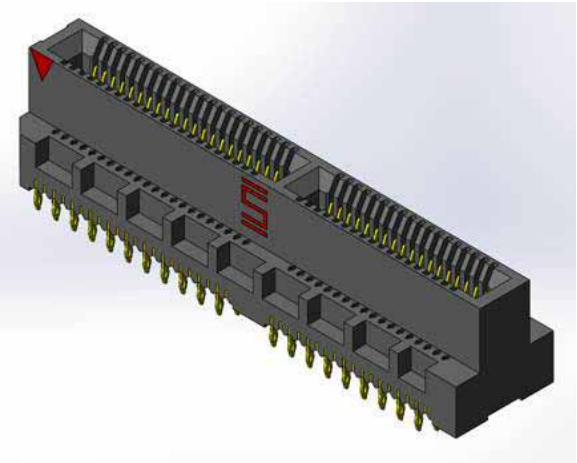
High Speed Characterization Report

MEC8-1XX-02-X-VP



Description:
0.80mm Mini Edge Card Connector,
Vertical Press Fit, Mates with 1.60mm thick cards

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Report Revision: 12/10/2013

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Table of Contents

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

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Connector Overview

The MEC8 series is a double row structure, high-speed mini edge-card socket connector on a 0.8mm (0.0315") pitch and available up to 140 pins polarized. The MEC8 connector is available in a vertical, right angle or edge-card mount style. The MEC8 accepts 1.6mm (0.062") thick cards.

The data in this report is applicable only to MEC8 double row vertical press fit connector mates to 1.6mm thick cards.

Connector System Speed Rating

MEC8 Mini Edge-Card Series, 0.8mm Pitch, mates to 1.6mm thick card

Signaling	Speed Rating
Single-Ended:	**8.5GHz/ 17Gbps**
Differential:	**8.5GHz/ 17Gbps**

The Speed Rating is based on the -3 dB insertion loss point of the connector system. The -3 dB point can be used to estimate usable system bandwidth in a typical, two-level signaling environment.

To calculate the Speed Rating, the measured -3 dB point is rounded-up to the nearest half-GHz level. The up rounding corrects for a portion of the test board's trace loss, since a short length of trace loss included in the loss data in this report. The resulting loss value is then doubled to determine the approximate maximum data rate in Gigabits per second (Gbps).

For example, a connector with a -3 dB point of 7.8 GHz would have a Speed Rating of 8 GHz/ 16 Gbps. A connector with a -3 dB point of 7.2 GHz would have a Speed Rating of 7.5 GHz/ 15 Gbps.

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Frequency Domain Data Summary

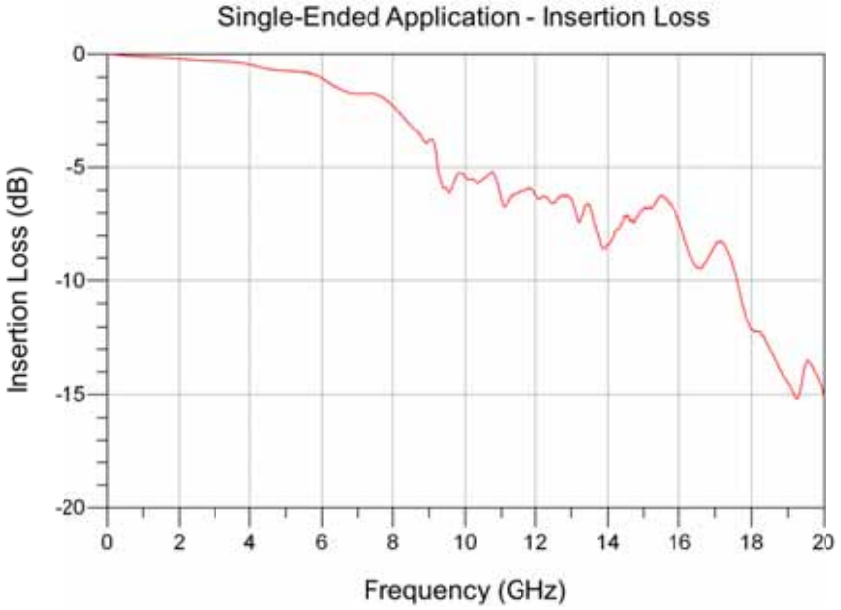
Table 1 - Single-Ended Connector System Performance				
Test Parameter	**Configuration**	**Driver**	**Receiver**	
Insertion Loss	GSG	Edge_Card_62	MEC8_62	3dB@ 8.4 GHz
Return Loss	GSG	Edge_Card_62	Edge_Card_62	>10dB to 5.9 GHz
Near-End Crosstalk	GAQG	Edge_Card_22	Edge_Card_24	<-20dB to 0.7 GHz
	GAGQG	Edge_Card_62	Edge_Card_66	<-20dB to 16.3 GHz
	Xrow, GAG to GQG	Edge_Card_61	Edge_Card_62	<-20dB to 9.2 GHz
Far-End Crosstalk	GAQG	Edge_Card_22	MEC8_24	<-20dB to 6.5 GHz
	GAGQG	Edge_Card_62	MEC8_66	<-20dB to 7.0 GHz
	Xrow, GAG to GQG	Edge_Card_62	MEC8_61	<-20dB to 20 GHz

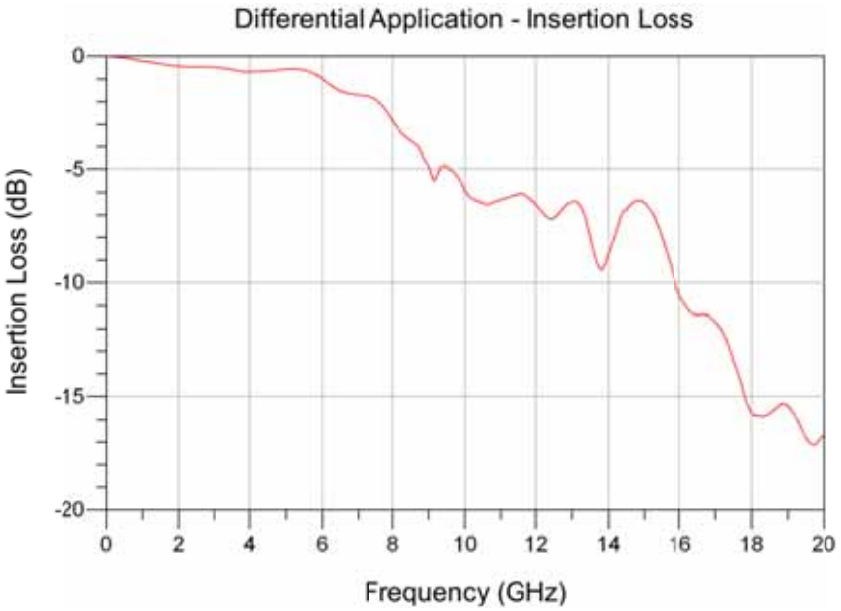
Table 2 - Differential Connector System Performance				
Test Parameter	**Configuration**	**Driver**	**Receiver**	
Insertion Loss	GSSG	Edge_Card_28,30	MEC8_28,30	3dB@ 8.1 GHz
Return Loss	GSSG	Edge_Card_28,30	Edge_Card_28,30	>10dB to 6.1 GHz
Near-End Crosstalk	GAAQQG	Edge_Card_28,30	Edge_Card_32,34	<-20dB to 3.1 GHz
	GAAGQQG	Edge_Card_28,30	Edge_Card_34,36	<-20dB to 20 GHz
	Xrow, GAAG to GQQG	Edge_Card_21,23	Edge_Card_22,24	<-20dB to 20 GHz
Far-End Crosstalk	GAAQQG	Edge_Card_28,30	MEC8_32,34	<-20dB to 5 GHz
	GAAGQQG	Edge_Card_28,30	MEC8_34,36	<-20dB to 20 GHz
	Xrow, GAAG to GQQG	Edge_Card_22,24	MEC8_21,23	<-20dB to 20 GHz

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Bandwidth Chart – Single-Ended & Differential Insertion Loss

MEC8 Connector Series





Series: MEC8-VP
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Time Domain Data Summary

Table 3 - Single-Ended Impedance (Ω)					
Signal Rise-time	**30ps**	**50ps**	**100ps**	**250ps**	**500ps**
Maximum Impedance	59.76	57.00	52.61	51.05	50.50
Minimum Impedance	43.93	44.99	48.10	49.94	49.96

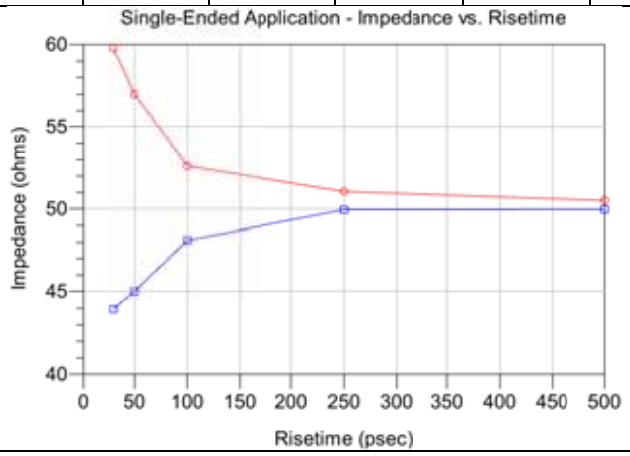
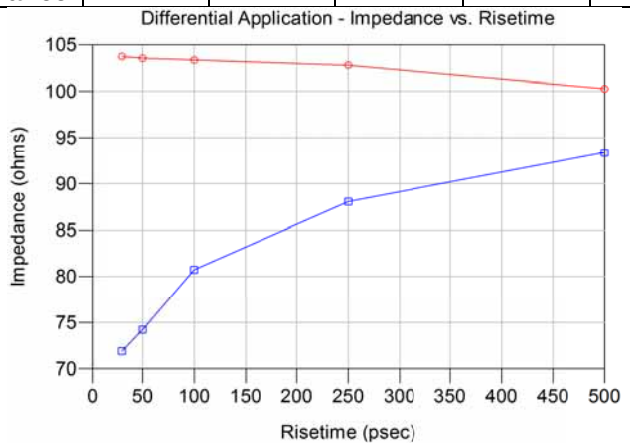


Table 4 - Differential Impedance (Ω)					
Signal Rise-time	**30ps**	**50ps**	**100ps**	**250ps**	**500ps**
Maximum Impedance	103.74	103.55	103.36	102.79	100.28
Minimum Impedance	71.88	74.23	80.73	88.07	93.37



Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Table 5 - Single-Ended Crosstalk (%)								
Input(t_r)	**Configuration**	**Driver**	**Receiver**	**30ps**	**50ps**	**100ps**	**250ps**	**500ps**
NEXT	GAQG	Edge_Card_22	Edge_Card_24	19.03	18.09	16.29	9.59	5.11
	GAGQG	Edge_Card_62	Edge_Card_66	3.83	3.61	3.08	1.74	0.91
	Xrow	Edge_Card_61	Edge_Card_62	2.25	2.02	1.39	0.69	0.36
FEXT	GAQG	Edge_Card_22	MEC8_24	3.79	3.02	1.39	0.38	0.23
	GAGQG	Edge_Card_62	MEC8_66	5.13	3.90	2.14	0.88	0.47
	Xrow	Edge_Card_62	MEC8_61	0.70	0.59	0.35	0.13	<0.1

Table 6 - Differential Crosstalk (%)								
Input(t_r)	**Configuration**	**Driver**	**Receiver**	**30ps**	**50ps**	**100ps**	**250ps**	**500ps**
NEXT	GAAQQG	Edge_Card_28,30	Edge_Card_32,34	5.62	5.06	4.38	2.20	1.10
	GAAGQQG	Edge_Card_28,30	Edge_Card_34,36	1.38	1.21	0.89	0.49	0.25
	Xrow	Edge_Card_21,23	Edge_Card_22,24	0.60	0.51	0.31	0.10	<0.1
FEXT	GAAQQG	Edge_Card_28,30	MEC8_32,34	7.56	5.95	3.36	1.50	0.85
	GAAGQQG	Edge_Card_28,30	MEC8_34,36	2.14	1.60	0.82	0.26	0.13
	Xrow	Edge_Card_22,24	MEC8_21,23	0.37	0.29	0.15	<0.1	<0.1

Table 7 - Propagation Delay (Mated Connector)	
Single-Ended	89 ps
Differential	85 ps

Series: MEC8-VP
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Characterization Details

This report presents data that characterizes the signal integrity response of a connector pair 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 connector pair 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 connector'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 and Single-Ended Data

Most Samtec connectors 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 both differentially and single-ended driven scenarios.

Connector Signal to Ground Ratio

Samtec connectors 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 connectors, a ground plane or blade, or an outer shield, is used as the signal return, while in others, connector 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. However, dedicating pins to ground reduces signal density of a connector. Therefore, care must be taken when choosing signal/ground ratios in cost or density-sensitive applications.

Series: MEC8-VP
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For this connector, the following configurations were evaluated:

Single-Ended Impedance**:**
- GSG (Ground-Signal-Ground)

Single-Ended Crosstalk**:**
- Electrical “worst case”: GAQG (Ground-Active-Quiet-Ground)
- Electrical “best case”: GAGQG (Ground-Active-Ground-Quiet-Ground)
- Across row: “xrow case”: GAG to GQG (from one row of terminals to the other row)

Differential Impedance**:**
- GSSG (Ground-positive Signal-negative Signal-Ground)

Differential Crosstalk**:**
- Electrical “worst case”: GAAQQG (Ground-Active-Active-Quiet-Quiet-Ground)
- Electrical “best case”: GAAGQQG (Ground-Active-Active-Ground-Quiet-Quiet-Ground)
- Across row: “xrow case”: GAAG to GQQG (from one row of terminals to the other row)

Only one single-ended signal or differential pair was driven for crosstalk measurements.

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” and “GSSG” configurations tested in the laboratory. Electrical characteristics in such applications could vary slightly from laboratory results. However, 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 rise time of the exciting signal. For this report, the fastest rise time used was 30 ps. Generally, this should demonstrate worst-case performance.

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

In many systems, the signal edge rate will be significantly slower at the connector 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.

For this report, measured rise times were at 10%-90% signal levels.

Frequency Domain Data

Frequency Domain parameters are helpful in evaluating the connector 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, Return Loss, and Near-End and Far-End Crosstalk. 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 directly from network analyzer measurements.

Time Domain Data

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

Impedance mismatch versus length is measured by DSA8200 Digital Serial Analyzer. Board related effects, such as pad-to-ground capacitance and trace loss, are included in the data presented in this report. The impedance data is provided in Appendix E of this report.

The measured S-Parameters from the network analyzer are post-processed using Agilent Advanced Design System to obtain the time domain response for signal propagation time and crosstalk. The Time Domain procedure is provided in Appendix E 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 connector and connector footprint. It includes 10 mils of PCB trace on the MEC8 connector and the edge-card side each. 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.

Crosstalk or coupled noise data is provided for various signal configurations. All measurements are single disturber. Crosstalk is calculated as a ratio of the input line voltage to the coupled line voltage. The input line is sometimes described as the active or drive

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

line. The coupled line is sometimes described as the quiet or victim line. Crosstalk ratio is tabulated in this report as a percentage. Measurements are made at both the near-end and far-end of the SUT.

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

As a rule of thumb, 10% crosstalk levels are often used as a general first pass limit for determining acceptable interconnect performance. However, modern system crosstalk tolerance can vary greatly. For advice on connector suitability for specific applications, please contact our Signal Integrity Group at sig@samtec.com.

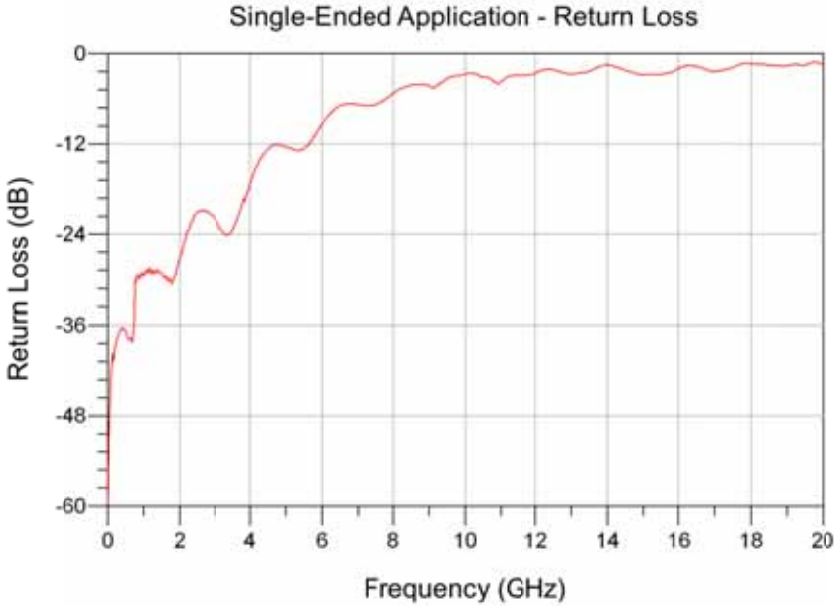
Additional information concerning test conditions and procedures is located in the appendices of this report. Further information may be obtained by contacting our Signal Integrity Group at sig@samtec.com.

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Appendix A – Frequency Domain Response Graphs

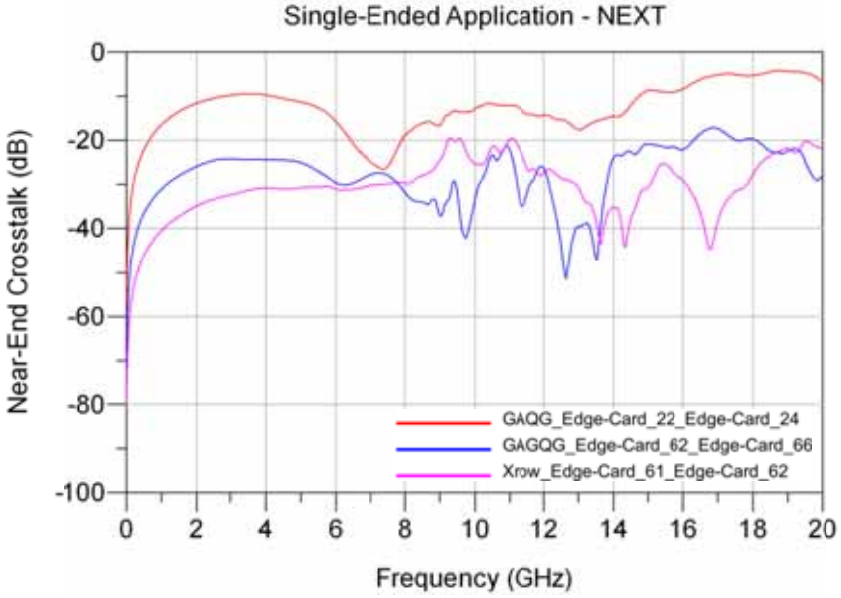
Single-Ended Application – Insertion Loss

Single-Ended Application – Return Loss

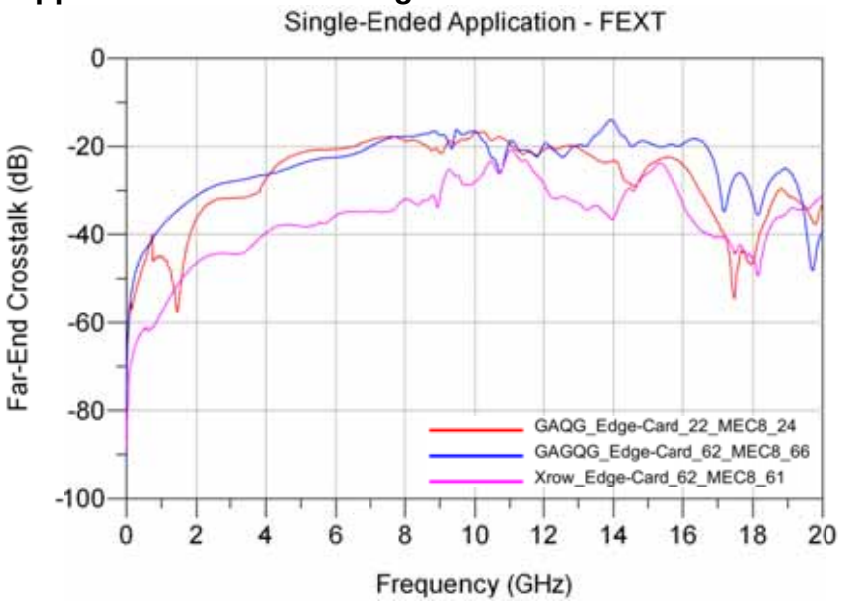


Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Single-Ended Application – NEXT Configurations

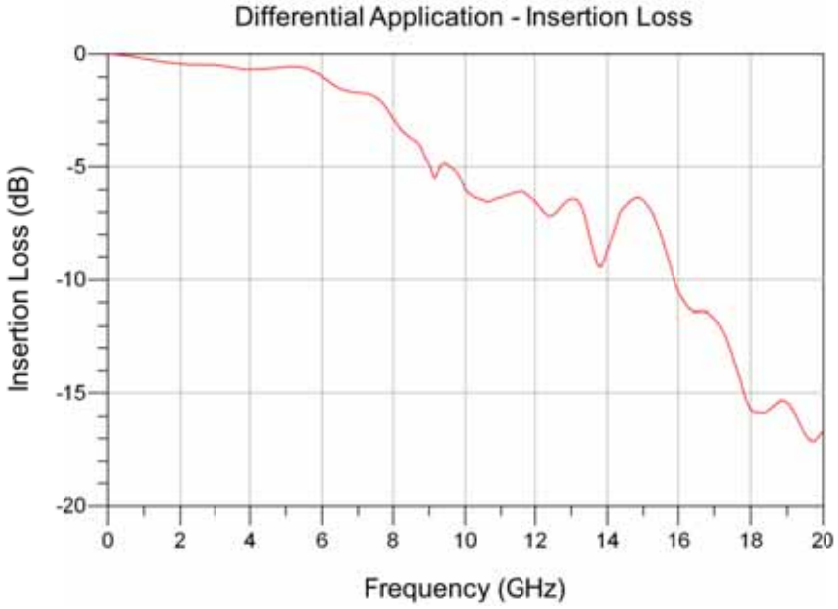


Single-Ended Application – FEXT Configurations

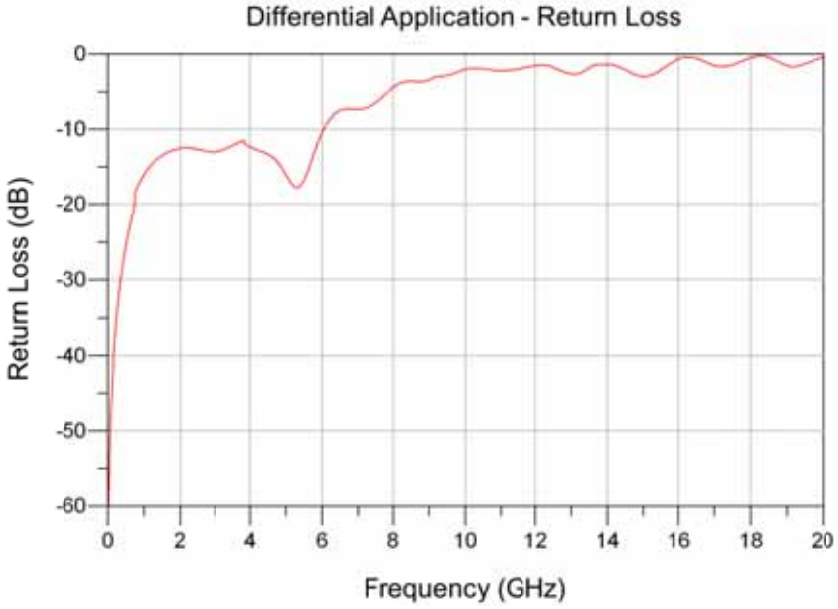


Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Differential Application – Insertion Loss



Differential Application – Return Loss



Series: MEC8-VP
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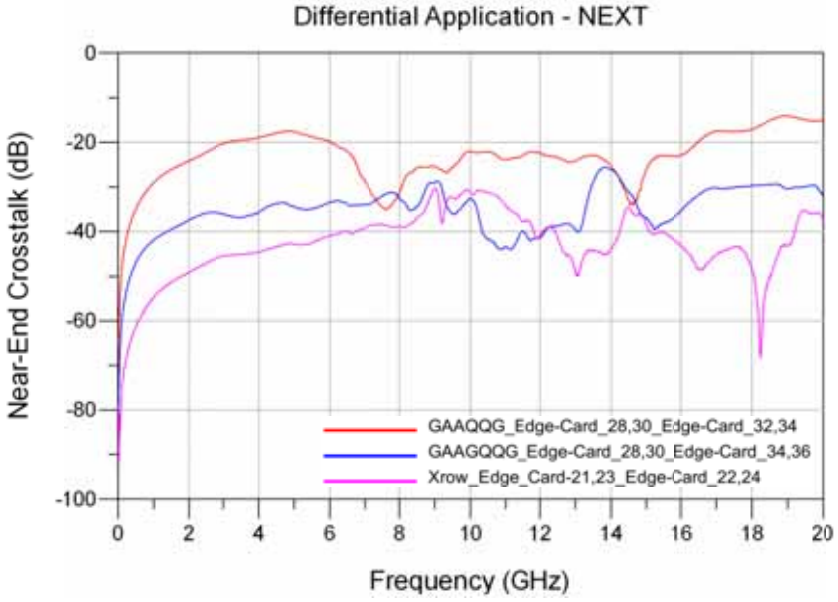
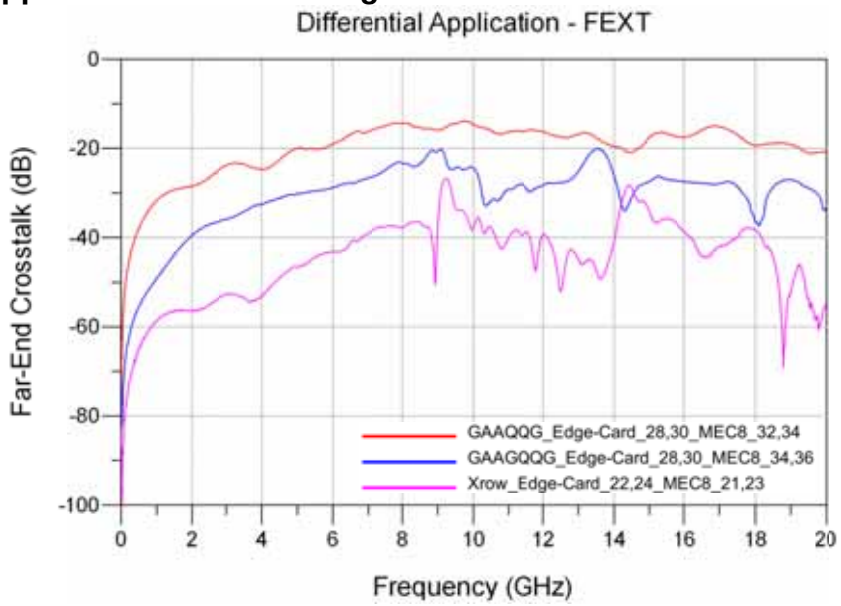
Differential Application – NEXT Configurations



Differential Application – FEXT Configurations



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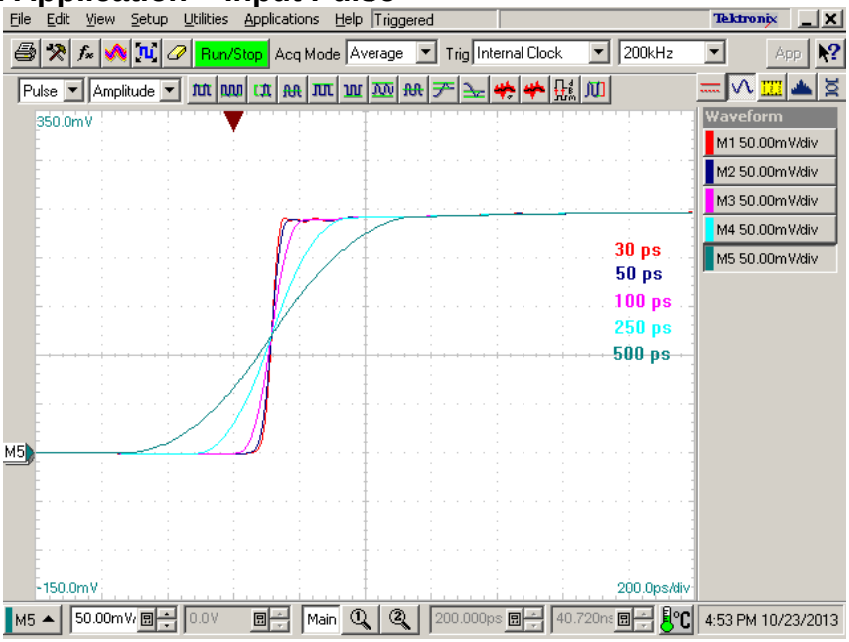
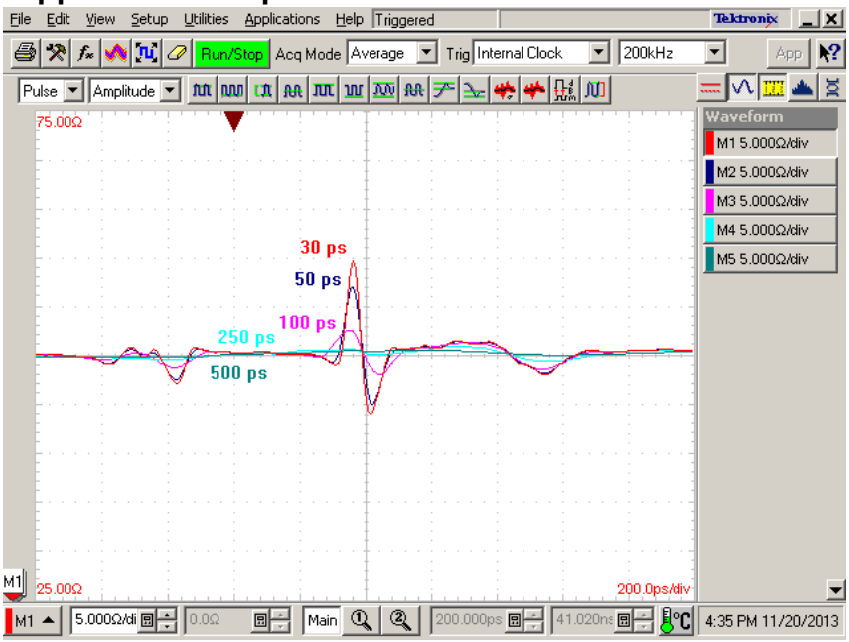
Appendix B – Time Domain Response Graphs

Single-Ended Application – Input Pulse



Single-Ended Application – Impedance



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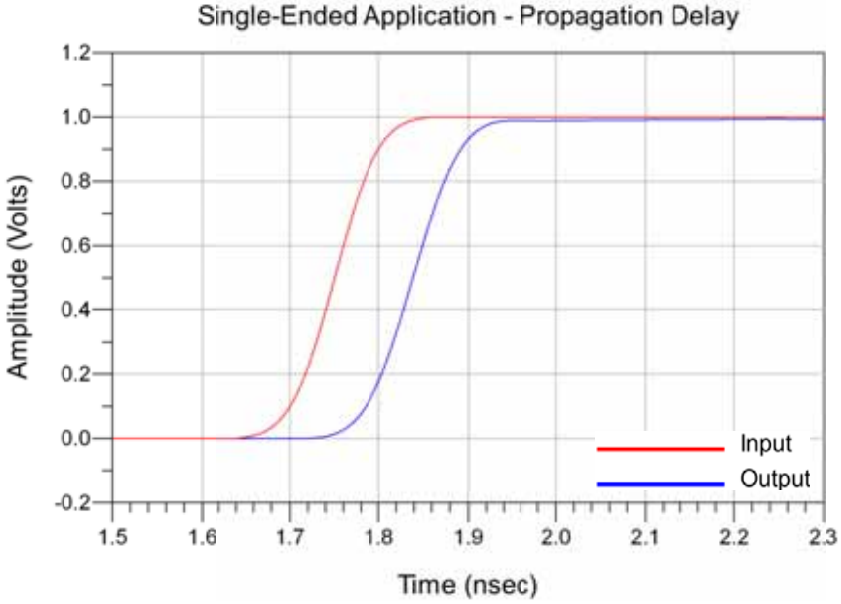
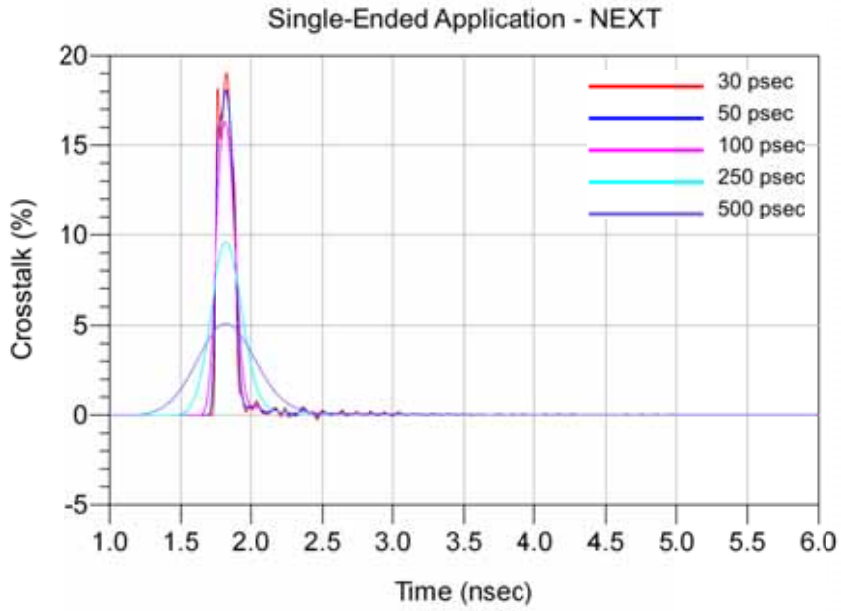
Single-Ended Application – Propagation Delay



Single-Ended Application – NEXT, Worst Case Configuration, Edge-Card_22_Edge-Card_24



Series: MEC8-VP
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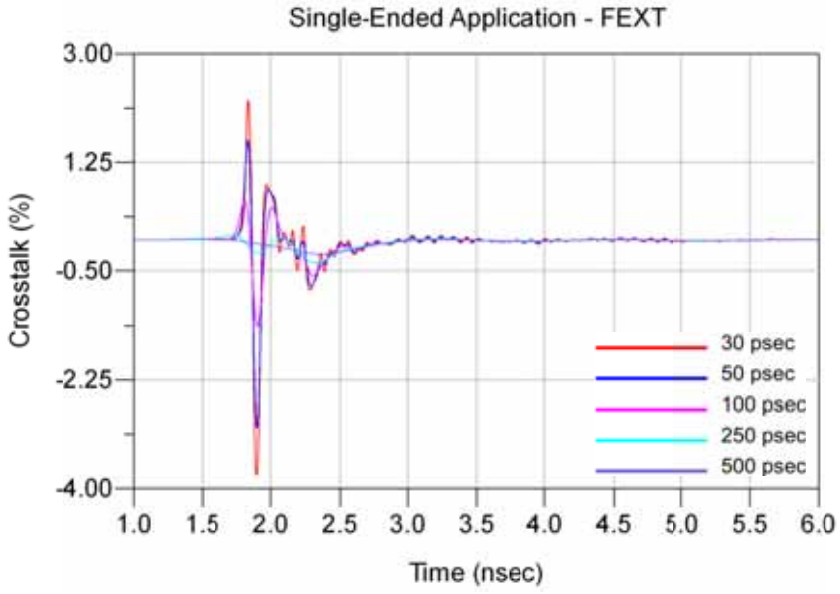
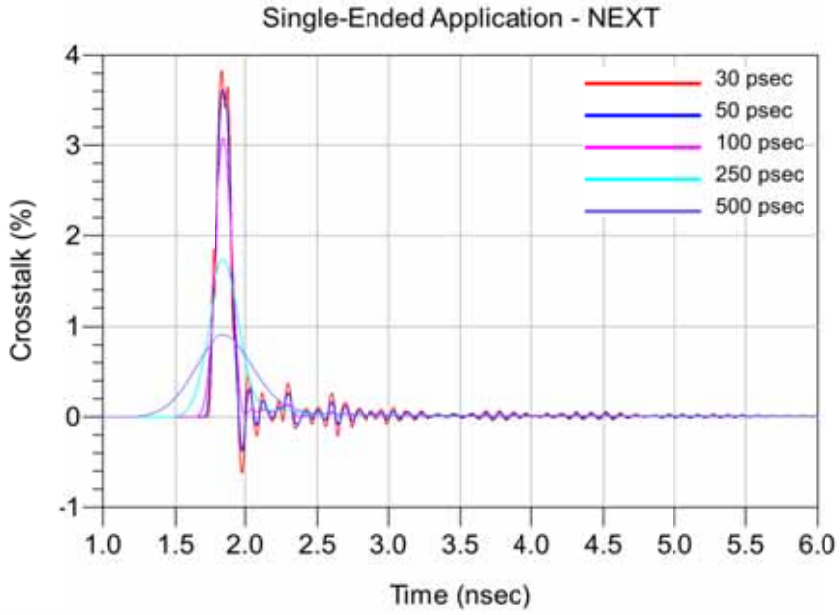
Single-Ended Application – FEXT, Worst Case Configuration, Edge-Card_22_MEC8_24



Single-Ended Application – NEXT, Best Case Configuration, Edge-Card_62_Edge-Card_66



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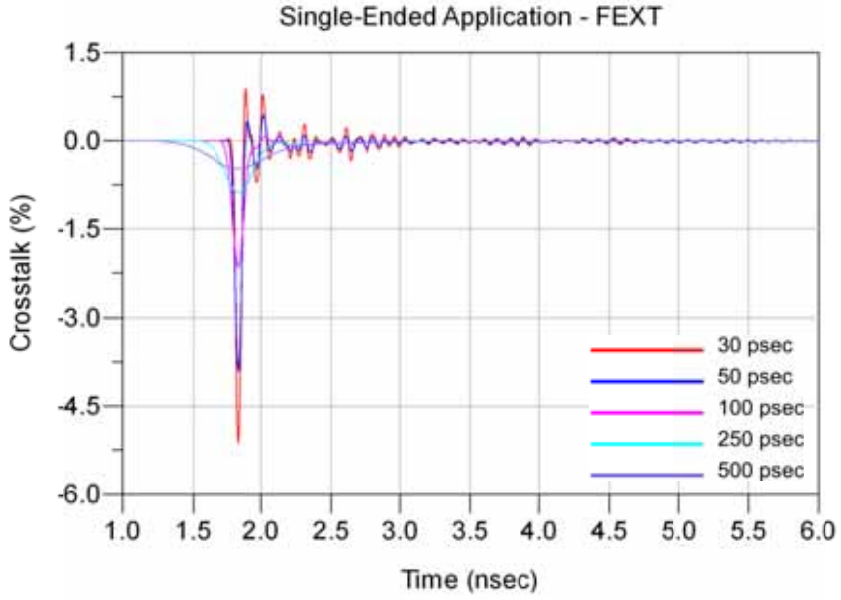
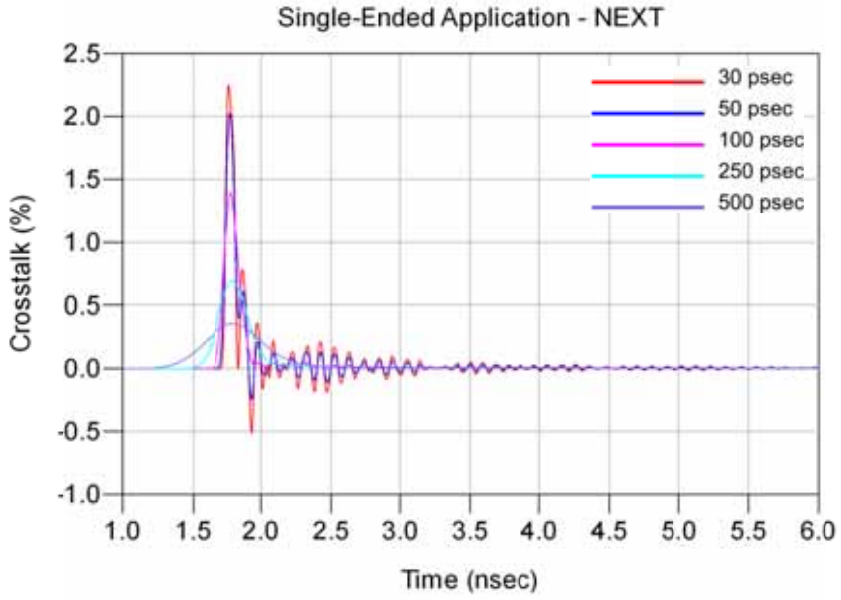
Single-Ended Application – FEXT, Best Case Configuration, Edge-Card_62_MEC8_66



Single-Ended Application – NEXT, Across Row Configuration, Edge-Card_61_Edge-Card_62



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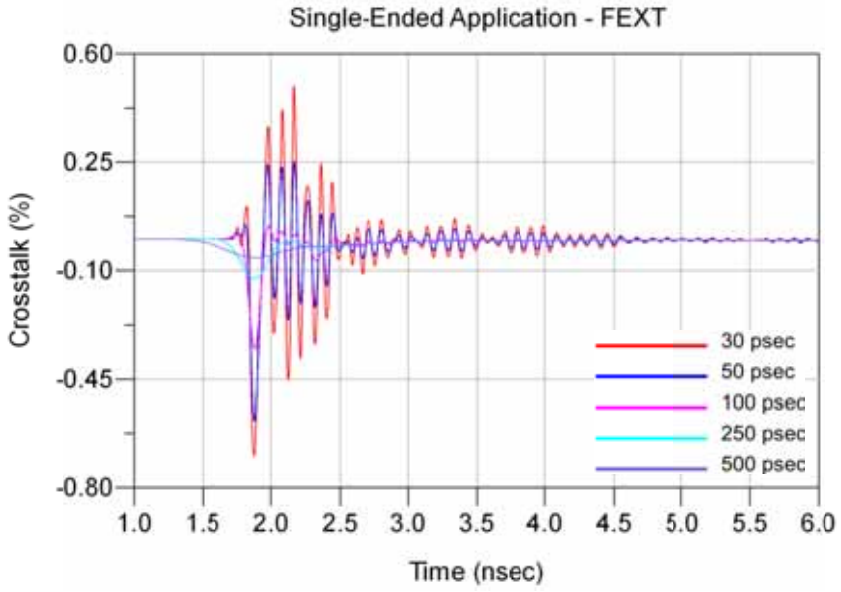
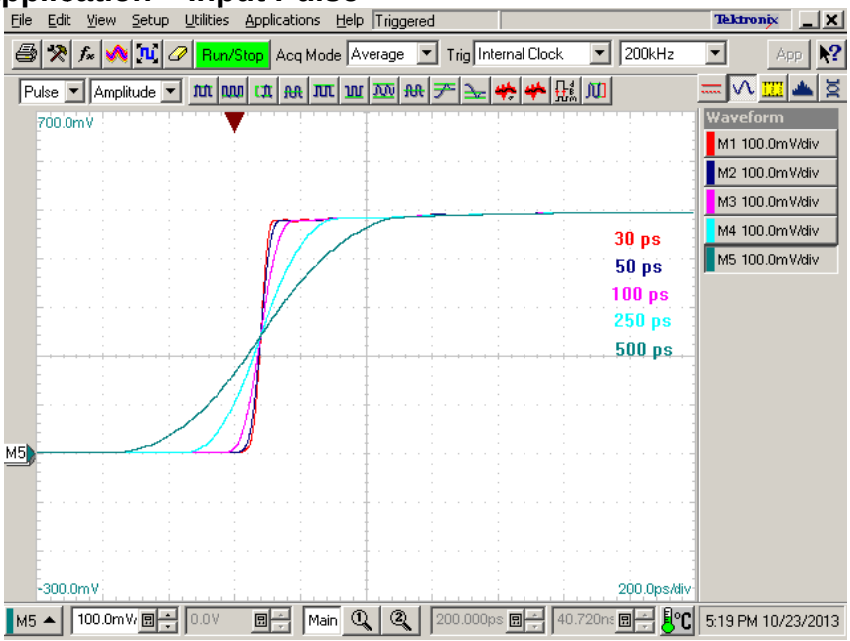
Single-Ended Application – FEXT, Across Row Configuration, Edge-Card_62_MEC8_61



Differential Application – Input Pulse



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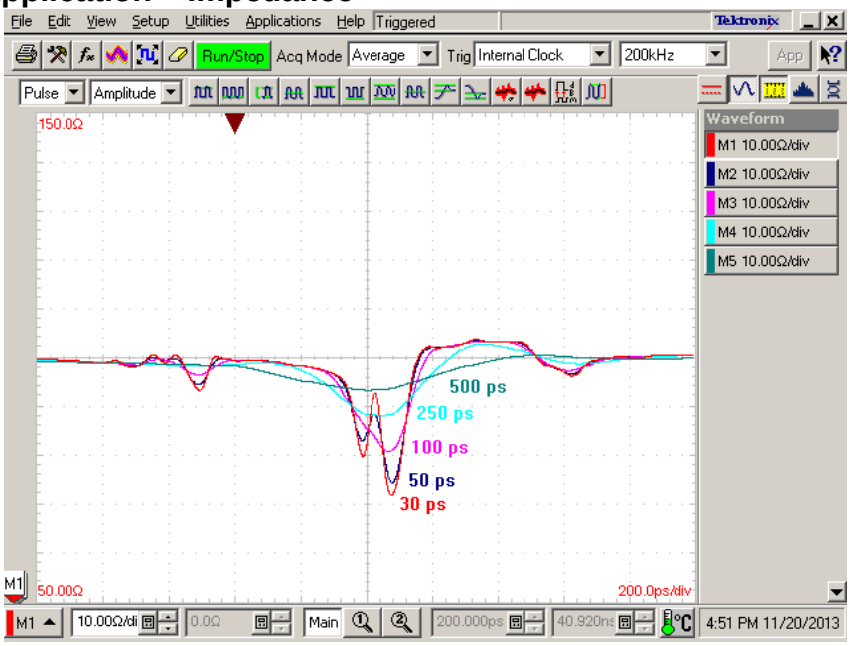
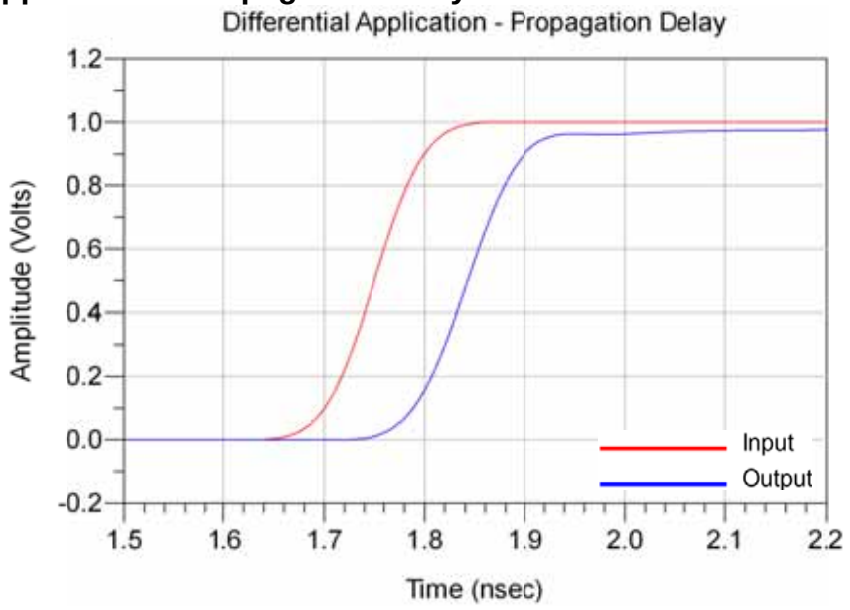
Differential Application – Impedance



Differential Application – Propagation Delay



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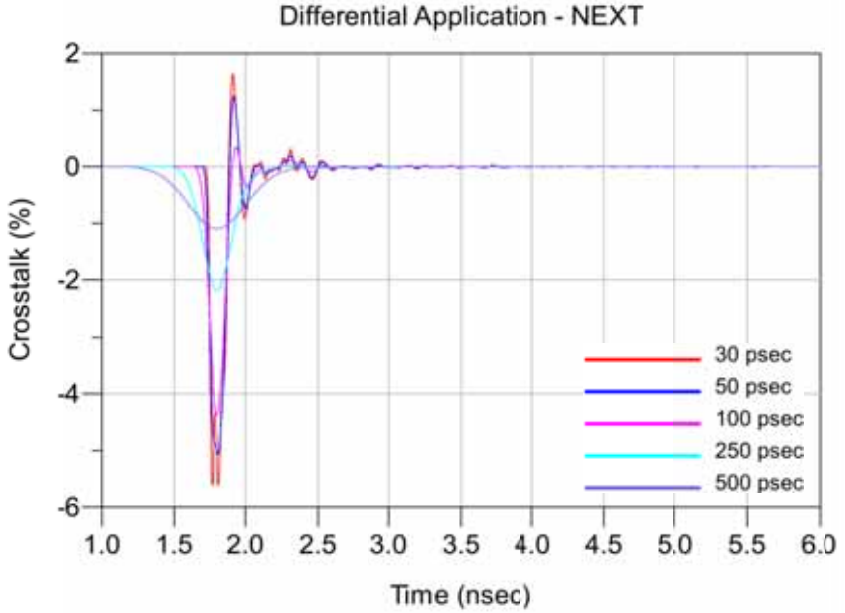
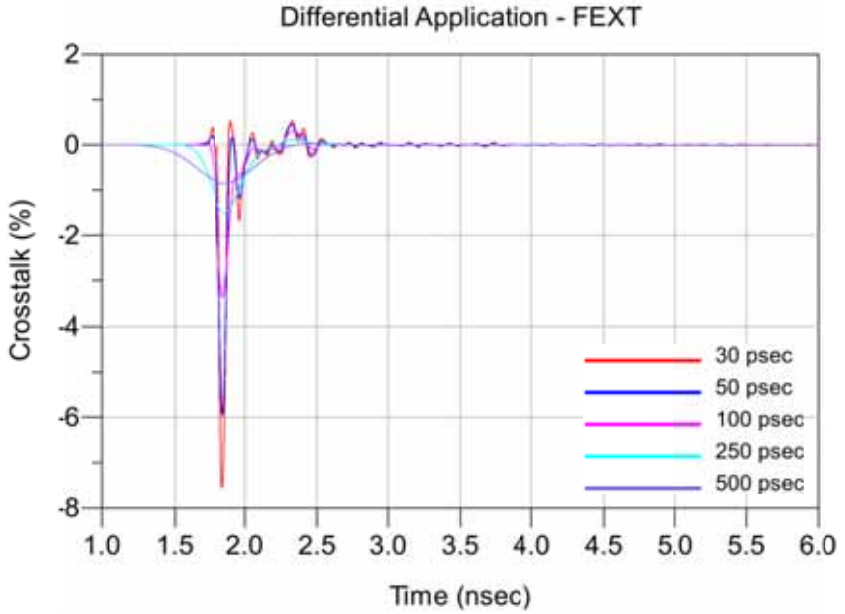
Differential Application – NEXT, Worst Case Configuration, Edge-Card_28,30_Edge-Card_32,34



Differential Application – FEXT, Worst Case Configuration, Edge-Card_28,30_MEC8_32,34



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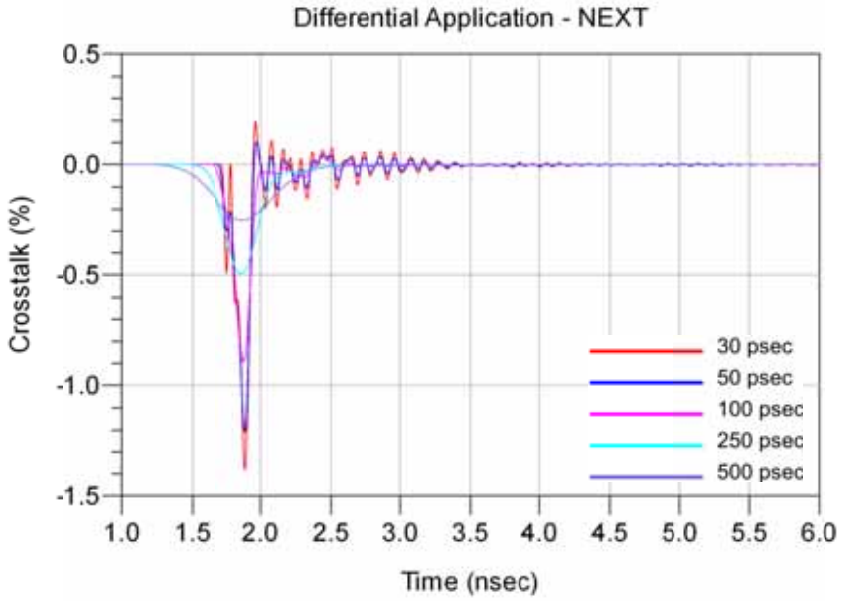
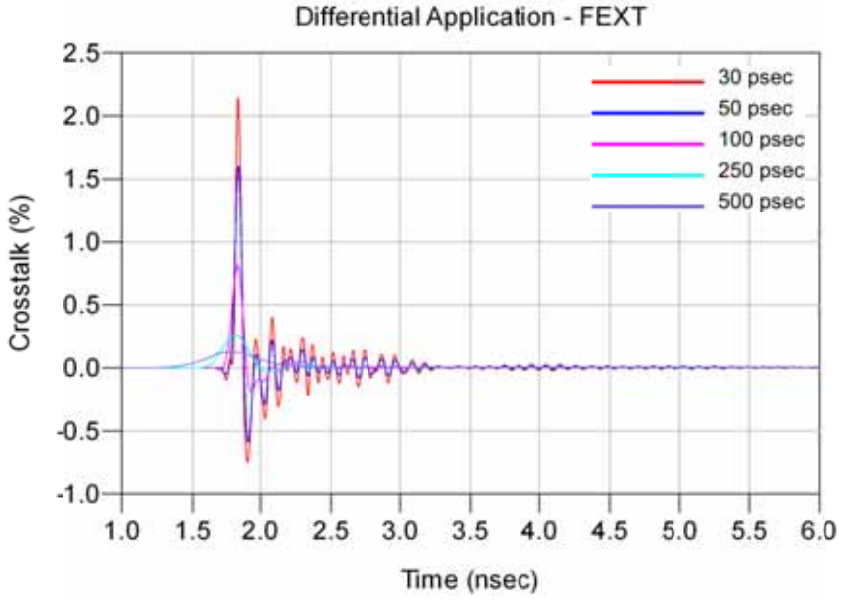
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Differential Application – NEXT, Best Case Configuration, Edge-Card_28,30_Edge-Card_34,36

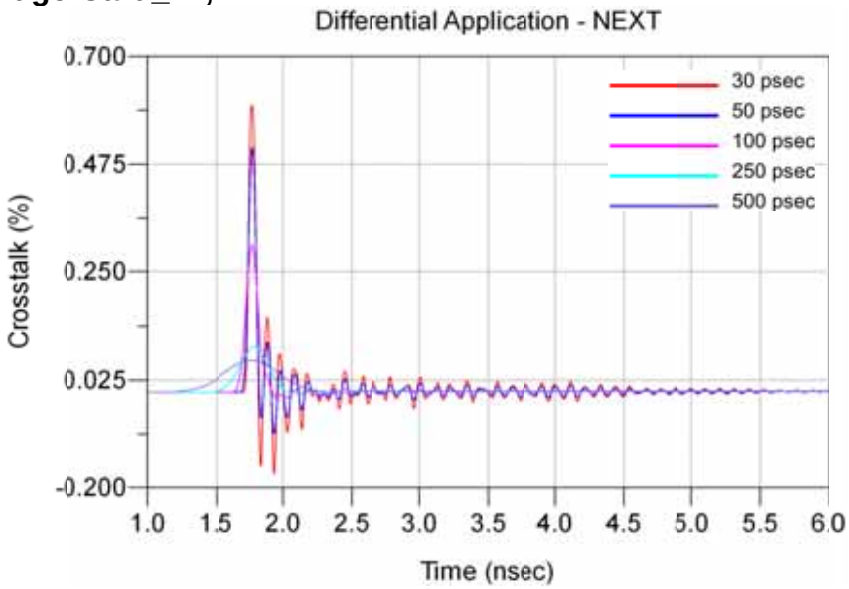


Differential Application – FEXT, Best Case Configuration, Edge-Card_28,30_MEC8_34,36

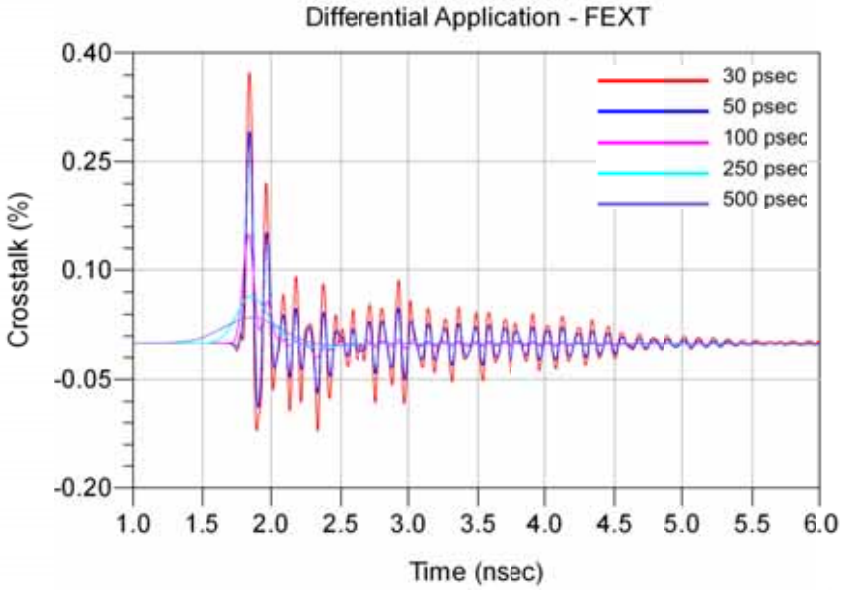


Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Differential Application – NEXT, Across Row Case Configuration, Edge-Card_21,23_Edge-Card_22,24



Differential Application – FEXT, Across Row Case Configuration, Edge-Card_22,24_MEC8_21,23



Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Appendix C – Product and Test System Descriptions

Product Description

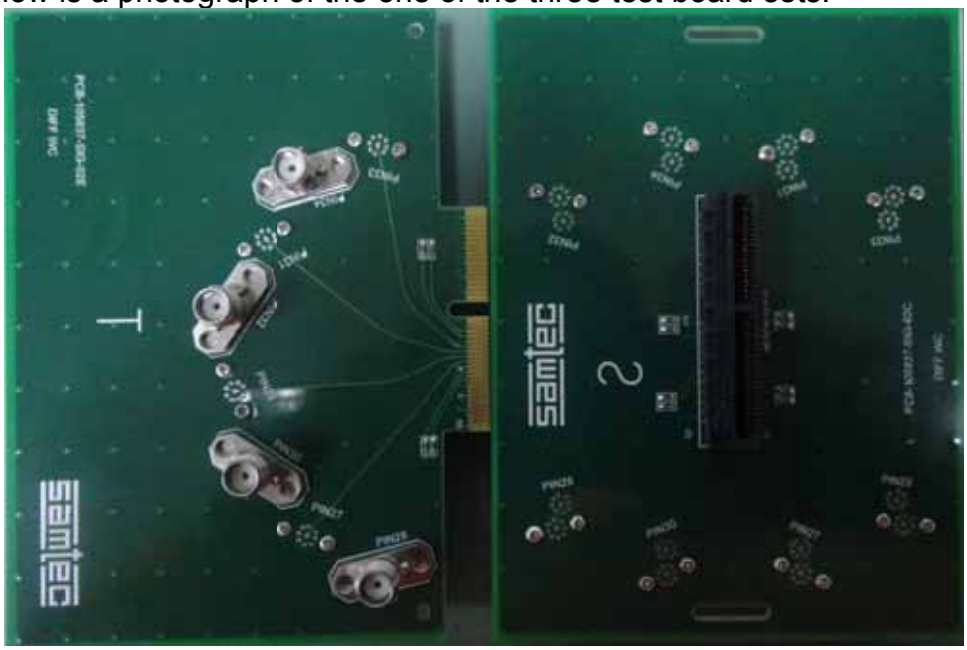
Product test samples are vertical press fit MEC8 Series connectors. The part number is MEC8-140-02-L-VP. Each connector has two rows of contacts evenly spaced on a 0.8mm (0.0315") pitch. A photo of the test articles mounted to SI test boards is shown below.

Test System Description

The test fixtures are composed of four-layer FR-4 material with 50Ω signal trace and pad configurations designed for the electrical characterization of Samtec high speed connector products. A PCB mount SMA connector is used to interface the test cables to test fixtures. Optimization of the SMA launch was performed using full wave simulation tools to minimize reflections. Six test fixtures are specific to the MEC8 series connector set and identified by part numbers PCB-105837-SIG-01C and E through PCB-105837-SIG-03C and E. Calibration standards specific to the MEC8 series are located on the calibration boards PCB-105837-SIG-04. To keep trace lengths short, three different test board sets were required to access the necessary signal pins.

PCB-105837-SIG-XX Test Fixtures

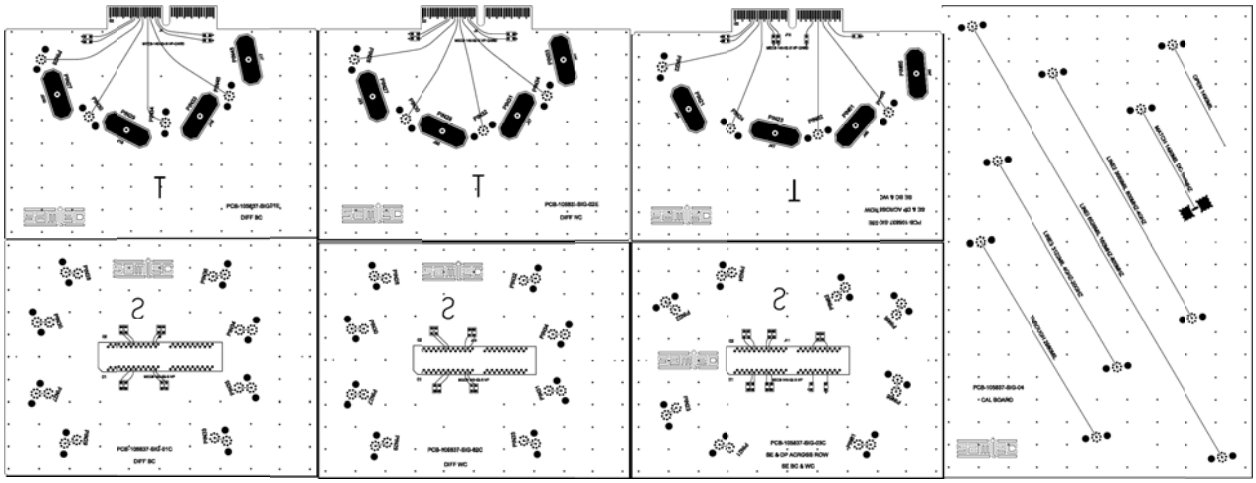
Shown below is a photograph of the one of the three test board sets.



Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

PCB-105837-SIG-XX PCB Layout Panel

Artwork of the PCB design is shown below.

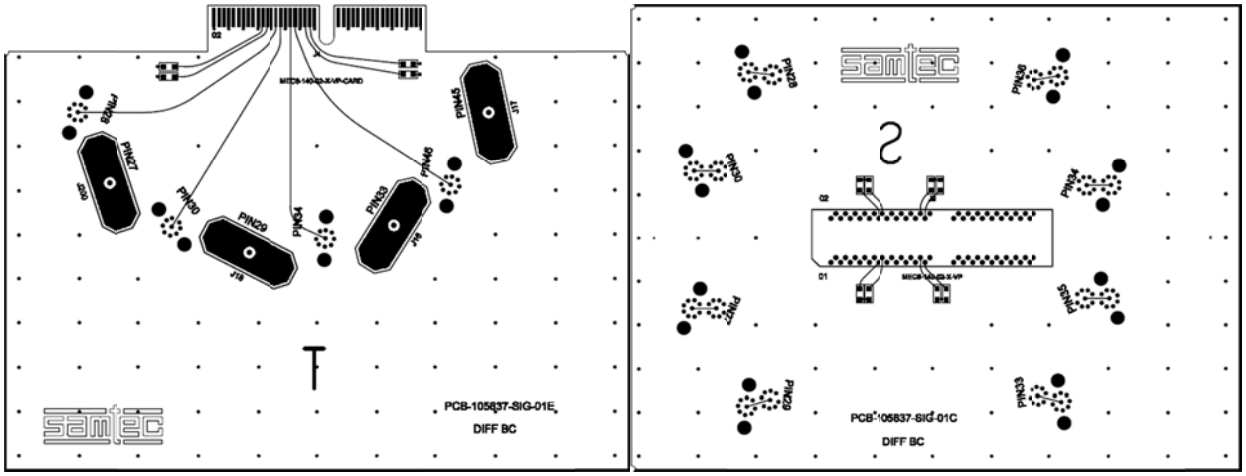


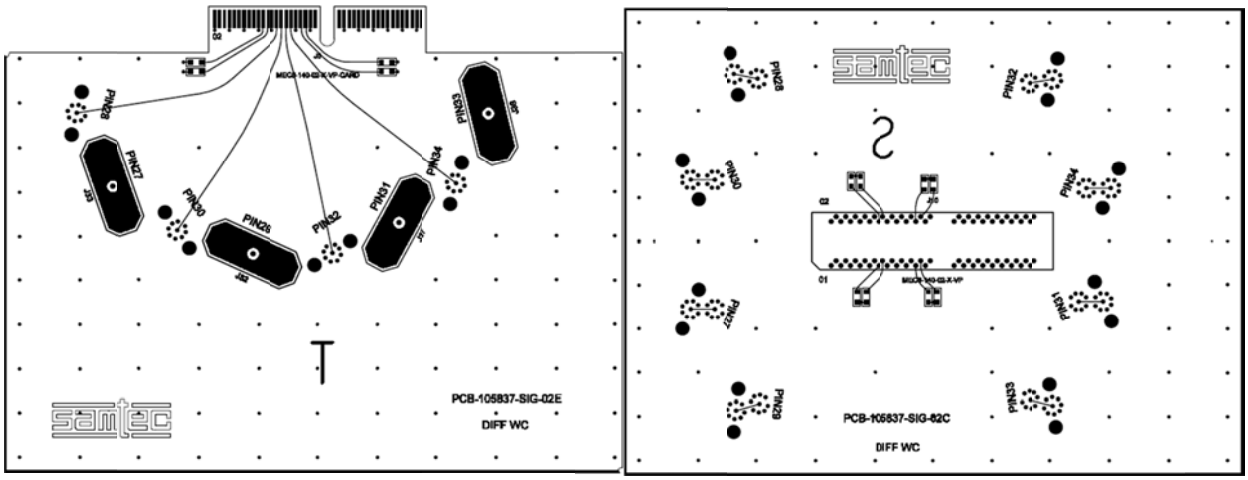
PCB Fixtures

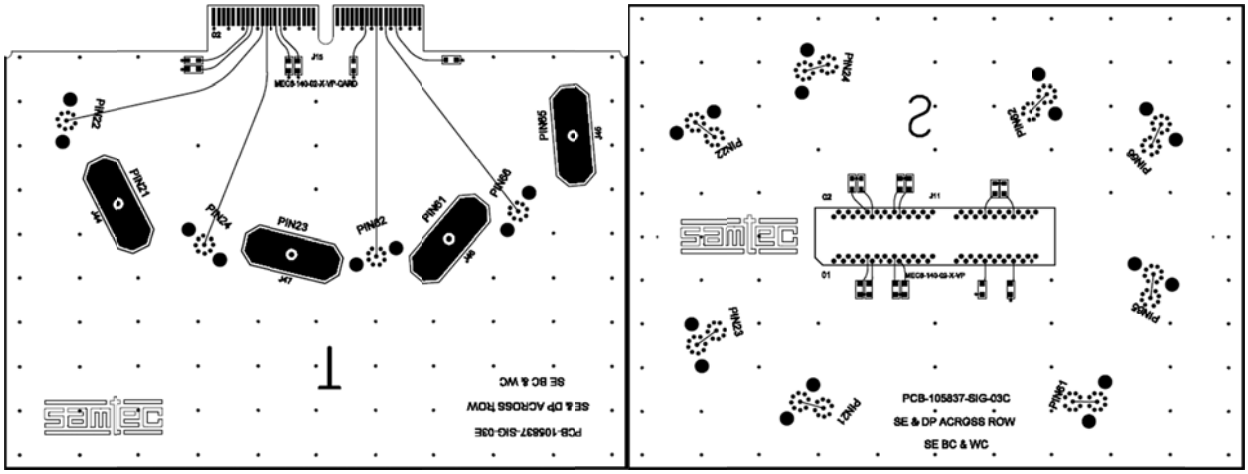
The test fixtures used are as follows:

PCB-105837-SIG-01C – MEC8-VP Series Test Board for differential best-case
PCB-105837-SIG -01E – Edge-Card for differential best-case
PCB-105837-SIG -02C – MEC8-VP Series Test Board for differential worst-case
PCB-105837-SIG -02E – Edge-Card for differential worst-case
PCB-105837-SIG -03C – MEC8-VP Series Test Board for single-ended best-case, worst-case and across-row, differential across-row
PCB-105837-SIG -03E – Edge-Card for single-ended best-case, worst-case and across-row, differential across-row

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards



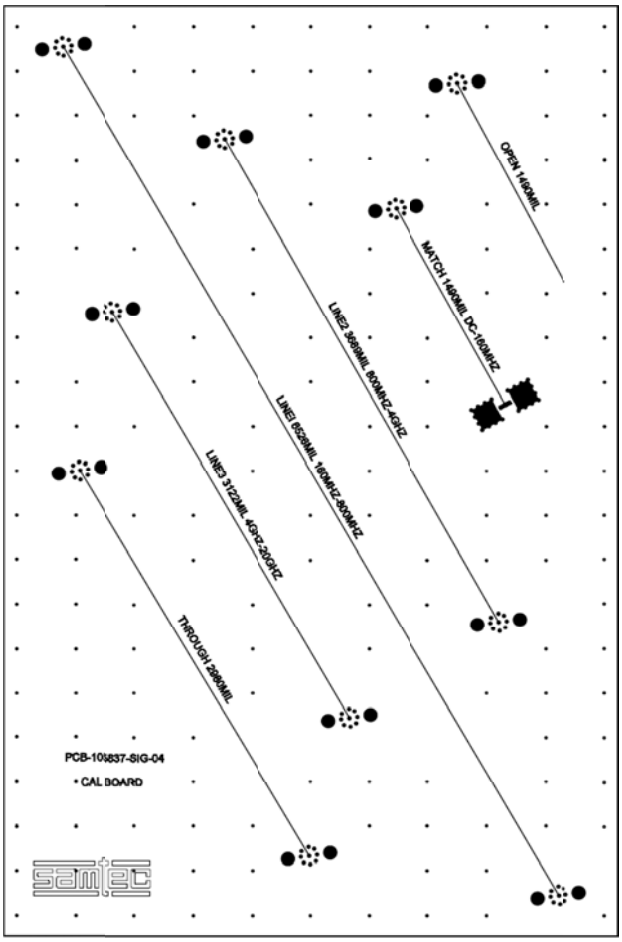




Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Calibration Board

Test fixture losses and test point reflections were removed from the data by use of TRL calibration. The calibration board is shown below. Prior to making any measurements, the calibration board is characterized to obtain parameters required to define the calibration kit. Once a calibration kit is defined, calibration using the standards on the calibration board can be performed. Finally, the device can be measured and the test board effects are automatically removed.



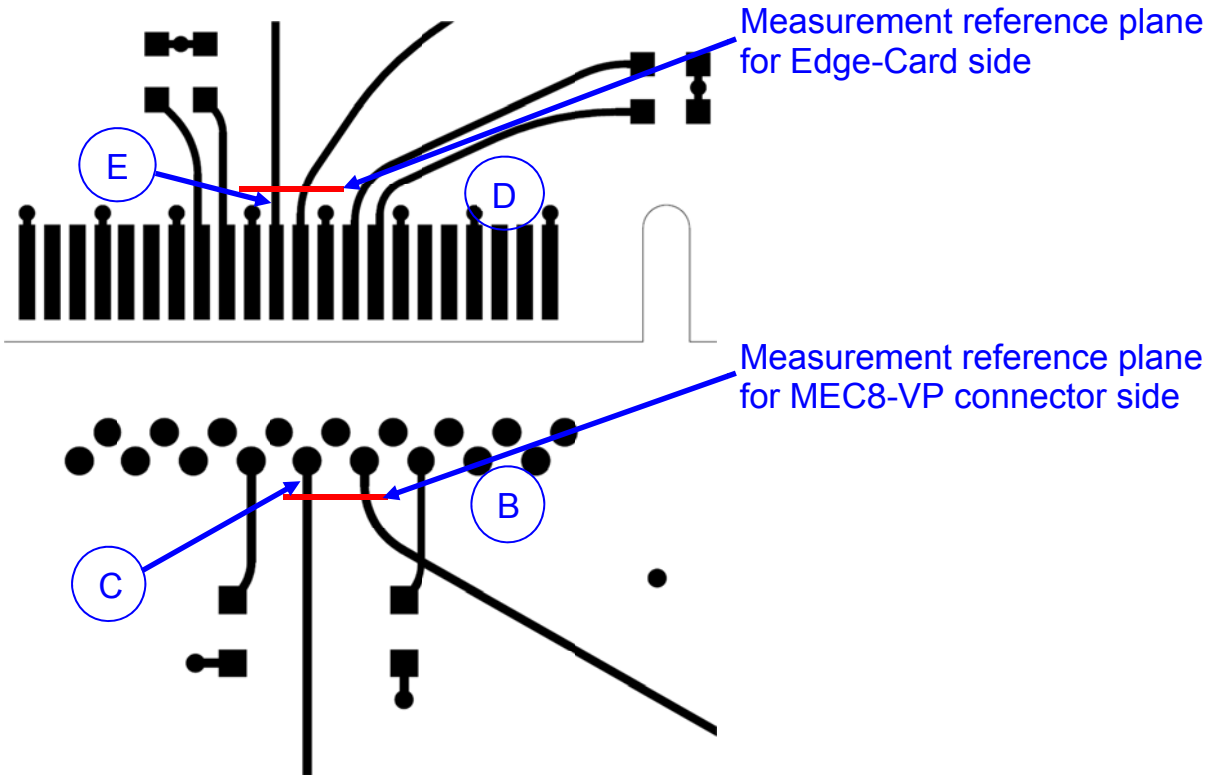
Thru line – 2980 mils
Open Reflect – 1490 mils
Line 1 – 6526 mils
Line 2 – 3689 mils
Line 3 – 3122 mils
Match – 1490 mils

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

All traces on the test boards are length matched to 1.5" measured from the edge of the pad to the SMA. The TRL calibration effectively removes 1.49" of test board trace effects. This means that 10 mils of test board trace length effects are included in the both sides of test boards in the measurement. The S-Parameter measurement includes:

A- The MEC8-VP Series connector set.
B- Test board vias, pads (footprint effects) for the MEC8-VP connector side.
C- 10 mils of 9.5 mil wide microstrip trace.
D- Test board vias, pads (footprint effects) for the Edge-Card side.
E- 10 mils of 9.5 mil wide microstrip trace.

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



Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

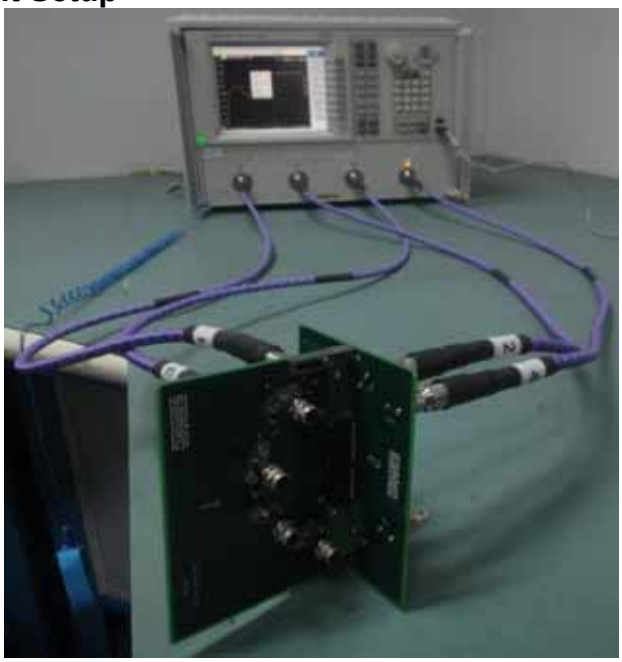
Appendix D – Test and Measurement Setup

For frequency domain measurements, the test instrument is the Agilent N5230C PNA-L network analyzer. Frequency domain data and graphs are obtained directly from the instrument. Post-processed time domain data and graphs are generated using convolution algorithms within Agilent ADS. The network analyzer is configured as follows:

Start Frequency – 300 KHz
Stop Frequency – 20 GHz
Number of points -1601
IFBW – 1 KHz

With these settings, the measurement time is approximately 20 seconds.

N5230C Measurement Setup



Test Instruments

QTY	Description
1	Agilent N5230C PNA-L Network Analyzer (300 KHz to 20 GHz)
1	Agilent N4433A ecal module (300 KHz to 20 GHz)

Test Cables & Adapters

QTY	Description
4	Gore OWD01D02039-4 (DC-50 GHz)

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

For impedance measurements, the test instrument is the Tektronix DSA8200 Digital Serial Analyzer mainframe and 80E04 sampling module. The impedance data and profiles are obtained directly from the instrument. The Digital Analyzer is configured as follows:

	Single-Ended Signal	Differential Signal
Vertical Scale:	5 ohm / Div:	10 ohm/ Div:
Offset:	Default / Scroll	Default / Scroll
Horizontal Scale:	200ps/ Div	200ps/ Div
Record Length:	4000	4000
Averages:	≥ 16	≥ 16

DSA8200 Measurement Setup

Test Instruments

QTY	Description
1	Tektronix DSA8200 Digital Serial Analyzer
2	Tektronix 80E04 Dual Channel 20 GHz TDR Sampling Module

Test Cables & Adapters

QTY	Description
2	Samtec RF405-01SP1-01SP1-0305 (DC-20 GHz)

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Appendix E - Frequency and Time Domain Measurements

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 LRM calibration standards, the SI test boards, and the selection of the PCB vendor.

The measurement process begins with a measurement of the LRM calibration standards. A coaxial SOLT calibration is performed using an N4433A ecal module. This measurement is required in order to obtain precise values of the line standard offset delay and frequency bandwidths. Measurements of the reflect and 2x through line standard can be used to determine the maximum frequency for which the calibration standards are valid. For the MEC8 Series test boards, this is greater than 20 GHz.

From the LRM calibration standard measurements, a user defined calibration kit is developed and stored in the network analyzer. Calibration is then performed on all 4 ports following the calibration wizard within the Agilent N5230C. This calibration is saved and can be recalled at any time. Calibration takes roughly 30 minutes to perform.

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 2009 update 1. 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://www.samtec.com/Technical_Library/reference/articles/pdfs/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 connector and footprint. A step pulse is applied to the touchstone model of the connector 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.

Series: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Near-End Crosstalk (TDT) & Far End Crosstalk (TDT)

A step pulse is applied to the touchstone model of the connector and the coupled voltage is monitored. The amplitude of the peak-coupled voltage is recorded and reported as a percentage of the input pulse.

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: MEC8-VP
Description: Mini Edge Card Vertical Socket, 0.8 mm Pitch, Mates with 1.6mm thick cards

Appendix F – Glossary of Terms

ADS – Advanced Design Systems
BC – Best Case crosstalk configuration
DUT – Device under test, term used for TDA IConnect & Propagation Delay waveforms
FD – Frequency domain
FEXT – Far-End Crosstalk
GSG – Ground–Signal-Ground; geometric configuration
GSSG - Ground–Signal-Signal-Ground; geometric configuration
HDV – High Density Vertical
NEXT – Near-End Crosstalk
OV – Optimal Vertical
OH – Optimal Horizontal
PCB – Printed Circuit Board
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
WC – Worst Case crosstalk configuration
Z – Impedance (expressed in ohms)