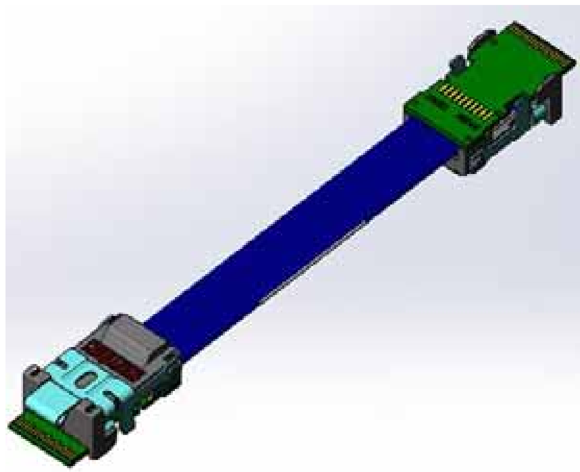
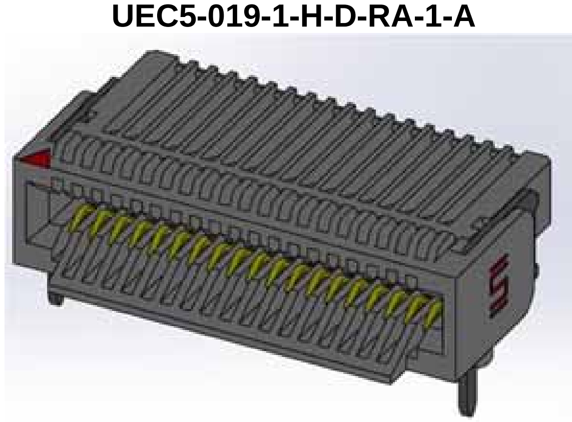
High Speed Characterization Report

ECUE-12-XXX-T1-FF-02-1



Mated with:

UEC5-019-1-H-D-RA-1-A



Description:

FireFly™ Micro Flyover System,
36 AWG Micro Twinax Ribbon Cable

Samtec Inc.
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Report Revision: 2/24/2016

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Cable Assembly Overview

Samtec's FireFly™ Micro Flyover System is a complete interconnect system that uses either micro footprint optical or copper interconnects. The FireFly™ system enables chip-to-chip, board-to-board, and system-to-system connectivity at rates up to 28Gbps. FireFly™ is based on a high performance interconnect system which allows the utilization of low-cost copper cables or high performance active optical engines. Firefly uses a 2 stage connector system. The UEC5 carries the high speed digital signals while the UCC8 carries the DC/low frequency status line. The performance of the ECUE to UCC8 is not considered in this report. The UCC8 is intended for low-speed signals and power only.

The test sample consists of two micro coaxial ribbon cables that contain 19 lines each. At each end of the cable there is a connector that is terminated to a small transition PCB. Each connector is soldered to its respective PCB. The connector terminals are on 0.5 mm centers. The cable assembly is wired to facilitate a Pin A1 to Pin B1 mapping between the cable terminations.

The ECUE cable assemblies were tested by mating to UEC5 at both ends. One sample of each length assembly was tested. The actual part numbers that were tested are shown in Table 1, which also identifies End 1 and End 2 of each assembly. A relative sample picture is shown in Figure1. Two pairs, the longest physical signal path (Long Path) and the shortest physical signal path (Short Path), of each assembly type were tested. The Long Path and Short Path are identified as, J1_ A2,A3 to J2_B2,B3 and the J1_ A17,A18 to J2_B17,B18, respectively.

Length	Part Number	End 1	End 2
30 cm	ECUE-12-030-T1-FF-02-1	J1	J2
50 cm	ECUE-12-050-T1-FF-02-1	J1	J2
100 cm	ECUE-12-100-T1-FF-02-1	J1	J2

Table 1: Sample Description

Figure 1: Test Sample

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Cable Assembly Speed Rating

The cable assembly Speed Rating is based on the -7 dB insertion loss point of the mated cable assembly. The -7 dB point can be used to estimate usable system bandwidth in a typical two-level signaling environment.

To calculate the Speed Rating, the measured -7 dB point is rounded up to the nearest half-GHz level. The up-rounding corrects for any loss from the test board traces. The resulting loss value is then doubled to determine the approximate maximum data rate in Gigabits per second (Gbps). The following table summarizes the Cable Assembly Speed Ratings for the ECUE cable assemblies tested.

Assembly			-7 dB Frequency	Speed Rating
ECUE-12-030-T1-FF-02-1	Differential	Long Path	15.0 GHz	30 Gbps
		Short Path	10.5 GHz	21 Gbps
ECUE-12-050-T1-FF-02-1	Differential	Long Path	12.5 GHz	25 Gbps
		Short Path	10.0 GHz	20 Gbps
ECUE-12-100-T1-FF-02-1	Differential	Long Path	5.0 GHz	10 Gbps
		Short Path	5.5 GHz	11 Gbps

Table 2: Cable Assembly Speed Rating

The Samtec Speed Rating is best considered a figure of merit for comparing relative performance between cable assemblies. The Speed Rating becomes less meaningful in systems using multi-level signaling or where crosstalk or impedance mismatch are more critical parameters. Modern high-speed digital transceivers can accommodate roughly 9 dB of loss and still operate reliably. The -7 dB rating is a conservative number that allocates 2 dB of system budget for other channel components such as short PCB traces and IC packaging effects.

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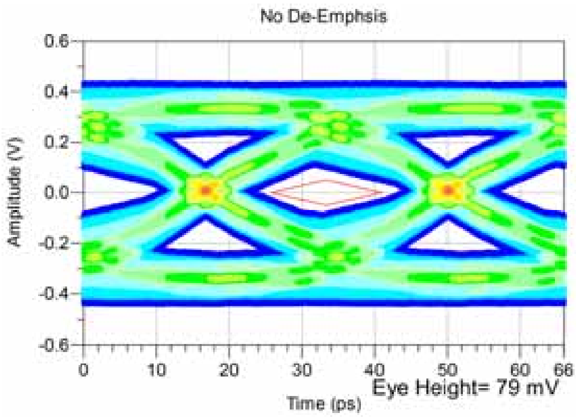
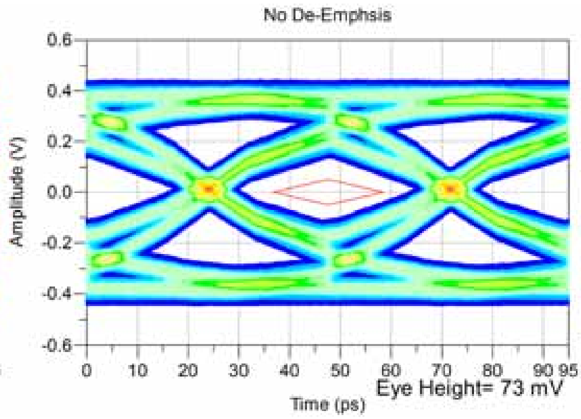
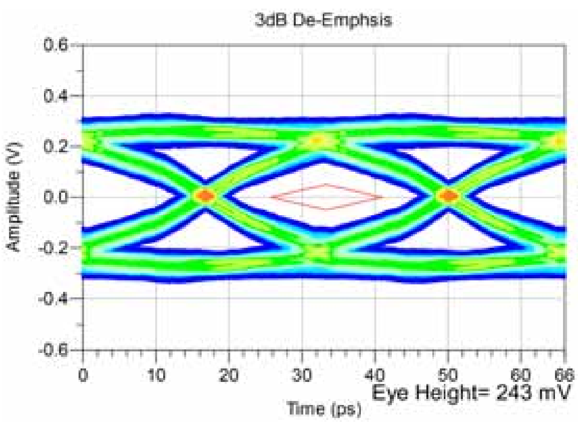
Eye Pattern Summary

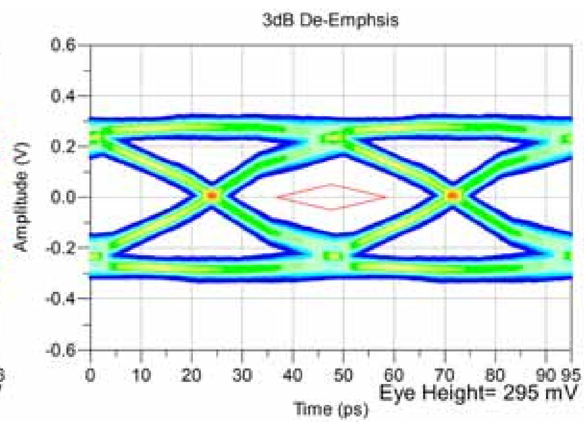
ECUE-12-030-T1-FF-02-1
Differential

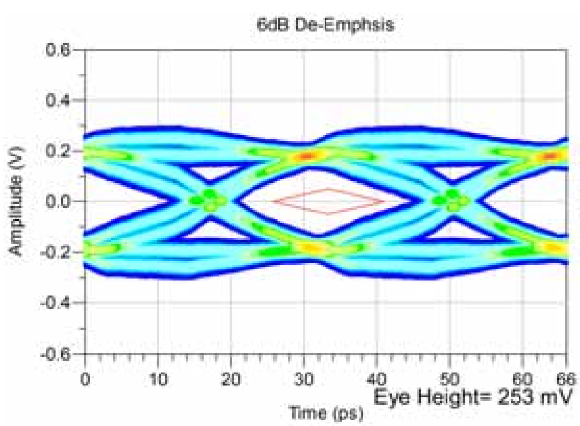
Long Path Output Eye: 30 Gbps   Short Path Output Eye: 21 Gbps

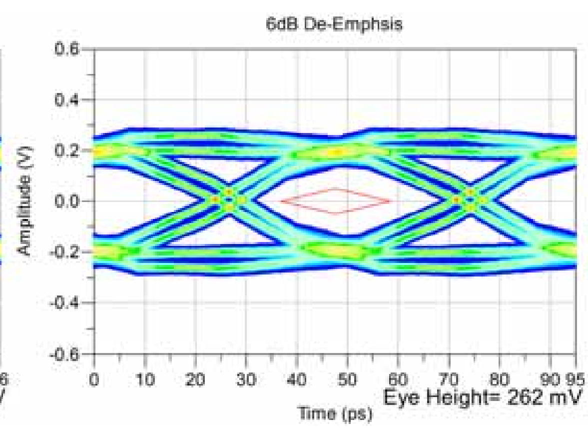












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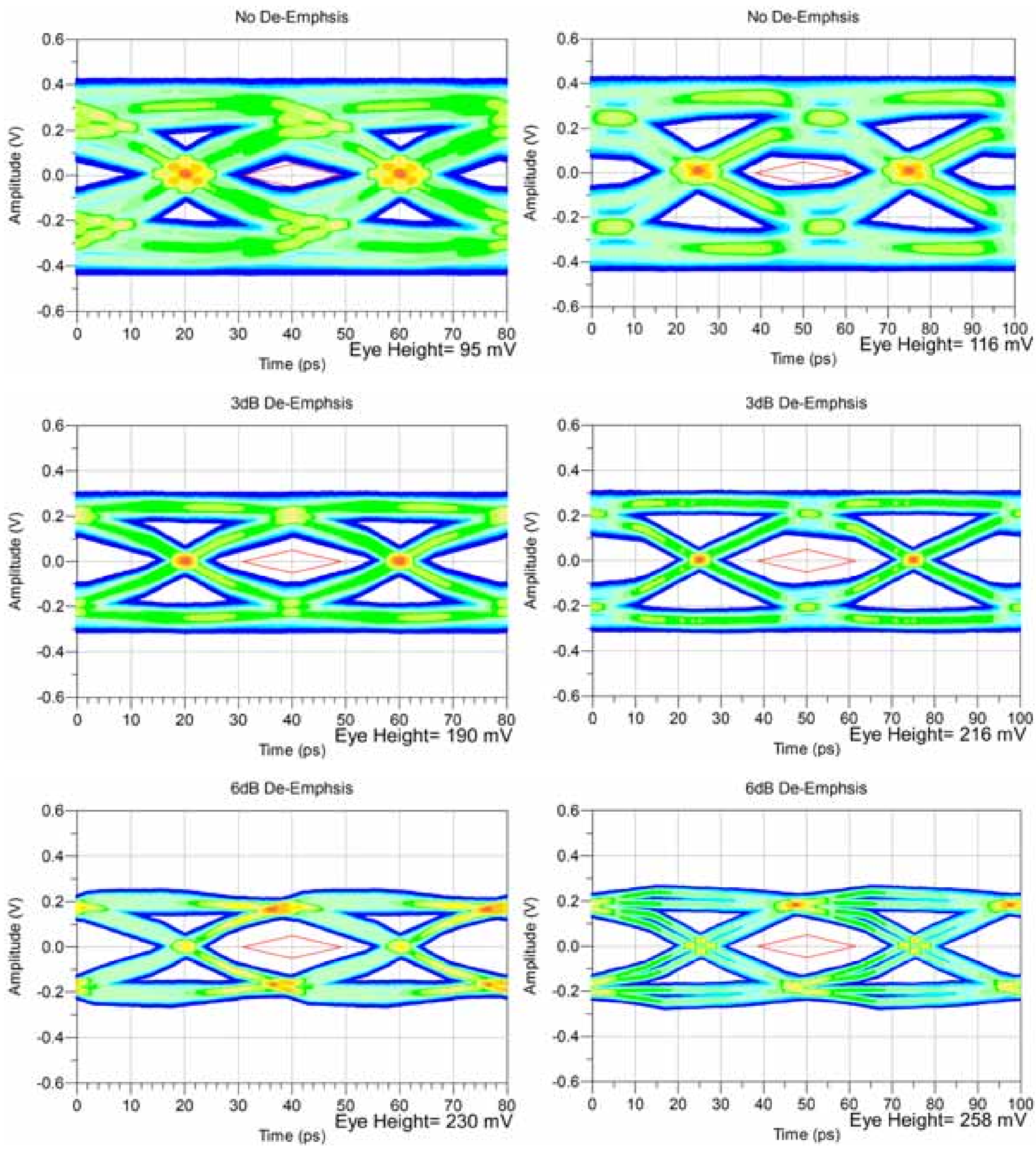
ECUE-12-050-T1-FF-02-1
Differential

Long Path Output Eye: 25 Gbps | Short Path Output Eye: 20 Gbps

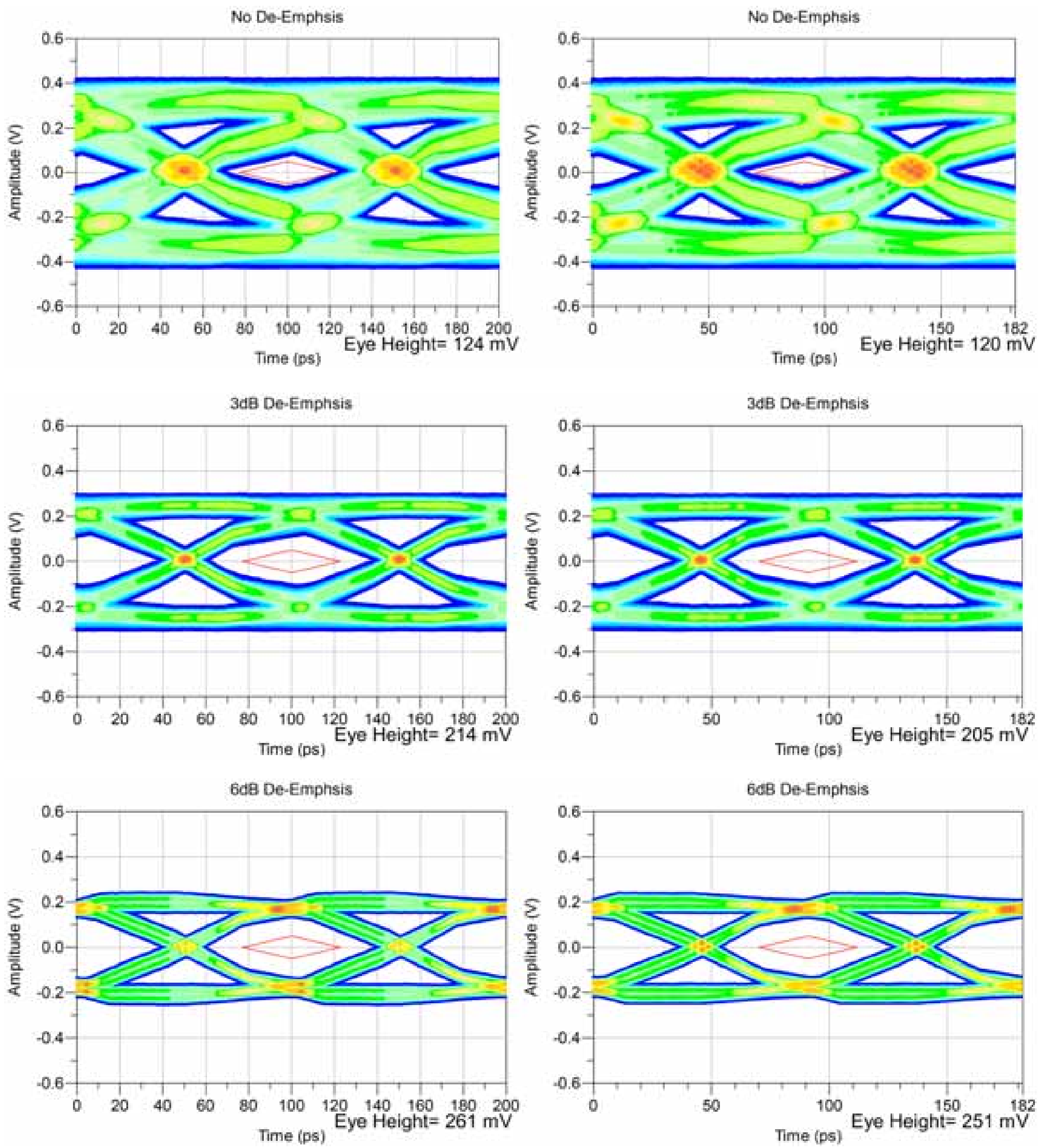


Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

ECUE-12-100-T1-FF-02-1
Differential

Long Path Output Eye: 10 Gbps

Short Path Output Eye: 11 Gbps



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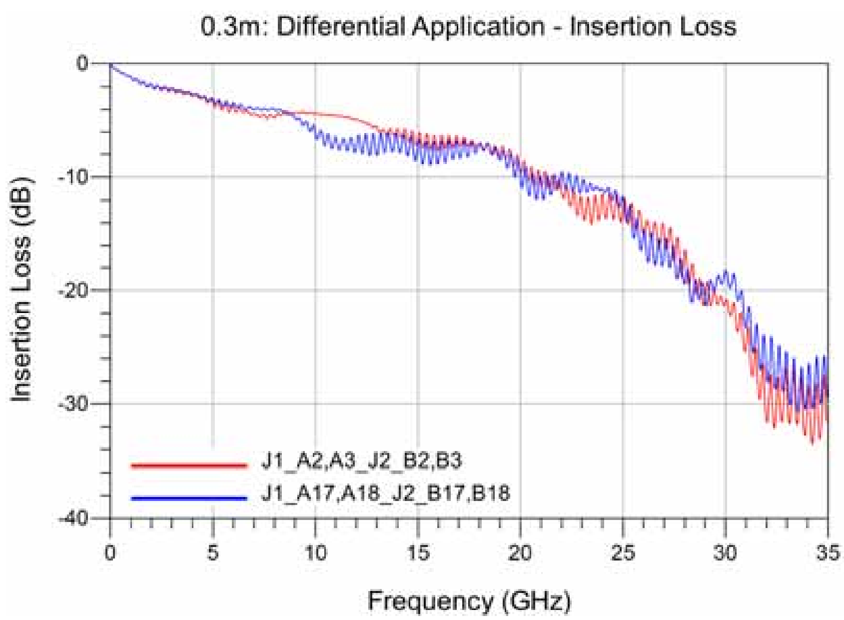
Frequency Domain Data Summary

Table 3 – Differential Cable System Performance

Test Parameter	Configu-ration	Driver	Receiver	0.23m	0.5m	1m
Insertion Loss	Long Path	J1_A2,A3	J2_B2,B3	7dB@ 14.86 GHz	7dB@ 12.49 GHz	7dB@ 4.79 GHz
	Short Path	J1_A17,A18	J2_B17,B18	7dB@ 10.39 GHz	7dB@ 9.62 GHz	7dB@ 5.12 GHz
Return Loss	Long Path	J1_A2,A3	J1_A2,A3	>10dB to 5.03 GHz	>10dB to 5.34 GHz	>10dB to 12.38 GHz
	Short Path	J1_A17,A18	J1_A17,A18	>10dB to 5.45 GHz	>10dB to 9.65 GHz	>10dB to 12.03 GHz

Bandwidth Chart – Differential Insertion Loss



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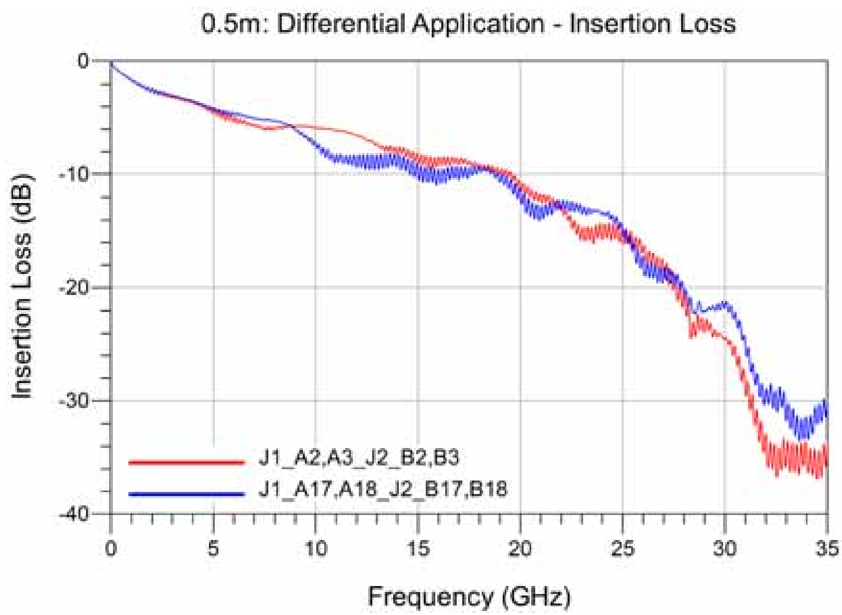

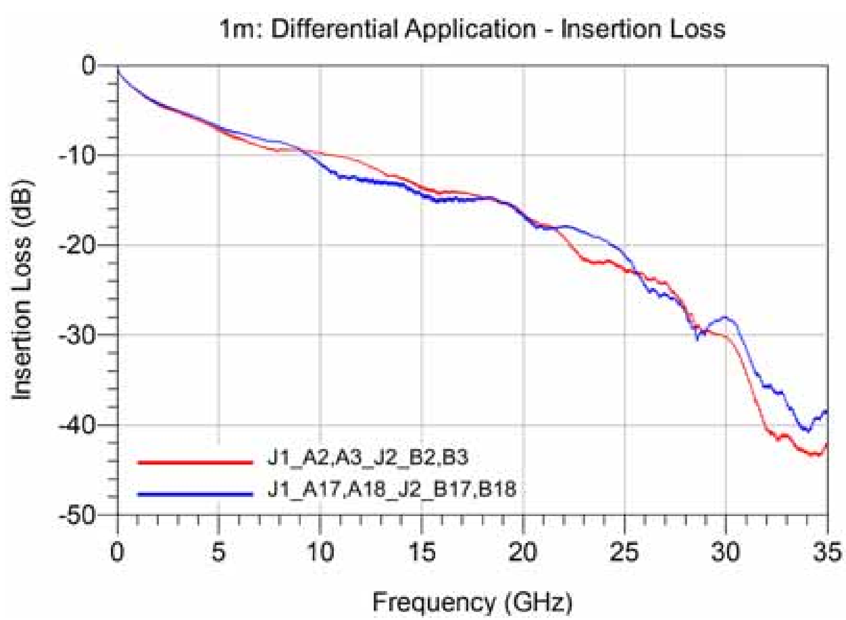

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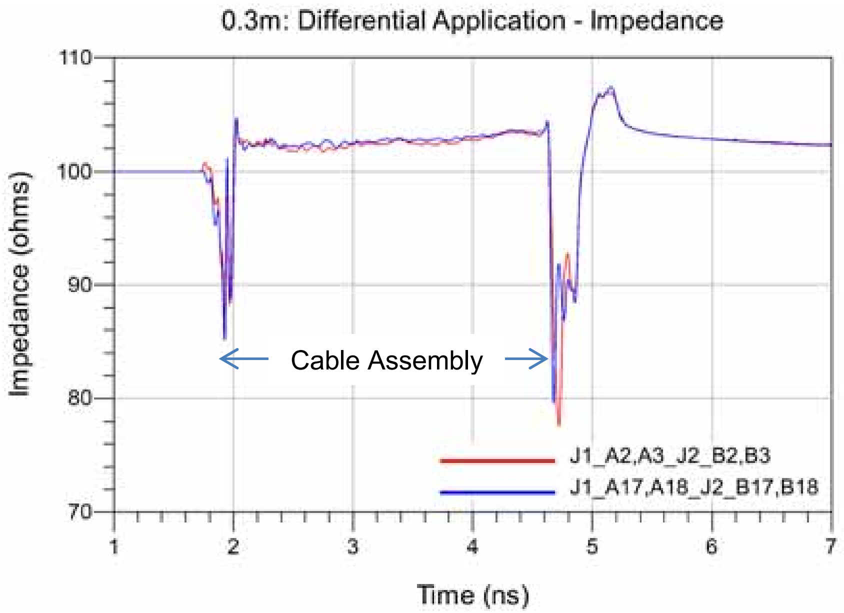
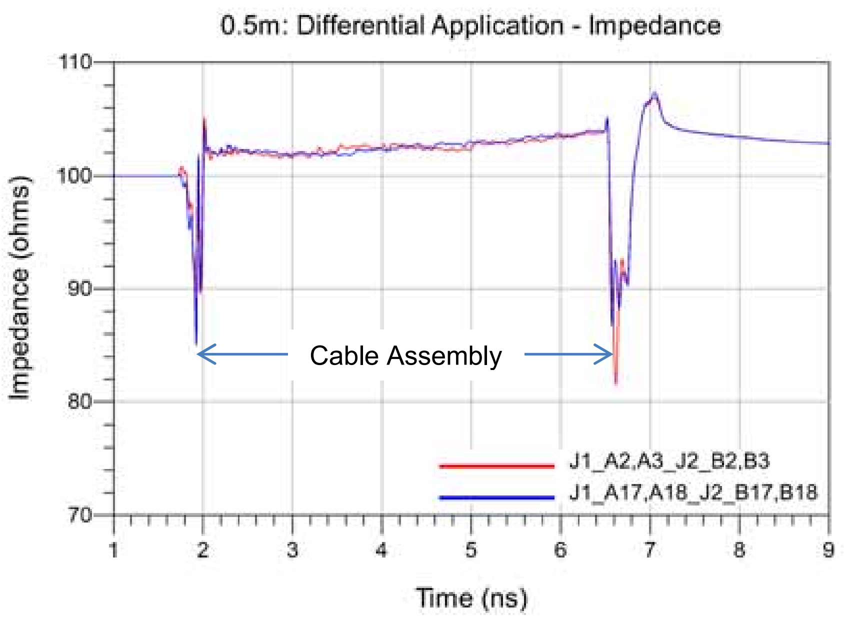
Time Domain Data Summary





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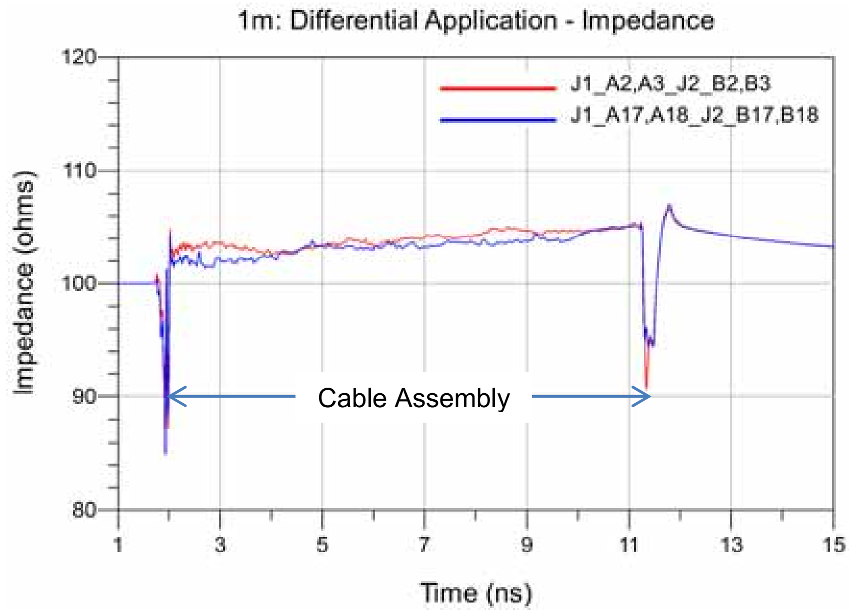

Table 4 - Propagation Delay (Cable Assembly)		
Cable length	**Driver/ Receiver**	**Driver/ Receiver**
	J1_A2,A3 / J2_B2,B3	J1_A17,A18 / J2_B17,B18
0.3m	1.671ns	1.663ns
0.5m	2.622ns	2.615ns
1m	5.000ns	4.993ns

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Characterization Details

This report presents data that characterizes the signal integrity response of a cable assembly in a controlled printed circuit board (PCB) environment. All efforts are made to reveal typical best-case responses inherent to the system under test (SUT).

In this report, the SUT includes the mating connectors, cable assembly, and footprint effects on a typical multi-layer PCB. PCB effects (trace loss) are de-embedded from test data. Board related effects, such as pad-to-ground capacitance, are included in the data presented in this report.

Additionally, intermediate test signal connections can mask the cable assembly's true performance. Such connection effects are minimized by using high performance test cables and adapters. Where appropriate, calibration and de-embedding routines are also used to reduce residual effects.

Differential Data

Most Samtec cable assemblies can be used successfully in both differential and single-ended applications. However, electrical performance will differ depending on the signal drive type. In this report, data is presented for "GSSG" differential drive configurations.

Cable assembly Signal to Ground Ratio

Samtec cable assemblies are most often designed for generic applications and can be implemented using various signal and ground pin assignments. In high speed systems, provisions must be made in the interconnect for signal return currents. Such paths are often referred to as "ground". In some cable assemblies, a ground plane or blade, or an outer shield, is used as the signal return, while in others, cable assembly pins are used as signal returns. Various combinations of signal pins, ground blades, and shields can also be utilized. Electrical performance can vary significantly depending upon the number and location of ground pins.

In general, the more pins dedicated to ground, the better electrical performance will be. But dedicating pins to ground reduces signal density of a cable assembly. Therefore, care must be taken when choosing signal/ground ratios in cost or density-sensitive applications.

For this cable assembly, the following array configurations are evaluated:

Differential Impedance**:**

- Long Path (furthest from test fixture)
- Short Path (closest to test fixture)

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See Appendix D – Product and Test System Descriptions for details

Other configurations can be evaluated upon request. Please contact sig@samtec.com for more information.

In a real system environment, active signals might be located at the outer edges of the signal contacts of concern, as opposed to the ground signals utilized in laboratory testing. For example, in a single-ended system, a pin-out of "SSSS", or four adjacent single ended signals might be encountered as opposed to the "GSG" configurations tested in the laboratory. Electrical characteristics in such applications could vary slightly from laboratory results. But in most applications, performance can safely be considered equivalent.

Signal Edge Speed (Rise Time)
In pulse signaling applications, the perceived performance of the interconnect can vary significantly depending on the edge rate or the rise time of the exciting signal. For this report, the fastest rise time used was 30 ps. Generally, this should demonstrate the worst-case performance.

In many systems, the signal edge rate will be significantly slower at the cable assembly than at the driver launch point. To estimate interconnect performance at other edge rates, data is provided for several rise times between 30ps and 500ps.

Unless otherwise stated, measured rise times were at 10%-90% signal levels.

Eye Diagram Data
Eye patterns are a time domain characterization of system level performance. Eye patterns are generated by sending continuous streams of data from a transmitter to a receiver, and overlaying the received signals upon one another. Over time, the received data builds to resemble an eye. Negative SI effects in the transmission path can cause the signal to distort, which over time, will cause the eye to "close". Specifications, such as an eyemask template, can be placed on the amount of open area required in the eye to ensure a functional system.

An eyemask template is a representation of the receiver's sensitivity and is often used as a metric of performance. While there are lot-to-lot and vendor-to-vendor variations in receiver sensitivity, some general guidelines can be developed. After reviewing several major industry standards (PCIe, Gigabit Ethernet), we find similar eyemask requirements and we will use these as the basis for a generic template in this report. For this report, we will assume a receiver amplitude sensitivity of 50 mVpp and a jitter margin of 0.5 UI. This results in a diamond shape eyemask template that is 50 mV high and 0.5 UI wide.

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Please contact our Signal Integrity Group at sig@samtec.com for more information.

Frequency Domain Data

Frequency Domain parameters are helpful in evaluating the cable assembly system's signal loss and crosstalk characteristics across a range of sinusoidal frequencies. In this report, parameters presented in the Frequency Domain are Insertion Loss and Return Loss. Other parameters or formats, such as VSWR or S-Parameters, may be available upon request. Please contact our Signal Integrity Group at sig@samtec.com for more information.

Frequency performance characteristics for the SUT are generated from network analyzer measurements.

Time Domain Data

Time Domain parameters indicate Impedance mismatch versus length and signal propagation time in a pulsed signal environment.

The measured S-Parameters from the network analyzer are post-processed using Agilent ADS to obtain the time domain response for impedance and signal propagation time. The Time Domain procedure is provided in Appendix F of this report. Parameters or formats not included in this report may be available upon request. Please contact our Signal Integrity Group at sig@samtec.com for more information.

In this report, propagation delay is defined as the signal propagation time through the cable assembly, mating connectors, and connector footprint. It also includes 40 mils of PCB trace on each connector side. Delay is measured at 100 picoseconds signal risetime. Delay is calculated as the difference in time measured between the 50% amplitude levels of the input and output pulses.

Data for other configurations may be available. Please contact our Signal Integrity Group at sig@samtec.com for further information.

Additional information concerning test conditions and procedures is located in the appendices of this report. Further information may be obtained by contacting our Signal Integrity Group at sig@samtec.com.

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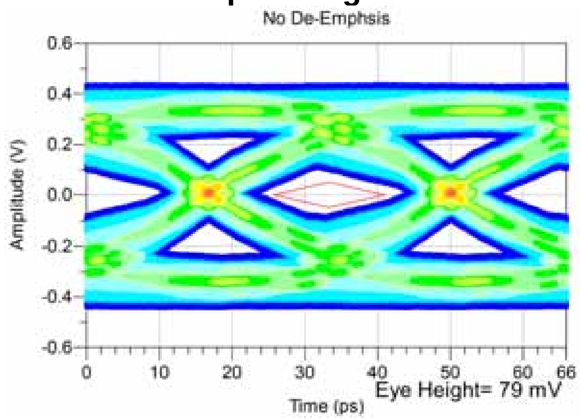
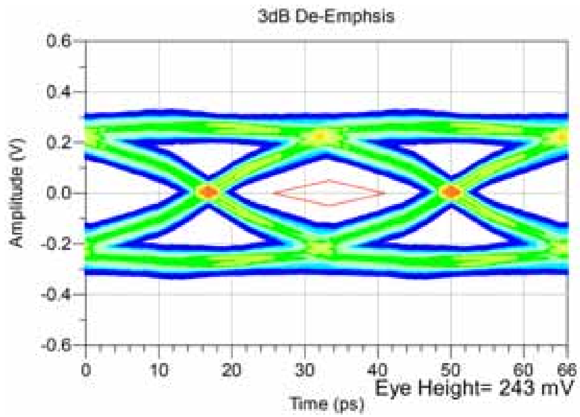
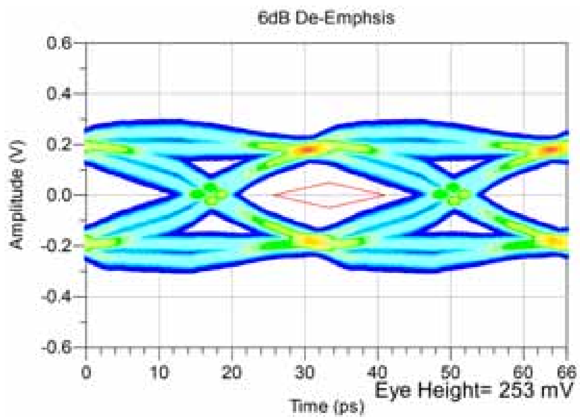
Appendix A – Eye Diagrams

ECUE-12-030-T1-FF-02-1
Differential

30Gbps: Long Path







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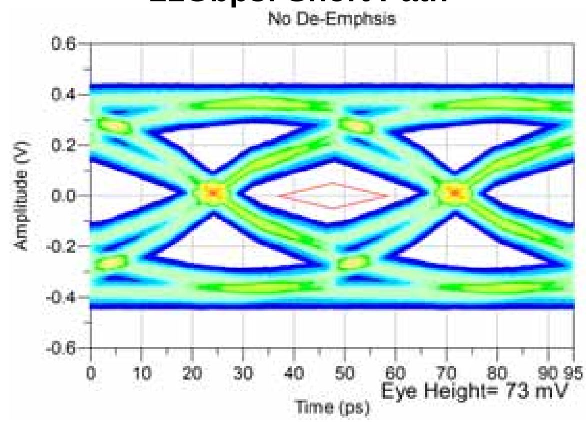
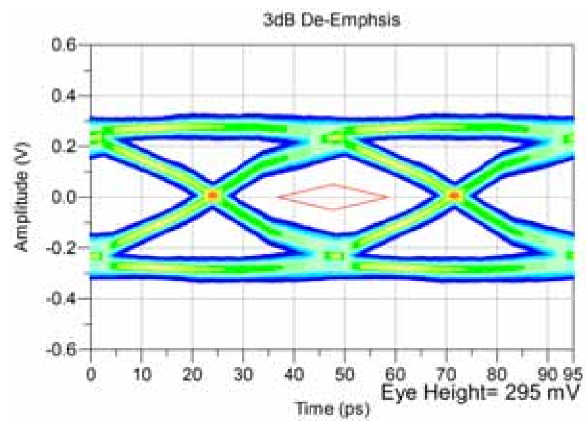
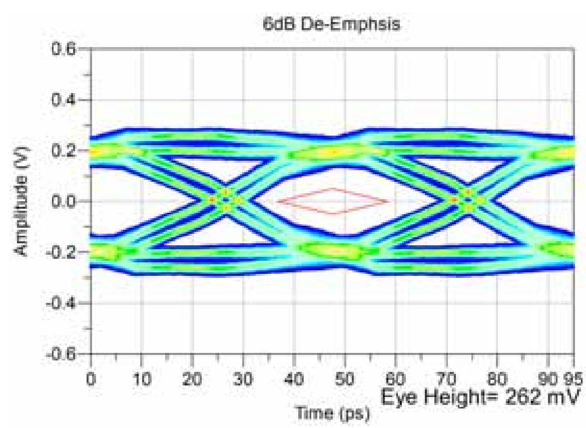
Differential

21Gbps: Short Path







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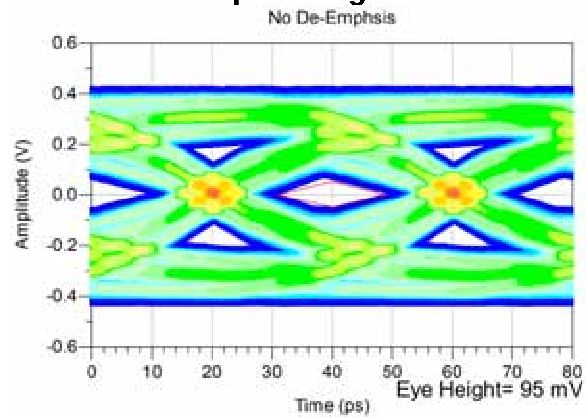
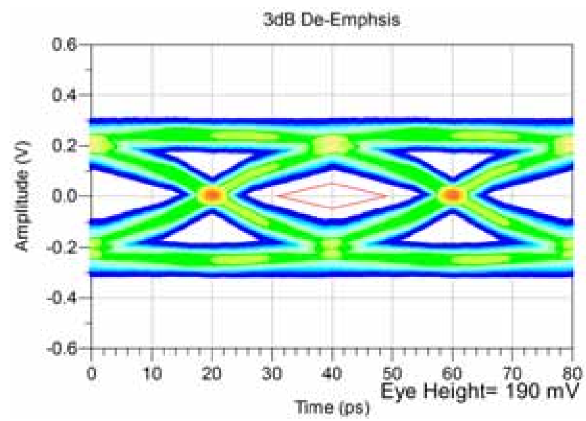
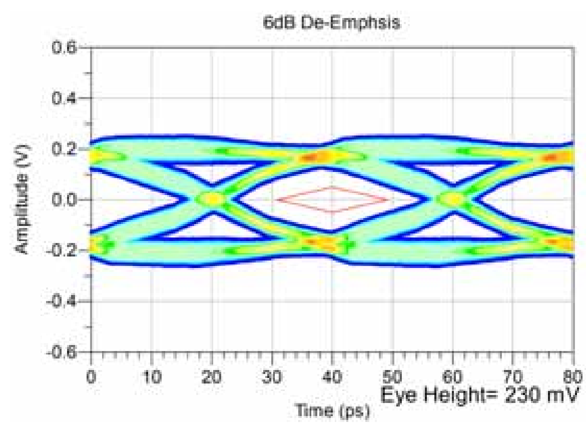
ECUE-12-050-T1-FF-02-1
Differential

25Gbps: Long Path







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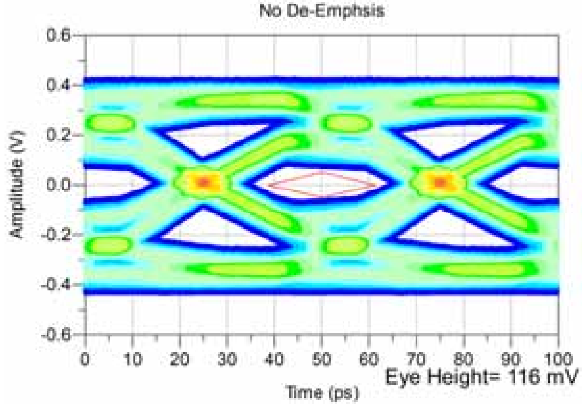
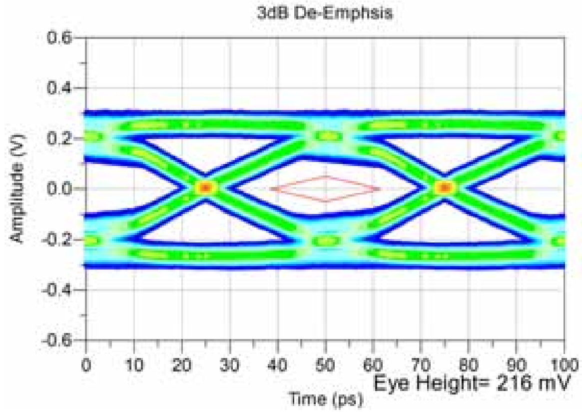
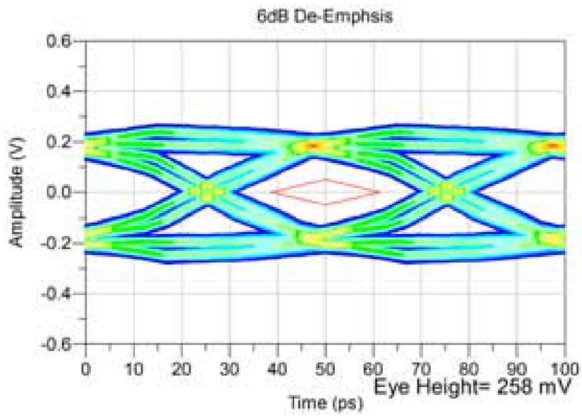
Differential

20Gbps: Short Path







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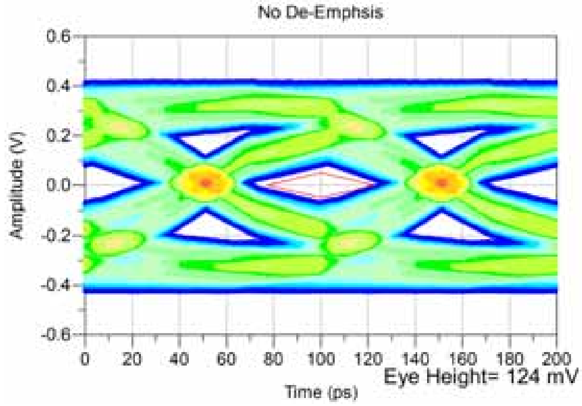
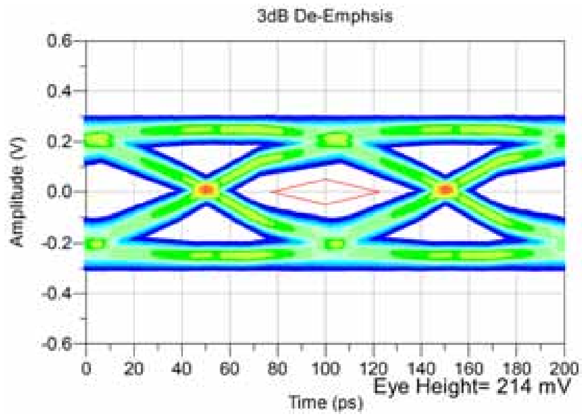
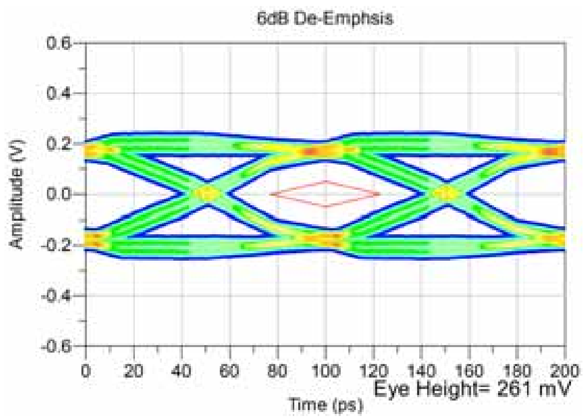
ECUE-12-100-T1-FF-02-1
Differential

10Gbps: Long Path







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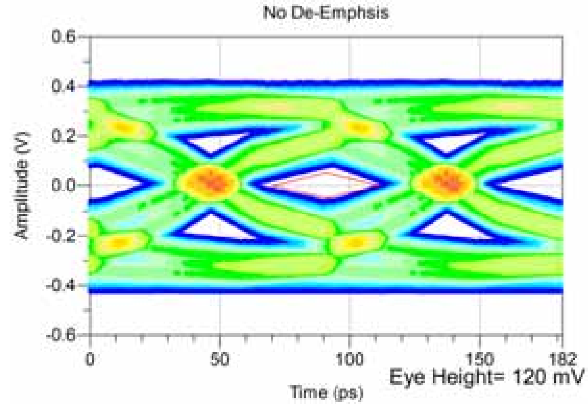
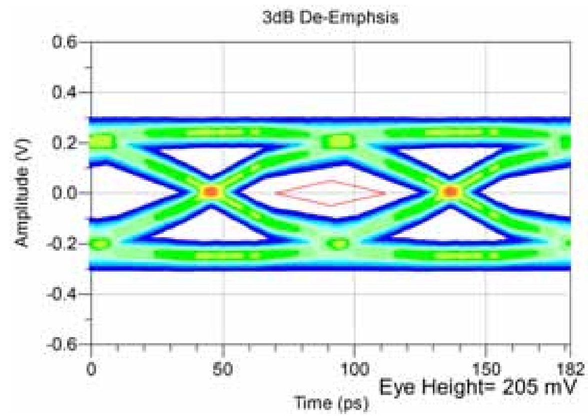
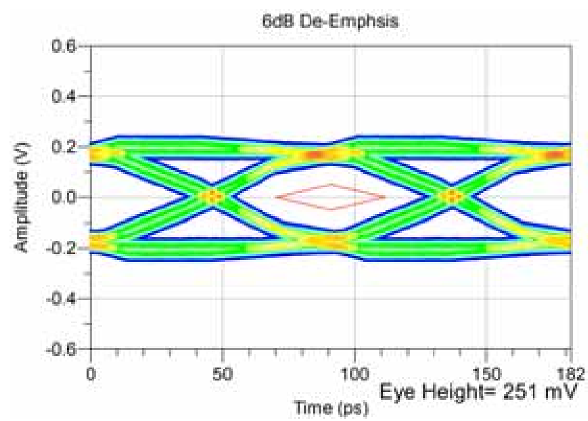
Differential

11Gbps: Short Path







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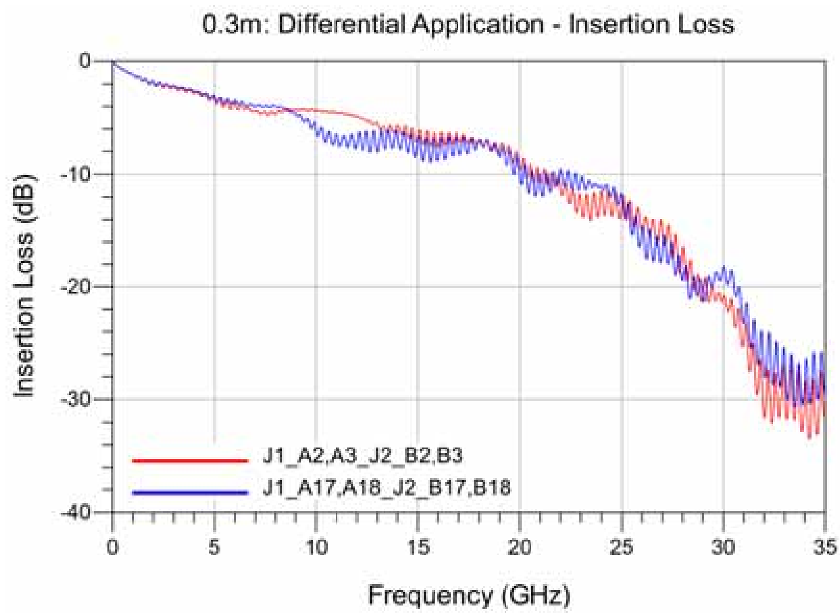
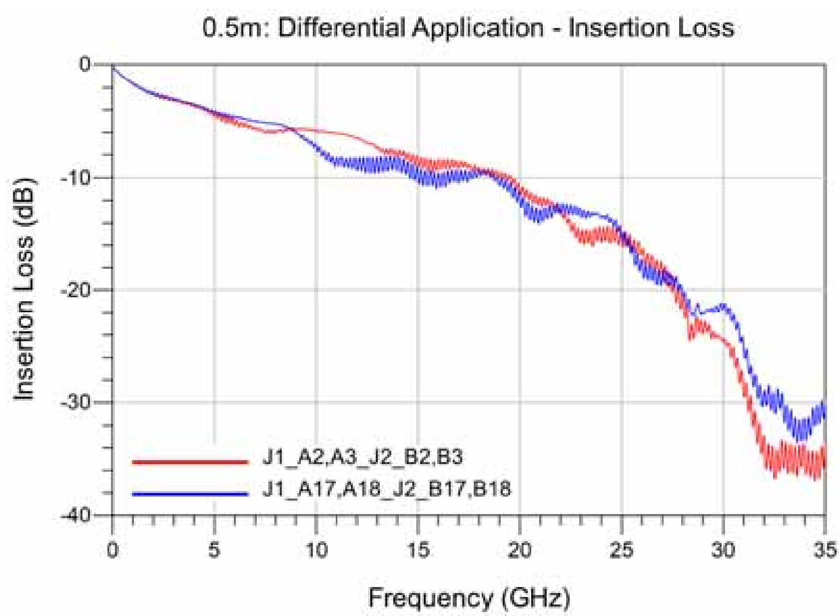
Appendix B – Frequency Domain Response Graphs

Differential Application – Insertion Loss





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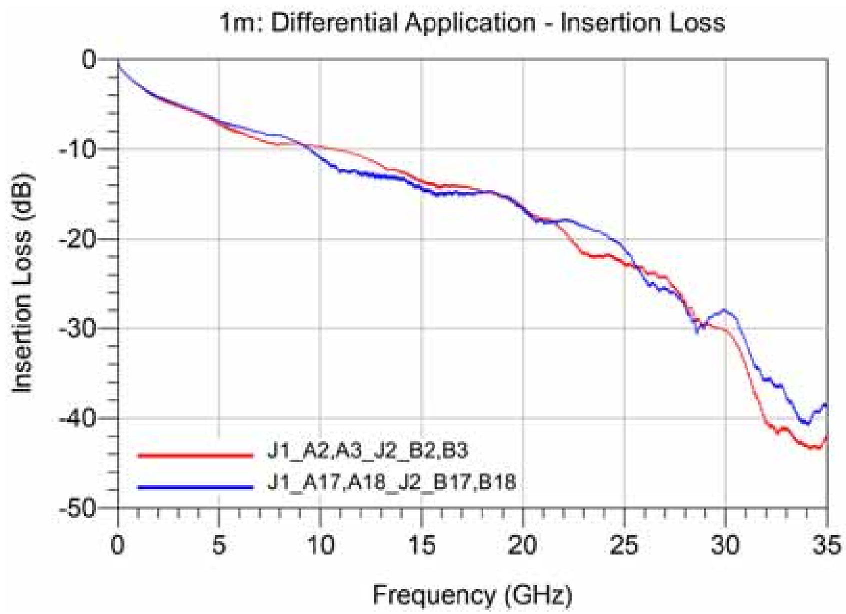
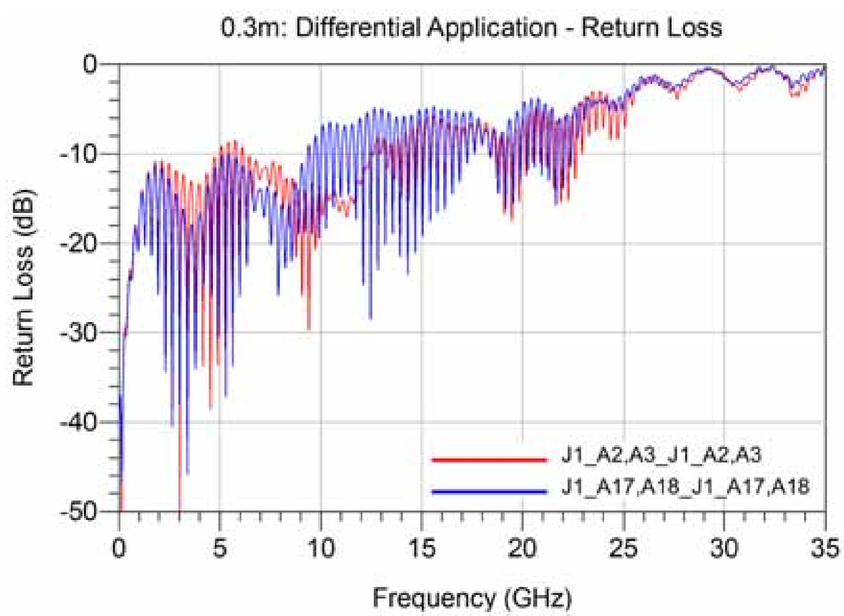


Differential Application – Return Loss



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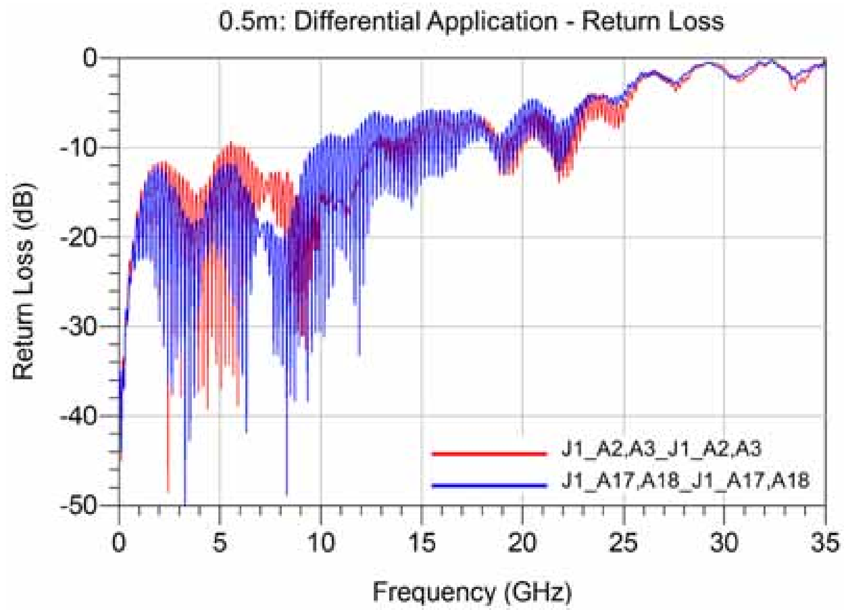
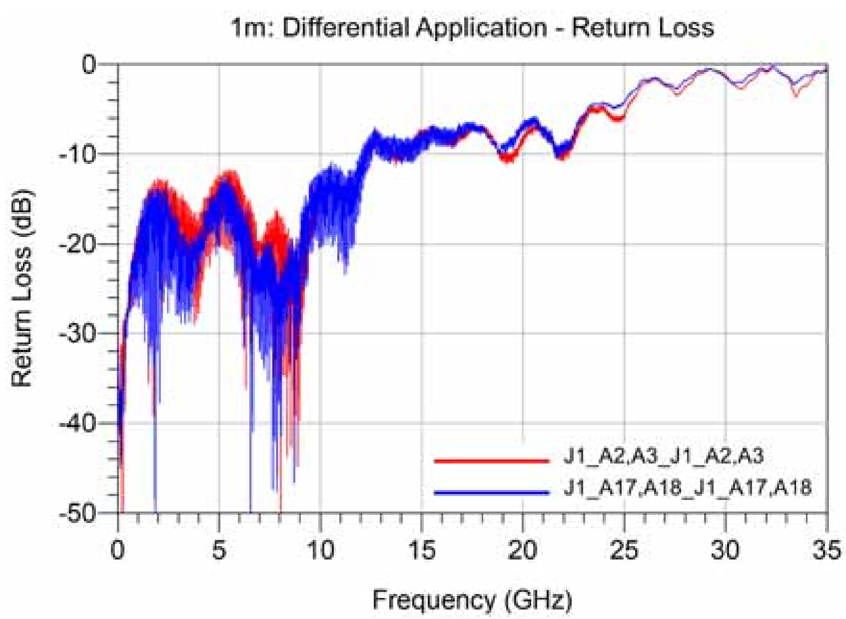
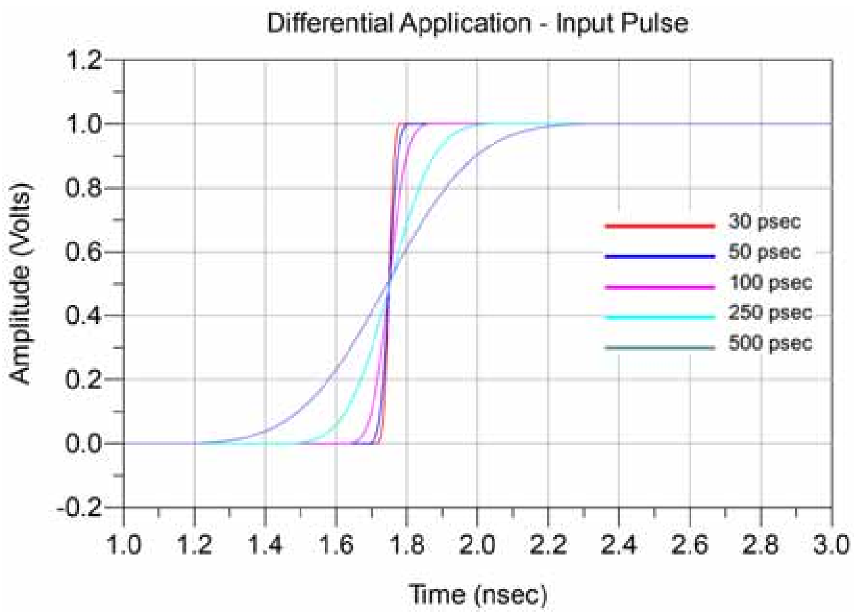




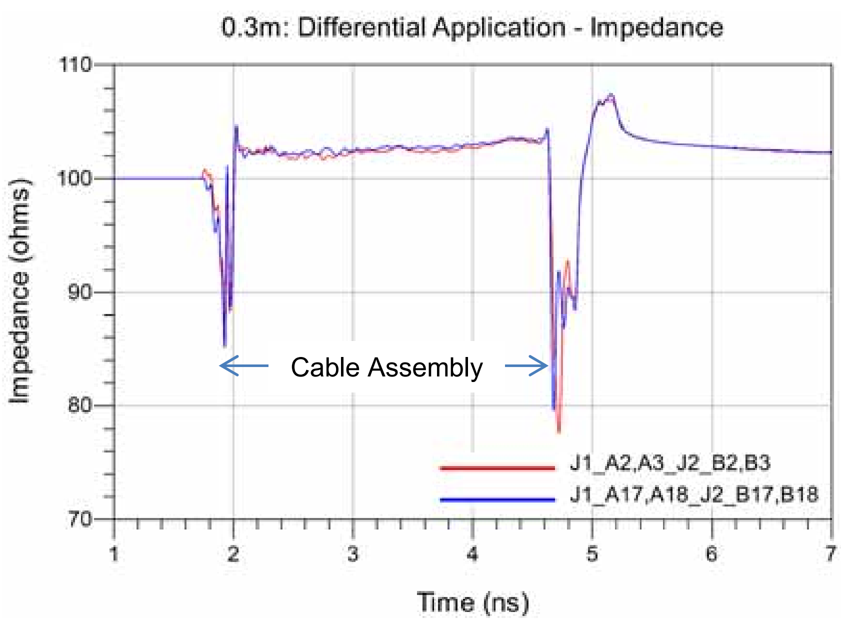
Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Appendix C – Time Domain Response Graphs

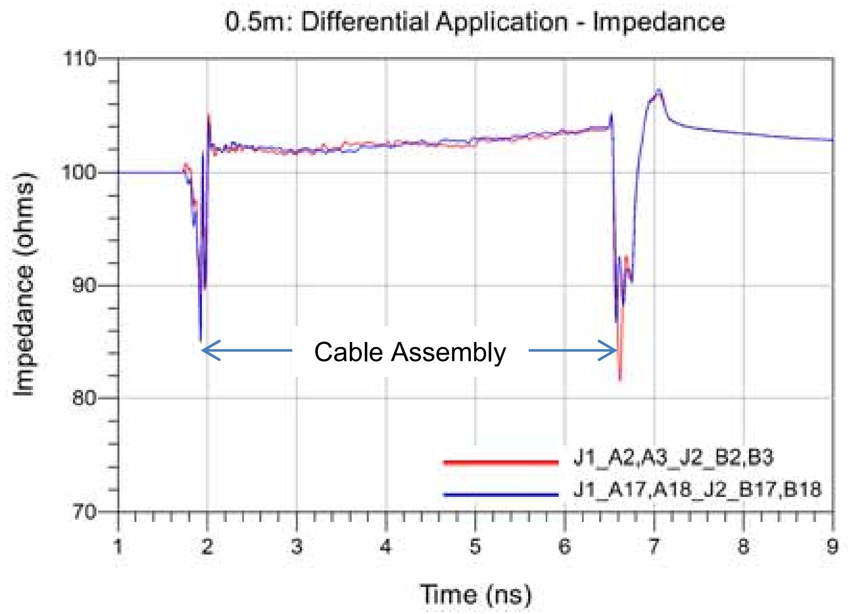
Differential Application – Input Pulse

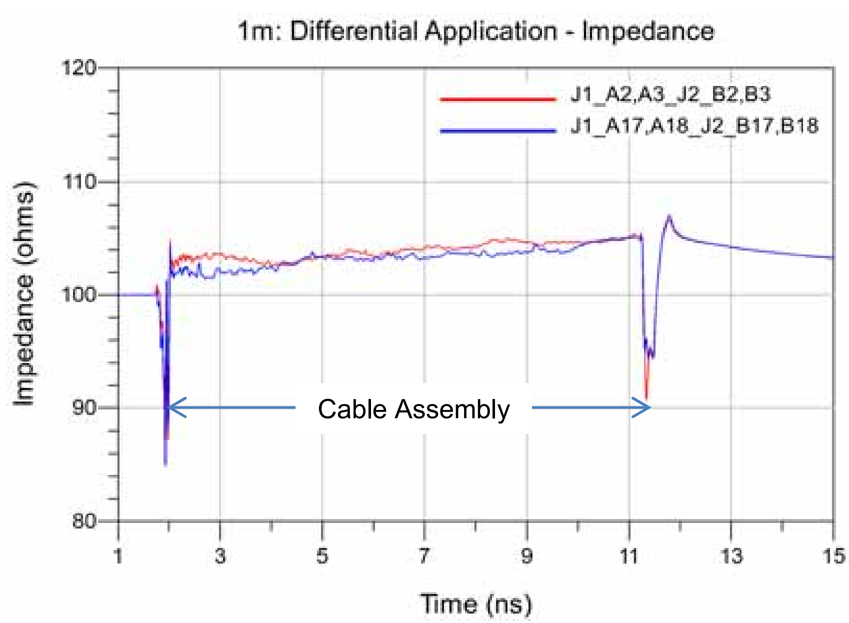


Differential Application – Cable Assembly Impedance



Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

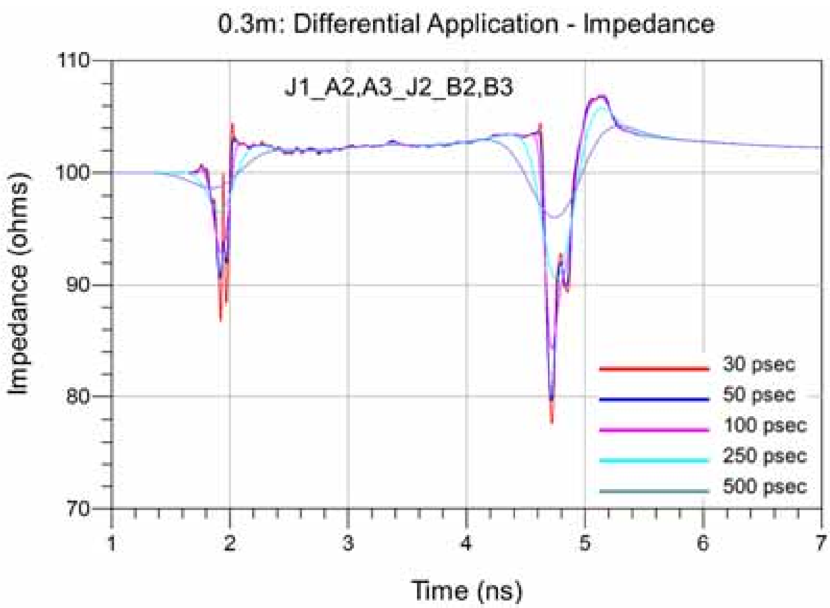


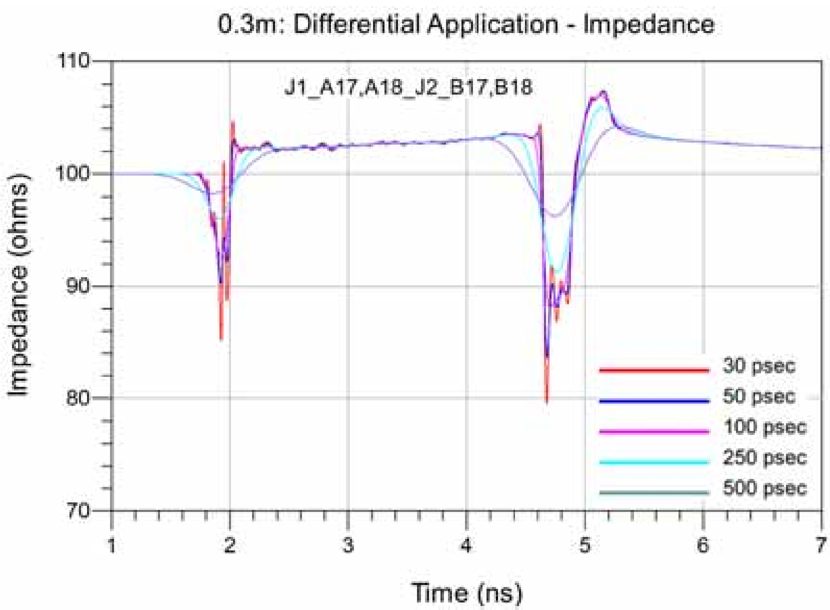


Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Differential Application – Cable assembly Impedance

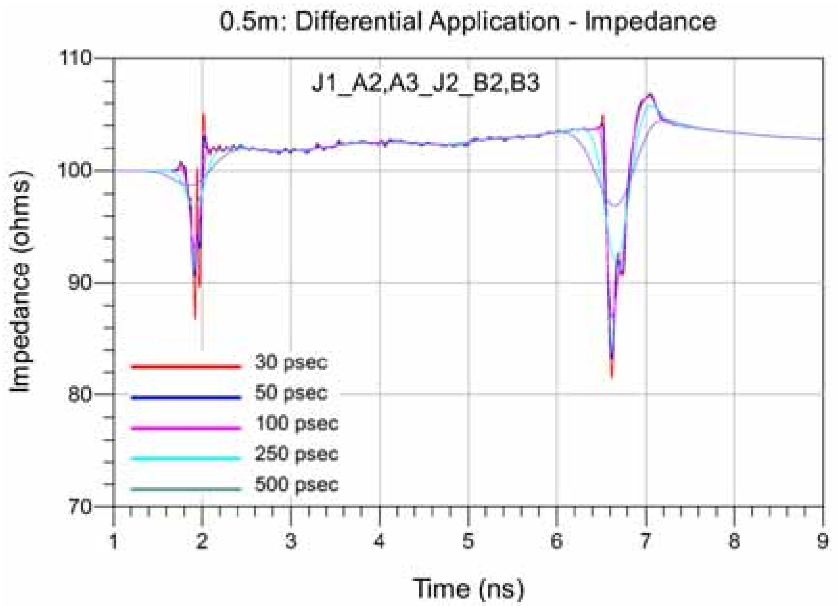
ECUE-12-030-T1-FF-02-1

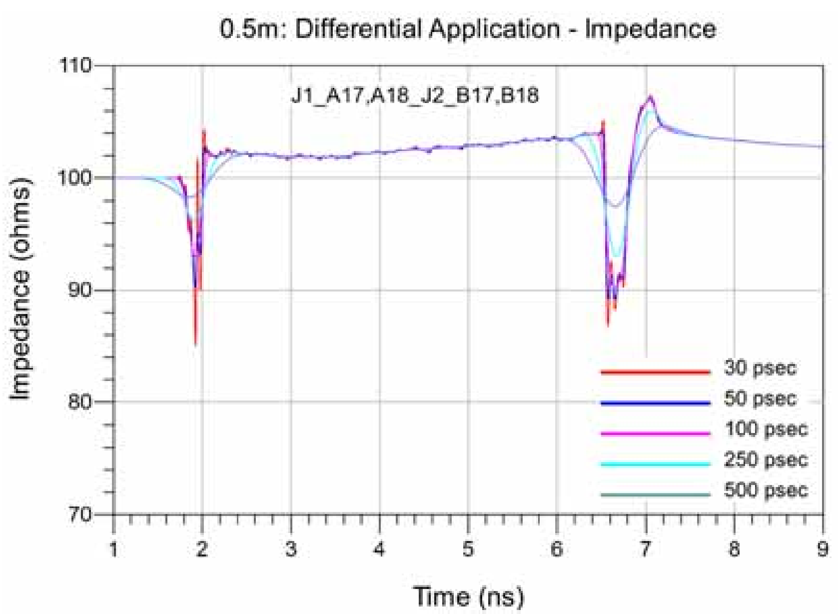




Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

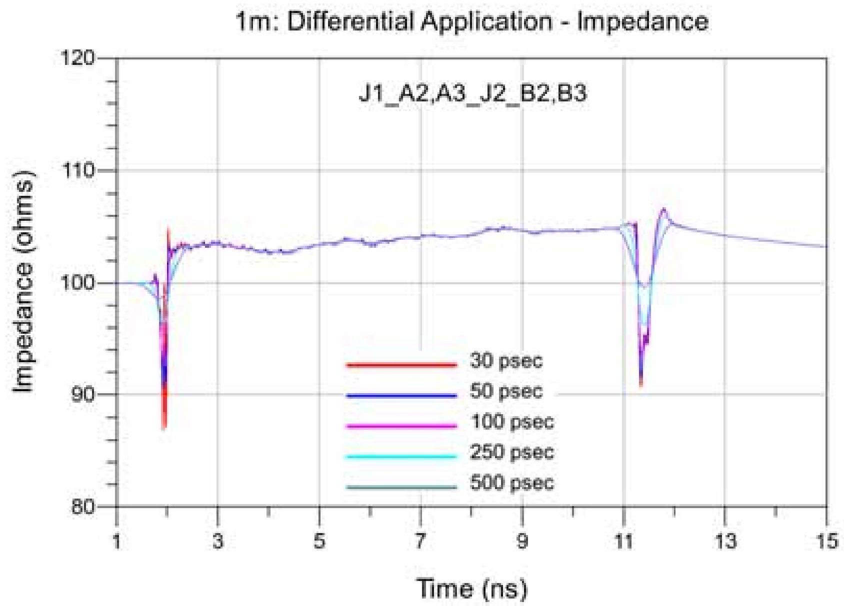
ECUE-12-050-T1-FF-02-1

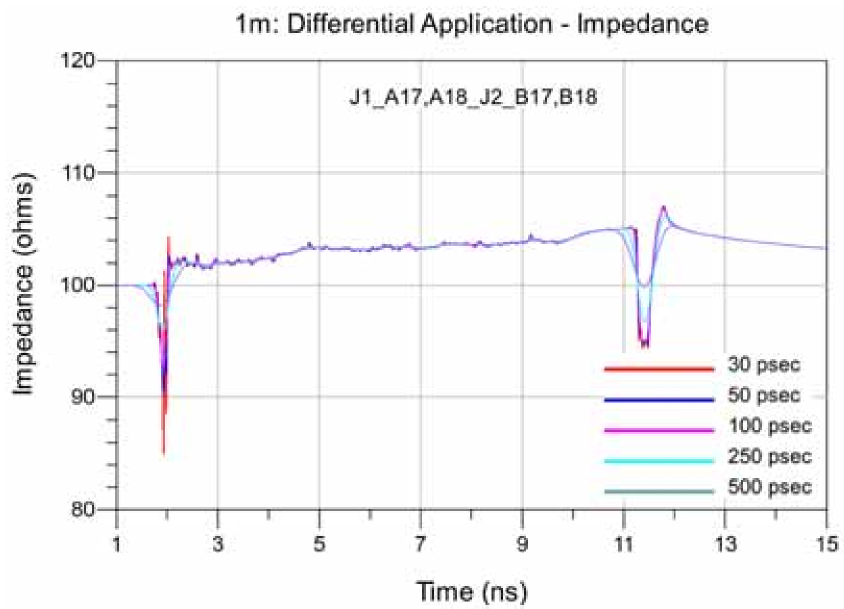




Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

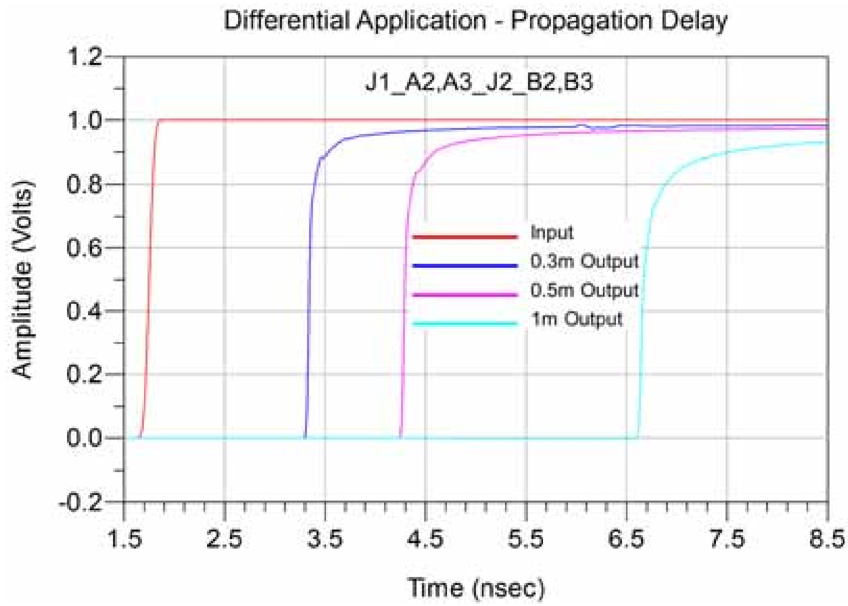
ECUE-12-100-T1-FF-02-1

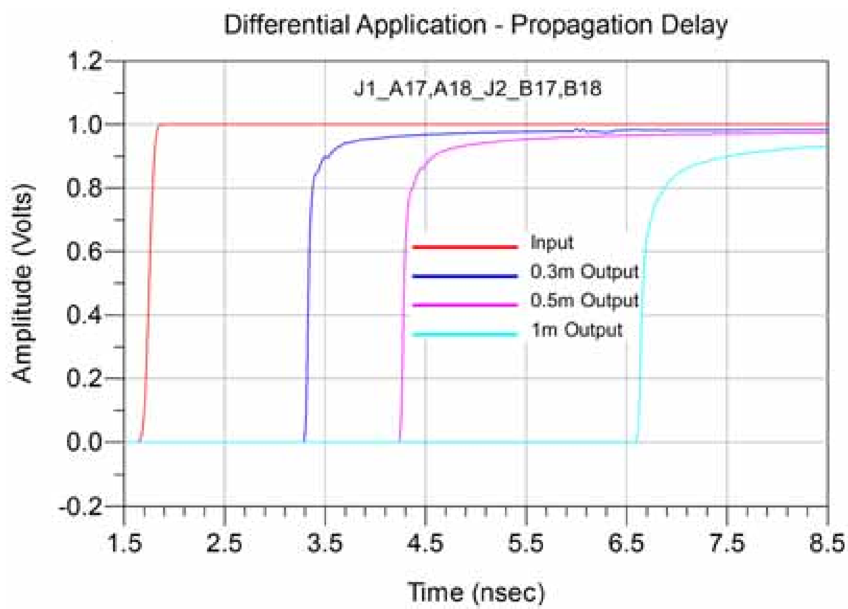




Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Differential Application – Propagation Delay





Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Appendix D – Product and Test System Descriptions

Product Description

Product test samples are 0.5 mm pitch copper FireFly™ Cable Assemblies. The part numbers are ECUE-12-030-T1-FF-02-1, ECUE-12-050-T1-FF-02-1 and ECUE-12-100-T1-FF-02-1. They mate with UEC5-019-1-H-D-RA-1-A. A photo of the mated test article mounted to SI test boards is shown below.

The cable assembly terminations had a particular signal line configuration. The respective signal line numbers are shown in Table 5 below. There are a total of 12 pairs.

J1	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19
NAME	G	S	S	G	S	S	G	S	S	G	S	S	G	S	S	G	S	S	G
J2	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19

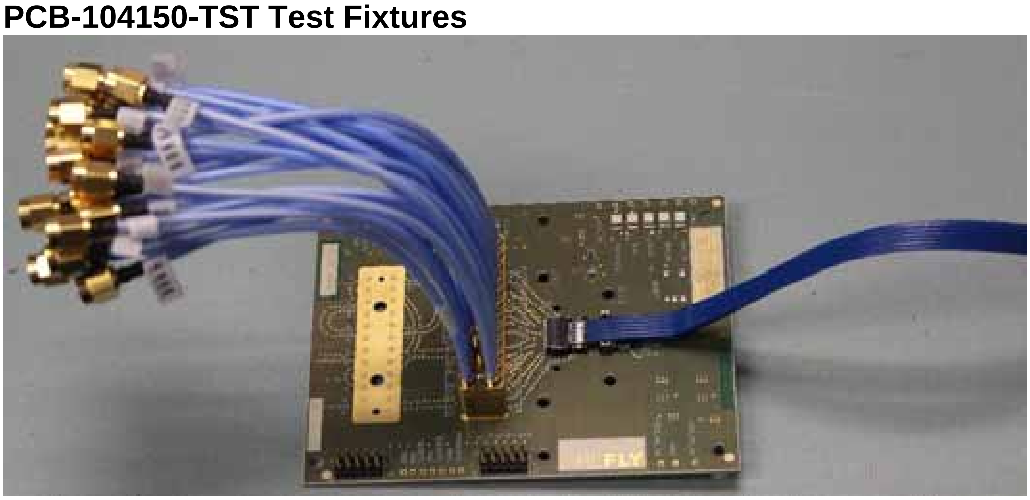
J1	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19
NAME	G	S	S	G	S	S	G	S	S	G	S	S	G	S	S	G	S	S	G
J2	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19

Table 5: Respective signal line numbers

Test System Description

The test fixtures are composed of six-layer FR-4 material with 100Ω differential signal trace and pad configurations designed for the electrical characterization of Samtec high speed cable assembly products. A PCB mount BullsEye™ connector is used to interface the VNA test cables to the test fixtures. Optimization of the BullsEye™ launch was performed using full wave simulation tools to minimize reflections. One test fixture is specific to FireFly™ series cable assembly set and identified by part numbers PCB-104150-TST. The Auto Fixture Removal (AFR) calibration structures designed specifically for the FireFly™ series are located on the same test board. Displayed on the following pages is the information for the BullsEye™ and AFR calibration structure and directives for the mating FireFly™ fixtures.

PCB-104150-TST Test Fixtures



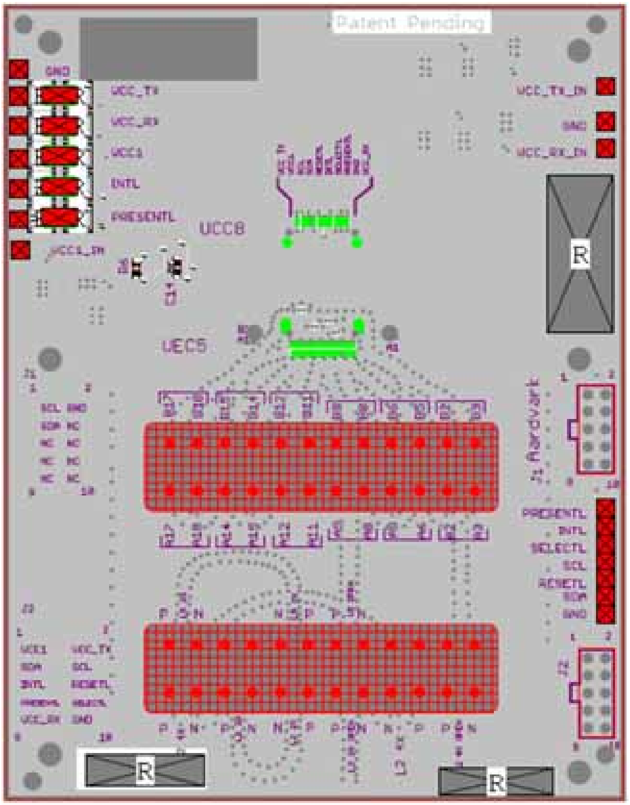
Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Artwork of the PCB design is shown below (Showed the signal layer 2 and layer 5).

Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

PCB Fixtures

The test fixtures used are as follows:



Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

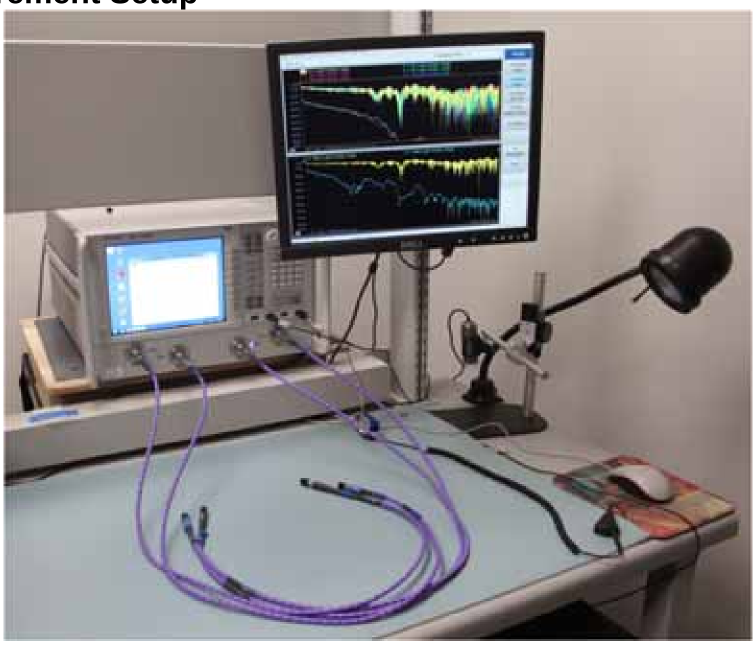
Appendix E – Test and Measurement Setup

For frequency domain measurements, the test instrument is the Agilent N5227A PNA-L network analyzer. Frequency domain data and graphs are extracted from the instrument by AFR application. Post-processed time domain data and graphs are generated using convolution algorithms within Agilent ADS. The network analyzer is configured as follows:

Start Frequency – 10 MHz	Number of points - 5000
Stop Frequency – 50 GHz	IFBW – 700 Hz

With these settings, the measurement time is approximately 30 seconds.

N5227A Measurement Setup



Test Instruments

QTY	Description
1	Agilent N5227A PNA-L Network Analyzer (10 MHz to 50 GHz)
1	Agilent N4694-60003 ECAL Module (10 MHz to 67 GHz)

Test Cables & Adapters

QTY	Description
4	Gore 0F0CA0CB 036.0-LF (DC-67 GHz)

Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Appendix F - Frequency and Time Domain Measurements

Eye Diagram Procedures

Eye Diagrams and statistical eye diagram metrics such as eye height can be generated by post-processing Frequency Domain measurements using Agilent ADS. Simulated data is sent over a touchstone model and the bits are overlain into an eye pattern.

Currently, no CEI specification is available for 7Gbps, so *CEI-28-VSR Working Clause Proposal, CEI Implementation agreement Draft 7.0*, dated May 14, 2012 was used for this report.

The simulation circuit is modeled as:
Agilent's Advanced Design System Tx and Rx modules that are configured to the *CEI-28-VSR Working Clause Proposal, CEI Implementation agreement Draft 7.0*, dated May 14, 2012.

- Tx parameters are specified in Section 1.3.3, *Module-to-Host Specifications*, Table 1-4, Page 7.
- Rx parameters defined in Section 1.3.2 *Host-to-Module Electrical Specifications*, Table 1-1, Page 5.
- A 1.0 inch length of Tx interconnect trace segment at the transmitter.
- SUT Cable Assembly S-Parameter measurements
  - 40 mils of 5 mil wide differential stripline signal trace
  - Test board vias, pads (footprint effects) for the UEC5 connector
  - The UEC5 series connector J1
  - The ECUE-12-XXX-T1-FF-02-1 cable assembly
  - The UEC5 series connector J2
  - Test board vias, pads (footprint effects) for the UEC5 connector
  - 40 mils of 5 mil wide differential stripline signal trace
- A 1.0 inch length of Rx interconnect trace segment at the receiver.

All traces were modeled as stripline on FR4 with the following parameters:

- The FR4 parameters are modeled using:
  - Er = 4.2 @ 1 GHz
  - Loss Tangent = 0.02 @ 1 GHz

- Copper is modeled as:
  - Conductivity = 4.5E+7 S-m
  - Surface roughness = 0.6 micron

- Traces are differential stripline with the following geometry:

Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

- Trace width: 5 mil
- Trace copper thickness: 2 mil
- Center-to-center spacing: 5.75 mil
- FR4 dielectric thickness: 4.4 mil

Eye Mask
The eye mask is set for 50mVpp, with a jitter margin of 0.5 UI.

Rise Time
The 10-90 risetime of the 9Gbps signal was determined to be 78psec, using the following formula:

Risetime = 0.35/Bandwidth

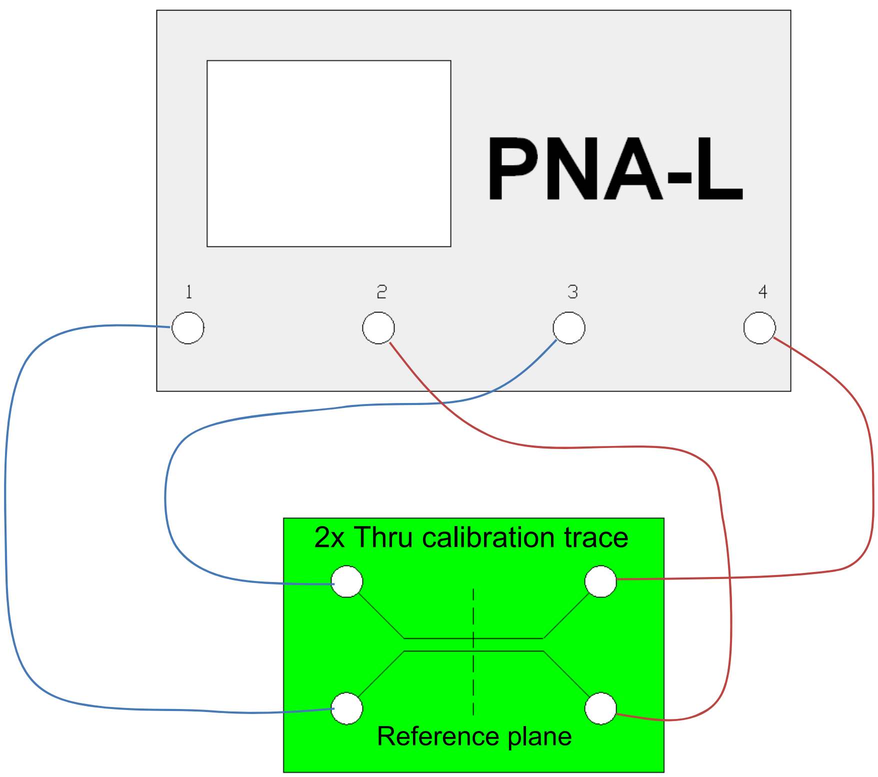
Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Frequency (S-Parameter) Domain Procedures

The quality of any data taken with a network analyzer is directly related to the quality of the calibration standards and the use of proper test procedures. For this reason, extreme care is taken in the design of the AFR calibration standards, the SI test boards and the selection of the PCB vendor.

The measurement process begins with a measurement of the AFR calibration standards. A coaxial SOLT calibration is performed using an N4694-60003 E-CAL module. This measurement is required in order to obtain precise values of the line standard offset delay and frequency bandwidths. Measurements of the 2x through line standard can be used to determine the maximum frequency for which the calibration standards are valid. For the ECUE test boards, this is greater than 35 GHz.

The figure below shows how the THRU reference traces are utilized to compensate for the losses due to the coaxial test cables and the test fixture during testing. The calibration board is characterized to obtain parameters required to define the 2x Thru.

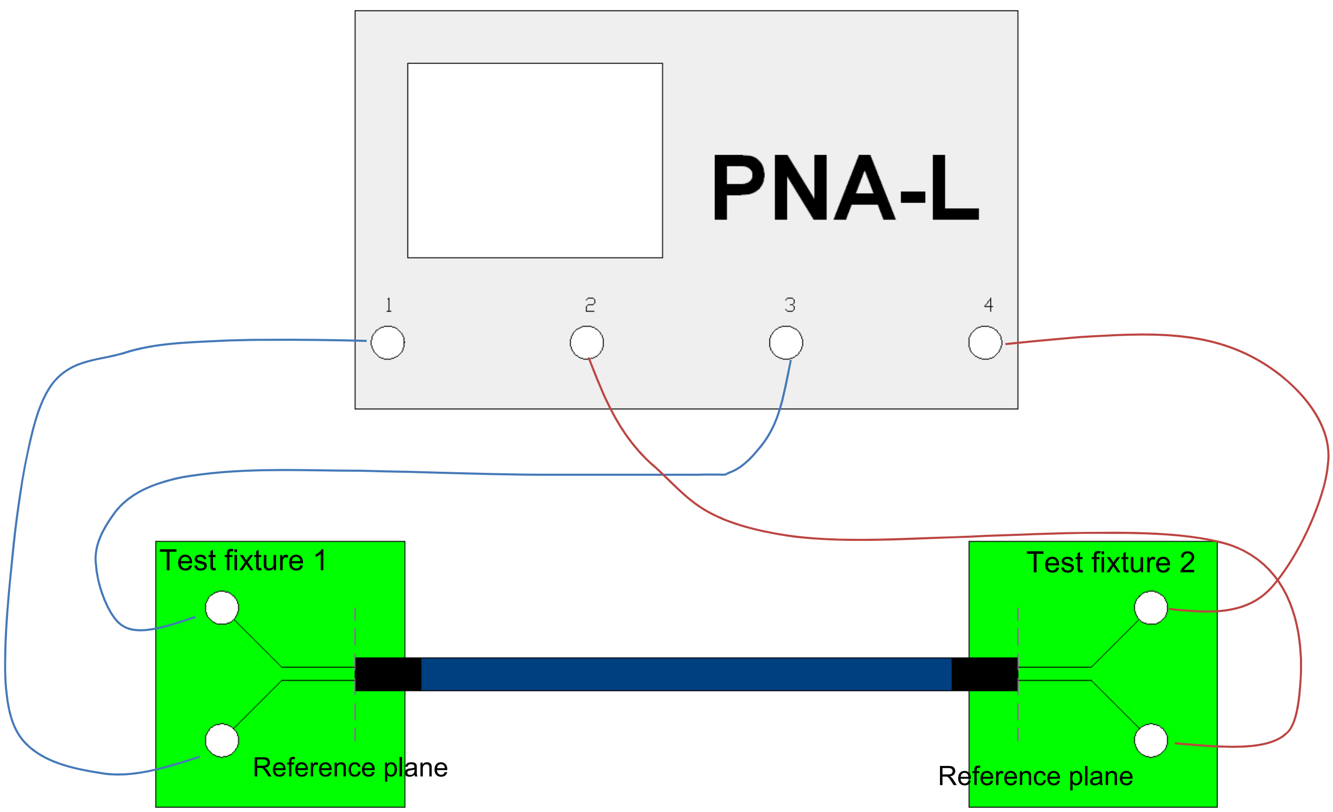


Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Measurements are then performed using the test boards as shown below. The test board effects are removed in post-processing via AFR in Agilent PLTS. The calibrated reference plane is located at the middle of the connector footprint on each side. The S-Parameter measurements include:

A. 40 mils of 5 mil wide differential stripline signal trace
B. Test board vias, pads (footprint effects) for the UEC5 connector
C. The UEC5 series connector J1
D. The ECUE-12-XXX-T1-FF-02-1 test cable
E. The UEC5 series connector J2
F. Test board vias, pads (footprint effects) for the UEC5 connector
G. 40 mils of 5 mil wide differential stripline signal trace

The figure below shows the location of the measurement reference plane.



Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Time Domain Procedures

Mathematically, Frequency Domain data can be transformed to obtain a Time Domain response. Perfect transformation requires Frequency Domain data from DC to infinity Hz. Fortunately, a very accurate Time Domain response can be obtained with bandwidth-limited data, such as measured with modern network analyzer.

The Time Domain responses were generated using Agilent ADS 2011 update 10. This tool has a transient convolution simulator, which can generate a Time Domain response directly from measured S-Parameters. An example of a similar methodology is provided in the Samtec Technical Note on domain transformation.
http://suddendocs.samtec.com/notesandwhitepapers/tech-note_using-plts-for-time-domain-data_web.pdf

Propagation Delay (TDT)
The Propagation Delay is a measure of the Time Domain delay through the cable assembly and footprint. A step pulse is applied to the touchstone model of the cable assembly and the transmitted voltage is monitored. The same pulse is also applied to a reference channel with zero loss, and the Time Domain pulses are plotted on the same graph. The difference in time, measured at the 50% point of the step voltage is the propagation delay.

Impedance (TDR)
Measurements involving digital pulses are performed using either Time Domain Reflectometer (TDR) or Time Domain Transmission (TDT) methods. The TDR method is used for the impedance measurements in this report.

The signal line(s) of the SUT's is energized with a TDR pulse and the far-end of the energized signal line is terminated in the test systems characteristic impedance (e.g.; 50Ω or 100Ω terminations). By terminating the adjacent signal lines in the test systems characteristic impedance, the effects on the resultant impedance shape of the waveform is limited. The "best case" signal mapping was tested and is presented in this report.

Series: ECUE
Description: FireFly™ Micro Flyover System, 36 AWG Micro Ribbon Twinax Cable, FireFly™ End 2

Appendix G – Glossary of Terms

ADS – Agilent Advanced Design System
AFR – Automatic Fixture Removal
CTLE – Continuous Time Linear Analyzer
CuFireFly™ - Copper FireFly™ assembly
DUT – Device under test
FD – Frequency domain
FEXT – Far-End Crosstalk
HDV – High Density Vertical
NEXT – Near-End Crosstalk
OV – Optimal Vertical
OH – Optimal Horizontal
PCB – Printed Circuit Board
PLTS – Agilent Physical Layer Design System
PPO – Pin Population Option
SE – Single-Ended
SI – Signal Integrity
SUT – System Under Test
S – Static (independent of PCB ground)
SOLT – acronym used to define Short, Open, Load & Thru Calibration Standards
TD – Time Domain
TDA – Time Domain Analysis
TDR – Time Domain Reflectometry
TDT – Time Domain Transmission
UI – Unit Interval
XROW – Across Row
Z – Impedance (expressed in ohms)

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