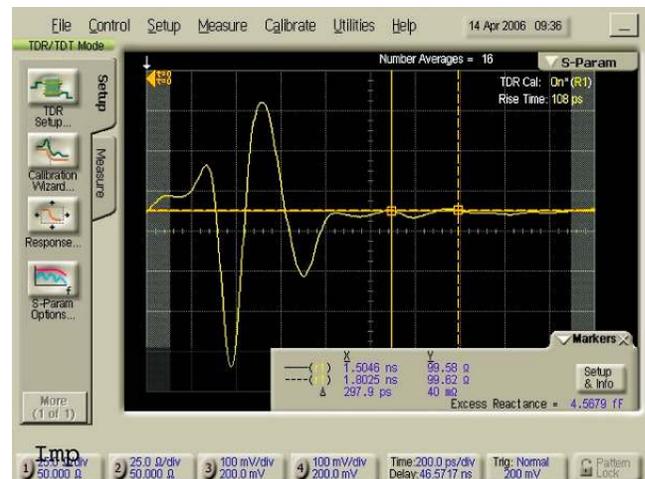


Figure 3. Mated Connector

B. Measure Mated Connector Impedance (SI-01), Receptacle B, Pair A

- 1 Plug-in receptacle B
- 2 Adjust the scope timebase and delay to display the mated connector impedance on the screen (see Figure 3).
- 3 Using the min/max measurement functions, measure and record the maximum and minimum values of mated connector differential impedance.
- 4 Observable Results: Mated connector differential impedance must be 100 ohms + 15%

C. Measure Mated Connector Impedance (SI-01), Receptacle A, Pair A

- 1 Unplug DUT receptacle B, plug in receptacle A
- 2 Adjust the scope timebase and delay to display the mated connector impedance on the screen (see Figure 3).
- 3 Using the min/max measurement functions, measure and record the maximum and minimum values of mated connector differential impedance.
- 4 Observable Results: Mated connector differential impedance must be 100 ohms + 15%

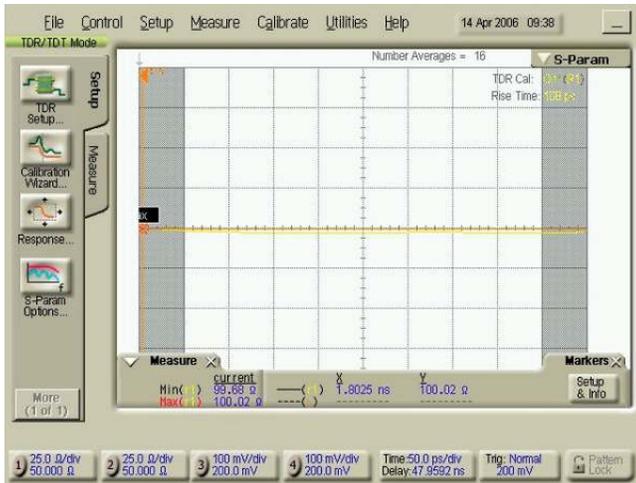


Figure 4. Cable Absolute Impedance

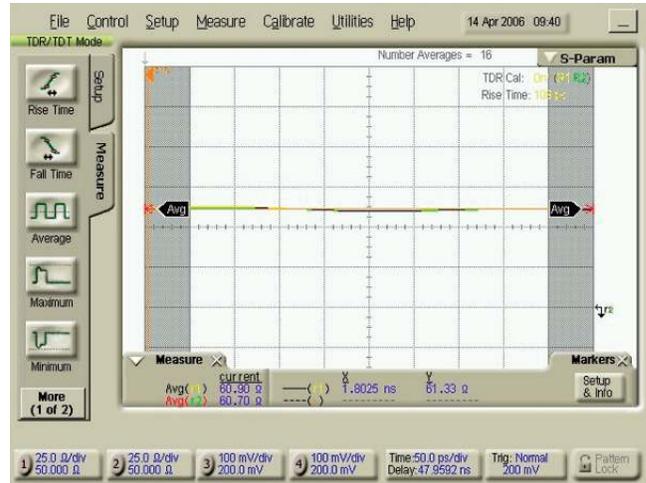


Figure 5. Common Mode Impedance

D. Measure Cable Absolute Differential Impedance (SI-02), Receptacle A, Pair A

- 1 Adjust the scope delay and time base to show the first 500 ps of cable response after any vestige of the connector response. You can use a vertical marker to tag the point on the trace where you want to start the measurement (typically 1.5 to 1.8 ns beyond the reference plane – see Figure 3), move that point to the left of the screen and set the time/div to 50 ps
- 2 Using the min/max measurement functions measure and record the minimum and maximum differential impedance (see Figure 4).
- 3 Observable Results: Cable absolute differential impedance must be 100 ohms + 10%

E. Measure Common Mode Impedance (SI-04), Receptacle A, Pair A

- 1 Setup for Common Mode:
 - (a) Click the Setup tab
 - (b) Touch the TDR setup icon on the left side of the screen
 - (i) Change stimulus to common mode
 - (ii) Close the setup screen
 - (c) Touch the TDR response icon on the left side of the screen
 - (i) Set response 1 to individual and turn it on
 - (ii) Set response 2 to individual and turn it on
- 2 Adjust the scope delay and time base to show the first 500 ps of cable response after any vestige of the connector response. (See step IID1).
- 3 Using the average measurement function measure and note the average impedance for response 1 – line 2, and response 2 – line 3 (See Figure 5). That is the average even mode impedance for each line.
- 4 Divide the average even mode impedance for each line by 2 and record the values. This is what the standard calls the “Common Mode Impedance”.
- 5 Observable Results: Common Mode Impedance must be 25–40 ohms.

III Measurements – Mated Connector Impedance (SI-01) Cable Absolute Impedance (SI-02) and Common Mode Impedance (SI-04), Pair B

A. Setup

- Recall setup for Pair B

 - 1 Touch the file drop down menu
 - 2 Choose “open” then “Instrument Setup” then “Pair B .set”
 - 3 Choose “open” then “TDR/TDT Calibration” then “Pair B.tdr”

B. Measure Mated Connector Impedance (SI-01), Receptacle B, Pair B

- 1 Plug-in receptacle B
- 2 Adjust the scope timebase and delay to display the mated connector impedance on the screen (see Figure 3).
- 3 Using the min/max measurement functions, measure and record the maximum and minimum values of mated connector differential impedance for receptacle B, Pair B.
- 4 Observable Results: Mated connector differential impedance must be 100 ohms + 15%

C. Measure Mated Connector Impedance (SI-01), Receptacle A, Pair B

- 1 Unplug DUT receptacle B, plug in receptacle A
- 2 Adjust the scope timebase and delay to display the mated connector impedance on the screen (see Figure 3).
- 3 Using the min/max measurement functions, measure and record the maximum and minimum values of mated connector differential impedance.
- 4 Observable Results: Mated connector differential impedance must be 100 ohms + 15%.

D. Measure Cable Absolute Differential Impedance (SI-02), Receptacle A, Pair B

- 1 Adjust the scope delay and time base to show the first 500 ps of cable response after any vestige of the connector response (see step IID1).
- 2 Using the min/max measurement functions measure and record the minimum and maximum differential impedance (see Figure 4).
- 3 Observable Results: Cable absolute differential impedance must be 100 ohms + 10%

E. Measure Common Mode Impedance (SI-04), Receptacle A, Pair B

- 1 Setup for Common Mode:
 - (a) Click the Setup tab
 - (b) Touch the TDR setup icon on the left side of the screen
 - (i) Change stimulus to common mode
 - (ii) Close the setup screen
 - (c) Touch the TDR response icon on the left side of the screen
 - (i) Set response 3 to individual and turn it on
 - (ii) Set response 4 to individual and turn it on
- 2 Adjust the scope delay and time base to show the first 500 ps of cable response after any vestige of the connector response (see step IID1).
- 3 Using the average measurement function measure and note the average impedance for response 3 - line 5, and response 4 - line 6 (see Figure 5). That is the average even mode impedance for each line.
- 4 Divide the average even mode impedance for each line by 2 and record the values. This is what the standard calls the "Common Mode Impedance".
- 5 Observable Results: Common Mode Impedance must be 25-40 ohms.

IV Measure Cable Pair Matching (SI-03), Receptacle A, Pair A

A. Single-ended impedance, Z1

- 1 Recall setup
 - (a) Touch the file drop down menu
 - (b) Choose "open" then "Instrument Setup" then "Z1.set"
 - (c) Choose "open" then "TDR/TDT Calibration" then "Z1.tdr"
- 2 Adjust the scope delay and time base to show the first 500 ps of cable response after any vestige of the connector response. (See step IID1).
- 3 Using the min/max measurement functions measure and note the minimum and maximum impedance for channel 1 (Z1 min and Z1 max). See Figure 6

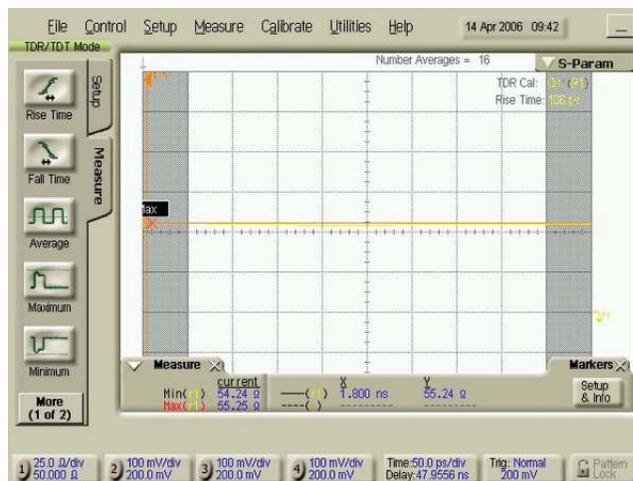


Figure 6. Cable Pair Match

B. Single-ended impedance, Z2

- 1 Recall setup
 - (a) Touch the file drop down menu
 - (b) Choose "open" then "Instrument Setup" then "Z2.set"
 - (c) Choose "open" then "TDR/TDT Calibration" then "Z2.tdr"
- 2 Adjust the scope delay and time base to show the first 500 ps of cable response after any vestige of the connector response. (See step IID1).
- 3 Using the min/max measurement functions measure and note the minimum and maximum impedance for channel 2 (Z2 min Z2 and max). See Figure 6.

C. Calculate and record the Match for Pair A:

$$Z_{Amax} = Z1_{max} - Z2_{max} \text{ and } Z_{Amin} = Z1_{min} - Z2_{min}.$$

D. Observable Results: Cable pair match must be + 5 ohms

V Measure Cable Pair Matching (SI-03), Receptacle A, Pair B

A. Single-ended impedance, Z3

- Recall setup
 - Touch the file drop down menu
 - Choose “open” then “Instrument Setup” then “Z3.set”
 - Choose “open” then “TDR/TDT Calibration” then “Z3.tdr”
- Adjust the scope delay and time base to show the first 500 ps of cable response after any vestige of the connector response. (See step IID1).
- Using the min/max measurement functions measure and note the minimum and maximum impedance for channel 3 (Z3 min and Z3 max). See Figure 6.

B. Single-ended impedance, Z4

- Recall setup
 - Touch the file drop down menu
 - Choose “open” then “Instrument Setup” then “Z4.set”
 - Choose “open” then “TDR/TDT Calibration” then “Z4.tdr”
- Adjust the scope delay and time base to show the first 500 ps of cable response after any vestige of the connector response. (See step IID1).
- Using the min/max measurement functions measure and note the minimum and maximum impedance for channel 4 (Z4 min and Z4 max). See Figure 6.

C. Calculate and record the Match for Pair B:

$$ZB_{max} = Z3_{max} - Z4_{max} \text{ and } ZB_{min} = Z3_{min} - Z4_{min}.$$

D. Observable Results: Cable pair match must be + 5 ohms

VI Measure Differential to Differential Cross Talk: NEXT (SI-08)

A. Setup

- Connect a second plug fixture to receptacle B of the DUT and install 50 ohm loads on each of the 4 lines
- Recall setup
 - Touch the file drop down menu
 - Choose “open” then “Instrument Setup” then “NEXT&DRT .set”
 - Choose “open” then “TDR/TDT Calibration” then “NEXT&DRT .tdr”

B. Measure NEXT (SI-08) Receptacle A:

- Display the differential TDT response and adjust the time/div to display 4–6X the cable length on the screen (see Figure 7 and note markers at start and 2X).
- Wait for 16 averages to complete, touch the S-Parameter tab on the top of the display and the shade will drop down displaying NEXT.

3 Adjust the time base to display frequencies up to 5 or 10 GHz.

4 Using a marker, find and record the maximum NEXT between 10 MHz and 4500 MHz. See Figure 8.

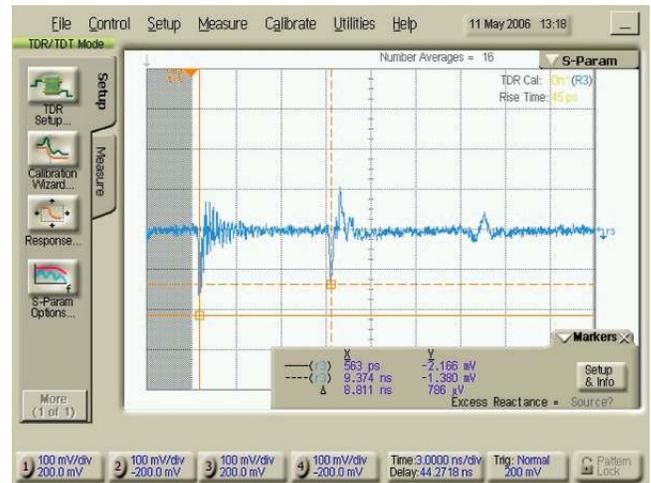


Figure 7. NEXT Time Domain

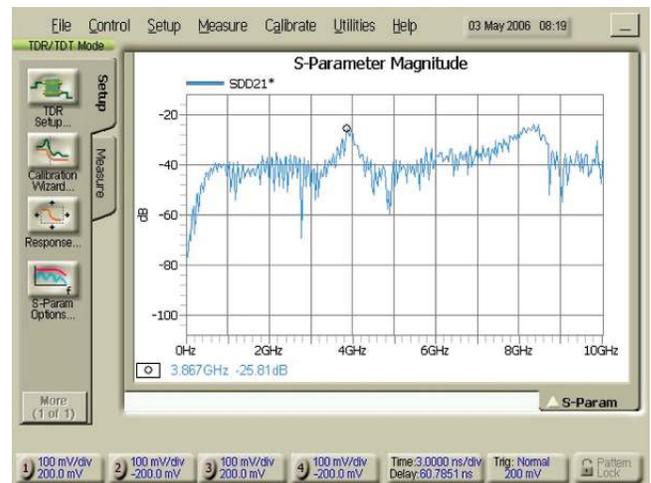


Figure 8. NEXT Frequency Domain

C. Measure NEXT (SI-08) Receptacle B:

- Remove the DUT and plug receptacle B of the DUT into the fixture connected to the scope, receptacle A into the fixture with the loads.
- Display the differential TDT response, wait for 16 averages to complete, touch the S-Parameter tab on the top of the display and the shade will drop down displaying NEXT.
- Adjust the time base to display frequencies up to 5 or 10 GHz.
- Using a marker, find and record the maximum NEXT between 10 MHz and 4500 MHz. See Figure 8.

D. If the cable fails the NEXT test in either direction, re-verify the NEXT of the fixtures used per step IF5f of this procedure

E. Observable Results: Differential to Differential Cross Talk from 10 to 4500 MHz must be less than -26 dB

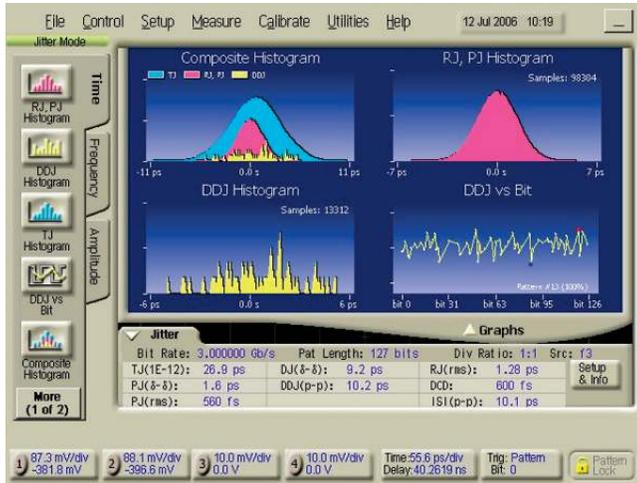


Figure 9. Inter-Symbol Interference

VII Inter-Symbol Interference (SI-09) for Pairs A and B

A. Setup for Pair A:

- 1 On the PPG, recall setup "SATA ISI"
- 2 On the 86100C DCA-J recall setup "SATA ISI A"
 - (a) Touch the file drop down menu
 - (b) Choose "open" then "Instrument Setup" then "SATA ISI A"
- 3 Disconnect the loads from the fixture on receptacle A and connect the differential outputs of the PPG to Pair A (lines 2 and 3) of the same fixture.
- 4 Turn on the data outputs of the PPG

B. Measure ISI (SI-09) for Pair A

- 1 Press the Jitter button. The 86100C DCA-J will determine the data rate and clock rate and the jitter shade will drop displaying jitter graphs and the jitter data table. See Figure 9.
- 2 From the table record the value for ISI.
- 3 Turn off the outputs of the PG.

C. Setup For Pair B:

- 1 On the 86100C DCA-J recall setup "SATA ISI B"
 - (a) Touch the file drop down menu
 - (b) Choose "open" then "Instrument Setup" then "SATA ISI B"
- 2 Disconnect the differential outputs of the PPG from Pair A of the fixture on Receptacle A and connect them to Pair B (lines 5 and 6) of the same fixture.
- 3 Turn on the outputs of the PPG.

D. Measure ISI (SI-09) for Pair B

- 1 Press the Jitter button. The 86100C DCA-J will determine the data rate and clock rate and the jitter shade will drop displaying jitter graphs and the jitter data table. See Figure 9.

2 From the table record the value for ISI. See Figure 9.

3 Turn off the outputs of the PG and disconnect it from the fixture.

E. Observable Results: Inter-Symbol Interference must be less than 50 ps

A. Differential Rise Time Setup

- 1 Connect scope channels 1 and 2 to pair A on the fixture (CH1 to line 2, CH2 to line 3) plugged into Receptacle A of the DUT.

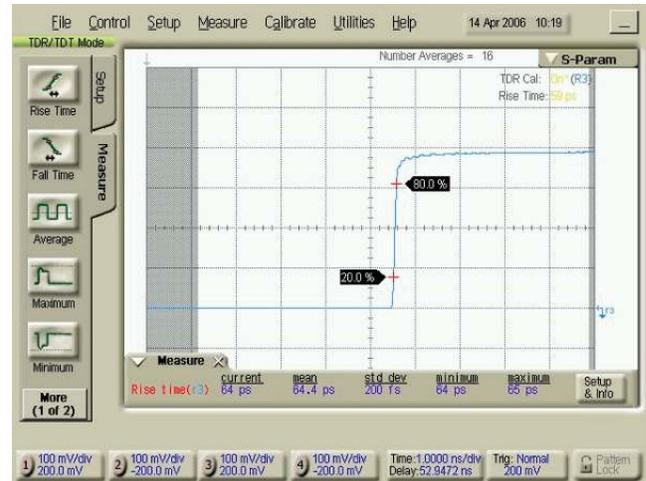


Figure 10. Differential Rise Time

VIII Insertion Loss (SI-07), Differential Rise Time (SI-05), and Intra-Pair Skew (SI-06), Receptacle A, Pair A

2 Connect scope channels 3 and 4 to Pair A on the fixture (CH3 to line 2, CH4 to line 3) plugged into receptacle B of the DUT.

3 Recall setup

- (a) Touch the file drop down menu
- (b) Choose "open" then "Instrument Setup" then "NEXT&DRT.set"
- (c) Choose "open" then "TDR/TDT Calibration" then "NEXT&DRT.tdr"

B. Measure Differential Rise Time (SI-05)

- 1 Using the rise time measurement, measure and record the rise time of the differential response. See Figure 10.
- 2 Observable results: Differential Rise Time must be less than or equal to 85 ps.

C. Recall the Insertion Loss and Differential Skew Setup

- 1 Touch the file drop down menu
- 2 Choose "open" then "Instrument Setup" then "IL&SKEW.set"
- 3 Choose "open" then "TDR/TDT Calibration" then "IL&SKEW.tdr"

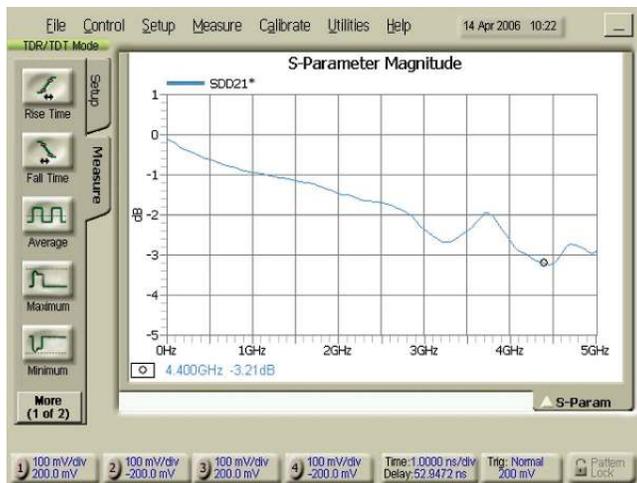


Figure 11. Insertion Loss

IX Insertion Loss (SI-07), Differential Rise Time (SI-05) and Intra-Pair Skew (SI-06), Receptacle A, Pair B

A. Differential Rise Time Setup

- 1 Disconnect scope channels 1 and 2 from lines 2 and 3 of the fixture for receptacle A and install them on lines 5 and 6 of the same fixture (CH1 to line 5, CH2 to line 6).
- 2 Disconnect scope channels 3 and 4 from lines 2 and 3 of the plug fixture for receptacle B and install them on lines 5 and 6 of the same fixture (CH3 to line 5, CH 4 to line 6)
- 3 Recall setup
 - (a) Touch the file drop down menu
 - (b) Choose "open" then "Instrument Setup" then "NEXT&DRT.set"
 - (c) Choose "open" then "TDR/TDT Calibration" then "NEXT&DRT.tdr"

B. Measure Differential Rise Time (SI-05)

- 1 Using the rise time measurement, measure and record the rise time of the differential response. See Figure 10.
- 2 Observable results: Differential Rise Time must be less than or equal to 85 ps

C. Recall the Insertion Loss and Differential Skew Setup

- 1 Touch the file drop down menu
- 2 Choose "open" then "Instrument Setup" then "IL&SKEW.set"
- 3 Choose "open" then "TDR/TDT Calibration" then "IL&SKEW.tdr"

D. Measure Insertion Loss (SI-07)

- 1 Display the TDT response, wait for 16 averages to complete, touch the S-Parameter tab on the top of the display. The shade will drop down displaying Insertion Loss.
- 2 Adjust the time base to display frequencies up to 5 or 10 GHz. Using a marker, find and record the maximum Insertion Loss between 10 MHz and 4500 MHz. See Figure 11.
- 3 Observable Results: Insertion Loss from 10 to 4500 MHz must be less than or equal to 6 dB
- 4 Touch the S-Parameter tab at the bottom of the shade to raise the shade.

E. Measure Intra-Pair Skew (SI-06)

- 1 Unplug the cable from the fixture connected to channels 3 and 4.
- 2 Go to the response menu and select "individual" for channels 1 and 2 and turn both responses on.
- 3 Using the delta time measurement, measure the skew between responses 1 and 2 (it may be negative) as the step exits the cable. See Figure 12. Since the measurement includes transit time to the cable end and back, divide the measured value by 2. This is the OUTPUT skew. Note the value.
- 4 Remove the cable and, using the delta time measurement, measure the skew between responses 1 and 2 (it may be negative) as the step exits the fixture. Since the measurement includes transit time to the fixture end and back, divide the measured value by 2. This is the INPUT skew. Note the value and
- 5 Calculate the Intra-pair Skew as ABS (Input Skew-Output Skew)
- 6 Observable results: Intra-Pair skew must be less than or equal to 10 ps.

D. Measure Insertion Loss (SI-07)

- 1 Display the TDT response, wait for 16 averages to complete, touch the S-Parameter tab on the top of the display. The shade will drop down displaying Insertion Loss.
- 2 Adjust the time base to display frequencies up to 5 or 10 GHz. Using a marker, find and record the maximum Insertion Loss between 10 MHz and 4500 MHz. See Figure 11.
- 3 Observable Results: Insertion Loss from 10 to 4500 MHz must be less than or equal to 6 dB
- 4 Touch the S-Parameter tab at the bottom of the shade to raise the shade.



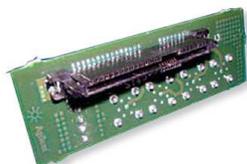
Figure 12. Intra-Pair

E. Measure Intra-Pair Skew (SI-06)

- 1 Unplug the cable from the fixture connected to channels 3 and 4.
- 2 Go to the response menu and select “individual” for channels 1 and 2 and turn both responses on
- 3 Using the delta time measurement, measure the skew between responses 1 and 2 (it may be negative) as the step exits the cable. See Figure 12. Since the measurement includes transit time to the cable end and back, divide the measured value by 2. This is the OUTPUT skew. Note the value.
- 4 Remove the cable and, using the delta time measurement, measure the skew between responses 1 and 2 (it may be negative) as the step exits the fixture. Since the measurement includes transit time to the fixture end and back, divide the measured value by 2. This is the INPUT skew. Note the value.
- 5 Calculate the Intra-pair Skew as ABS (Input Skew-Output Skew)
- 6 Observable results: Intra-Pair skew must be less than or equal to 10 ps.



Drive Fixtures



Test Procedure, SATA II PHY Tx and Rx Testing

Keysight wishes to thank Andy Baldman and the University of New Hampshire Interoperability Lab for the creation of the SATA MOI from which the following test procedure was developed:

Introduction

This procedure describes how to set up and use the 86100C DCA-J to make the following measurements on a SATA internal drive channel as defined in Section 2.11 and 2.13 of the SATA Interoperability Unified Test Document:

- Tx-01 Pair Differential Impedance
- Tx-02 Single Ended Impedance
- Tx-03 Gen2 Differential Mode Return Loss
- Tx-04 Gen2 Common Mode Return Loss
- Tx-05 Gen2 Impedance Balance
- Tx-06 Gen1 Differential Mode Return Loss

- Rx-01 Pair Differential Impedance
- Rx-02 Single Ended Impedance
- Rx-03 Differential Mode Return Loss
- Rx-04 Common Mode Return Loss
- Rx-05 Impedance Balance
- Rx-06 Gen1 Differential Mode Return Loss

All the tests use Time Domain Reflectometry (TDR) techniques to measure impedance in the time domain with test results reported in the time or frequency domain (S-Parameters) as required by the standard. The 86100C DCA-J with option 202 can easily translate between the time and frequency domains with a single button push.

The test procedure is formatted to group tests with similar setups and instrument connections together. Further throughput improvement can be realized by automating the test process.

Equipment Requirements

- 1 - Keysight 86100C DCA-J with option 202
- 1 - Keysight 54754A TDR module installed in the left slot
- 2 - high quality SMA cables
- 1 - Keysight SAS Drive X2 Primary Test Fixture, Keysight P/N N5421-26401 OR 1 - Coax style SATA Cable test fixture, Receptacle side, COMAX P/N H303000204A
- 1 - Keysight N1024B Cal Kit
- 2 - Keysight 11742A DC blocking capacitors
- 2 - 4 dB attenuators (0-18 GHz or better)
- 1 - Means by which to power DUT and configure if for BIST TX modes (e.g. Ulink DriveMaster, or vendor-specific means.)

I Instrument Setup and Calibration

A. Initialize 86100C DCA-J:

- 1 Ensure the 86100C DCA-J has been running for at least 1 hour for proper warm-up.
- 2 Remove all cables from the instrument and press the Default Setup button.
- 3 Perform Module Calibration:

This process accomplishes several things within the module to maximize measurement accuracy. The sampler gain and bandwidth are optimized for the different bandwidth settings, amplitude linearity correction is performed and TDR step voltage is calibrated.

- (a) Touch the calibrate drop-down menu
- (b) Touch “all calibrations”
- (c) Touch “calibrate left module” and follow prompts, using the 50 ohm load from the calibration kit as required.

- 4 Using the torque wrench, connect the attenuators, cables and DC blocking capacitors to channels 1 and 2.

Note 1: Not all drives will have DC blocking capacitors in their data channels so these capacitors are added to allow for a DC mismatch between the instrument and DUT.

Note 2: The attenuators are required when testing the Tx side of the DUT in order to limit the step driven into the Tx output to no more than 139 mV. Although the attenuators are not required for testing the Rx side of the DUT, they can be used. If you are using a DCA-J with 2 TDR modules you may use the attenuators on the Tx side only.

B. Setup – Differential Impedance and Return Loss

- 1 Touch the TDR setup icon on the left side of the screen to display the setup dialog box (Figure 2).
- 2 Setup the TDR for:
 - (a) A two port device (choose the 2-Port DUT from the bottom of the screen)
 - (b) Differential stimulus (choose “differential” as the stimulus mode from the top of the screen)
 - (c) Show the Differential Response (check “Diff TDR” in the Measurement Results window on the left of the screen).
- 3 Set TDR Pulse Rate:
 - (a) *Why change the TDR pulse rate?*
Some devices have reactive components that can be quickly charged by the TDR step but do not have time to discharge before the next step arrives which further charges the device. While that charging effect does not make TDR measurements impossible, for accurate measurements the device must be able to discharge between TDR steps. Experimentation on many SATA devices has demonstrated that reducing the TDR pulse rate to 30 kHz is optimum for most devices.

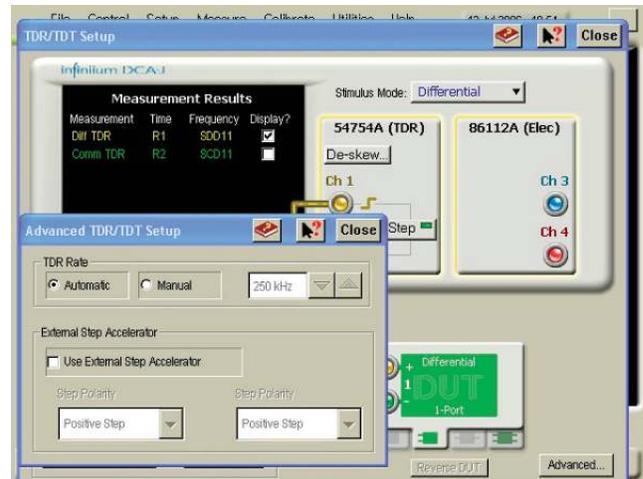


Figure 13. TDR Pulse

- (b) From the TDR setup dialog box click the “advanced” button to bring up the TDR pulse rate dialog box (see Figure 13).
- (c) Select “manual” (default is “automatic”)
- (d) Set the pulse rate to 30 kHz
- (e) Close the TDR pulse rate dialog box

4 Deskew

- (a) Why Deskew?
 - (i) *This process corrects for the effects of using unequal length cables to connect to the device to be tested. If cables used in testing a differential line aren't identical in length, the “skew” induced by the different length cables results in 2 detrimental effects:*
 - (i) *The steps, launched from the TDR module at the same time, arrive at the DUT out of alignment (one arrives before the other).*
 - (ii) *Reflections from the DUT will also be skewed as those reflections travel along the non-equal length cables back to the receivers in the module.*
 - (ii) *The deskew process does two things to correct for the effects of the unequal length cables.*
 - (i) *The steps are launched from the module at different times so they will arrive at the end of the cables – at the DUT – at the same time.*
 - (ii) *A trigger delay is added to one of the receivers so reflections that enter the cables from the DUT at the same time are sampled by the receivers at the “same” time*

- (b) Des skew Process
 - (i) Set averaging to 64:
 - (ii) From the drop down menu choose "Setup" then "Averaging"
 - (iii) In the "Number of Averages" box enter 64
 - (iv) Des skew both pairs of cables using the procedure for TDR des skew found in the 86100C DCA-J on-line help (Help-Contents-S-Skew-Differential TDR Skew) or refer to Appendix A.
 - (v) Set averaging back to 16

5 Calibration:

- (a) Why Calibrate?

This process, which is part of each measurement setup in this procedure, requires connecting known standards (a short, a 50 ohm load and, for TDT measurements, a thru) to the instrument at the measurement reference plane. The instrument then reads the value of the standards, establishes a "time 0" reference and develops a digital filter that compensates for the non-ideal frequency response of the test system (step, test cables/fixtures and receiver) in a manner similar to the calibration process used with a vector network analyzer. By compensating for the non-ideal response of the system, measurement results reflect the performance of the DUT alone and not the measurement system plus DUT.
- (b) Calibration Process
 - (i) Set the Horizontal Scale to 1.000 ns/div.
Note that this time base setting is required in order to get adequate resolution in the frequency domain for the Return Loss measurements.
 - (ii) Touch the Calibration Wizard icon at the bottom of the setup screen which will guide you through the TDR calibration process.
 - (iii) Use the SHORTS and LOADS from the N1024B Cal Kit as needed.
 - (iv) Ensure the rising edge (indicating the "open" at the end of the cable) is approximately between the first and second graticules on the left of the screen
 - (v) Close the setup dialog box.

6 Establish a Differential TDR rise time of 100 ps:

- (a) Connect the cables to the Keysight SAS/SATA fixture (either port will do.)
- (b) Touch the "measure" tab on the left side of the screen and choose "rise time" to measure the rise time of the differential stimulus .
- (c) Touch the "setup/info" button to the right of the measurement results, choose "Configure Meas..." and choose 20%, 50%, 80% for the threshold.
- (d) Go back to the TDR setup screen and adjust the effective rise time until the measured rise time is 100 ps (set to 100 + 20 ps).
- (e) Change the units for channels 1 and 2 to ohms.

7 Save Configuration

- (a) Save the setup (File-Save-Instrument Setup) as "Pair A set"
- (b) Save the calibration as (File-Save-TDR/TDT Calibration) as "Pair A TDR 100"

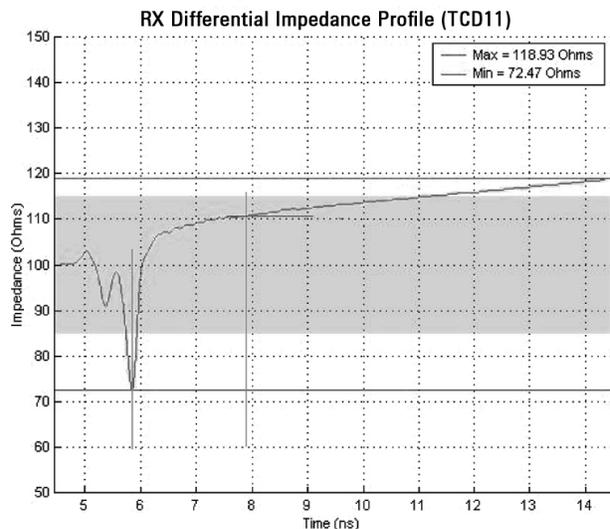


Figure 14. Tx/Rx Impedance

II Tx-01 – Pair Differential Impedance

- A. Follow the setup instructions in step I
- B. Ensure that the DUT is powered on and sourcing MFTP signaling at 1.5 Gb/s (via BIST or vendor-specific mode.)
- C. Connect the TDR cables to the fixture so they will test the DUT Tx pair when the fixture is connected to the DUT.
- D. Adjust the scope time base and delay to display the Pair Differential Impedance on the screen.
- E. Setup Number of Points, Set Averaging, Adjust TDR Rate:

Because the transmitter will be measured while it is transmitting data, a large data signal, uncorrelated to the TDR step, will be riding on the small reflected TDR pulse. A large number of averages will be required in order to "remove" the data content of the signal so the reflected TDR step can be properly evaluated.

1 Set acquisition points to 512

- (a) Click the "Setup" drop down menu
- (b) Choose "Acquisition" The Acquisition Window will open
- (c) Click the "Waveform" Tab
- (d) Under "Point/Waveform" clock "manual" and enter 512

2 Set Averaging to 2048

- (a) Choose the "Averaging" Tab
- (b) Averaging should already be enabled but check the enable averaging box if it is not checked already
- (c) Choose "Best Flatness"
- (d) Enter 2048 for the number of averages
- (e) Close the Acquisition window

- 3 Adjust Averaging and TDR Rate:
For the vast majority of devices this setup will yield good results. However, for some devices effects from the transmitted data may still be very visible. For those devices, increasing averaging to maximum (4096) and/or slightly adjusting the TDR rate (trial and error) will resolve the problem.

F. Setup the Peeled trace:

- 1 Why peel?
 - (a) *TDR theory explains that when a TDR step travels along a transmission line and encounters the first discontinuity, some of the energy is reflected from that discontinuity back to the TDR module and you can see the discontinuity on the TDR display with high accuracy. With less energy now in the “original” step, it continues down the transmission line. When the reduced-energy step encounters the second discontinuity the reflection will be less than it would have been if the step hadn’t lost energy at the first discontinuity. In addition, the reflected energy from the second discontinuity, which is now headed back to the TDR module, will encounter the first discontinuity and some of the energy in that reflected pulse will be reflected again – away from the TDR module. In summary, as you look “deeper” into the DUT the accuracy of the measurements from 2nd, 3rd, 4th, etc. discontinuities will be less than the accuracy from the first discontinuity (although errors are typically quite small unless the previous discontinuities were large). Peeling attempts to remove the effects each discontinuity has on subsequent discontinuities resulting in improved accuracy. A peeled trace is sometimes referred to as an “impedance profile” rather than simply a TDR trace.*

2 Peeling Process

- (a) With the 86100C DCA-J peeling is a simple math function. Choose Measure from the menu along the top of the screen and then Math to display the Math dialog box.
- (b) Click the tab for function 3 (will provide a blue trace), choose “TDR Peeling” as the operator and choose “Response 1” (Differential TDR) as Source 1. Close the Math dialog box.
- (c) You will now see a blue trace – the peeled trace – on the screen along with the other responses you have turned on. You may want to click on the “Response” icon to get into the Response dialog box and turn off all the responses so you can see only the peeled trace.
- (d) Adjust TDR rate if required.

G. Using the cursors on the function 3 trace, determine the time point of the last major capacitive dip on the peeled trace.

- H. Record the impedance value at the point occurring 2 ns after the last major capacitive dip (see Figure 14).
- I. Also record the overall minimum and maximum impedance values over the entire observation window.
- J. Open the Math dialog box and turn off the peeled trace (function 3).
- K. **Observable Results:** All measured impedance values shall be between 85 and 115 ohms for 1.5G devices, as well as 3.0G devices operating in 1.5G mode.

- 1. Note 1: The verification of this result may not be required. If a product which supports 1.5 Gb/s passes TX-06, then it is not required that this result be verified (though the test should still be performed). This result must be verified for a 1.5 Gb/s product if it fails TX-06.
- 2. Note 2: The 2 ns measurement result is considered informative for this test. Conformance is based on the overall impedance profile.



Figure 15. Tx-03 and Tx-06

III Tx-06 – Gen1 (1.5 Gb/s) Dif Mode Return Loss

- A. From the Math dialog box, turn off function 3 (the peeled trace).
- B. Go into the Response dialog box and turn on Response one configured to show the Diff TDR response.
- C. Adjust the scope time base and delay to display the Differential Mode Impedance on the screen.
- D. Display the Differential Mode Return Loss by selecting the “S-Param” pulldown in the upper right corner of the display.
- E. Using the cursors, verify that the Return Loss meets or exceeds the values shown in the table below.
- F. **Observable Results:** The Tx Differential Mode Return Loss shall be at or above the minimum limits shown below.

Frequency Range	Minimum Limit (1.5G)
75 - 150 MHz	14 dB
150 - 300 MHz	8 dB
300 - 600 MHz	6 dB
600 - 1200 MHz	6 dB
1200 - 2400 MHz	3 dB
2400 - 3000 MHz	1 dB

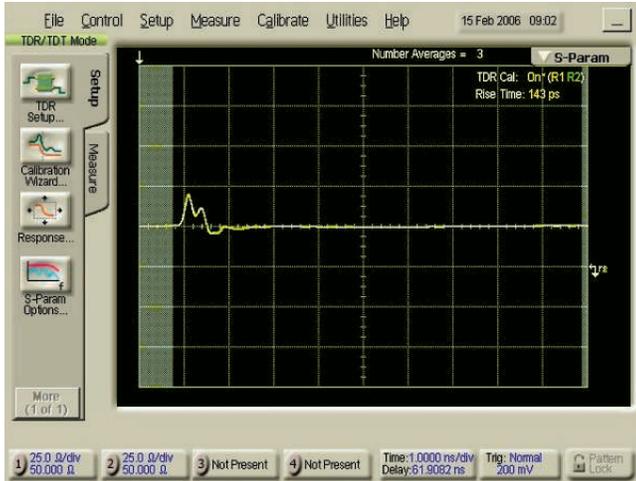


Figure 16. Tx-02

IV Tx-02 – Gen1 (1.5 Gb/s) Single-Ended Impedance

- Go to the TDR set up screen and choose common mode stimulus. Close the set up screen.
- Open the response screen and choose response 1 to be single-ended and response 2 to be single-ended and uncheck the "Display On" box for each response so the responses are not shown on the screen as we want to show only the peeled traces.
- Open the Math dialog box and turn on Function 3 (TDR peeling for Response 1) and Function 4 (TDR Peeling for Response 2).
- Adjust the scope time base and delay to display the peeled even mode impedance traces on the screen
- Using the min/max measurement functions, measure and record the maximum and minimum values of the Pair Single-Ended Impedance for the peeled traces.
- Open the Math dialog box and turn off the Peeled traces (functions 3 and 4).
- Observable Results: The measured impedance value shall be greater than 40 ohms for 1.5G devices, as well as 3.0G devices operating in 1.5G mode.
 - Note: The single-ended impedance test requirement is only applicable to products running at 1.5 Gb/s and the measurement result is considered informative.

V Tx-03 – Gen2 (3 Gb/s) Dif Mode Return Loss

- Change the DUT mode so it is sourcing MFTP signaling at 3 Gb/s (via BIST or vendor-specific mode).
- Go to the TDR set up screen and choose differential mode stimulus. Close the set up screen.
- Open the response screen and choose response 1 to be the Differential TDR response, check the "Display On" box for response 1 and uncheck the "Display On" for all other responses.
- Adjust the scope time base and delay to display the Pair Differential Impedance on the screen.
- Adjust Averaging and TDR Rate: For the vast majority of devices this setup will yield good results. However, for some devices effects from the transmitted data may still be very visible. For those devices increasing averaging to maximum (4096) and/or slightly adjusting the TDR rate (trail and error) will resolve the problem.

- Display the Differential Mode Return Loss by selecting the "S-Param" pulldown in the upper right corner of the display.
- Observable Results: Using the cursors, verify that the Return Loss is at or above the minimum limits shown below.

Frequency Range	Lower Rloss limit(3G)
150 - 300 MHz	14 dB
300 - 600 MHz	8 dB
600 - 1200 MHz	6 dB
1200 - 2400 MHz	6 dB
2400 - 3000 MHz	3 dB
3000 - 5000 MHz	1 dB



Figure 17. Tx-04

VI Tx-04 – Common Mode Return Loss

- Open the response screen and choose response 2 to be differential mode TDR and turn off response 1.
- Adjust the scope time base and delay to display the differential mode response to the common mode stimulus on the screen.
- Display the Impedance Balance by selecting the "S-Param" pulldown in the upper right corner of the display.
- Using the cursors, verify that the Return Loss meets or exceeds the values shown in the table below.
- Observable Results: The Tx Common Mode Return Loss shall be above the minimum limits specified in reference [1] for Gen2i and Gen2m devices. For convenience, the values are reproduced below.

Frequency Range	Lower Rloss limit(3G)
150 - 300 MHz	8 dB
300 - 600 MHz	5 dB
600 - 1200 MHz	2 dB
1200 - 2400 MHz	1 dB
2400 - 3000 MHz	1 dB
3000 - 5000 MHz	1 dB



Figure 18. Tx-05

VII Tx-05 - Impedance Balance

- A. Open the response screen and choose response 1 to be common mode TDR and turn off response 2.
- B. Open the setup screen and choose common mode stimulus.
- C. Adjust the scope time base and delay to display the Common Mode Impedance on the screen.
- D. Display the Impedance Balance by selecting the “S-Param” pulldown in the upper right corner of the display.
- E. Using the cursors, verify that the Return Loss meets or exceeds the values shown in the table below.
- F. Observable Results: The Tx Impedance Balance shall be above the minimum limits specified in reference [1] for Gen2i and Gen2m devices. For convenience, the values are reproduced below.

Frequency Range	Lower Rloss limit(3G)
150 - 300 MHz	30 dB
300 - 600 MHz	20 dB
600 - 1200 MHz	10 dB
1200 - 2400 MHz	10 dB
2400 - 3000 MHz	4 dB
3000 - 5000 MHz	4 dB

VIII Rx-01 – Pair Differential Impedance

- A. The procedure for this test is identical to that of test Tx-01, with the exception that the TDR cables shall be connected to the fixture so they will test the DUT Rx pair when the fixture is connected to the DUT.
- B. Observable Results: Verify the measured impedance value shall be between 85 and 115 ohms for 1.5G devices, as well as 3.0-G devices operating in 1.5-G mode.
 1. **Note 1:** The verification of this result may not be required. If a product which supports 1.5 Gb/s passes Tx-06, then it is not required that this result be verified (though the test should still be performed). This result must be verified for a 1.5 Gb/s product if it fails Tx-06.

2. **Note 2:** The 2 ns measurement result is considered informative for this test. Conformance is based on the overall impedance profile.

IX Rx-02 – Single-Ended Impedance

- A. The procedure for this test is identical to that of test Tx-02, with the exception that the TDR cables shall be connected to the fixture so they will test the DUT Rx pair when the fixture is connected to the DUT.
- B. Observable Results: Verify the Rx Single-Ended Impedance is 40 Ohms or greater.
 - Note 2:** The single-ended impedance test requirement is only applicable to products running at 1.5 Gb/s and the measurement result is considered informative.

X Test Rx-03 – Gen2 (3 Gb/s) Differential Mode Return Loss

- A. The procedure for this test is identical to that of test Tx-02, with the exception that the TDR cables shall be connected to the fixture so they will test the DUT Rx pair when the fixture is connected to the DUT.
- B. Observable Results: Using the cursors, verify the Rx Differential Mode Return Loss is at or above the minimum limits specified for 3.0 Gb/s devices.

Frequency Range	Lower Rloss limit (3 GS/s)
150 - 300 MHz	18 dB
300 - 600 MHz	14 dB
600 - 1200 MHz	10 dB
1200 - 2400 MHz	8 dB
2400 - 3000 MHz	3 dB
3000 - 5000 MHz	1 dB

XI Test Rx-04 – Common Mode Return Loss

- A. The procedure for this test is identical to that of test Tx-02, with the exception that the TDR cables shall be connected to the fixture so they will test the DUT Rx pair when the fixture is connected to the DUT.
- B. Observable Results: Using cursors, verify the Rx Common Mode Return Loss is at or above the minimum limits specified for 3.0 Gb/s devices.

Frequency Range	Lower Rloss limit (3 GS/s)
150 - 300 MHz	5 dB
300 - 600 MHz	5 dB
600 - 1200 MHz	2 dB
1200 - 2400 MHz	2 dB
2400 - 3000 MHz	2 dB
3000 - 5000 MHz	1 dB

XII Test Rx-05 – Impedance Balance

- A. The procedure for this test is identical to that of test Tx-05, with the exception that the TDR cables shall be connected to the fixture so they test the Rx pair of the DUT.
- B. Observable Results: Using cursors, verify the Rx Common Mode Return Loss is at or above the minimum limits specified for 3.0 Gb/s devices.

Frequency Range	Lower Rloss limit(3G)
150 - 300 MHz	30 dB
300 - 600 MHz	30 dB
600 - 1200 MHz	20 dB
1200 - 2400 MHz	10 dB
2400 - 3000 MHz	4 dB

XIII Test Rx-06 – Gen1 (1.5 Gb/s) Differential Mode Return Loss

- A. The procedure for this test is identical to that of test Tx-06, with the exception that the TDR cables shall be connected to the fixture so they will test the DUT R pair when the fixture is connected to the DUT.
- B. Observable Results: Using cursors, verify the Rx Differential Mode Return Loss is at or above the minimum limits specified for 1.5 Gb/s devices.

Frequency Range	Minimum Rloss Limit (3.0 Gb/s)
75 - 150 MHz	18 dB
150 - 300 MHz	14 dB
300 - 600 MHz	10 dB
600 - 1200 MHz	8 dB
1200 - 2400 MHz	3 dB
2400 - 3000 MHz	1 dB

Summary and Conclusion

Keysight's 86100C DCA-J and 54754A TDR modules, combined with high performance SATA test fixtures/adapters developed by COMAX or Keysight Technologies, provides the flexibility and performance needed to meet the demanding SATA II test requirements.

With built-in TDR calibration, option 202 Enhanced Impedance and S-Parameter software and option 200 Jitter Analysis software, the 86100C DCA-J provides the full functionality you need in one integrated, easy to use package.

References

1. Serial ATA Backgrounder
Serial ATA Revision 2.6 Specification
Serial ATA Interoperability Program Unified Test Document rev 1.1
86100C DCA-J Differential TDR Deskew procedure (on-line Help)
University of New Hampshire Inter-Operability Laboratory SATA TxRx MOI for the Keysight 86100C Rev 1.0 RC

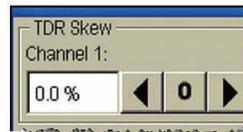
Appendix A TDR/TDT Deskew

Differential TDR Skew

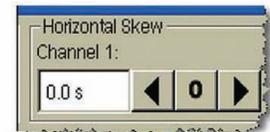
Differential TDR skew allows you to use two cables of unequal lengths to make differential or common stimulus measurements. This button is only visible in the setup wizard when differential or common stimulus is selected. Also, the button can not be selected if the stimulus is turned off.

The actual skew adjustment consists of applying equal amounts of TDR and Horizontal skew to minimize round-trip measurement errors. During the skew adjustment, only the front-panel time-per-division, time delay, and autoscale functions are active. After adjusting the skew, you can continue to make selections in the Setup Wizard.

When you know the propagation delay (Δ) of the longer cable, enter 50% of that value in the Horizontal Skew box for the channel the cable is connected to. In the TDR Skew box for the same channel, enter the negative percentage value necessary to completely skew the delay until the apparent delay of both cables is equal.



TDR skew regulates the time differential between the launches of TDR steps.



Horizontal skew adjusts the time differential between sampling for both channels and changes the timebase delay for an individual target channel.

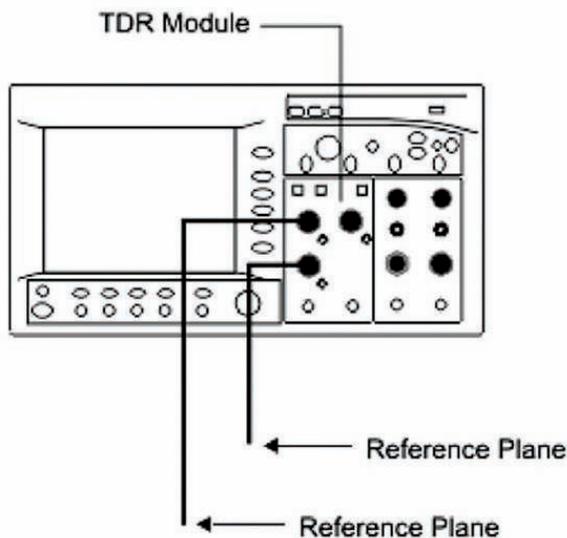
Once you have entered the correct values needed for TDR and Horizontal skew, you can save your settings in an instrument setup file. Saving the setup allows you to avoid repeating the propagation measurement when using the same cables in the future.

Follow the TDR and TDT skew procedures carefully. The procedures are not difficult to follow. Improperly performed skew adjustments can result in unexpected measurement behavior.

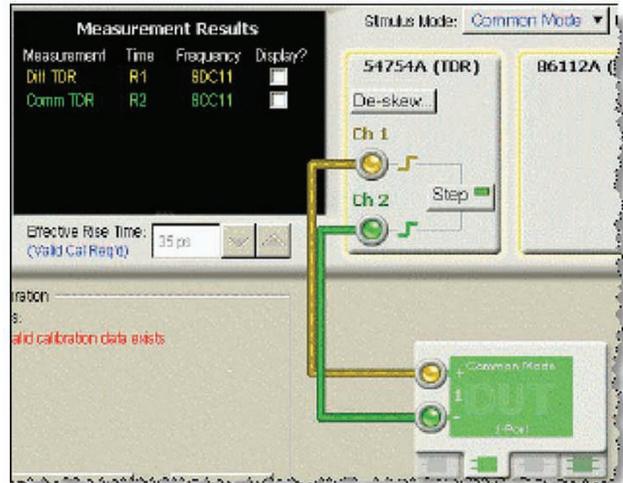
To adjust differential TDR skew

Use this procedure to compensate for unequal cable lengths in differential TDR test setups. Skew adjustments can only be performed when differential or common stimulus is active on differential TDR modules.

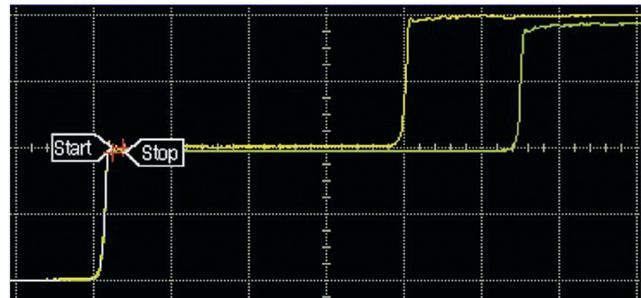
1. In order to match the steps in this procedure, install the TDR module in the mainframe's left slot. Although this procedure uses channels 1 and 2, you could install the module in the right slot and use channels 3 and 4.
2. Turn on the instrument, and allow the instrument to warm up for one hour.
3. Press the Default Setup button.
4. Press the TDR/TDT Mode button.
5. On the Calibrate menu, click All Calibrations. Select the Modules tab.
6. Click Calibrate Left Module to calibrate the TDR module. Follow any prompts to complete the calibration. When prompted to connect high quality termination, enter the measured resistance of the load termination. Always use high quality terminations for the best results.
7. Optional step to make waveforms easier to view: On the Setup toolbar, click on S-Param Options, if it is displayed. In the dialog box, clear the Show Windowed Region and click Close. This feature is only installed on instruments having option 202, Enhanced Impedance and S-Parameter Software.
8. Connect the test setup cables and adapters for your test setup. The end of the cables will be the measurement reference plane, where you will connect your test device. Do not connect the test device.



9. On the Setup toolbar, click TDR Setup.
10. In the dialog box, select the one-port balanced test device with the connections as shown in the following figure. For Stimulus Mode, select Common or Differential, as the procedure for either stimulus is the same. The pictures in this topic were taken with Common stimulus. You can also change the stimulus after completing this procedure.



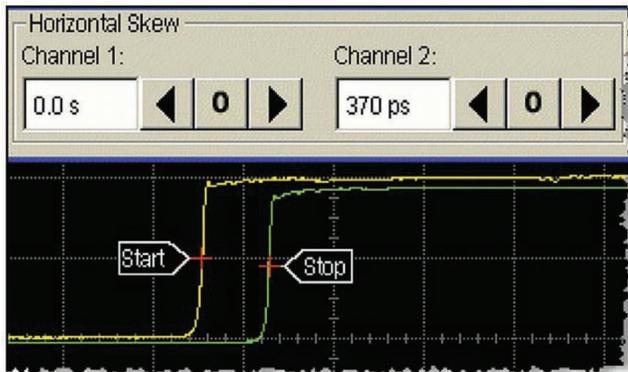
11. Clear all the measurements listed in Measurement Results.
12. Click De-skew. The Differential TDR Skew dialog box is displayed, and the Stop and Start marker annotations are placed on the waveform.



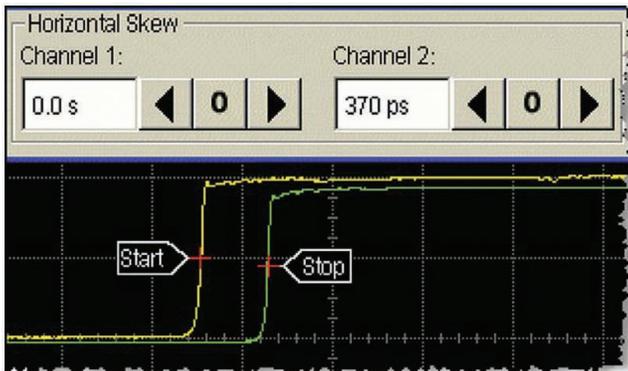
13. If the markers are located on the incident (first) step response as shown above, you must move them to the reflected (second) step response. Adjust the horizontal position knob to move the incident step response off the left edge of the display. The markers will automatically move to the reflected step response.



14. In the Measure table, locate the mean delta time value. This represents the added travel time (out and back) introduced by the additional cable length.
15. Identify the channel with the longest path (waveform closest to the display's right edge). The yellow waveform identifies Channel 1; the green waveform identifies Channel 2.
16. In the Differential TDR Skew dialog box's Horizontal Skew setting for the longest channel, enter half the mean delta time value. In this example, 370 ps on channel 2.



17. Next, adjust the TDR Skew setting. Entered values represent the percentage of available adjustment range. Try entering a positive 20% value for the channel with the longest path and a negative 20% value for the channel with the shortest path. Adjust as needed to adjust the mean delta time value to as close to a value of zero as possible.



18. Click Close.
19. Close the TDR Setup.
20. On the File menu, click Save, Instrument Setups to save your skew settings. As long as you use the identical channels, cables, and connections, you can recall these settings for future measurements and avoid having to repeat the skew measurement and setup steps.

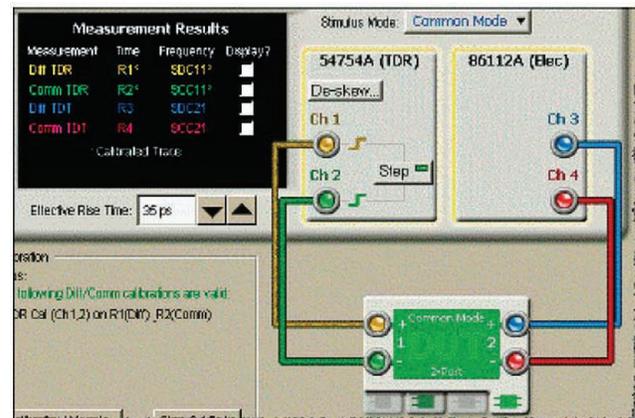
Do not perform a module calibration after adjusting the channel skew. Performing a module calibration after adjusting the channel skew could affect the values that you entered in this procedure.

21. On the Setup toolbar, click TDR Setup. Select all the measurements that you want to view.
22. Connect your test device at the end of the cables, and click Calibration Wizard to perform a TDT/TDR calibration.
23. After the calibration procedure completes, close the Calibration Wizard and TDR Setup.

To adjust differential TDT skew

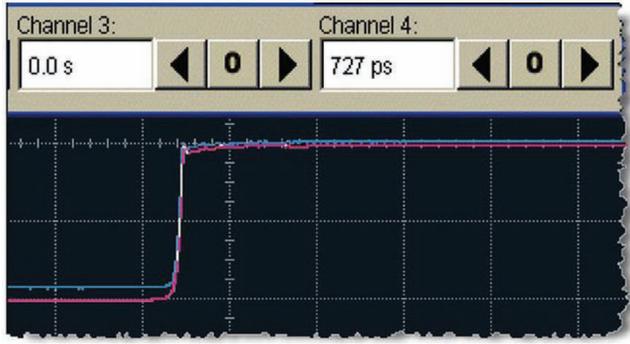
Use this procedure to compensate for unequal cable lengths in differential TDT test setups. Skew adjustments can only be performed when differential or common stimulus is active on differential TDR modules. Before you begin this procedure, you should be familiar with using TDR/TDT Setup <TDR_Setup> topic and the Calibration Wizard <TDR_TDT_Calibration_Wizard> topic.

1. In order to match the steps in this procedure, install the TDR module in the mainframe's left slot and the receiver in the right slot. Although this procedure uses the TDR module in the left slot, you could swap the positions of the two modules.
2. Turn on the instrument, and allow the instrument to warm up for one hour.
3. Complete the steps in the procedure To adjust differential TDR skew <tdr_skew_procedure> topic.
4. Connect the test setup cables and adapters for your TDT test setup completing the path from the TDR module channels to the input channels on the receiver module. Use adapters in the place of your test device. Do not connect the test device.
5. On the Setup toolbar, click TDR Setup.
6. In the dialog box, select the two-port balanced test device {bmc tdr_wiz103.bmp} and make the connections as shown in the following figure. Select Common. After this procedure, if you plan to make a differential stimulus measurement, return to TDR Setup and change this setting.



7. Clear all the measurements listed in Measurement Results. Click Close.
8. Press the front-panel channel buttons to turn on the display of Channels 3 and 4.
9. Adjust the horizontal position knob to center the responses.
10. On the Calibrate menu, select Horizontal Skew Adjust, Manual

11. Turn on the TDR marker, assign it to channel 3, and place it on the rising-edge of the step response.
12. Turn on the TDR marker, assign it to channel 4, and place it on the rising-edge of the step response
13. In the Horizontal Skew Adjust dialog box, identify the channel (3 or 4) with the shortest path. Enter the absolute value of the delta time marker as the skew adjusts for this channel.



14. Click Close, and turn off the markers.
15. Press the front-panel channel buttons to turn off the display of Channels 3 and 4.
16. On the File menu, click Save, Instrument Setups to save your skew settings. As long as you use the identical channels, cables, and connections, you can recall these settings for future measurements and avoid having to repeat the skew measurement and setup steps.
17. On the Setup toolbar, click TDR Setup. Select all the measurements that you want to view.
18. Click Calibration Wizard, and perform a TDT/TDR calibration.

Do not perform a module calibration after adjusting the channel skew. Performing a module calibration after adjusting the channel skew could affect the values that you entered in this procedure.

19. After the calibration procedure completes, close the Calibration Wizard and TDR Setup.



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