PCI Express Card Electromechanical Specification

Revision 4.0, Version 1.0

August 7, 2019

Revision	Revision History	Date
1.0	Initial release.	7/22/2002
1.0a	Incorporated WG Errata C1-C7 and E1.	4/15/2003
1.1	Incorporated approved Errata and ECNs.	3/28/2005
2.0	Added support for 5.0 GT/s data rate.	4/11/2007
3.0	• Added support for 8.0 GT/s data rate and incorporated approved Errata and ECNs. Incorporated the *PCI Express x16 Graphics 150W-ATX Specification* and the *PCI Express 225 W/300 W High Power Card Electromechanical Specification*. • Re-imported all figures • Updated Figure 6-1 and Figure 6-3 • Fixed text notes in Chapter 6 and 9 Figures (took notes out of Illustrator and made them part of the Word file) • Changed 306.67 MAX dimension to 326.03 MIN in Figure 9-3	7/21/2013
4.0	• Added support for 16.0 GT/s data rate and incorporated approved Errata and ECNs. • Significant PCB layout updates to support signal integrity	10/11/2013
4.0 r 0.7	Incorporated the following: • CEM Comment tracking for 0.7 rev of 4.0 sent 2018 Feb 14, comments updated 03 March: • 10.12.2017 - Cisco Comments on v0.7 r4.0 CEM, 10.02.2017 draft • PCIe3 0_CEM_Embedding_Issue_Comm_Rev1_0 • Incorporated new drawings • CEM Comment tracking for 0.7 rev of 4.0 sent 2018 Feb 14, comments updated 03 March Wig	03/22/2018
4.0, 0.9	• Updated drawings for clarity • Miscellaneous text changes • Incorporated AMD comments	07/10/2019
4.0, 1.0	• Replaced Figure 63, Figure 66, Figure 69, and Figure 90 • Added Section 2.1.3, Clock Architecture Requirements • Added Table 1. Clocking Architecture Requirements and Table 2. Common Clock Architecture Details • Updated Achknowledgements Release Candidate	08/07/2019

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1. Introduction

This specification is a companion for the *PCI Express® Base Specification, Revision 4.0*. Its primary focus is the implementation of an evolutionary strategy with the current PCI™ desktop/server mechanical and electrical specifications. The discussions are confined to Advanced Technology eXtended (ATX) or ATX-based form factors. Other form factors, such as PCI Express® Mini Card are covered in separate specifications. This specification also provides additional capabilities for PCI Express Add-in Cards within the existing framework of an evolutionary strategy that is based on existing system board form factors. This specification has features designed to deliver additional electrical power to a PCI Express Add-in Card and provide increased card volume for the management of thermals. The *Balanced Technology Extended (BTX) Interface Specification* is acknowledged as another form factor. The support of PCI Express 150 W in a BTX system was considered during the development of this specification, and it was agreed that this version should target the ATX form factor. Expanding this specification in the future to support other form factors may be considered when compelling needs arise. As graphics power and thermal requirements have risen over time, the targeted application for this specification is broadened over the technology (AGP) that it replaces. As such, the *PCI Express 150 W-ATX* portions of this specification are intended to support both workstation and consumer graphics along with other applications requiring additional power.

This specification addresses only the single card scenario for 150 W, 225 W, and 300 W cards. It is expected that, with tight cooperation between graphics card vendors or other high-power card vendors and system OEMs, systems able to scale and support multiple high-power cards in a modular fashion.

This specification supports multiple distinct maximum power levels for Add-in Cards: 10 W, 25 W, 75 W, 150 W, 225 W, and 300 W. To achieve maximum interoperability and a non-compromised end user experience, intermediate power levels leveraging optional components of *PCI Express Base Specification* are outside the scope of this specification.

This specification does not support the optional Hot-Plug functionality for 150 W, 225 W, or 300 W cards, nor does it preclude such support using an implementation-specific method.

1.1. Terms and Definitions

Add-in Card	A card that is plugged into a connector and mounted in a chassis slot.
AIC	Add-in Card.
AGP	Accelerated Graphics Port.
ATX	Advanced Technology eXtended, a system board form factor. Refer to the ATX Specification
ATX-based form factor	Refers to the form factor that does not exactly conform to the ATX specification, but uses the key features of ATX, such as the slot spacing, I/O panel definition, etc.
Auxiliary power connector	An Add-in card connector, other than the CEM slot connector, through which the Add-in Card receives a power rail. This specification defines these types of such connectors: 2 x 3 connector; 2 x 4 connector.
Auxiliary signals	Signals, some of which are defined in the *PCI Express Base Specification*, that are used in conjunction with PCI Express signaling. Some are necessary for basic PCI Express operation (e.g., reference clock and reset) while others provide ancillary capabilities (e.g., the SMBus signals). See also Sideband signaling.
Basic bandwidth	Contains one PCI Express Lane.
x1, x2, x4, x8, x12, x16	x1 refers to one PCI Express Lane of basic bandwidth; x4 refers to a collection of four PCI Express Lanes; etc.
Card	An Add-in Card that is plugged into a connector and mounted in a chassis slot.
Card Interoperability	Ability to operate with a PCI Express card plugged into different Link width connectors, for example, plugging a x1 card into a x16 slot.
CEM	Card Electromechanical.
Down-plugging	Plugging a larger Link mechanical width card into a smaller Link mechanical width connector, for example, plugging a x4 card into a x1 connector.
DUAL-SLOT Card	A card that plugs into a single edge connector – but whose volume occupies a total of two adjacent expansion slots.
ECN	Engineering Change Notice.
Evolutionary strategy	A strategy to develop the PCI Express connector and card form factors within today's chassis and system board form factor infrastructure constraints.
High bandwidth	Supports a larger number of PCI Express Lanes, such as a x16 card or connector.
HE	High-End.
Hot-Plug	Hot insertion and/or Hot removal of a card into an active backplane or system board as defined in PCI Standard Hot-Plug Controller and Subsystem Specification.
Hot swap	Insertion and/or removal of a card into a passive backplane. The card must satisfy specific requirements to support Hot swap.
Link	A collection of one or more PCI Express Lanes.
Low profile card	An Add-in Card whose height is no more than 68.90 mm (2.731 inches).
microATX	An ATX-based system board form factor. Refer to the microATX Motherboard Interface Specification
OBFF	Optimized Buffer Flush/Fill.

PCIe	PCI Express.
PCI Express Lane	One PCI Express Lane contains two differential lines for Transmitter and two differential lines for Receiver. A xN Link is composed of N Lanes.
PCI Express Mini Card	PCI Express for mobile form factor, similar to Mini PCI. Refer to the *PCI Express Mini Card Electromechanical Specification.*
Receiver path	The path from the connector to the receiver for a differential data pair (system) or the edge finger to the receiver (Add-in Card).
REFCLK	The reference clock differential pair consisting of auxiliary signals REFCLK+ and REFCLK-.
Sentry Via	Additional ground via located adjacent to Auxiliary and Reserved signal pins in the through-hole connector footprint, intended to improve signal integrity.
SINGLE-SLOT Card	A card that uses a single expansion slot.
Sideband signaling	A method for signaling events and conditions using physical signals separate from signals forming the Link between two components. See also Auxiliary signals.
Standard height card	An Add-in Card whose maximum height is no more than 111.28 mm (4.381 inches).
Transmitter path	The path from the transmitter to the connector for a differential data pair (system) or the transmitter to the edge-finger (Add-in Card).
TRIPLE-SLOT Card	A card that plugs into a single edge connector – but whose volume occupies a total of three adjacent expansion slots.
Up-plugging	Plugging a smaller Link mechanical width card into a larger Link mechanical width connector, for example, plugging a x1 card into a x4 connector.
Wakeup	A mechanism used by a component to request the reapplication of main power when in the L2 Link state. Two such mechanisms are defined in the PCI Express Base Specification: Beacon and WAKE#. This specification requires the use of WAKE# on any Add-in Card or system board that supports wakeup functionality.

1.2. Reference Documents

This specification references the following documents:

- *PCI Express Base Specification*, Revision 4.0
- *PCI Local Bus Specification*, Revision 3.0
- *PCI Express Jitter Modeling*
- *PCI Express Jitter and BER*
- *ATX Specification*, Revision 2.2
- *microATX Motherboard Interface Specification*, Revision 1.2
- *SMBus Specification*, Revision 2.0
- *IEEE Standard 1149.1, Test Access Port and Boundary Scan Architecture*
- *PCI Standard Hot-Plug Controller and Subsystem Specification*, Revision 1.0
- *PCI Hot-Plug Specification*, Revision 1.1
- *Compact PCI Hot-swap Specification*
- *EIA-364-1000.01: Environmental Test Methodology for Assessing the Performance of Electrical Connectors and Sockets Used in Business Office Applications*

- *EIA-364: Electrical Connector/Socket Test Procedures Including Environmental Classifications*
- *ISO 3744, Acoustics – Determination of Sound Power Levels of Noise Sources Using Sound Pressure – Engineering Method in an Essentially Free Field Over a Reflecting Plane*
- *ISO 7779, Acoustics – Measurement of Airborne Noise Emitted by Information Technology and Telecommunications Equipment*
- *PCI Bus Power Management Interface Specification*, Revision 1.2
- *PCI Express Label Specification and Usage Guidelines*, revision 1.1
- *PCI Express Architecture, PHY Test Specification*, Revision 4.0 for PCI Express Architecture
- *Balanced Technology Extended (BTX) Interface Specification*
- *PCI Express Mini-CEM Specification*, Revision 1.0
- *PCI Bus Power Management Interface Specification*
- *PCI Express Graphics Card Thermal Mechanical Design Guidelines*
- *EIA 364-101 – Attenuation Test Procedure for Electrical Connectors, Sockets, Cable Assemblies or Interconnection Systems*
- *EIA 364-90 – Crosstalk Ratio Test Procedure for Electrical Connectors, Sockets, Cable Assemblies or Interconnection Systems*
- *EIA 364-108 – Impedance, Reflection Coefficient, Return Loss, and VSWR Measured in the Time and Frequency Domain Test Procedure for Electrical Connectors, Sockets, Cable Assemblies, or Interconnection Systems*
- *PCI Express Connector High Speed Electrical Test Procedure*

1.3. Specification Contents

This specification contains the following information:

- Auxiliary signals
- Add-in Card Hot insertion and Hot removal
- Power delivery
- Add-in Card electrical budget
- Connector specification
- Card form factors and implementation
- System requirements
- Supplemental power connector specification

1.4. Objectives

The objectives of this specification are:

- Support 16.0 GT/s, 8.0 GT/s, 5.0 GT/s and 2.5 GT/s data rate (per direction)
- Enable Hot-Plug and Hot swap where they are needed
- Leverage desktop and server commonality
- Allow co-existence of both PCI and PCI Express Add-in Cards
- No chassis or other PC infrastructure changes
- Forward looking for future scalability
- Extensible for future bandwidth needs
- Allows future evolution of PC architecture

- Maximize card interoperability for user flexibility
- Low cost
- Support for PCI Express Add-in Cards that have higher power requirements
- Allow evolution of the PC architecture including graphics
- Upgradeability
- Enhanced end user experience

1.5. Electrical Overview

The electrical part of this specification covers auxiliary signals, Hot insertion and Hot removal, power delivery, and Add-in Card interconnect electrical budgets for the evolutionary strategy. The PCI Express Transmitter and Receiver electrical requirements are specified in the *PCI Express Base Specification*.

Besides the signals that are required to transmit/receive data on the PCI Express interface, there are also signals that may be necessary to implement the PCI Express interface in a system environment, or to provide certain desired functions. These signals are referred to as the auxiliary signals. They include:

- Reference clock (REFCLK-/REFCLK+), must be supplied by the system (see Section 2.1.1)
- Add-in Card presence detect pins (PRSNT1# and PRSNT2#), required
- PERST#, required
- CLKREQ#, optional
- JTAG, optional
- SMBus, optional
- Wake (WAKE#), required only if the device/system supports wakeup and/or the Optimized Buffer Flush/Fill (OBFF) mechanism
- Power Brake (PWRBRK#), optional
- +3.3 Vaux, optional

REFCLK, CLKREQ#, JTAG, SMBus, PERST#, WAKE# and PWRBRK# are described in Chapter 2; +3.3Vaux is described in Chapter 4; and PRSNT1# and PRSNT2# are described in Chapter 3.

Both Hot-Plug and Hot swap of PCI Express Add-in Cards are supported, but their implementation is optional. Hot-Plug is supported with the evolutionary Add-in Card form factor. Hot swap is supported with other form factors and will be described in other specifications.

To support Hot-Plug, presence detect pins (PRSNT1# and PRSNT2#) are defined in each end of the connectors and Add-in Cards. The presence detect pins are staggered on the Add-in Cards such that they are last-mate and first-break, detecting the presence of the Add-in Cards. Chapter 3 discusses the detailed implementation of PCI Express Hot-Plug.

Chapter 4 specifies the PCI Express Add-in Card electrical requirements, which include power delivery and interconnect electrical budgets. Power is delivered to the PCI Express Add-in Cards via Add-in Card connectors, using three voltage rails: +3.3V, +3.3Vaux, and +12V. The +3.3 Vaux voltage rail is not required for all platforms (refer to Section 4.1 for more information on the required usage of 3.3 Vaux). The maximum Add-in Card power definitions are based on the card size and Link widths (described in Section 4.2). Chapter 4 describes the interconnect electrical budgets, focusing on the Add-in Card loss and jitter requirements.

1.6. Mechanical Overview

PCI Express is used in many different applications in desktop, mobile, server, as well as networking and communication equipment. Consequently, multiple variations of form factors and connectors will exist to suit the unique needs of these different applications.

Figure 1 shows an example of the vertical edge-card PCI Express connector to be used in ATX or ATX-based systems. There is a family of such connectors, containing one to 16 PCI Express Lanes. The basic bandwidth (BW) version supports a single PCI Express Lane and could be used as the replacement for the PCI connector. The high bandwidth version supports 16 PCI Express Lanes and is used for applications that require higher bandwidth, such as graphics.

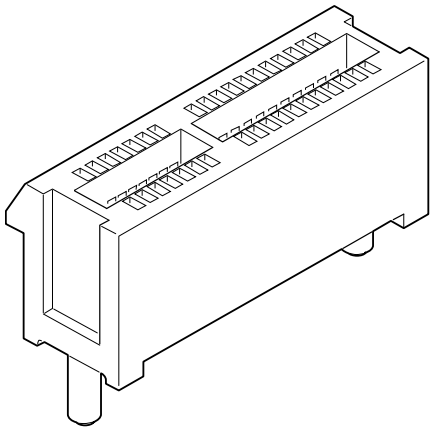

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Figure 1: Vertical Edge-Card Connector

Vertical edge card connectors also have applications in the server market segment. Figure 2 shows an example of a server configuration using a PCI Express riser card.

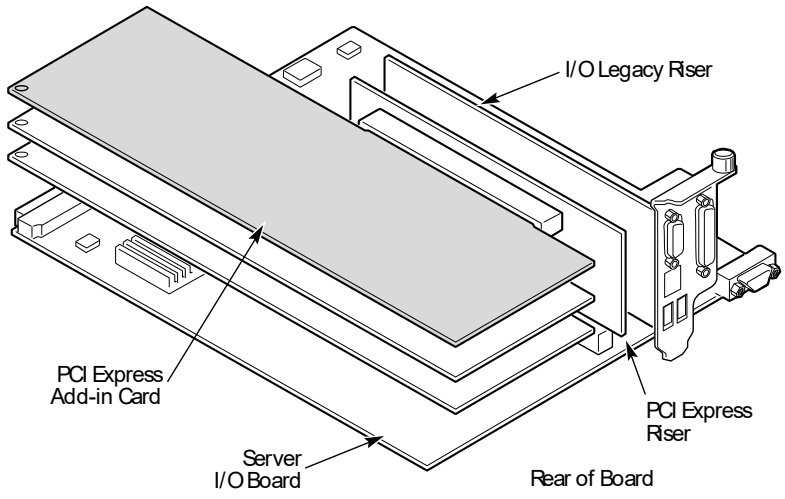

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Figure 2: Example Server I/O Board with PCI Express Slots on a Riser

This specification focuses on the vertical edge card PCI Express connectors and form factor requirements by covering the following:

- Connector mating interfaces and footprints including both through-hole and surface mount technologies
- Electrical, mechanical, and reliability requirements of the connectors, including the connector testing procedures
- Add-in Card form factors – including their keepout areas within the card as well as the keepout areas required to exit the chassis including the I/O connectors and mating cables for a typical desktop system chassis (ATX/microATX form factor).
- Connector and Add-in Card locations, as well as keepouts on a typical desktop system board (ATX/microATX form factor)

Connector definitions and requirements are addressed in Chapter 6 and Add-in Card form factors and implementation issues are discussed in Chapter 9.

1.7. 150 W Overview

A PCI Express 150 W-ATX Add-in Card is defined as a card that consumes greater than 75 W with support for up to 150 W inclusive. A card that uses a single expansion slot is described as a SINGLE-SLOT Add-in Card. A card that extends into the adjacent expansion slot is described as a DUAL-SLOT Add-in Card. A card that extends into the two adjacent expansion slots is described as a TRIPLE-SLOT Add-in Card. A 150 W Add-in Card, as with any CEM Add-in Card, may be SINGLE-SLOT, DUAL-SLOT, or TRIPLE-SLOT. A system that supports a PCI Express 150W-ATX Add-in Card is required to ensure that sufficient power and thermal support exists. For example, in an ATX form factor system, the adjacent expansion slot can be vacant, allowing for 1.37 inches of clearance for the Add-in Card (illustrated in Figure 3) to support a 150 W or lower power DUAL-SLOT Add-in Card.

The DUAL-SLOT Add-in Card plugs into the standard PCI Express connector but is not permitted to plug into any other adjacent Add-in Card connectors for any purpose.

The PCI Express 150 W-ATX Add-in Card draws a maximum of 75 W from the standard PCI Express connector. Additional power, up to 75 W, is provided through an additional connector that is detailed in this specification. Therefore, the maximum power that must be provided to a PCI Express 150 W-ATX Add-in Card is 150 W.

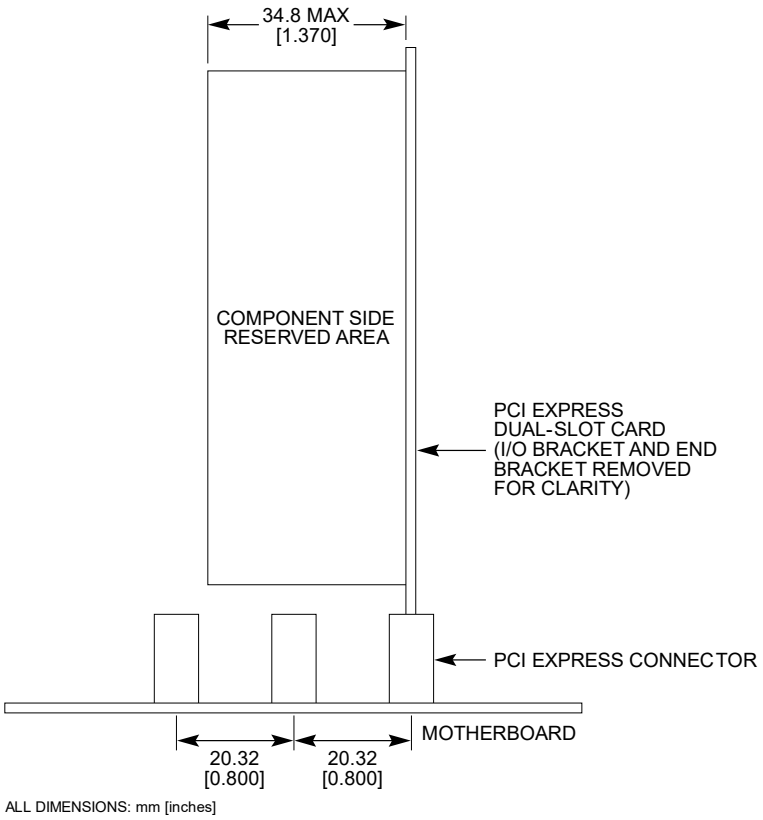


Figure 3: Example Orientation for DUAL-SLOT Add-in Cards

1.8. 225 W and 300 W Add-in Card Overview

A PCI Express 225 W Add-in Card is defined as a card that exceeds PCI Express 150 W power delivery or thermal capability and, as such, consumes greater than 150 W with support for up to 225 W inclusive. This card, as with any CEM Add-in Card, may be a SINGLE-SLOT, DUAL-SLOT, or TRIPLE-SLOT Add-in Card. A system that supports a PCI Express 225 W Add-in Card is required to ensure that sufficient power and thermal support exists. For example, in an ATX system, the adjacent expansion slot may be left vacant allowing for 34.8 mm (1.37 inches) maximum clearance for the Add-in Card, as illustrated in Figure 3. The area on the Add-in CardAdd-in Card that utilizes this height, as well as the restricted height of the secondary side, is determined by the general PCI Express Add-in Card requirements for these dimensions.

A PCI Express 300 W Add-in Card is defined as a card that consumes greater than 225 W with support for up to 300 W inclusive. This card, as with any CEM Add-in Card, may be a SINGLE-SLOT, DUAL-SLOT, or TRIPLE-SLOT Add-in Card. A system that supports a PCI Express 300 W Add-in Card is required to ensure that sufficient power and thermal support exists. As another example, in an ATX form factor system, the adjacent expansion slot may be left vacant allowing for 55.12 mm (2.17 inches) maximum clearance for the Add-in Card, as illustrated in Figure 4. The area on the Add-in Card that utilizes this height, as well as the restricted height of the secondary side, is determined by the general PCI Express Add-in Card requirements for these dimensions.

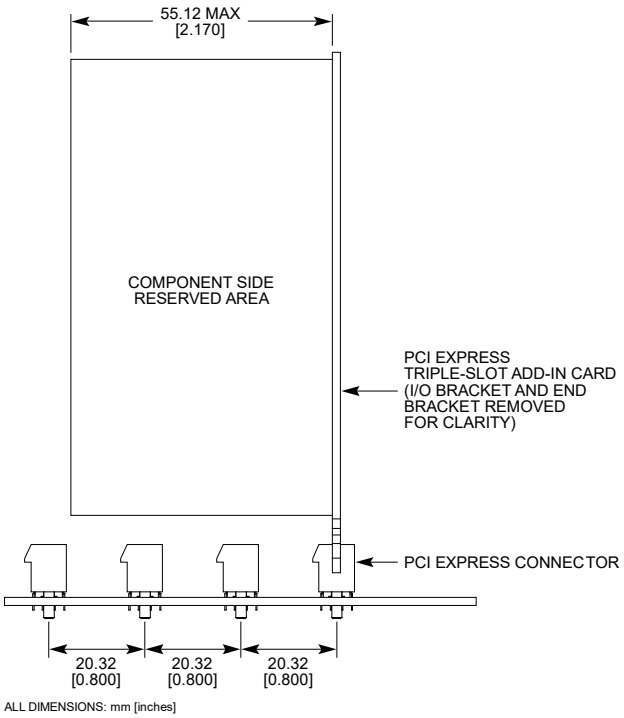


Figure 4: Example Orientation for TRIPLE-SLOT Cards

The PCI Express 225 W/300 W Add-in Card draws a maximum of 75 W through the standard connector. Additional power, up to 150 W for the 225 W Add-in Card and up to 225 W for the 300 W Add-in Card, is provided through additional auxiliary connector(s) that is(are) detailed in this specification.

2

2. Auxiliary Signals

The auxiliary signals are provided on the connector to assist with certain system-level functionality or implementation. The high-speed signal voltage levels are compatible with advanced silicon processes. The optional low speed signals are defined to use the +3.3V or +3.3Vaux supplies, as they are the lowest common voltage available. Most ASIC processes have high voltage (thick gate oxide) I/O transistors compatible with +3.3 V. Use of the +3.3 V supply allows PCI Express signaling to be used with existing control bus structures, avoiding a buffered set of signals and bridges between the buses.

The PCI Express connector and Add-in Card interfaces support the following auxiliary signals:

- **REFCLK-/REFCLK+** (required): Low voltage differential signals. Requirements for REFCLK for a system are defined in *PCI Express Base Specification*. A system board must provide a reference clock that meets all requirements for the common clock architecture defined for the reference clock in the *PCI Express Base Specification* and all the requirements defined in this specification.
- **PERST#** (required): Indicates when the applied main power is within the specified tolerance and stable. PERST# goes inactive after a delay of T_{PVPERL} time from the power rails achieving specified tolerance on power up.
- **WAKE#:** (optional) An open-drain, active low signal that is driven low by a PCI Express function to re-activate the PCI Express Link hierarchy's main power rails and reference clocks. It is required on any Add-in Card or system board that supports wakeup functionality compliant with this specification. WAKE# is also used by the system to signal to the PCI Express function in conjunction with the Optimized Buffer Flush/Fill (OBFF) mechanism.
- **SMBCLK** (optional): The SMBus interface clock signal. It is an open-drain signal.
- **SMBDAT** (optional): The SMBus interface address/data signal. It is an open-drain signal.
- **JTAG** (TRST#, TCLK, TDI, TDO, and TMS) (optional): The pins to support IEEE Standard 1149.1, Test Access Port and Boundary Scan Architecture (JTAG). They are included as an optional interface for PCI Express devices. IEEE Standard 1149.1 specifies the rules and permissions for designing an 1149.1-compliant IC.
- **PRSNT1#** (required): Add-in Card presence detect pin. See Chapter 3 for a detailed description.
- **PRSNT2#** (required): Add-in Card presence detect pin. See Chapter 3 for a detailed description.
- **CLKREQ#** (optional): The CLKREQ# signal is an open drain, active low signal that is driven low by the card to request that the PCI Express reference clock be available (active clock state) to allow the PCI Express interface to send/receive data. See the *PCI Express Mini-CEM Specification* for details on the functional and electrical requirements for the CLKREQ# signal. The CLKREQ# signal is used by the optional L1 PM Substates mechanism. In this case, CLKREQ# is asserted by either the system or Add-in Card to initiate an L1 exit. See the *PCI Express Base Specification* for details on the functional requirements for the CLKREQ# signal when implementing L1 PM Substates.

- **PWRBRK#** (optional): An open-drain, active low signal that is driven low by the system to signal an Emergency Power Reduction mechanism.
- **RSVD**: Reserved must not be used for any non-standard purpose..

All Add-in Card edge fingers that are assigned to auxiliary signals among pins A12/B12 through A82/B82 must be both present and terminated even if their electrical functions are not implemented, as described in 9.2.2 and 9.2.6. This applies to the pin positions for PWRBRK#; RSVD, CLKREQ#; and all PRSNT2# edge finger contacts, including positions where the Hot-Plug electrical function is not implemented, as described in Section 6.1.

The SMBus interface pins are collectively optional for both the Add-in Card and the system board. If the optional management features are implemented, SMBCLK and SMBDAT are both required. Similarly, the JTAG pins are collectively optional. If this test mode is implemented, all the JTAG pins are required. For additional system requirements related to these signals refer to the *PCI Local Bus Specification*.

2.1. Reference Clock

2.1.1. Low Voltage Swing, Differential Clocks

To reduce jitter and allow for future silicon fabrication process changes, low voltage swing, differential clocks are used, as illustrated in Figure 5. The nominal single-ended swing for each clock is 0 V to 0.7 V and a nominal frequency of 100 MHz ±300 PPM. The clock has a defined crossover voltage range and monotonic edges through the input threshold regions as specified in Chapter 4.

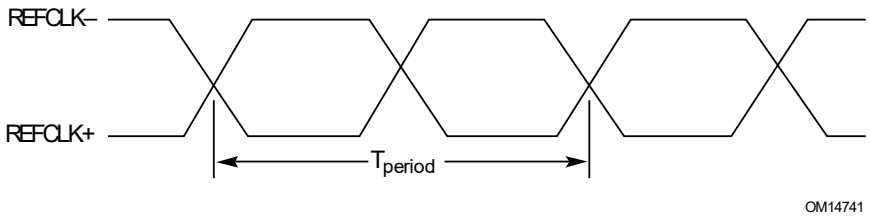


Figure 5: Differential REFCLK Waveform

The reference clock pair is routed point-to-point to each connector from the system board per best-known clock routing rules. The reference clock distribution to all devices must be matched to within 15 inches on the system board. The transport delay delta between the data and clock at the Receiver must be less than 12 ns. The combination of the maximum reference clock mismatch and the maximum channel length will contribute approximately 9-10 ns and the remaining time is allocated to the difference in the insertion delays of the Tx and Rx devices. The routing of each signal in any given clock pair between the clock source and the connector must be well matched in length (< 0.005 inch) and appropriately spaced away from other non-clock signals to avoid excessive crosstalk.

The system board must provide any terminations required by the clock source. . An example termination topology for a current-mode clock generator is shown in Figure 6. EMI emissions will be reduced if clocks to open sockets are shut down at the clock source. The method for detecting the presence of a card in a slot and controlling the clock gating is platform specific and is not covered in this specification.

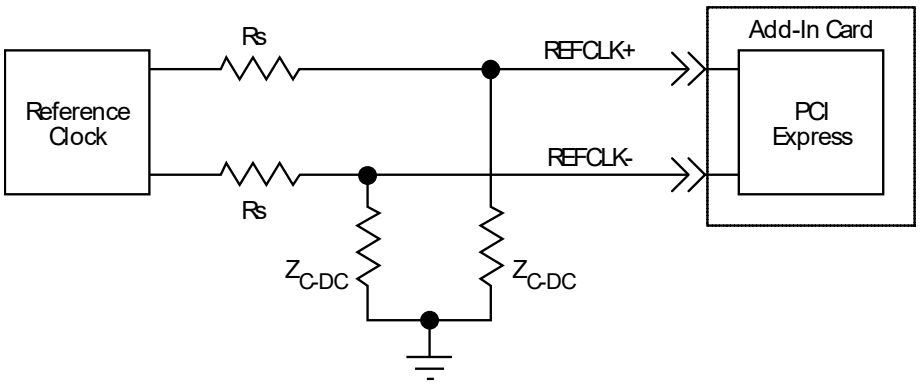


Figure 6: Example Current Mode Reference Clock Source Termination

Termination on the Add-in Card using discrete components on the PCB is allowed and is not covered by the specifications in Section 2.1.3. While the same measurement techniques can be used as specified in that section, Receiver termination will reduce the nominal swing and rise and fall times by half. The low input swing and low slew rates need to be validated against the clock Receiver requirements as they can cause excessive jitter in some clock input buffer designs.

The reference clock timings are based on nominal 100 Ω, differential pair routing with approximately 0.127 mm (5 mil) trace widths. This timing budget allows for a maximum Add-in Card trace length of 4.0 inches. No specific trace geometry, however, is explicitly defined in this specification.

2.1.2. Spread Spectrum Clocking (SSC)

The reference clocks may support spread spectrum clocking. Any given system design may or may not use this feature contingent on platform-level timing requirements. The minimum clock period cannot be violated. The required method is to adjust the spread technique to not allow for modulation above the nominal frequency. This technique is often called "down-spreading." The requirements for spread spectrum modulation rate and magnitude are given in the *PCI Express Base Specification*.

IMPLEMENTATION NOTE

Separate REFCLK Independent SSC (SRIS/SRNS) Considerations

Support of SRIS/SRNS clocking via a standard PCI Express connector is a proprietary implementation and is not defined in CEM. Implementations that support SRIS/SRNS on CEM form factor risk interoperability with other CEM compliant implementations. The CEM form factor requires that the system board provide a common reference clock to all Add-in Cards connected to the system board via standard CEM compliant PCIe connectors. Similarly, Add-in Cards are required to use the provided common clock as the reference clock when communicating via a standard CEM compliant PCIe connector.

2.1.3. Clock Architecture Requirements

Table 1 lists the clocking architecture requirements and Table 2 lists the common clock architecture details.

Table 1. Clocking Architecture Requirements

Clock Architecture	System Board (Motherboard)	Add-in Card
Common Clock	Required	Required
SRIS	Not Compliant	Not Compliant
SRNS	Not Compliant	Not Compliant

Table 2. Common Clock Architecture Details

Common Clock Details	System Board (Motherboard)	Add-in Card
Clock Source	Required	Not Allowed
SSC	Optional	Not Applicable
CLKREQ#	Optional	Optional

2.1.4. REFCLK AC Specifications

Prior to the *PCI Express Card Electromechanical Specification Revision 4.0*, the definition of these requirements was in the form factor specification, but now they have been moved to the *PCI Express Base Specification, Revision 4.0*. REFCLK must meet the requirements defined in Chapter 8 of the PCI Express Base Specification. All specifications are to be measured using a test configuration as described in the *PCI Express Base Electrical Specification* with a circuit as shown in Figure 7.

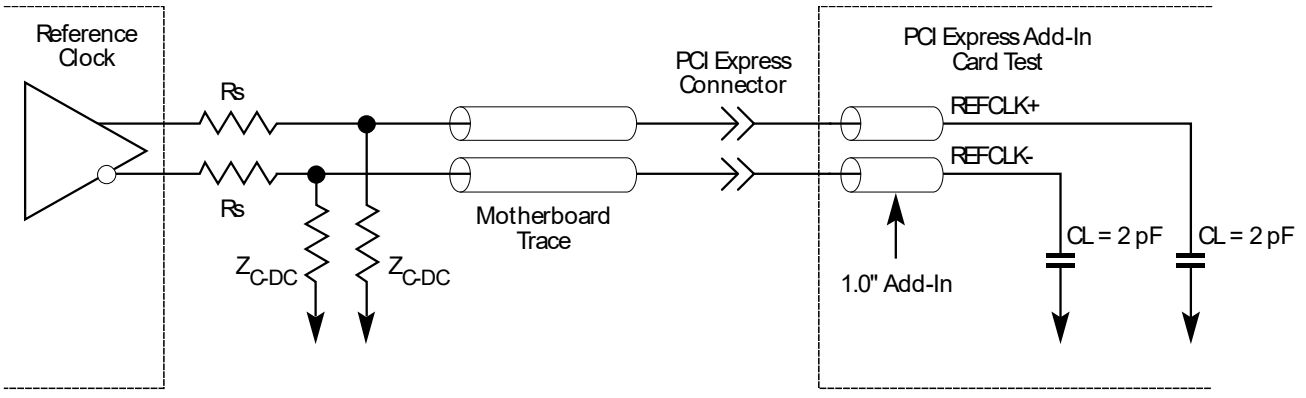


Figure 7: Reference Clock System Measurement Point and Loading

2.1.5. REFCLK Phase Jitter Specification for 2.5 GT/s, 5.0 GT/s, 8.0 GT/s and 16.0GT/s Signaling Support

The phase jitter specification and measurement methodology are discussed in the PCI Express Base Specification.

To account for phase jitter on the REFCLK, a two-port methodology for simultaneously assessing the system board data and reference clock is described with specified limits in the appropriate sections below.

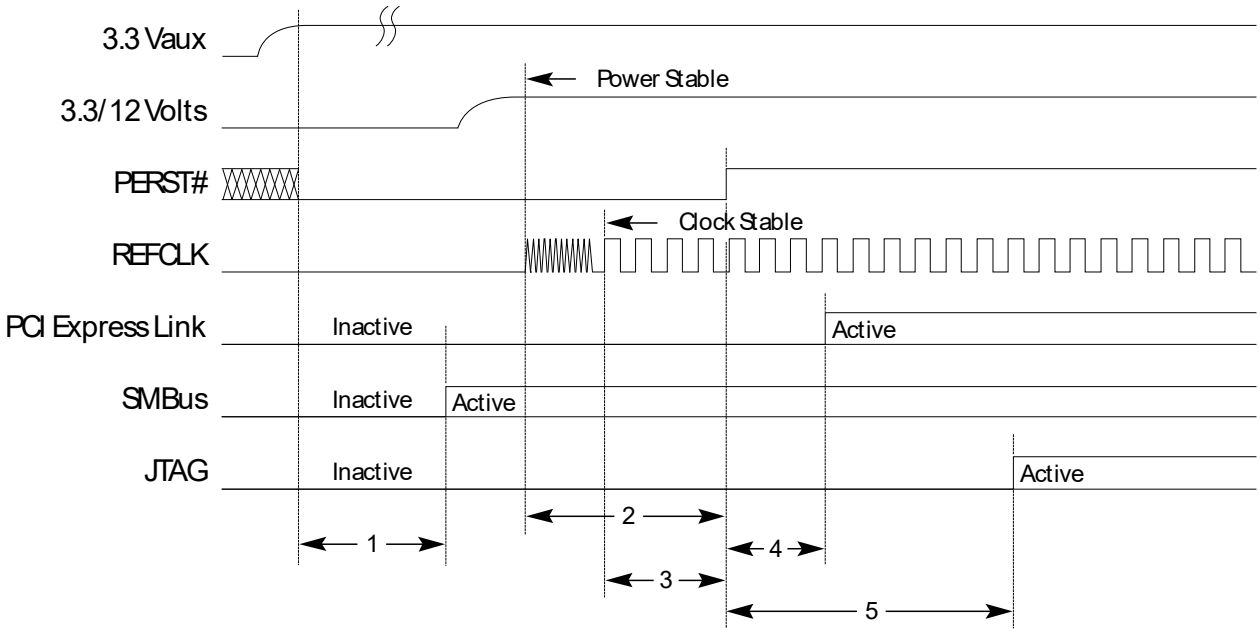
2.2. PERST# Signal

The PERST# signal is used to indicate when the power supply is within its specified voltage tolerance and is stable. It also initializes a component's state machines and other logic once power supplies stabilize. On power-up, the de-assertion of PERST# is delayed 100 ms (TpvpERL) from the power rails achieving specified operating limits. Also, within this time, the reference clocks (REFCLK+, REFCLK-) also become stable, at least $T_{PERST\text{-}CLK}$ before PERST# is de-asserted. PERST# is asserted in advance of the power being switched off in a power-managed state like S3. PERST# is asserted when the power supply is powered down, but without the advanced warning of the transition.

2.2.1. Initial Power Up (G3 to S0)

While PERST# is active, all PCI Express functions are held in reset. The main supplies ramp up to their specified levels (+3.3 V and +12 V). During this stabilization time, the REFCLK starts and stabilizes. After there has been time (TPVPERL) for the power and clock to become stable, PERST# is de-asserted high and the PCI Express functions can start up.

On initial power-up, the hardware default state of the Active State Power Management Control field in the Link Control register must be set to 00b. The state of this field may be changed by the system BIOS or the operating system. Other software agents must not change this field.



1. 3.3Vaux stable to SMBus driven (optional). If no 3.3Vaux on platform, the delay is from +3.3V stable
2. Minimum time from power rails within specified tolerance to PERST# inactive (T_{PVPERL})
3. Minimum clock valid to PERST# inactive ($T_{PERST-CLK}$)
4. Minimum PERST# inactive to PCI Express link out of electrical idle
5. Minimum PERST# inactive to JTAG driven (optional)

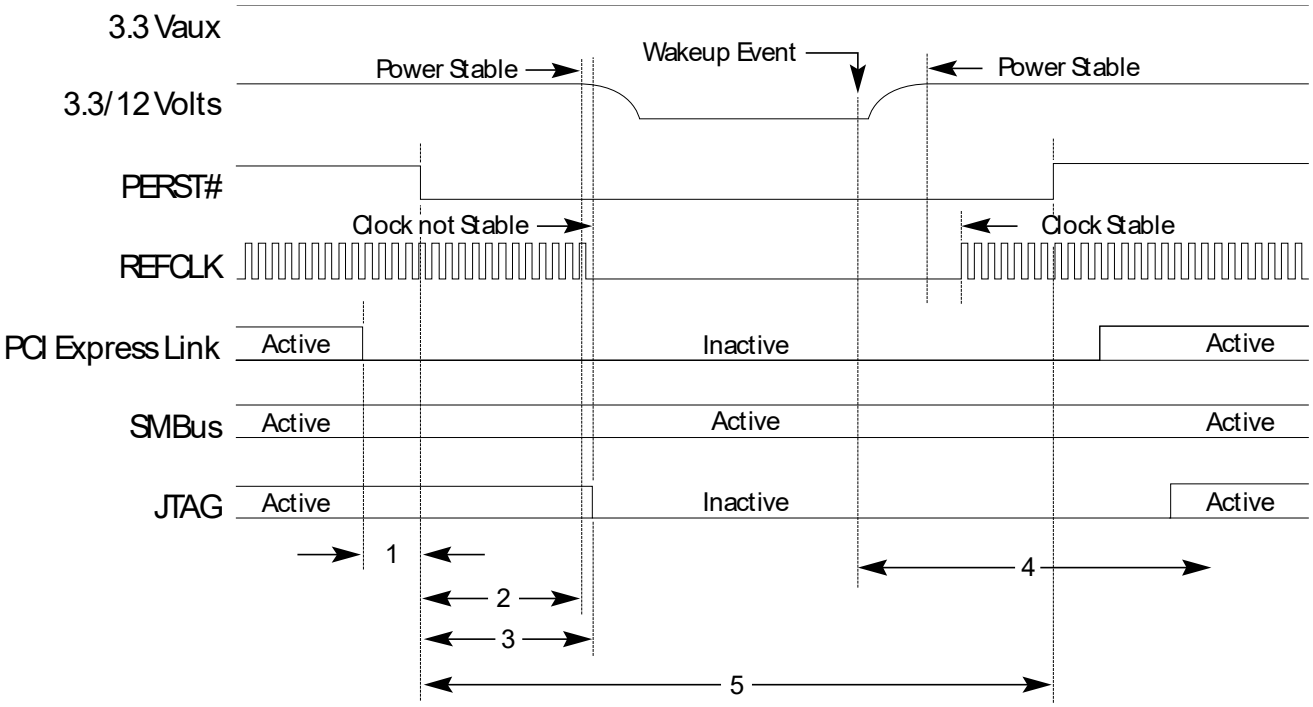
OM14742B

Figure 8: Power Up

2.2.2. Power Management States (S0 to S3/S4 to S0)

If the system wants to enter S3/S4, devices are placed into $D3_{hot}$ states with Links in L2 prior to any power transitions at the slot. The main power and reference clock supplied to the PCI Express slot will go inactive and stay inactive until a wakeup event. Because of the removal of main power, devices enter the D3cold state. During the D3cold state, +3.3 Vaux remains at +3.3 V. On the wakeup event, the power manager restores the main power and reference clocks. As in the last section, PERST# de-asserts TPVPERL after the clock and power are stable.

On resume from a D3cold state, the hardware default state of the Active State Power Management Control field in the Link Control register must be set to 00b. The state of this field may be changed by the system BIOS or the operating system. Other software agents must not change this field.



1. The PCI Express link will be put into electrical idle prior to PERST# going active.
2. PERST# goes active before the power on the connector is removed.
3. Clock and JTAG go inactive after PERST# goes active.
4. A wakeup event resumes the power to the connector, restarts the clock, and the sequence proceeds as in power up.
5. The minimum active time for PERST# is T_{PERST}.

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Figure 9: Power Management States

2.2.3. Power Down

A power rail (+12V, +3.3V, or +3.3Vaux) is deemed to be valid or stable if the specified voltage is within the associated voltage tolerances defined in Table 3. Once a power rail is deemed stable, an invalid or unstable rail is defined as a rail that has dropped below the specified minimum voltage levels (e.g., below +3.00 V for the +3.3V rails). For purposes of detecting an out-of-tolerance power source, the threshold for detection must be established in a window range of no more than 500 mV below the specified minimum voltage level for the +3.3V and +3.3Vaux rails (i.e., +2.50 V) and +1.34 V below for the +12V rail (i.e., +9.70 V). Figure 10 illustrates these threshold windows.

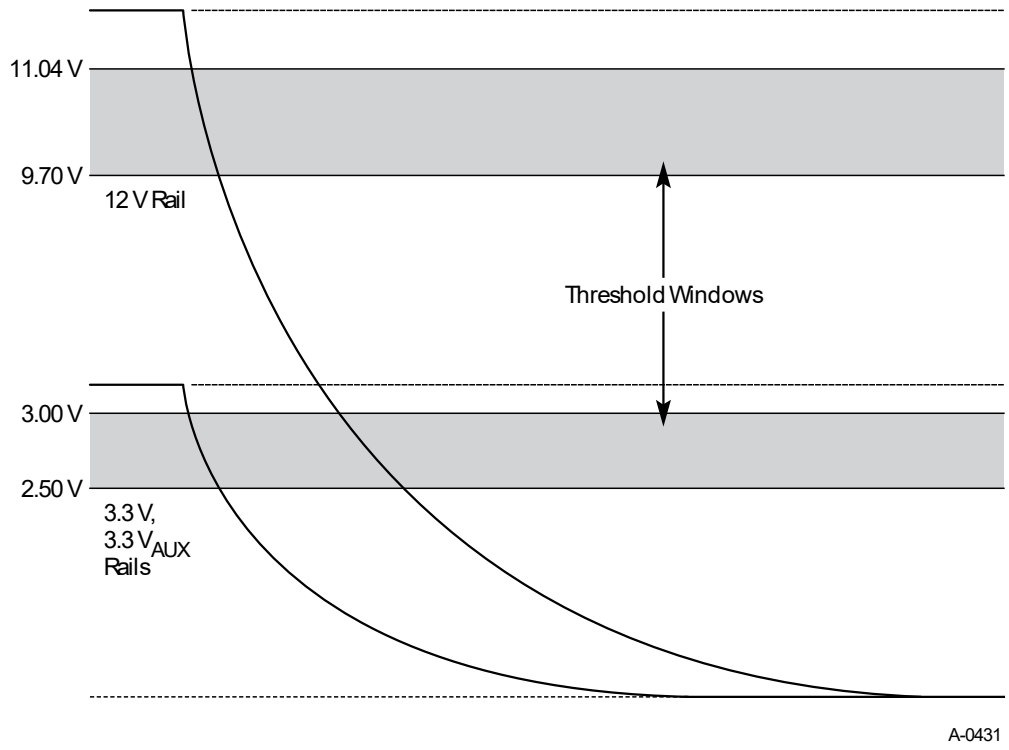
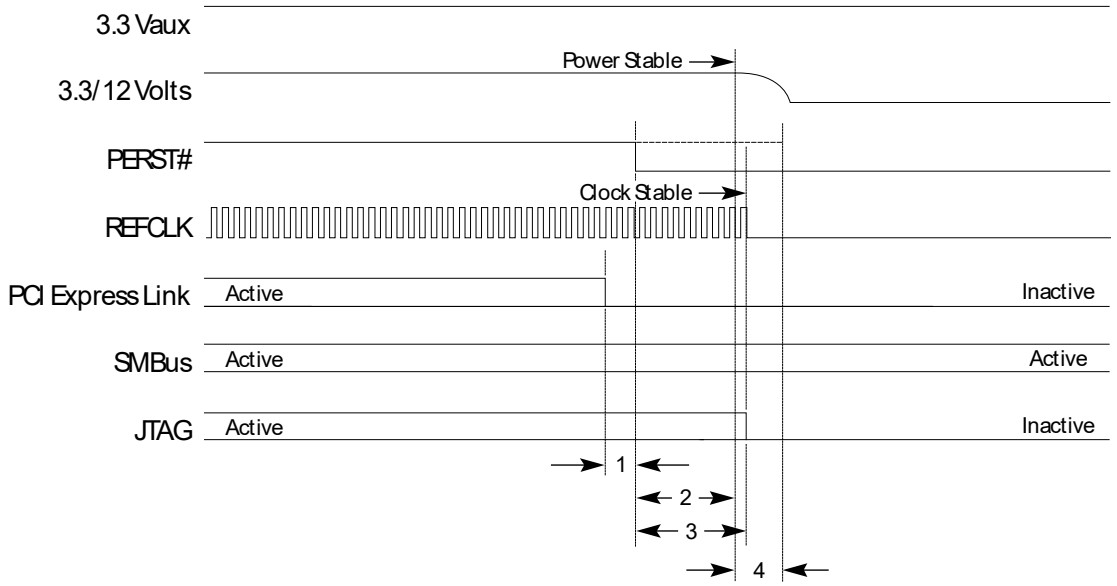


Figure 10: Out-of-tolerance Threshold Windows



1. The PCI Express link will be put into an inactive state (Device in $D3_{hot}$) prior to PERST# going active, except in the case of a surprise power down.
2. PERST# goes active before the power on the connector is removed.
3. Clock and JTAG go inactive after PERST# goes active.
4. In the case of a surprise power down, PERST# goes active T_{FAIL} after power is no longer stable.

OM14744E

Figure 11: Power Down

2.3. WAKE# Signal

The WAKE# signal is an open drain, active low signal that is driven low by a PCI Express Add-in Card to reactivate the PCI Express slot's main power rails and reference clocks. The Downstream Ports also use the WAKE# signal to signal to functions on the Add-in Card in conjunction with the OBFF mechanism. Only Add-in Cards that support either the wake process or the OBFF mechanism connect to this pin. If the Add-in Card has wakeup capabilities, it must support the WAKE# function. Likewise, only systems that support the wakeup function or the OBFF mechanism need to connect to this pin. Such systems are not required to support Beacon as a wakeup mechanism but are encouraged to support it. If the wakeup process is used, the +3.3Vaux supply must be present and used for this function. The assertion and de-assertion of WAKE# are asynchronous to any system clock. (See Chapter 5 of the *PCI Express Base Specification,* for more details on PCI-compatible power management.)

If the WAKE# signal is supported by a slot, the signal is connected to the platform's power management (PM) controller. The WAKE# signal can either be bused to multiple PCI Express Add-in Card connectors forming a single input connection at the PM controller, or the individual connectors have individual connections to the PM controller. Hot-Plug requires that the WAKE #signal is isolated between connectors and driven inactive during the Hot-Insertion/Hot removal events. See Section 6.1 for the WAKE# signal connector pin assignment.

Auxiliary power (+3.3Vaux) must be used by the asserting and receiving ends of the WAKE# signal to revive the hierarchy. The system vendor must also provide a pull-up on WAKE# with its bias voltage reference being supplied by the auxiliary power source in support of Link reactivation. The voltage that the system board uses to terminate the WAKE# signal can be lower than the auxiliary supply voltage to be compatible with lower voltage processes of the system PM controller. However, all potential drivers of the WAKE# signal must be +3.3 V tolerant.

The WAKE# signal is only asserted by the Add-in Card when all of its functions are in the D3 state and at least one of its functions is enabled for wakeup generation using the PME Enable bit in the PMCSR.

The WAKE# signal is not PME# and must not be attached to the PCI-PME# interrupt signals. WAKE# causes power to be restored but must not directly cause an interrupt.

If the PCI Express Add-in Card supports the OBFF mechanism defined in the *PCI Express Base Specification*, then the WAKE# signal may be used as an input to the Add-in Card.
Refer to Chapter 6 of the *PCI Express Base Specification* for specifics of the OBFF mechanism.

WAKE# has additional electrical requirements over and above standard open drain signals that allow it to be shared between devices that are powered off and those that are powered on using auxiliary power for example. The additional requirements include careful circuit design to ensure that a voltage applied to the WAKE# signal network never causes damage to a component even if that particular component's power is not applied.

Additionally, the device must ensure that it does not pull WAKE# low unless WAKE# is being intentionally asserted in all cases, including when the related function is in $D3_{cold}$.

This means that any component implementing WAKE# must be designed such that:

- Unpowered WAKE# output circuits are not damaged if a voltage is applied to them from other powered "wire-ORed" sources of WAKE#.
- When power is removed from its WAKE# generation logic, the unpowered output does not present a low impedance path to ground or any other voltage.

These additional requirements ensure that the WAKE# signal network continues to function properly when a mixture of auxiliary powered and unpowered components have their WAKE# outputs wire-ORed together. Be aware that most commonly available open drain and tri-state buffer circuit designs used "as is" do not satisfy the additional circuit design requirements for WAKE#.

Other requirements on the system board/Add-in Card designs include:

- Common ground plane reference between slots/components attached to the same WAKE# signal.
- Split voltage power planes (+3.3Vaux vs. +3.3V) are required if +3.3Vaux is supplied to the connector(s).
- If +3.3Vaux is supplied to one PCI Express connector in a chassis, it must be supplied to all PCI Express connectors in that chassis.
- If WAKE# is supported on one PCI Express connector in a chassis, it must be supported on all PCI Express connectors in that chassis.
- If the system does not support +3.3Vaux or the wakeup function, the +3.3Vaux connector pin is left open on the system board. See the *PCI Bus Power Management Interface Specification*, for +3.3Vaux power requirements.

- +3.3Vaux voltage supply may be present even if the device is not enabled for wakeup events.
- +3.3V at the PCI Express connector may be switched off by the system.
- Add-in Cards are permitted to generate the Beacon wakeup mechanism in addition to using the WAKE# mechanism, although the system is not required to provide support for Beacon.
- If the Add-in Card uses the Beacon mechanism in addition to the WAKE# mechanism, the Beacon may be ignored by the system. Circuits that support the wake function and are intended to work in any PCI Express system must be designed to generate the Beacon on their PCI Express data lines.

PCI Express Add-in Card designers must be aware of the special requirements that constrain WAKE# and ensure that Add-in Cards do not interfere with the proper operation of the WAKE# network. The WAKE# input into the system may de-assert as late as 100 ns after the WAKE# output from the function de-asserts (i.e., the WAKE# pin must be considered indeterminate for several cycles after it has been de-asserted).

The value of the pull-up resistor for WAKE# on the system board must be derived taking into account the total possible capacitance on WAKE# to ensure that WAKE# charges up to a logic high voltage level in no more than 100 ns. (Refer to Chapter 4 of the *PCI Local Bus Specification,* for information on pull-up resistors.)

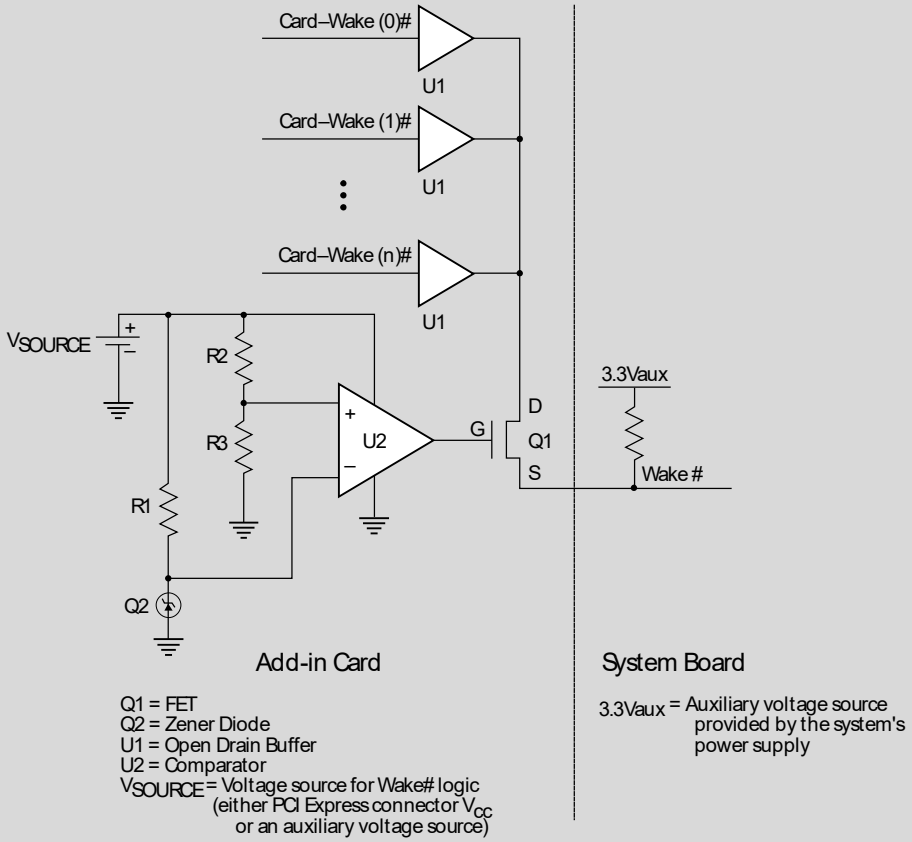
IMPLEMENTATION NOTE

Example WAKE# Circuit Design

The following diagram is an example of how the WAKE# generation logic could be implemented. In this example, multiple PCI Express functions have their WAKE# signals ganged together and connected to the single WAKE# pin on the PCI Express Add-in Card connector.

The circuit driving the gate of transistor Q1 is designed to isolate the Add-in Card's WAKE# network from that of the system board whenever its power source (V_{SOURCE}) is absent.

If the card supplies power to its WAKE# logic with the PCI Express connector's +3.3V supply (i.e., it does not support wakeup from $D3_{cold}$), then all WAKE# sources from the card will be isolated from the system board when the Add-in Card's +3.3V rail is switched off. Add-in Cards that support wakeup from $D3_{cold}$ have an auxiliary power source (+3.3Vaux) to power the WAKE# logic which maintains connection of these WAKE# sources to the system board's WAKE# signal network even when the Link hierarchy's power (+3.3V) has been switched off.



This example assumes that all sources of WAKE# on the Add-in Card are powered by either the +3.3V or +3.3Vaux (VSOURCE). If WAKE# from D3cold is supported by some, but not all of the Add-in Card's functions that generate WAKE#, the Add-in Card designer must ensure that there is separate isolation control for each of the WAKE# generation power sources.

PCI Express component designers could choose to integrate the "power fail detect" isolation circuitry with their WAKE# output pin physically corresponding to the source of FET Q1. Alternatively, all isolation control logic could be implemented externally on the Add-in Card.

This example is meant as a conceptual aid and is not intended to prescribe an actual implementation.

2.4. SMBus (Optional)

The optional System Management Bus (SMBus) is a two-wire interface through which various system component chips can communicate with each other and with the rest of the system. It is based on the principles of operation of I^2C.

SMBus provides a control bus for system and power management related tasks. A system may use SMBus to pass messages to and from devices instead of tripping individual control lines. Removing the individual control lines reduces pin count. Accepting messages ensures future expandability.

With SMBus, a device can provide manufacturer information, tell the system what its model/part number is, save its state for a suspend event, report different types of errors, accept control parameters, and return its status.

SMBus is described in *System Management Bus (SMBus) Specification*. Refer to this specification for DC characteristics and all AC timings. If the system board or Add-in Card supports SMBus, it must adhere to additional requirements that may be found in Chapter 8 of the *PCI Local Bus Specification*.

The system board provides pull-ups to the +3.3Vaux rail per the above specification and the components attached to these signals need to have a +3.3 V signaling tolerance.

2.4.1. Capacitive Load of High-power SMBus Lines

Capacitive load for each bus line includes all pin, wire, and connector capacitances. The maximum capacitive load affects the selection of the pull-up resistor or the current source to meet the rise time specifications of SMBus.

Normally, pin capacitance is defined as the total capacitive load of one SMBus device as seen in a typical manufacturer's data sheet. The value in the DC specifications (C_{OUT} in Table 1) is a recommended guideline so that two SMBus devices may, for example, be populated on an Add-in Card.

2.4.2. Minimum Current Sinking Requirements for SMBus Devices

While SMBus devices used in low-power segments have practically no minimum current sinking requirements due to the low pull-up current specified for low-power segments, devices in high-power segments are required to sink a minimum current of 4 mA while maintaining the V_{OL}(max) of 0.4 V. The requirement for 4 mA sink current determines the minimum value of the pull-up resistor R_P that can be used in SMBus systems.

2.4.3. SMBus "Back Powering" Considerations

Unpowered devices connected to either a low-power or high-power SMBus segment must provide, either within the device or through the interface circuitry, protection against "back powering" the SMBus. Unpowered devices connected to high-power segments must meet leakage specifications in Chapter 3 of the *System Management Bus (SMBus) Specification*.

2.4.4. Power-on Reset

SMBus devices detect a power-on event in one of three ways:

- By detecting that power is being applied to the device
- By PERST# being asserted
- For self-powered or always-powered devices, by detecting that the SMBus is active (clock and data lines have gone high after being low for more than 2.5 s)

SMBus devices must respond to a power-on event by bringing the device into an operational state within t_{POR}, defined in Layer 1 of the *System Management Bus (SMBus) Specification*, after the device has been supplied power that is within the device's normal operating range. Self-powered or always-powered devices, such as Smart Batteries, are not required to do a complete power-on reset, but they must be in an operational state within 500 ms after the SMBus becomes active.

2.5. JTAG Pins (Optional)

The *IEEE Standard 1149.1, Test Access Port and Boundary Scan Architecture*, is included as an optional interface for PCI Express devices. *IEEE Standard 1149.1* specifies the rules and permissions for designing an 1149.1-compliant interface. Inclusion of a Test Access Port (TAP) on an Add-in Card allows boundary scan to be used for testing of the card on which it is installed. The TAP is comprised of four pins (optionally five) that are used to interface serially with a TAP controller within the PCI Express device.

TCK	in	*Test Clock* is used to clock state information and test data into and out of the device during operation of the TAP.
TDI	in	*Test Data Input* is used to serially shift test data and test instructions into the device during TAP operation.
TDO	out	*Test Output* is used to serially shift test data and test instructions out of the device during TAP operation.
TMS	in	*Test Mode Select* is used to control the state of the TAP controller in the device.
TRST#	in	*Test Reset* provides an asynchronous initialization of the TAP controller. This signal is optional in *IEEE Standard 1149.1*.

These TAP pins operate at +3.3 V, the same as the other single-ended I/O signals of the PCI Express connector. The drive strength of the TDO pin is not required to be the same as other PCI Express pins. The Add-in Card vendor must specify TDO drive strength. The direction of these TAP pins is defined from the perspective of the Add-in Card.

The system vendor is responsible for the design and operation of the 1149.1 serial chains ("rings") required in the system. The signals are supplementary to the PCI Express interface. Additional information can be found in the *PCI Local Bus Specification,* Chapter 2.

2.6. PWRBRK# Signal (Optional)

The PWRBRK# signal is an optional normative capability applicable to the CEM form factor. Only Add-in Cards that support Emergency Power Reduction connect to this pin. Likewise, only systems that support the Emergency Power Reduction mechanism connect to this pin. The assertion and de-assertion of PWRBRK# are asynchronous to any system clock. An Add-in Card that supports Emergency Power Reduction must provide a weak pull-up on PWRBRK# (minimum 95 KΩ). A system that supports Emergency Power Reduction must provide a stronger pull-up on PWRBRK#. These pull-up resistor values must ensure meeting the rise time specification of T_{PWRBRK}.

The PWRBRK# signal is used to communicate requests to enter and exit the Emergency Power Reduction State. Refer to Chapter 6 in the *PCI Express Base Specification*.

PWRBRK# is an open-drain, active low signal that is driven low by an external enclosure component. When asserted, Add-in Cards that support Emergency Power Reduction must quickly reduce their power consumption. When de-asserted, Add-in Cards that support Emergency Power Reduction are permitted to resume normal power consumption. The Add-in Card must debounce this input to avoid thrashing the system with rapid transitions in and out of the Emergency Power Reduction State.

This mechanism is an emergency fail-safe intended to be used to prevent system damage and is not intended to provide normal dynamic power management. The external enclosure must control how it asserts/de-asserts this signal to avoid thrashing the system with rapid transitions in and out of the Emergency Power Reduction State. The amount of power consumed in the Emergency Power Reduction state is communicated through the Power Budgeting extended capability as defined in the *PCI Express Base Specification* (see Chapter 7). The time allowed to achieve this power reduction ($T_{PWRBRK\text{-}AIC\text{-}ENTER\text{-}LP\text{-}MODE}$) is defined in Table 2.

Add-in Cards that support Emergency Power Reduction may contain any mix of Devices that advertise support for PWRBRK# or that don't advertise such support. Software is not required to configure or enable use of PWRBRK#. Software can optionally use the mechanisms defined in the *PCI Express Base Specification* to determine support for PWRBRK# and, if supported, to determine the associated power saving. Software can detect that a supporting Function has entered the Emergency Power Reduction State.

Electrical specifications for PWRBRK# at the PCI Express connector are defined in Table 1 and Figure 12. Timing requirements are defined in Table 2 and Figure 13.

PWRBRK# signal may be bused to multiple PCI Express Add-in Card connectors, forming a single output connection at the external enclosure component, or individual connectors may have individual connections to the external enclosure component.

2.7. Auxiliary Signal Parametric Specifications

2.7.1. DC Specifications

Table 3 lists the auxiliary signal DC specifications for PERST#, WAKE#, CLKREQ#, SMBus and PWRBRK#.

Table 3: Auxiliary Signal DC Specifications – PERST#, WAKE#, CLKREQ#, SMBus and PWRBRK#

Symbol	Parameter	Conditions	Min	Max	Unit	Notes
V_{IL1}	Input Low Voltage		-0.5	+0.8	V	2, 6, 7
V_{IH1}	Input High Voltage		+2.0	V_{cc3_3} + 0.5	V	2, 6, 7
V_{IL2}	Input Low Voltage		-0.5	+0.8	V	4
V_{IH2}	Input High Voltage		+2.1	+3.3 Vaux + 0.5	V	4
V_{OL1}	Output Low Voltage	4.0 mA		+0.2	V	1, 3
V_{HMAX}	Max High Voltage			V_{cc3_3} + 0.5	V	3
V_{OL2}	Output Low Voltage	4.0 mA		+0.4	V	1, 4
I_{in}	Input Leakage Current	0 to +3.3 V	-10	+10	μA	2, 4, 7
I_{lkg}	Output Leakage Current	0 to +3.3 V	-50	+50	μA	3, 5
C_{in}	Input Pin Capacitance			7	pF	2, 7
C_{out}	Output (I/O) Pin Capacitance			30	pF	3, 4
$R_{PULL-UP}$	Pull-up Resistance		9	60	kΩ	8

Notes:

1. Open-drain output a pull-up is required on the system board. There is no V_{OH} specification for these signals. The number given is the maximum voltage that can be applied to this pin.
2. Applies to PERST#.
3. Applies to WAKE# and CLKREQ#.
4. Applies to SMBus signals SMBDAT and SMBCLK.
5. Leakage at the pin when the output is not active (high impedance).
6. Applies to WAKE# issued by Switch Downstream Ports and Root Complex for signaling of OBFF indications as received at the input of the Endpoint(s).
7. Applies to PWRBRK#.
8. Applies to CLKREQ# pull-up on host system.

2.7.2. AC Specifications

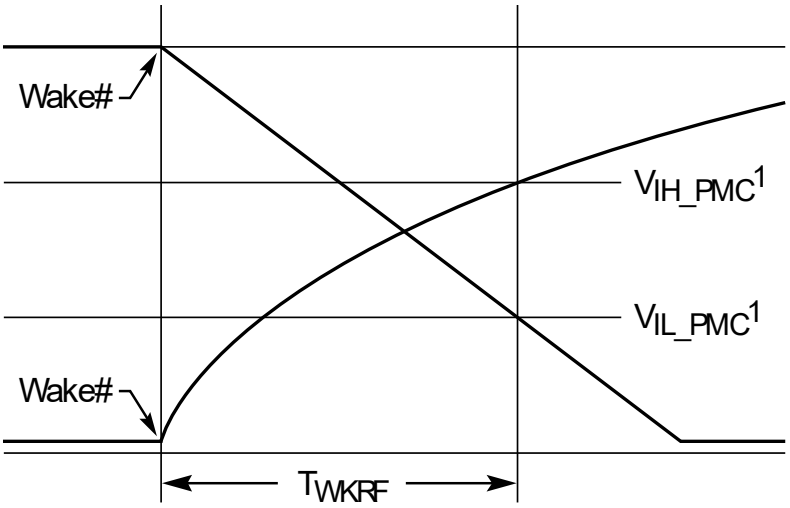
Table 4 lists the power sequencing and Reset signal timing.

Table 4: Power Sequencing and Reset Signal Timings

Symbol	Parameter	Min	Max	Units	Notes	Figure
T_{PVPERL}	Power stable to PERST# inactive	100		ms	1	Figure 8
$T_{PERST-CLK}$	REFCLK stable before PERST# inactive	100		µs	2	Figure 8
T_{PERST}	PERST# active time	100		µs		Figure 9
T_{FAIL}	Power level invalid to PERST# active		500	ns	3	Figure 11
T_{WKRF}	WAKE# rise – fall time		100	ns	4	Figure 12
$T_{WAKE-TX-MIN-PULSE}$	Minimum WAKE# pulse width; applies to both active-inactive-active and inactive-active-inactive cases	300		ns	5	
$T_{WAKE-FALL-FALL-CPU-ACTIVE}$	Time between two falling WAKE# edges when signaling CPU Active	700	1000	ns	5	
$T_{PWRBRKRF}$	PWRBRK# rise – fall time		100	ns	6	
$T_{PWRBRK-FALL-RISE-ACTIVE}$	Time PWRBRK# is active	1		ms	6	
$T_{PWRBR-K-RISE-FALL-INACTIVE}$	Time PWRBRK# is inactive	1		ms	6	
$T_{PWRBRK-AIC-ENTER-LP-MODE}$	Time for Add-in Card to enter low power mode		10	µs		

Notes:

1. Any supplied power is stable when it meets the requirements specified for that power supply.
2. A supplied reference clock is stable when it meets the requirements specified for the reference clock. The PERST# signal is asserted and de-asserted asynchronously with respect to the supplied reference clock.
3. The PERST# signal must be asserted within T_{FAIL} of any supplied power going out of specification.
4. Measured from WAKE# assertion/de-assertion to valid input level at the system PM controller. Since WAKE# is an open-drain signal, the rise time is dependent on the total capacitance on the platform and the system board pull-up resistor. It is the responsibility of the system designer to meet the rise time specification.
5. Refers to timing requirement for indicating an active window.
6. Refers to PWRBRK# timing diagram in Figure 13.



Note 1: Power Management Controller input switching levels are platform dependent and are not set by this specification.

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Figure 12: WAKE# Rise and Fall Time Measurement Points

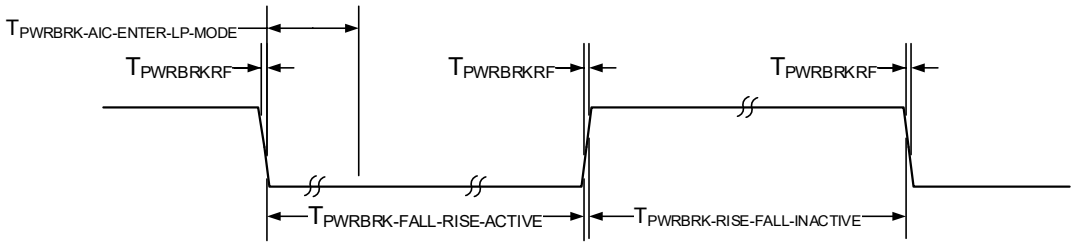

Figure 13: PWRBRK# Timing Requirement Diagram

3

3. Hot insertion and Hot removal

In the following text, all references to mechanical elements must be interpreted in the context of the PCI Express card form factor definition, unless otherwise stated.

3.1. Scope

The PCI Express specification natively supports Hot-Plug/Hot removal of PCI Express Add-in Cards. However, hardware support of Hot-Plug/Hot-Removal on the system board is optional. Since the PCI Express evolutionary form factor is designed as a direct PCI connector replacement and utilizes an edge card connector, the PCI Express Native Hot-Plug model is based on the standard usage model defined in the *PCI Standard Hot-Plug Controller and Subsystem Specification*.

Section 3.2 describes the Add-in Card presence detect and PCI Express Native Hot-Plug signals. For a detailed explanation of the register requirements and standard usage model, see Chapter 7 of the *PCI Express Base Specification*.

3.2. Presence Detect

The PCI Express Hot-Plug controller detects the presence of an Add-in Card using the PRSNT2# signal as shown in Figure 14. It is the responsibility of the Downstream Port to determine the presence of the Add-in Card and set the presence detected bits in the appropriate register as described in Chapter 7 of the *PCI Express Base Specification*. In addition to the Hot-Plug controller, the system board uses the PRSNT2# signal to recognize the presence of the Add-in Card to enable the auxiliary signals: REFCLK, PERST#, SMBus group, and JTAG group. The two signals, PRSNT1# and PRSNT2#, described in Figure 14, are required on the PCI Express connector and must be supported by all PCI Express Add-in Cards.

Both PRSNT1# and PRSNT2# signals are required to detect the presence of the Add-in Card and to ensure that it is fully inserted in the connector. The pads on the Add-in Card for the PRSNT1# and PRSNT2# signals are shorter than the rest of the pads to have about 1 ms difference of insertion time. Unused PRSNT2# pads on x4, x8, and x16 Add-in Cards are either standard length or shorter. This scheme is used to allow the power switches to isolate the power to the card during surprise removal. The mechanical details are provided in Chapter 6.

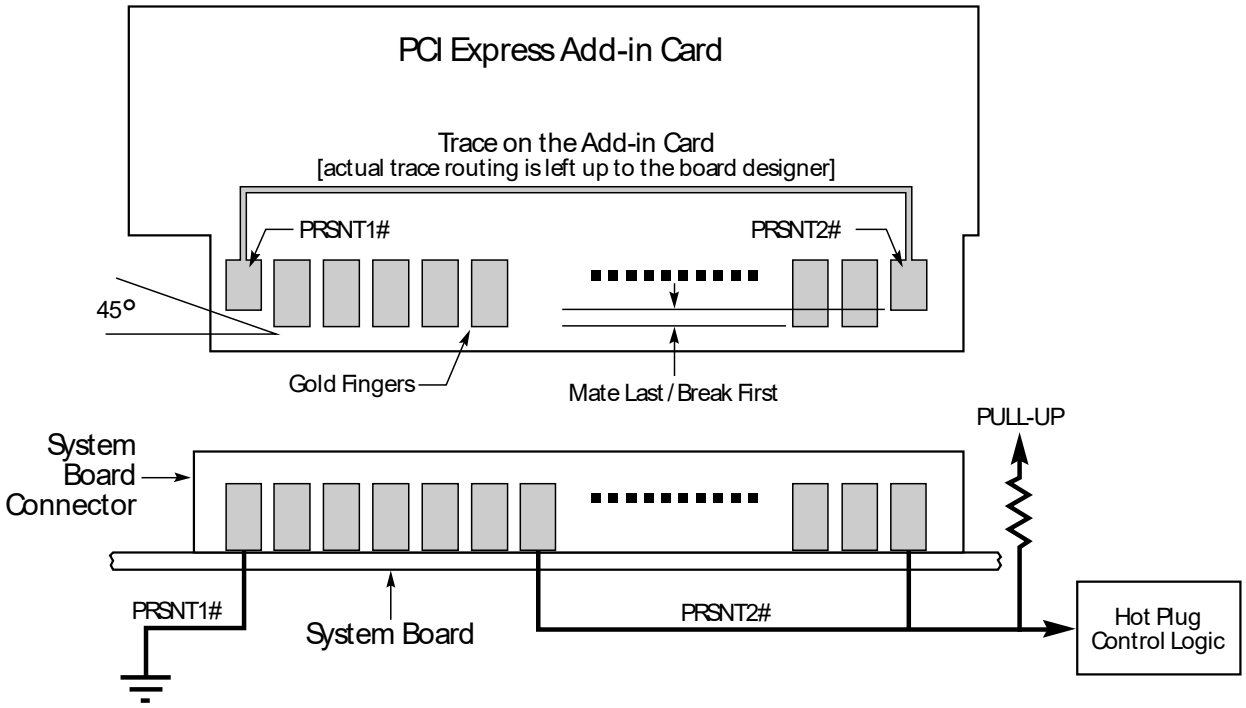

Figure 14: Presence Detect in a Hot-Plug Environment

It is required that all PCI Express Add-in Cards implement variable-length edge-finger pads and tie the PRSNT1# and PRSNT2# signals together. There is more than one PRSNT2# pin defined in the x4, x8, and x16 PCI Express connectors; these are needed to support up-plugging. The PRSNT1# signal is connected to the most distant PRSNT2# signal position on all Add-in Cards with a single trace in between them as shown in Figure 14. For example, a x4 Add-in Card would connect PRSNT1# with PRSNT2# on pin B31, and a x8 Add-in Card would connect PRSNT1# with PRSNT2# on pin B48. See Table 38 for connector pin numbering and definition. If the system board designer chooses to implement Hot-Plug support, the system board must connect PRSNT1# to GND and separately connect all the PRSNT2# pins together to a single pull-up resistor, as shown in Figure 14. The system board designer determines the pull-up resistor voltage and associated use of applicable Hot-Plug control logic. If the system board designer chooses not to implement Hot-Plug support, PRSNT1# and PRSNT2# connector pins on the system board must be left unconnected, grounded, or terminated with the AC terminated scheme described in Chapter 9.2.6. All PRSNT2# pin positions on the Add-in Card must be populated, and connected with an AC-terminated edge finger, as described in Section 9.2.

Since the x8 Add-in Card may plug into a x8 connector with a x4 Link only, the system board shall have the two PRSNT2# pins (B31 and B48) connected. This is required to sense the presence of the x8 Add-in Card in a x8 connector that supports a x4 Link only. See Section 9.5 for card interoperability discussions.

4

4. Electrical Requirements

Power delivery requirements defined in this chapter apply not only to Add-in Cards, but also to connectors and systems.

4.1. Power Supply Requirements

All PCI Express Add-in Card connectors require two power rails: +12V and +3.3V, with a third, optional +3.3Vaux rail. Systems that provide PCI Express Add-in Card connectors are required to provide both the +12V and +3.3V rails to every PCI Express Add-in Card connector in the system. The +3.3Vaux rail may be supplied to the PCI Express Add-in Card connectors at the system board designers' discretion. However, if a system board designer does supply +3.3Vaux to the PCI Express Add-in Card connector, the +3.3Vaux rail must be supplied to all PCI Express Add-in Card connectors. In addition, as described in Chapter 2, if the platform with the PCI Express interface supports the WAKE# signal, the +3.3Vaux rail (as well as the WAKE# signal) must be supplied to all PCI Express Add-in Card connectors.

Table 5 provides the required specifications for the power supply rails available at the PCI Express slots and any auxiliary power connectors. The system designer is responsible for ensuring that the power delivered to the PCI Express connectors meets the specifications called out in Table 5.

An effort is currently underway to refine the power management capabilities described below. Specifically, additional support for power levels greater than 300 W including finer granularity of power utilization, e.g. 5 W steps, is being considered. A mechanism of specifying and measuring dynamic power utilization is being developed. This work will be included in the next revision of this specification.

Table 5: Power Supply Rail Requirements

Power Rail	10 W Slot	25 W Slot	75 W Slot	2 x 3 Connector	2 x 4 Connector
+3.3V (V_{cc3_3})					
Voltage tolerance	± 9% (max)	± 9% (max)	± 9% (max)	N/A	N/A
Supply Current	3.0 A (max)	3.0 A (max)	3.0 A (max)		
Capacitive Load	1000 μF (max)	1000 μF (max)	1000 μF (max)		
+12V					
Voltage tolerance	± 8%	± 8%	± 8%	+5% / -8% (max)	+5% / -8% (max)
Supply Current	0.5 A (max)	2.1 A (max)	5.5 A (max)	6.25 A (max)	
Capacitive Load	300 μF (max)	1000 μF (max)	2000 μF (max)		12.5 A (max)
+3.3Vaux					
Voltage tolerance	± 9% (max)	± 9% (max)	± 9% (max)	N/A	N/A
Supply Current					
Wakeup Enabled	375 mA (max)	375 mA (max)	375 mA (max)		
Non-wakeup Enabled	20 mA (max)	20 mA (max)	20 mA (max)		
Capacitive Load	150 μF (max)	150 μF (max)	150 μF (max)		

Notes:

1. The maximum current slew rate for each Add-in Card shall be no more than 0.1 A/μs.
2. Each Add-in Card shall limit its bulk capacitance on each power rail to less than the values shown in Table 3.
3. System boards that support Hot-Plug Add-in Cards shall limit the voltage slew rate so that the inrush current to the card shall not exceed the specified maximum current. This is calculated by the equation dV/dt = I/C; where:
   - I = maximum allowed current (A)
   - C = maximum allowed bulk capacitance (F)
   - dV/dt = maximum allowed voltage slew rate (V/s)
4. The maximum voltage variation between +12 V inputs is ±1.92 V.

A system that supports a PCI Express 150 W / 225 W/300 W Add-in Card must deliver the +12V to the standard connector and the additional +12V via additional auxiliary power supply connector(s), from the same or different rails in the power supply (see Table 6). This is up to the discretion of the system designer. For each 2 x 3 or 2 x 4 auxiliary power connector, the power supplied through the different pins must come from the same rail in the power supply. For Add-in Card requirements, see Chapter 5.

660 **Table 6: 150 W / 225 W / 300 W Power Supply Rail Requirements**

Power Rail		75 W Slot	2 x 3 Connector	2 x 4 Connector	Remarks
+12 V Voltage Tolerance Supply Current		±8% 5.5 A	+5/-8% 6.25 A	+5/-8% 12.5 A	Maximum voltage variation between +12V inputs is 1.92 V.

661
662

663 **IMPLEMENTATION NOTE**

664 **PCI Express Slot Requirements**

665 The 75 W slot requirements are defined in this specification. PCI Express 150 W / 225 W / 300 W Add-in
666 Cards must accommodate the maximum voltage variation between the 75 W slot, 2 x 3, and 2 x 4
667 connector +12 V inputs.

4.2. Power Consumption

668 This specification supports multiple card sizes for system implementation. For each size (see Table 54
669 for card size definitions), the maximum power consumption is limited at power on until software
670 configures it for high power (refer to Chapter 6 of the *PCI Express Base Specification* for information on
671 the power configuration mechanism). Following is the maximum power dissipation for each size:

672 • x1 standard height, half-length card is limited to a 10 W maximum power dissipation.
673 • x1 low profile card is limited to a 10 W maximum power dissipation.
674 • x1 standard height, full-length card is limited to a 10 W maximum power dissipation at initial power
675 up. When the card is configured for high power, by default, it must not exceed 25 W maximum
676 power dissipation or optionally it must not exceed 75 W maximum power dissipation. A x4/x8 or a
677 x16 standard height or low profile card is limited to a 25 W maximum power dissipation at initial
678 power up. When a card is configured for high power, it must not exceed 75 W maximum power
679 dissipation.

680

681 Following are additional power considerations:

682 • Power for cards that support a 75 W maximum power dissipation can be drawn via a combination of
683 +12V and +3.3V rails but each rail draw is limited as defined in Table 5, and the sum of the draw on
684 the two rails cannot exceed 75 W.
685 • The card power limits represent the associated system power and cooling capacity for the slot.
686 • The 10 W limit assumes natural convection cooling in a system that provides air exchanges.
687 • The 25 W and above limits assume that sufficient cooling is provided to the slot by the cards in the
688 present chassis environment. In general, the power limits above assume a chassis environment with a
689 maximum internal temperature of 55 °C on the primary component side of the card and natural
690 convection cooling in system that provides air exchanges. Implementation of other chassis
691 environments must pay special attention to system level thermal requirements.

692 PCI Express specifies support for 150 W-300 W cards. For such solutions, implementers need to pay
693 special attention to the system-level thermal, acoustic, structure, and power delivery requirements.

IMPLEMENTATION NOTE

Power, Thermal Mechanical, and Labeling Considerations

Implementers should pay special attention to the following:

Implementers should follow Chapter 6 of the *PCI Express Base Specification* and comprehend how software can control the maximum power that a card can consume per slot.

After a card is reset, the initial slot power limit value may be lower than the previous one.

High-power implementations may result in increased card weight. Implementations should use appropriately sized connectors and retention mechanisms to ensure connector mechanical integrity is not compromised.

Implementers should read the latest version of the *PCI Express Label Specification* to comprehend how to appropriately label slots and cards to communicate their maximum power capabilities.

4.3. Power Budgeting Capability

The Power Budget Capability structure, as defined in the *PCI Express Base Specification*, is implemented for:

- Cards capable of using more power than initially allowed at power-up (see Section 4.2)
- Cards utilizing auxiliary power connections (150 W, 225 W, 300 W, etc.)
- Sustained Thermal and Maximum Thermal values include all thermal power that is produced by the card.
- Populated values shall include all power used by the card including power drawn from auxiliary power connections.
- For multi-device cards, an instance of the Power Budget Capability structure reports power at a device or card level. For multi-device cards, such as a Switch with devices behind it, system software aggregates all instances of the Power Budget Capability structure implemented at or beneath the base device of the card.

4.4. Power Supply Sequencing

There is no specific requirement for power supply sequencing of each of the three power supply rails. They may come up or go down in any order. The system, however, must assert the PERST# signal whenever any of the three power rails goes outside of the specifications provided in Table 5 (see Section 2.2 for specific information on the function and proper use of the PERST# signal).

If a PCI Express Add-in Card requires power supply rail sequencing, it is the responsibility of the Add-in Card designer to provide appropriate circuitry on the Add-in Card to meet any power supply rail sequencing requirements.

4.5. Power Supply Decoupling

Due to the low level signaling of the PCI Express interface, it is strongly recommended that sufficient decoupling of all power supplies be provided. This is recommended to ensure that power supply noise does not interfere with the recovery of data from a remote upstream PCI Express device. Some basic guidelines to help ensure a quiet power supply are provided below.

The following points are guidelines only. It is the responsibility of the Add-in Card designer to properly test the design to ensure that Add-in Card circuitry does not create excessive noise on power supply or ground signals at the Add-in Card edge-fingers.

- The Add-in Card device decoupling capacitance must average 0.01 μF per device power rail pin (for all devices on the Add-in Card).
- The trace length between a decoupling capacitor and the power supply or ground via must be less than 0.2 inches (5.08 mm) and be a minimum of 0.02 inches (0.508 mm) in width.
- A bulk decoupling capacitor (greater than 10 μF) is recommended at the Add-in Card edge finger for each power supply.
- A bulk decoupling capacitor (greater than 10 μF) is recommended on each power supply used within a device on the Add-in Card. This bulk decoupling capacitor must be near the Add-in Card device.

4.6. Electrical Topologies and Link Definitions

The remainder of this chapter describes the electrical characteristics of PCI Express Add-in Cards. The electrical characteristic at the card interface is defined in terms of electrical budgets. This budget allocation decouples the electrical specification for the system designer and the card vendor and ensures successful communication between the PCI Express signal input and output Links at the system board and Add-in Card interface. Unless otherwise indicated, the specifications contained herein apply to all high-speed signals of each interface width definition. The signaling rate for encoded data is 16.0 GT/s, 8.0 GT/s, 5.0 GT/s, or 2.5 GT/s and the signaling is point-to-point. Requirements are called out separately for 16.0 GT/s, 8.0 GT/s, 5.0 GT/s, and 2.5 GT/s signaling rates. CEM motherboards and Add-in Cards must support at least 2.5 GT/s signaling and must support all data rates below the maximum data rate the motherboard or Add-in Card supports.

4.6.1. Topologies

The electrical topologies supported by this specification are:

- PCI Express devices across one connector on a system with a system board and an Add-in Card.
- PCI Express devices across two connectors on a system with a system board, a riser card, and an Add-in Card.

Note that the two connector topologies with higher loss are likely to need retimers, especially if they support the 16.0 GT/s data rate.

It is never allowed to use three or more retimers before the Add-in Card PCI Express connector on the system board or two or more retimers beyond the Add-in Card PCI Express connector on the Add-in Card. The Add-in Card PCI Express connector is the only PCI Express connector for the one-connector topology and the farthest connector from the root port for the two-connector topology.

The PCI-SIG protocol does not support more than 2 retimers in a link (between each upstream and downstream port). If there are more than two retimers present – link training may fail. It is expected in most scenarios that there will be zero or one retimers before the Add-in Card PCI Express connector on the system board and that there will be zero retimers on the Add-in Card. It can use two retimers on the system board (before the Add-in Card CEM connector) or to use a retimer on the Add-in Card – but these cases create the possibility for interoperability problems because more than two retimers could exist in a link.

This specification supports only the one and two connector topologies. The "PCI Express on-board" configuration is used for two-PCI Express devices on a common PCB (see Figure 15). Since there are no Add-in Cards involved in this topology, refer to the *PCI Express Base Specification,* for implementation of this topology.

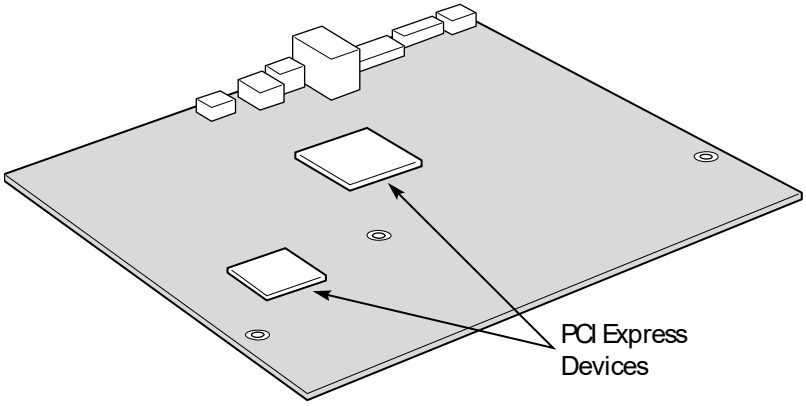

Figure 15: PCI Express on the System Board

The topology of PCI Express with one connector allows a plug-in PCI Express Add-in Card, like a standard PCI or AGP Add-in Card, to interface with a system board using a PCI Express vertical edge connector (Figure 16). In this topology, only one connector-card interface exists:

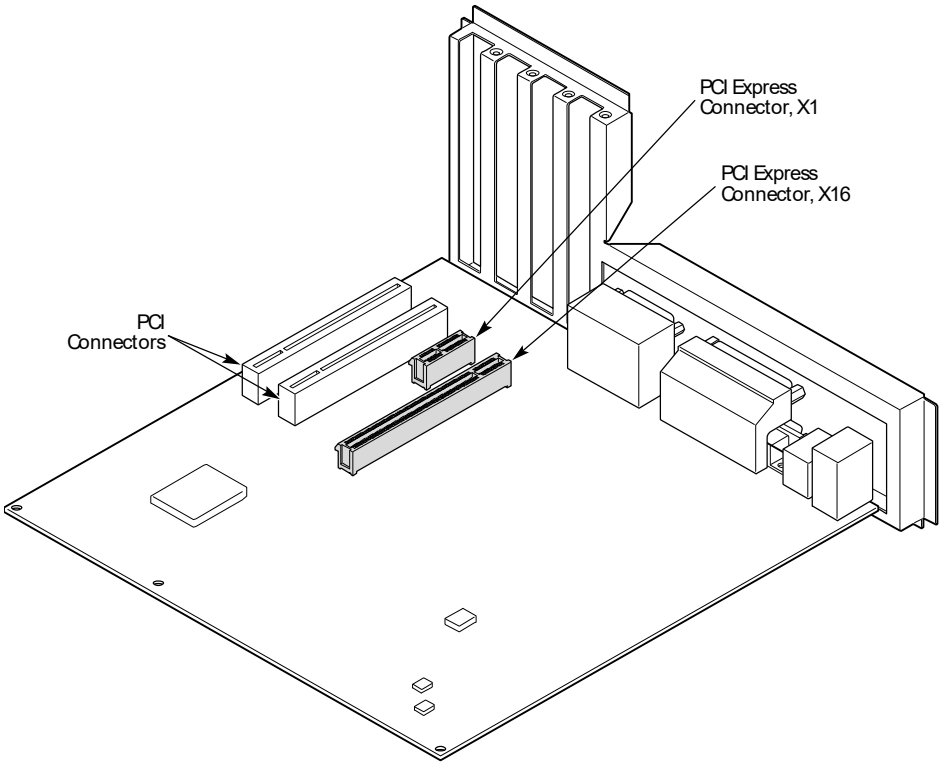

Figure 16: PCI Express Connector on System Board with an Add-in Card

The topology of "PCI Express with two connectors on a riser card" allows for a plug-in PCI Express Add-in Card, similar to a standard PCI or AGP Add-in Card, to interface with a riser card using a PCI Express connector (Figure 17). The riser card plugs to the system board using another riser connector (either PCI Express or another connector). In this topology, two connector-card interfaces exist. The Riser Board is part of the system electrical specifications and must be included during System compliance testing. In many cases, depending on design and data rates supported, addition of a Repeater could be required.

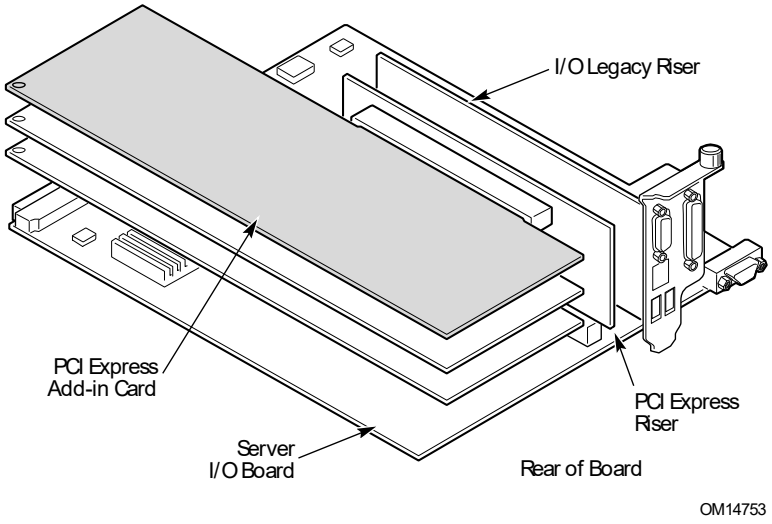

Figure 17: PCI Express Connector on a Riser Card with an Add-in Card

4.6.2. Link Definition

Typical PCI Express Links consist of the following:

- Transmitters/Receivers on an ASIC on a system board
- Package fan-in-out trace topologies
- PCB coupled microstrip and/or stripline
- Vias for layer transitions
- Optional proprietary PCI Express connector and riser card interface
- Optional riser card with microstrip and/or stripline trace
- PCI Express connector and Add-in Card interface
- Coupled microstrip line and/or stripline traces on Add-in Card
- AC-coupling capacitors
- Transmitter/Receivers on an ASIC on the Add-in Card

The electrical parameters for the Link are subdivided into two components (Figure 18):

- Add-in Card
- System board and PCI Express connector (and riser card with associated connector if it exists)

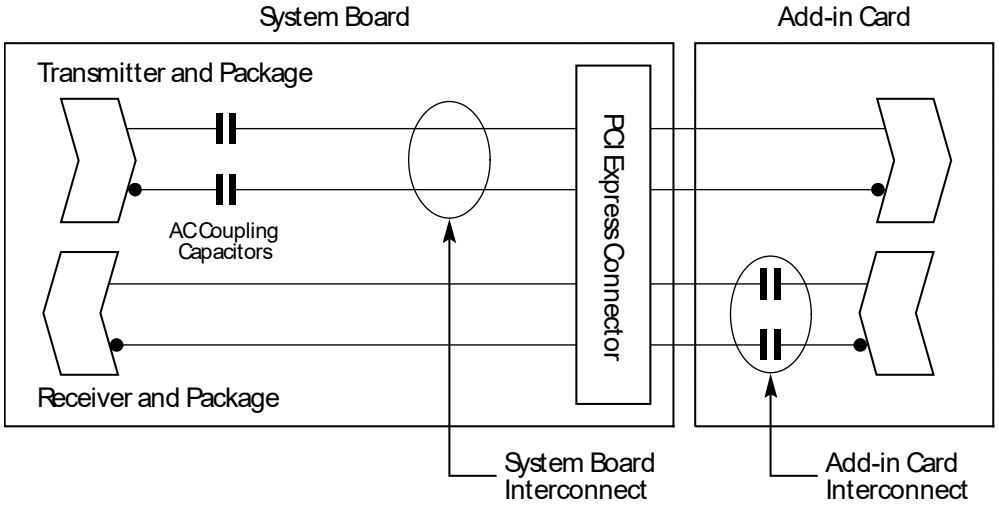

Figure 18: Link Definition for Two Components

The electrical impact on the Link due to discontinuities such as vias, bends, and test-points must be included in the respective components.

4.7. Electrical Budgets

A budget is defined for each of the following electrical parameters associated with the Link:

- AC coupling capacitors
- Insertion Loss (Voltage Transfer Function)
- Jitter
- Lane-to-Lane skew
- Crosstalk
- Equalization
- Skew within a differential pair
- Differential data trace impedance
- Differential data trace propagation delay
- The electrical budgets are different for each of the two Link components:
- Add-in Card budget
- System board and PCI Express connector budgets

The interconnect Link budget allocations associated with the Transmitters and Receivers differ. This is to account for any electrical characteristics the AC coupling capacitors may contribute to the Link.

4.7.1. AC Coupling Capacitors

The PCI Express Add-in Card and system board shall incorporate AC coupling capacitors on the Transmitter differential pair. This is to ensure blocking of the DC path between the PCI Express Add-in Card and the system board. The specific capacitance values are specified in the *PCI Express Base Specification*.

Attenuation or jitter caused by the coupling capacitors must be accounted for as part of the budget allocation for the physical interconnect component's path on which the capacitors are mounted. There may be parasitic effects associated with the component's placement as mounted on the printed circuit board.

4.7.2. Insertion Loss Values (Voltage Transfer Function)

Appendix A contains background information on maximum insertion loss assumptions that were made in computing the 2.5 GT/s eye diagram requirements. This section is provided only for information purposes.

4.7.3. Jitter Values

The maximum jitter values in terms of percentage of Unit Interval (UI = 400 ps for 2.5 GT/s, 200 ps for 5.0 GT/s, 125 ps for 8.0 GT/s and 62.5 ps for 16.0 GT/s) are specified for the system board and the Add-in Card. The jitter associated with the riser card and associated proprietary connector will be part of the system board jitter budget. The jitter values are defined with respect to 100 Ω differential termination, realized as two 50 Ω resistances. These resistances are referenced to ground at the interface (see Figure 19).

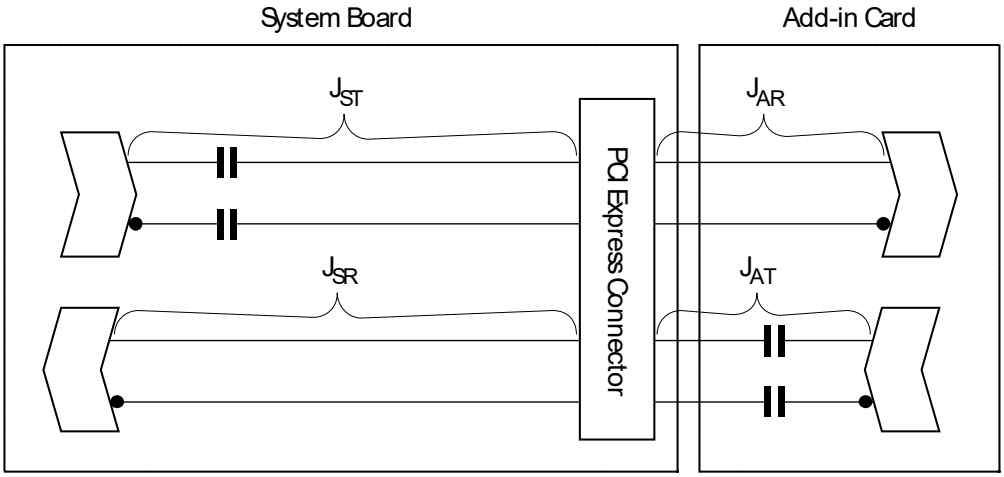

Figure 19: Jitter Budget

The total system jitter budget is derived with the assumption of a minimum Rj for each of the four budget items. This minimum Rj component is used to determine the overall system budget. The probability distribution of the Rj component is at the Bit Error Rate (BER) indicated and is Gaussian. See Table 7 for total system jitter budget for 2.5 GTs signals.

For any jitter distribution, the total Tj must always be met at the BER. The Rj of the components are independent and convolve as the root sum square (see Table 8). Tradeoffs of Rj and Dj are allowed, provided the total Tj is always met. More information on the calculation of the system budget can be found in *PCI Express Jitter and BER*.

Table 7: Total System Jitter Budget for 2.5 GT/s Signaling

Jitter Contribution	Min Rj (ps)	Max Dj (ps)	Tj at BER 10^{-12} (ps), (Note 1)	Tj at BER 10^{-6} (ps)(Note 2)
Tx	2.8	60.6	100	87
Ref Clock	4.7	41.9	108	86
Media	0	90	90	90
Rx	2.8	120.6	160	147
Linear Total Tj:			458	410
Root Sum Square (RSS) Total Tj:			399.13	371.52

Notes:

1. RSS equation for BER 10^{-12} Tj = $\sum Dj_n$ + 14.069 * $\sqrt{\sum Rj_n^2}$
2. RSS equation for BER 10^{-6} Tj = $\sum Dj_n$ + 9.507 * $\sqrt{\sum Rj_n^2}$
3. This column provides jitter limits at different BER values on a bathtub curve. If bathtub curves are not used in jitter measurements, then the jitter limit in the 10^{-6} column must be used as the total jitter limit for measurements using approximately 10^6 unit intervals of data.

Table 8: Allocation of Interconnect Jitter Budget for 2.5 GT/s Signaling

Jitter Parameter	Jitter Budget Value (UI)		Comments
PCI Express Add-in Card	J_{AR} < 0.0575	J_{AT} < 0.0650	Notes 1, 2
System Board and Connector	J_{ST} < 0.1675	J_{SR} < 0.1600	Notes 1, 3
Total Jitter	J_T < 0.225		Note 1

Notes:

1. All values are referenced to 100 Ω, realized as two 50 Ω resistances. The jitter budget values include all possible crosstalk impacts (near-end and far-end) and potential mismatch of the actual interconnect with respect to the 100 Ω reference load. The *PCI Express Base Specification,* allows an interconnect jitter budget of 0.225 UI (equivalent to 90 ps for a 400 ps Unit-Interval). The allocated jitter budget values in Table 7 and Table 8 directly correlate to the eye diagram widths in Section 4.8. Tradeoffs in terms of attenuation, crosstalk, and mismatch can be made within the budget allocations specified. No additional guard band is specifically allocated.
2. The jitter allocations are then assumed per differential pair per the table. These allocation assumptions must also include any effects of far-end crosstalk. The Add-in Card budget does not include the Add-in Card edge-finger or connector. However, it does include potential jitter from the AC coupling capacitors on the Transmitter (TX) interconnect of the Add-in Card. The budget allocations generally allow for a maximum of 4-inch trace lengths for differential pairs having an approximate 0.127 mm (5 mil) trace width. No specific trace geometry, however, is explicitly defined in this specification. The subscripts of the symbol designators, T and R, represent the Transmitter and Receiver respectively.
3. The system board budget includes the PCI Express connector and assumes it is mated with the card edge-finger. Refer to Section 0 for specifics on the standalone connector budget. The system board budget includes potential jitter from the AC coupling capacitors on the Transmitter (TX) interconnect on the system board. The subscripts of the symbol designators, T and R, represent the Transmitter and Receiver respectively.

The total system jitter budget for 5.0 GT/s signaling specifies separate Rj and Dj limits for each of the four components in the jitter budget. Refer to the *PCI Express Base Specification,* for a more detailed discussion of the system jitter budget, Rj and Dj (see Table 9).

Table 9: Total System Jitter Budget for 5.0 GT/s Signaling

Jitter Contribution	Max RMS Rj (ps)	Max Dj (ps)	Tj at BER 10^{-12} (ps)[1]
Tx	1.4	30	50
Ref Clock	3.1	0	43.6
Media	0	58	58
Rx	1.4	60	80
Linear Total Tj:			231.6
Root Sum Square (RSS) Total Tj:			200

Notes:

1. RSS equation for BER 10^{-12} Tj = $\sum Dj_n$ + 14.069 * $\sqrt{\sum Rj_n^2}$

The total system jitter budget for 8.0 GT/s and 16.0 GT/s signaling does not set separate Rj and Dj limits for all four components in the jitter budget. Refer to the *PCI Express Base Specification,* for a more detailed discussion of the system jitter budget at 8.0 GT/s and 16.0 GT/s.

The jitter budget distributions above are used to derive the eye diagram widths as described later in this chapter. However, they are provided here only as a design guideline. Compliance measurements must be verified against the eye diagrams themselves as defined in Section 4.8.

4.7.4. Crosstalk

Add-in Cards must ensure they can pass Transmitter Path and Receiver Path Eye Diagram requirements at 2.5, 5.0, 8.0, and 16.0 GT/s. Cross-talk is included directly or indirectly in these tests. See the following sections for specific information:

- 4.8.1, Add-in Card Transmitter Path Compliance Eye Diagram at 2.5 GT/s
- 4.8.2, Add-in Card Transmitter Path Compliance Eye Diagrams at 5.0 GT/s
- 4.8.3, Add-in Card Transmitter Path Compliance Eye Diagrams at 8.0 GT/s
- 4.8.4, Add-in Card Transmitter Path Compliance Eye Diagrams at 16.0 GT/s
- 4.8.6, Add-in Card Minimum Receiver Path Sensitivity Requirements at 2.5 GT/s
- 4.8.7, Add-in Card Minimum Receiver Path Sensitivity Requirements at 5.0 GT/s
- 4.8.8, Add-in Card Minimum Receiver Path Sensitivity Requirements at 8.0 GT/s
- 4.8.9, Add-in Card Minimum Receiver Path Sensitivity Requirements at 16.0 GT/s

System boards must ensure they can pass Transmitter Path and Receiver Path Eye Diagram requirements at 2.5, 5.0., 8.0, and 16.0 GT/s. Cross-talk is included directly or indirectly in these tests. See the following sections for specific information:

- 4.8.10, System Board Transmitter Path Compliance Eye Diagram at 2.5 GT/s
- 4.8.11, System Board Transmitter Path Compliance Eye Diagram at 5.0 GT/s
- 4.8.12, System Board Transmitter Path Compliance Eye Diagram at 8.0 GT/s
- 4.8.13, System Board Transmitter Path Compliance Eye Diagram at 16.0 GT/s
- 4.8.14, System Board Minimum Receiver Path Sensitivity Requirements at 2.5 GT/s
- 4.8.15, System Board Minimum Receiver Path Sensitivity Requirements at 5.0 GT/s
- 4.8.16, System Board Minimum Receiver Path Sensitivity Requirements at 8.0 GT/s
- 4.8.17, System Board Minimum Receiver Path Sensitivity Requirements at 16.0 GT/s

4.7.5. Lane-to-Lane Skew

The skew at any point is measured using zero crossings of differential voltage of the compliance pattern, while simultaneously transmitting on all physical Lanes (see Table 10. The compliance pattern is defined in the *PCI Express Base Specification*.

Table 10: Allowable Interconnect Lane-to-Lane Skew

Skew Parameter	Symbol	Skew Values	Comments
Total Interconnect Skew	S_T	1.6 ns	This does not include Transmitter output skew, $L_{TX\text{-}SKEW}$ (specified in the *PCI Express Base Specification*). The total skew at the Receiver (S_T + $L_{TX\text{-}SKEW}$) is smaller than $L_{RX\text{-}SKEW}$ (specified in the *PCI Express Base Specification*) to minimize latency for this Add-in Card topology.
PCI Express Add-in Card	S_A	0.35 ns	Estimates about a 2-inch trace length delta on FR4 boards.
System Board	S_S	1.25 ns	Estimates about a 7-inch trace length delta on FR4 boards.

4.7.6. Transmitter Equalization

To reduce ISI, 3.5 dB below the first bit de-emphasis in the Transmitter is required for the Add-in Card and the system board for 2.5 GT/s signaling. 6.0 dB or 3.5 dB de-emphasis is required for the Add-in Card and system board for 5.0 GT/s signaling. For Add-in Cards or system boards that support 8.0 GT/s and/or 16.0 GT/s signaling, refer to the *PCI Express Base Specification* for equalization preset requirements. For implementation details, refer to the *PCI Express Base Specification.* A motherboard must meet eye diagram requirements defined in the *PCI Express Base Specification* at 8.0 GT/s and 16.0 GT/s on each lane with one or more preset equalization setting.

IMPLEMENTATION NOTE

Preset Test Requirements at 8.0 GT/s and 16.0 GT/s

All Add-in Cards and system boards operating at 8.0 GT/s and / or 16.0 GT/s are required to meet the preset test as described in the *PCI Express Base Specification*. The test consists of acquiring the Tx compliance waveforms from the device under test for each preset then analyzing the waveforms together to confirm that the preset requirements have been met.

A system board shall meet the following additional rules for this specification:

- The system board initial TX preset at 8.0 GT/s shall be P1, P7, or P8.
- If the equivalent of the ps21 parameter defined in the *PCI Express Base Specification,* measured at data rates of 8.0 GT/s at the end of the 5.0 GT/s System-Board Test Channel without de-embedding shows a loss of more than 12 dB, then the system board initial TX preset at 8.0 GT/s shall be P7 or P8. The system board initial Tx preset at 16.0 GT/s shall be P7 if the Add-in Card does not request an initial preset.
- An Add-in Card shall meet the following additional rules for this specification:
- If the system board loss is less than 12 dB the Add-in Card shall receive with a BER of at least 10^{-4} at 8.0 GT/s with presets P1, P7, and P8.
- If the system board loss is more than 12 dB, the Add-in Card shall receive with a BER of at least 10^{-4} at 8.0 GT/s with presets P7 and P8.
- The Add-in Card shall receive with a BER of at least 10^{-4} at 16.0 GT/s with preset P7 if it does not request a specifc initial preset at 16.0 GT/s. If the Add-in Card does request an initial preset at 16.0 GT/s it must be able to receive with a BER of at least 10^{-4} at the request preset.

4.7.7. Skew within the Differential Pair

The skew within the differential pair gives rise to a common-mode signal component, which can, in turn, increase Electromagnetic Interference (EMI). The differential pair shall be routed such that the skew within differential pairs is less than 0.064 mm (2.5 mil) for the Add-in Card and 0.127 mm (5 mil) for the system board.

4.7.8. Differential Data Trace Impedance

The PCB trace pair differential impedance for a 5.0 GT/s capable data pair must be in the range of 68 Ω to 105 Ω. The PCB trace pair differential impedance for an 8.0 GT/s capable data pair must be in the range of 70 Ω to 100 Ω. The PCB trace pair differential impedance for 16.0 GT/s capable data pair must be in the range of 72.5 Ω to 97.5 Ω. These limits apply to both the Add-in Card and the system board.

IMPLEMENTATION NOTE

Differential PCB Trace Impedance

The PCB trace impedance requirement specified in Section 4.7.8 only applies to topologies that support 5.0 GT/s, 8.0 GT/s or 16.0 GT/s covered by this form factor specification that use the connector defined in this form factor specification.

Specifically, the *PCI Express Card Electromechanical Specification* covers the following two topologies (as defined in Section 4.6.1):

- PCI Express devices across one card electromechanical connector on a system with a system board and an Add-in Card.
- PCI Express devices across two card electromechanical connectors on a system with a system board, a riser card, and an Add-in Card, where the connector between the riser card and the Add-in Card is a card electromechanical connector.

Motherboards with lossy or reflective channels may need to have tighter impedance control.

Designers should attempt to minimize the impedance discontinuities from vias, the connectors, package traces, cables, and other similar structures.

Further, designers should follow the Add-in Card and system board layout requirements and recommendations as described in sections 9.2 and 9.3 when developing devices that operate at 16.0 GT/s.

Other topologies governed by different specifications may impose different impedance requirements or leave the impedance unspecified.

For example, the topology of "PCI Express devices on the same system board" does not fit within a form factor specification and hence must only follow the requirements of the *PCI Express Base Specification*. The *PCI Express Base Specification* does not define a PCB trace impedance requirement so with this topology designers can choose the PCB trace impedance that is best for their applications.

4.7.9. Differential Data Trace Propagation Delay

The propagation delay for an Add-in Card data trace from the edge finger to the Receiver/Transmitter must not exceed 750 ps.

4.7.10. Add-in Card Insertion Loss Limit for 16.0 GT/s

The insertion loss from the top of edge finger to the silicon pad including the package insertion loss for both Receiver and Transmitter interconnect must not exceed 8 dB at 8 GHz.

4.8. Eye Diagrams at the Add-in Card Interface

The eye diagrams defined in this section represent the compliance eye diagrams that must be met for both the Add-in Card and a system board interfacing with such an Add-in Card. The specific measurement requirements (probe test points, calibrated system board specifics, etc.) for compliance of physical components are to be specified in the *PCI Express Architecture, PHY Test Specification* document. A minimum sample size of 1×10^6 UI is required for the eye diagram measurements at data rates of 2.5 GT/s and 5.0 GT/s. A minimum sample size of 1.5×10^6 UI is required at 8.0 GT/s. A minimum sample size of 2.0×10^6 UI is required at 16.0 GT/s. These compliance eye diagrams with BER of 10^{-12} can also be used for simulation by following the guidelines explained in Section 4.7. The eye diagrams specified for 5.0 GT/s include de-emphasis jitter effects. De-emphasis jitter is not derated in 5.0 GT/s measurements.

4.8.1. Add-in Card Transmitter Path Compliance Eye Diagram at 2.5 GT/s

The eye diagrams for the Add-in Card's Transmitter path compliance at 2.5 GT/s are defined in Table 11 and Figure 20.

Table 11: Add-in Card Transmitter Path Compliance Eye Requirements at 2.5 GT/s

Parameter	Min	Max	Unit	Comments
V_{TXA}	514	1200	mV	Notes 1, 2, 5
V_{TXA_d}	360	1200	mV	Notes 1, 2, 5
T_{TXA}	287		ps	Notes 1, 3, 5
$J_{TXA\text{-}MEDIAN\text{-}to\text{-}MAX\text{-}JITTER}$		56.5	ps	Notes 1, 4, 5

Notes:

1. An ideal reference clock without jitter is assumed for this specification. All Links are assumed active while generating this eye diagram.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{TXA_d}). V_{TXA} and V_{TXA_d} are minimum differential peak-peak output voltages.
3. T_{TXA} is the minimum eye width. The sample size for this measurement is 10^6 UI. This value can be reduced to 274 ps for simulation purpose at BER 10^{-12}.
4. $J_{TXA\text{-}MEDIAN\text{-}to\text{-}MAX\text{-}JITTER}$ is the maximum median-to-max jitter outlier as defined in the *PCI Express Base Specification*. The sample size for this measurement is 10^6 UI. This value can be increased to 63 ps for simulation purpose at BER 10^{-12}.
5. The values in Table 11 are referenced to an ideal 100 Ω differential load at the end of the interconnect path at the edge-finger boundary on the Add-in Card (see Figure 19). The eye diagram is defined and centered with respect to the jitter median. Exact conditions required for verifying compliance while generating this eye diagram are given in the *PCI Express Architecture, PHY Test Specification*.

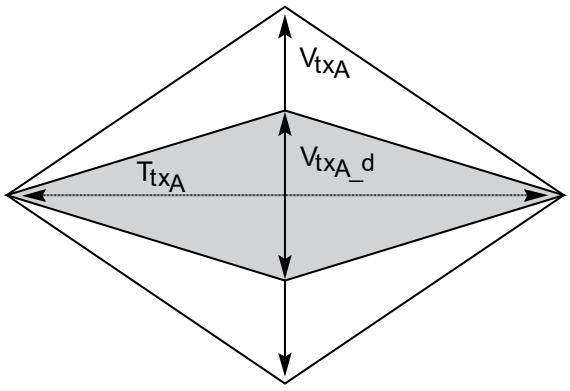

Figure 20: 2.5 GT/s Add-in Card Transmitter Path Compliance Eye Diagram

4.8.2. Add-in Card Transmitter Path Compliance Eye Diagrams at 5.0 GT/s

The eye diagrams for the Add-in Card's Transmitter path compliance at 5.0 GT/s are defined in Table 11, Table 12, Table 13, Table 14, Table 15, and Figure 21.

Table 12: Add-in Card Transmitter Path Compliance Eye Requirements at 5.0 GT/s and 3.5 dB De-emphasis

Parameter	Min	Max	Unit	Comments
V_{TXA} V_{TXA_d}	380 380	1200 1200	mV mV	Notes 1, 2, 4 Notes 1, 2, 4
T_{TXA} (with crosstalk) T_{TXA} (without crosstalk)	123 126		ps ps	Notes 1, 3, 4

Notes:

1. An ideal reference clock without jitter is assumed for this specification. All Links are assumed active while generating this eye diagram. The eye diagram requires that CMM pattern (*PCI Express Base Specification,* Chapter 4) is being transmitted during the test.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{TXA_d}). V_{TXA} and V_{TXA_d} are minimum differential peak-peak output voltages.
3. T_{TXA} is the minimum eye width. The recommended sample size for this measurement is at least 10^6 UI. This calculated eye width at BER 10^{-12} to meet or exceed T_{TXA}. If the Add-in Card board uses non-interleaved routing, then crosstalk will be present in the measured data. If the Add-in Card board uses interleaved routing, then crosstalk is not present, and an adjusted minimum eye width is used.
4. The values in Table 12 are referenced to an ideal 100 Ω differential load at the end of an isolated 3-inch long 85 Ω differential trace behind a standard PCI Express connector. This channel shall be referenced as the 5.0 GT/s Add-in Card Test Channel. Exact conditions required for verifying compliance while generating this eye diagram are given in the *PCI Express® Architecture, PHY Test Specification*.

The Add-in Card total jitter for the Transmitter and the Transmitter interconnect must meet the requirements in Table 11 when decomposed into random and deterministic jitter.

Table 13: Add-in Card Jitter Requirements for 5.0 GT/s Signaling at 3.5 dB De-emphasis

	Max Rj (ps RMS)	Max Dj (ps)	Tj at BER 10^{-12} (ps)
With crosstalk	1.4	57	77
Without crosstalk	1.4	54	74

Table 14: Add-in Card Transmitter Path Compliance Eye Requirements at 5.0 GT/s at 6.0 dB De-emphasis

Parameter	Min	Max	Unit	Comments
V_{TXA} V_{TXA_d}	306 260	1200 1200	mV mV	Notes 1, 2, 4 Notes 1, 2, 4
T_{TXA} (With crosstalk) T_{TXA} (Without crosstalk)	123 126		ps ps	Notes 1, 3, 4

Notes:

1. An ideal reference clock without jitter is assumed for this specification. All Links are assumed active while generating this eye diagram. The eye diagram requires that CMM pattern (*PCI Express Base Specification,* Chapter 4) is being transmitted during the test.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{TXA_d}). V_{TXA} and V_{TXA_d} are minimum differential peak-peak output voltages.
3. T_{TXA} is the minimum eye width. The recommended sample size for this measurement is at least 10^6 UI. This calculated eye width at BER 10^{-12} must meet or exceed T_{TXA}. If the Add-in Card board uses non-interleaved routing, then crosstalk will be present in the measured data. If the Add-in Card board uses interleaved routing, then crosstalk will not be present, and an adjusted minimum eye width is used.
4. The values in Table 14 are measured using the 5.0 GT/s Add-in Card Test Channel. Exact conditions required for verifying compliance while generating this eye diagram are given in the *PCI Express® Architecture, PHY Test Specification, Revision 4.0* document.

The Add-in Card total jitter for the Transmitter and the Transmitter interconnect must meet the requirements in Table 15 when decomposed into random and deterministic jitter.

Table 15: Add-in Card Jitter Requirements for 5.0 GT/s Signaling at 6.0 dB De-emphasis

	Max Rj (ps RMS)	Max Dj (ps)	Tj at BER 10^{-12} (ps)
With crosstalk	1.4	57	77
Without crosstalk	1.4	54	74

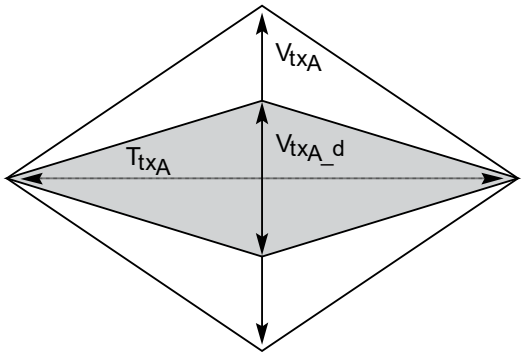

Figure 21: 5.0 GT/s Add-in Card Transmitter Path Compliance Eye Diagram

4.8.3. Add-in Card Transmitter Path Compliance Eye Diagrams at 8.0 GT/s

The eye diagrams for the Add-in Card's Transmitter path compliance at 8.0 GT/s are defined in Table 16. The Add-in Card shall pass the eye diagram requirements with at least one of the TX equalization presets defined in the *PCI Express Base Specification.* The eye diagram requirements are evaluated after the behavioral CDR and the behavioral RX Equalization Algorithm defined in the *PCI Express Base Specification* are applied.

Table 16: Add-in Card Transmitter Path Compliance Eye Requirements at 8.0 GT/s

Parameter	Min	Max	Unit	Comments
V_{TXA}	34	1300	mV	Notes 1, 2, 4
V_{TXA_d}	34	1300	mV	Notes 1, 2, 4
T_{TXA}	41.25		ps	Notes 1, 3, 4

Notes:

1. A worst-case reference clock with 1 ps RMS jitter is assumed for this revision of the specification. All Links are assumed active while generating this eye diagram. The eye diagram requires that the compliance pattern in 128b/130b (refer to the *PCI Express Base Specification,* Chapter 4) is being transmitted during the test.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{TXA_d}). V_{TXA} and V_{TXA_d} are minimum differential peak-peak output voltages. The voltage measurements are done at a BER of 10^{-12}. For lab use, an informative voltage limit (V_{TXA} and V_{TXA_d}) at a BER of 10^{-6} is 46 mV.
3. T_{TXA} is the minimum eye width. The recommended sample size for this measurement is at least 10^6 UI. This calculated eye width at BER 10^{-12} must meet or exceed T_{TXA}.
4. The values in Table 16 are referenced to an ideal 100 Ω differential load at the end of an isolated (no crosstalk) test channel consisting of approximately four inches of 85 Ω trace, followed by a second PCI Express connector, followed by approximately 10.8 inches of 85 Ω trace, followed by a reference receiver package all behind a standard PCI Express connector. This channel shall be referenced as the 8.0 GT/s Add-in Card Test Channel. S-parameters for the channel are provided with the specification. Additional loss from the measurement set-up must be removed. The Add-in Card Test Channel is a reference channel for testing and does not represent the worst possible channel that could be implemented on a CEM compliant motherboard.

4.8.4. Add-in Card Transmitter Path Compliance Eye Diagrams at 16.0 GT/s

The eye diagrams for the Add-in Card's Transmitter path compliance at 16.0 GT/s are defined in Table 17. The Add-in Card shall pass the eye diagram requirements with at least one of the TX equalization presets defined in the *PCI Express Base Specification.* The eye diagram requirements are evaluated after the behavioral CDR and the behavioral RX Equalization Algorithm defined in the *PCI Express Base Specification,* are applied.

Table 17: Add-in Card Transmitter Path Compliance Eye Requirements at 16.0 GT/s

Parameter	Min	Max	Unit	Comments
V_{TXA}	23.0	1300	mV	Notes 1, 2, 4
V_{TXA_d}	23.0	1300	mV	Notes 1, 2, 4
T_{TXA}	24.75		ps	Notes 1, 3, 4

Notes:

1. A worst-case reference clock with 0.7 ps RMS jitter at the receiver of the Add-in Card is assumed for this revision of the specification. All Links are assumed active while generating this eye diagram. The eye diagram requires that the compliance pattern in 128b/130b (refer to the *PCI Express Base Specification,* Chapter 4) is being transmitted during the test.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{TXA_d}). V_{TXA} and V_{TXA_d} are minimum differential peak-peak output voltages. The voltage measurements are done at a BER of 10^{-12}.
3. T_{TXA} is the minimum eye width. The recommended sample size for this measurement is at least 2×10^{6} UI. This calculated eye width at BER 10^{-12} must meet or exceed T_{TXA}.
4. The values in Table 17 are referenced to an ideal 100 Ω differential load at the end of an isolated (no crosstalk) test channel consisting of 85 Ω FR4 trace with an insertion loss of 14 dB at Nyquist., followed by a root reference package all behind a standard PCI Express connector. This channel shall be referenced as the 16.0 GT/s Add-in Card Test Channel. S-parameters for the channel provided with the specification. Additional loss from the measurement set-up must be removed. The Add-in Card Test Channel is a reference channel for testing and does not represent the worst possible channel that could be implemented on a CEM compliant motherboard.

4.8.5. Add-in Card Transmitter Path Pulse Width Jitter at 16.0 GT/s

The Uncorrelated Total and Deterministic Pulse Width Jitter ($T_{TX\text{-}UPW\text{-}TJ}$ and $T_{TX\text{-}UPW\text{-}DJDD}$) at a BER of 10^{-12} are defined in Table 18. The Add-in Card shall pass the timing requirements with the Jitter Measurement Pattern defined in the *PCI Express Base Specification*. The pulse width jitter requirements are evaluated after the -12 dB CTLE curve from the behavioral reference equalizer defined in the *PCI Express Base Specification,* is applied.

Table 18: Add-in Card Transmitter Path Uncorrelated Pulse Width Jitter Requirements at 16.0 GT/s

Parameter	Min	Max	Unit	Comments
$T_{TX\text{-}UPW\text{-}TJ}$	0	12.5	ps PP @ BER 10^{-12}	
$T_{TX\text{-}UPW\text{-}DJDD}$	0	5.0	ps PP @ BER 10^{-12}	

4.8.6. Add-in Card Minimum Receiver Path Sensitivity Requirements at 2.5 GT/s

The minimum sensitivity values for the Add-in Card's Receiver path compliance at 2.5 GT/s are defined in Table 19, and a representative eye diagram is shown in Figure 22.

Table 19: Add-in Card Minimum Receiver Path Sensitivity Requirements at 2.5 GT/s

Parameter	Min	Max	Unit	Comments
V_{RXA}	238	1200	mV	Notes 1, 2, 5
V_{RXA_d}	219	1200	mV	Notes 1, 2, 5
T_{RXA}	246		ps	Notes 1, 3, 5
$J_{RXA\text{-}MEDIAN\text{-}to\text{-}MAX\text{-}JITTER}$	77		ps	Notes 1, 4, 5

Notes:

1. An ideal reference clock without jitter is assumed for this specification. All Links are assumed active while generating this eye diagram.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{RXA_d}). V_{RXA} and V_{RXA_d} are differential peak-peak output voltages.
3. T_{RXA} is the eye width. The sample size for this measurement is 10^6 UI. This value can be reduced to 233 ps for simulation purpose at BER 10^{-12}.
4. $J_{RXA\text{-}MEDIAN\text{-}to\text{-}MAX\text{-}JITTER}$ is the maximum median-to-peak jitter outlier as defined in *the PCI Express Base Specification*. The sample size for this measurement is 10^6 UI. This value can be increased to 83.5 ps for simulation purpose at BER 10^{-12}.
5. The values in Table 19 are initially referenced to an ideal 100 Ω differential load. The resultant values, when provided to the Receiver interconnect path of the Add-in Card, allow for a demonstration of compliance of the overall Add-in Card Receiver path. The sensitivity requirements are defined and centered with respect to the jitter median. Exact conditions required for verifying compliance against these values are given in the *PCI Express® Architecture, PHY Test Specification, Revision 4.0* document.

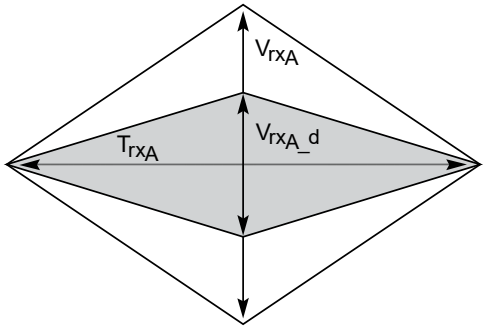

Figure 22: 2.5 GT/s Representative Composite Eye Diagram for Add-in Card Receiver Path Compliance

4.8.7. Add-in Card Minimum Receiver Path Sensitivity Requirements at 5.0 GT/s

The minimum sensitivity values for the Add-in Card's Receiver path compliance at 5.0 GT/s are defined in Table 20, and a representative eye diagram is shown in Figure 23.

Table 20: Add-in Card Minimum Receiver Path Sensitivity Requirements at 5.0 GT/s

Parameter	Min	Max	Unit	Comments
V_{RXA}	225	1200	mV	Notes 1, 2, 3
V_{RXA_d}	225	1200	mV	Notes 1, 2, 3
1.5 – 100 MHz RMS Jitter	3.4		ps RMS	
33 kHz REFCLK Residual	75		ps PP	
< 1.5 MHz RMS Jitter	4.2		ps RMS	
1.5 – 100 MHz Dj	30		ps PP	
> 100 MHz Dj	27		ps PP	

Notes:

1. An ideal reference clock without jitter is assumed for this specification. All Links are assumed active while generating this eye diagram. The CMM pattern must be transmitted during the test.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{RXA_d}). V_{RXA} and V_{RXA_d} are differential peak-peak output voltages.
3. The values in Table 20 are initially calibrated with a reference channel consisting of a 5.0 GT/s Add-in Card Test Channel followed by a 5.0 GT/s System-Board Test Channel. After reference calibration, the 5.0 GT/s System-Board Test Channel is removed and the Add-in Card to be tested is placed into a standard PCI Express connector. The resultant values, when provided to the Receiver interconnect path of the Add-in Card, allow for a demonstration of compliance of the overall Add-in Card Receiver path. The exact setup and methodology for injecting this signal into the Receiver interconnect path of the Add-in Card are not specified. The values in Table 19 may need to be adjusted based on the exact test setup and methodology. For example, if the impedance of the test setup does not create the worst-case mismatch that could be present with a real system board or the test setup does not provide crosstalk (only a single Lane is tested, etc.) the values in Table 19 must be adjusted accordingly.

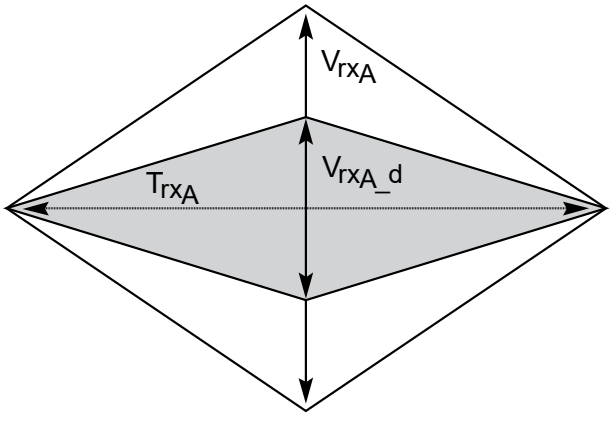

Figure 23: 5.0 GT/s Representative Composite Eye Diagram for Add-in Card Receiver Path Compliance

4.8.8. Add-in Card Minimum Receiver Path Sensitivity Requirements at 8.0 GT/s

The minimum sensitivity values for the Add-in Card's Receiver path compliance at 8.0 GT/s are defined in Table 21. The receiver path shall be tested with a worst-case eye to verify that it achieves a BER < 10^{-12}. This worst-case eye is calibrated using TX equalization settings that are optimal with the reference equalizer for each calibration channel. After calibration, the test-generator's TX equalization may be adjusted using the transmitter equalization setting in the required TX equalization space preferred by the device under test, without changing any other parameter of the test signal or recalibrating the test signal.

If the test generator's TX equalization settings are adjusted away from the optimal settings and the test generator is not able to change transmitter equalization without impacting other calibrated parameters – then the other parameters must be adjusted back to the specified values.

If the test is not run in a way that produces the worst-case cross-talk that would be present with all lanes active, the additional cross-talk must be accounted for in some other way. The test is performed with two different test channels, a long test channel and a short test channel. While the receiver's capacity to adapt its own equalization is part of the test, its ability to request the link partner's transmitter to change its transmitter equalization is tested by applying a signal whose equalization level is suboptimal compared to the jitter sensitivity test signal described above. For this signal, the reference receiver would not be able to achieve proper equalization by means of its own CTLE and DFE alone. Such a signal can be defined using the signal resulting from the calibration method described above and adjusting the test-generator equalization. If the RX under test is more capable than the reference (CTLE+DFE) receiver, the RX under test may not require the TX to change its equalization levels to achieve a BER < 10^{-12}. In any case, equalization settings resulting from this procedure must be used for the RX test and if the RX requires the TX equalization to change, such change must be accommodated by the test set-up used.

A specific methodology for this procedure is outside the scope of this specification. Refer to compliance program test procedures for specific test equipment for specific methodology details.

Table 21: Long Channel Add-in Card Minimum Receiver Path Sensitivity Requirements at 8.0 GT/s

Parameter	Min	Max	Unit	Comments
$V_{RX\text{-}EH\text{-}8G}$ Eye Height	34	34	mV	Notes 1, 2, 4
$T_{RX\text{-}EH\text{-}8G}$ Eye Width	0.33	0.38	UI	Notes 1, 2
Rj (Random Jitter)	3		ps RMS	Notes 5, 6
Sj (Sinusoidal Jitter) 100 MHz	12.5		ps PP	Note 6
Differential Mode Sinusoidal Interference 2.1 GHz	14		mV PP	Note 3

Notes:

1. An ideal reference clock without jitter is assumed for this specification. The 128/130b compliance pattern must be used during calibration for this test. Modified compliance pattern is used when the receiver test is run. Eye height and width values reference BER = 10^{-12}.
2. The values in Table 21 are initially calibrated with a reference channel consisting of an 8.0 GT/s Add-in Card Test Channel followed by 8.0 GT/s System-Board Test Channel at the TX SMP connectors on the System-Board Test Channel. The calibration is done with the same post processing as the System Board 8.0 GT/s TX test. After reference calibration, the 8.0 GT/s System-Board Test Channel is removed and the Add-in Card to be tested is placed into a standard PCI Express connector.
3. Eye height and width are specified after the application of the reference receiver. When the optimization of the reference receiver's CTLE and DFE yields an eye height and/or eye width larger than specified, the value for DM-interference is increased.
4. Eye height limits do not account for limitations in test equipment voltage resolution.
5. Rj is applied over the following range. The low frequency limit may be between 1.5 MHz and 10 MHz, and the upper limit is 1.0 GHz. While the nominal value is specified at 3.0 ps RMS, it may be adjusted to meet the value for $T_{RX\text{-}EH\text{-}8G}$ Eye Width.
6. Rj and Sj are measured without post-processing filters.

Table 22: Short Channel Add-in Card Minimum Receiver Path Sensitivity Requirements at 8.0 GT/s

Parameter	Min	Max	Unit	Comments
$V_{RX-EH-8G}$ Eye Height	N/A	N/A	mV	Notes 1, 2, 5
$T_{RX-EH-8G}$ Eye Width	N/A	N/A	UI	Notes 1, 2, 5
Rj (Random Jitter)	3		ps RMS	Note 4
Sj (Sinusoidal Jitter) 100 MHz	12.5		ps PP	
Differential Mode Sinusoidal Interference 2.1 GHz	14		mV PP	Note 3

Notes:

1. An ideal reference clock without jitter is assumed for this specification. The 128/130b compliance pattern must be used during calibration for this test. Modified compliance pattern is used when the receiver test is run. Eye height and width values refer to a BER = 10^{-12}.
2. The values in Table 22 are initially calibrated with a reference channel consisting of a 5.0 GT/s Add-in Card Test Channel followed by 5.0 GT/s System-Board Test Channel at the TX SMP connectors on the System-Board Test Channel. The calibration is done with the same post processing as the System Board 5.0 GT/s TX test. After reference calibration, the 5.0 GT/s System-board Test Channel is removed and the Add-in Card to be tested is placed into a standard PCI Express connector.
3. Eye height and width are specified after application of the reference receiver. When the optimization of the reference receiver's CTLE and DFE yields an eye height and/or eye width larger than specified, the value for DM-interference is increased.
4. Rj is applied over the following range. The low frequency limit may be between 1.5 MHz and 10 MHz, and the upper limit is 1.0 GHz.
5. For the short channel test, the calibrated test equipment transmitter settings from the long channel test are used. Eye height and eye width are not separately re-calibrated.

4.8.9. Add-in Card Minimum Receiver Path Sensitivity Requirements at 16.0 GT/s

The minimum sensitivity values for the Add-in Card Receiver path compliance at 16.0 GT/s are defined in Table 23. The receiver path shall be tested with a worst-case eye to verify that it achieves a BER < 10^{-12}. This worst-case eye is calibrated using TX equalization settings that are optimal with the reference equalizer for the calibration channel. After calibration, the test-generator's equalization settings may be adjusted using the transmitter equalization setting in the required TX equalization space preferred by the device under test, without changing any other parameter of the test signal or recalibrating the test signal. This adjustment is done through running the PCI Express training protocol.

If the test generator's TX equalization settings are adjusted away from the optimal settings and the test generator is not able to change transmitter equalization without impacting other calibrated parameters – then the other parameters must be adjusted back to the calibrated values.

If the test is not run in a way that produces the worst-case cross-talk that would be present with all lanes active, the additional cross-talk must be accounted for in some other way.

Table 23. Channel Add-in Card Minimum Receiver Path Sensitivity Requirements at 16 GT/s

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Parameter	Min	Max	Unit	Comments
$V_{RX-EH-16G}$ Eye Height	15	15	mV	Notes 1, 2, 4
$T_{RX-EH-16G}$ Eye Width	0.3	0.3	UI	Notes 1, 2
Rj (Random Jitter)	1.0		ps RMS	Notes 5, 6
Sj (Sinusoidal Jitter) 100 MHz	6.25		ps PP	Note 6
Differential Mode Sinusoidal Interference 2.1 GHz	14		mV PP	Note 3

Notes:

1. An ideal reference clock without jitter is assumed for this specification. The 128/130b compliance pattern must be used during calibration for this test. Modified compliance pattern is used when the receiver test is run. Eye height and width values refer to BER = 10^{-12}.
2. The values in Table 21 are initially calibrated with a reference channel consisting of an 16.0 GT/s Add-in Card Test Channel followed by an 16.0 GT/s System-Board Test Channel at the TX SMP connectors on the System-Board Test Channel. The calibration is done with the same post processing as the System Board 16.0 GT/s TX test. After reference calibration, the 16.0 GT/s System-Board Test Channel is removed and the add-in card to be tested is placed into a standard PCI Express connector. The end to end CEM calibration channel must meet the requirements (insertion loss and return loss masks) defined for the 16.0 GT/s calibration channel in the *PCI Express Base Specification.*
3. Eye height and width are specified after the application of the reference receiver. $V_{RX-EH-16G}$ and $T_{RX-EH-16G}$ are adjusted following the same process described in the *PCI Express Base Specification* for calibrating the 16.0 GT/s stressed eye test. When the channel insertion loss is varied as part of the 16.0 GT/s stressed eye calibration process the variation must occur in the 16.0 GT/s Add-in Card Test Channel portion of the channel
4. Eye height limits do not account for limitations in test equipment voltage resolution.
5. Rj is applied over the following range. The low frequency limit may be between 1.5 MHz and 10 MHz, and the upper limit is 1.0 GHz.
6. Rj and Sj are measured without post-processing filters.

4.8.10. System Board Transmitter Path Compliance Eye Diagram at 2.5 GT/s

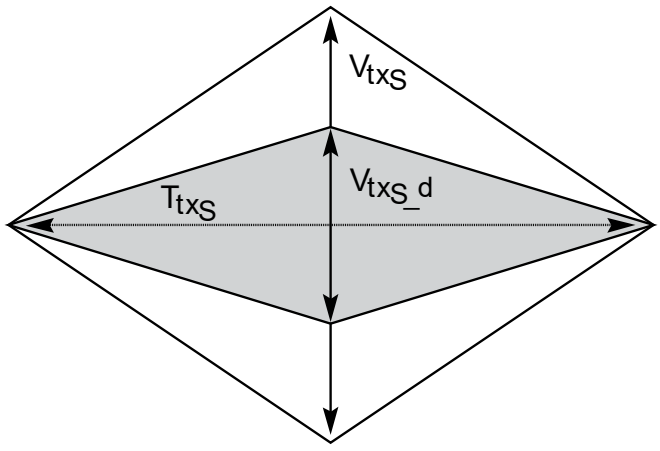
The eye diagram for the system board's Transmitter compliance at 2.5 GT/s is defined in Table 24 and Figure 24.

Table 24: System Board Transmitter Path Compliance Eye Requirements at 2.5 GT/s

Parameter	Min	Max	Unit	Comments
V_{TXS}	274	1200	mV	Notes 1, 2, 5
V_{TXS_d}	253	1200	mV	Notes 1, 2, 5
T_{TXS}	246		ps	Notes 1, 3, 5
$J_{TXS\text{-}MEDIAN\text{-}to\text{-}MAX\text{-}JITTER}$		77	ps	Notes 1, 4, 5

Notes:

1. An ideal reference clock without jitter is assumed for this specification. All Links are assumed active while generating this eye diagram.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{TXS_d}). V_{TXS} and V_{TXS_d} are minimum differential peak-peak output voltages.
3. T_{TXS} is the minimum eye width. The sample size for this measurement is 10^6 UI. This value can be reduced to 233 ps for simulation purposes at BER 10^{-12}.
4. $J_{TXS\text{-}MEDIAN\text{-}to\text{-}MAX\text{-}JITTER}$ is the maximum median-to-max jitter outlier as defined in *the PCI Express Base Specification*. The sample size for this measurement is 10^6 UI. This value can be increased to 83.5 ps for simulation purpose at BER 10^{-12}.
5. The values in Table 24 are referenced to an ideal 100 Ω differential load at the end of the interconnect path at the edge-finger boundary on the Add-in Card when mated with a connector (see Figure 19). The eye diagram is defined and centered with respect to the jitter median. Exact conditions required for verifying compliance while generating this eye diagram are given in the *PCI Express® Architecture, PHY Test Specification, Revision 4.0* document.



A-0335

Figure 24: 2.5 GT/s System Board Transmitter Path Composite Compliance Eye Diagram

4.8.11. System Board Transmitter Path Compliance Eye Diagram at 5.0 GT/s

The system board Transmitter path measurements at 5.0 GT/s are made using a two-port measurement methodology. Figure 25 shows a functional block diagram for a system board and Add-in Card that shows the measurement points for the two-port method.

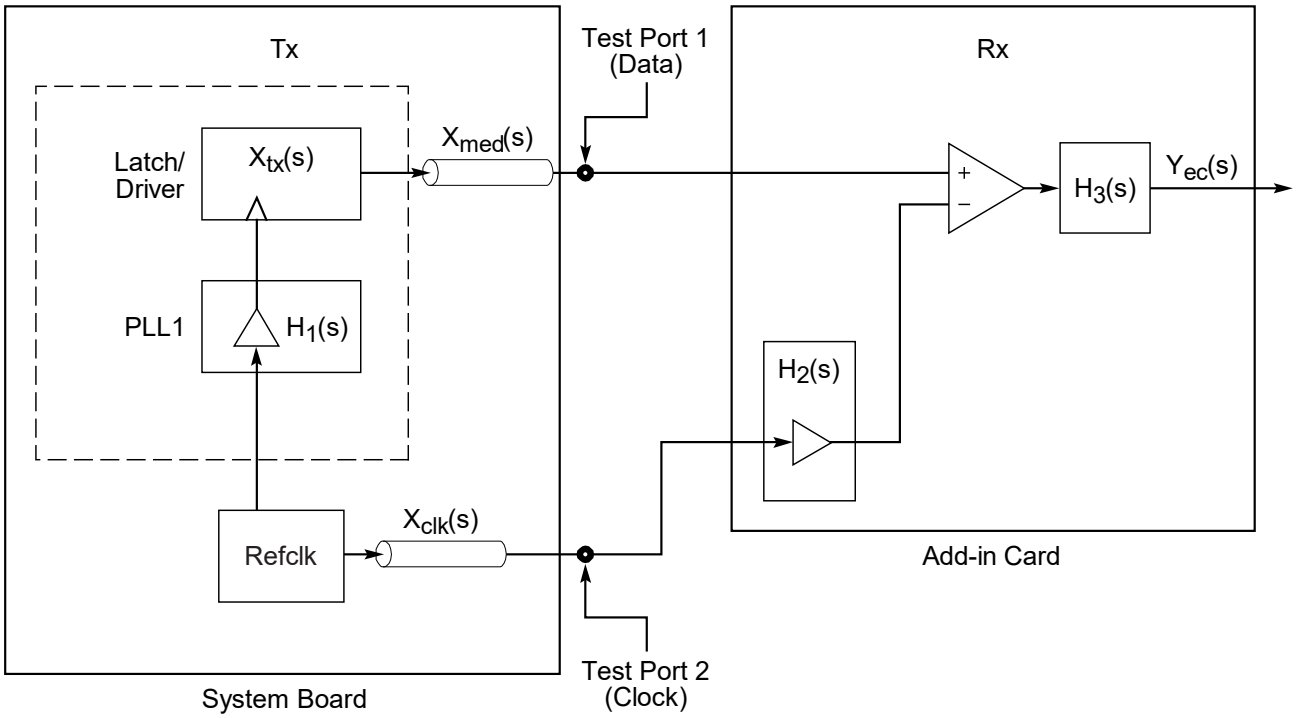


Figure 25: 5.0 GT/s Two Port Measurement Functional Block Diagram

Equations for the jitter at test port 1 and test port 2 and the eye closure at the Add-in Card Receiver from the test port signals are provided as follows:

Data Port Measurement (Test Port 1):

$$\text{Eq.(1)} \qquad X_{dm}(s) = X_{clk}(s)H_1(s)e^{-sT_{d1a}} + X_{tx}(s) + X_{med}(s)$$

Clock Port Measurement (Test Port 2):

$$\text{Eq.(2)} \qquad X_{cm}(s) = X_{clk}(s)e^{-sT_{d1b}}$$

Eye Closure at Receiver Due to Signals at Clock and Data Ports:

Eq.(3) $$Y_{ec}(s) = \{[X_{clk}(s)H_1(s)e^{-sT_{d1a}} + X_{tx}(s) + X_{med}(s)] - [X_{clk}(s)e^{-sT_{d1b}}][H_2(s)e^{-sT_{d2}}]\} \bullet H_3(s)$$

$$= (X_{dm}(s) - X_{clk}(s)H_2(s)e^{-sT_{d2}}) \bullet H_3(s)$$

Where $X_{clk}(s)$ is the reference clock transfer function, T_{d1a} is the delay from the reference clock to the data port, T_{d1b}, is the delay from the reference clock to the test port, $X_{tx}(s)$ is the driver/latch transfer function, and $X_{med}(s)$ is the interconnect transfer function. Where the RX PLL transfer function $H_2(s)$ and the PI transfer function $H_3(s)$ are the same as those defined in the *PCI Express Base Specification* with parameters that give rise to the largest eye closure $Y_{ec}(s)$. The delay T_{d2} is swept from –3 ns to 3 ns – consistent with the maximum transport delay that can occur in the Add-in Card.

Use the following procedure for the two-port measurement methodology:

1. Gather Data from test port 1 and test port 2 to obtain the spectrum $X_{dm}(s)$ and $X_{cm}(s)$ or equivalent.
2. Calculate the eye closure $Y_{ec}(s)$ or $Y_{ec}(t)$ based on equation 3. T_{d2} is swept from -3 ns to 3 ns. $H_3(s)$ is defined in the *PCI Express Base Specification*. $H_2(s)$ is one of the following values:

$$H_2(s) = \frac{2\zeta\omega_{n2}s + \omega_{n2}^2}{s^2 + 2\zeta\omega_{n2}s + \omega_{n2}^2}$$

$$where: \zeta = 0.54\,(3\,dB\,PK), \omega_{n2} = 8.61 * 2\pi\,(16MHz\,3dB\,BW)\ \ Mrad/s \text{ or}$$

$$\zeta = 0.54\,(3\,dB\,PK), \omega_{n2} = 4.31 * 2\pi\,(8\,Mhz\,3dB\,BW)\,Mrad/s \text{ or}$$

$$\zeta = 1.16\,(1\,dB\,PK), \omega_{n2} = 1.82 * 2\pi\,(5\,MHz\,3dB\,BW)\,Mrad/s$$

3. Calculate the eye closure at BER=10^{-12} based on $Y_{ec}(t)$. The maximum eye closure for any parameters of $T_{d2\ and}$ $H_2(s)$ in the defined ranges is the total jitter assigned to the system board Transmitter, Transmitter interconnect, and the reference clock.

Table 25: System Board Transmitter Path Compliance Eye Requirements at 5.0 GT/s

Parameter	Min	Max	Unit	Comments
V_{TXS} V_{TXS_d}	225 225	1200 1200	mV	Notes 1, 2, 4 Notes 1, 2, 4
T_{TXS} (with crosstalk) T_{TXS} (without crosstalk)	95 108		ps ps	Notes 1, 3, 4

Notes:

1. All Links are assumed active while generating this eye diagram. The eye diagram requires that CMM pattern (*PCI Express Base Specification,* Chapter 4) is being transmitted during the test using the de-emphasis level that the system board will use in normal operation.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{TXS_d}). V_{TXS} and V_{TXS_d} are minimum differential peak-peak output voltages.
3. T_{TXS} is the minimum eye width. The recommended sample size for the dual port measurement is at least 10^6 UI. The minimum eye opening at BER 10^{-12} is calculated based on the measured data and must exceed T_{TXS}. If the system board uses non-interleaved routing, then crosstalk will be present in the measured data. If the system uses interleaved routing, then crosstalk will not be present, and an adjusted minimum eye width is used.
4. The values in Table 25 are referenced to an ideal 100 Ω differential load at the end of an isolated 2-inch 85 Ω differential trace behind a standard PCI express edge-finger. This channel shall be referenced as the 5.0 GT/s System Board Test Channel. Exact conditions required for verifying compliance while generating this eye diagram are given in the *PCI Express® Architecture, PHY Test Specification*.

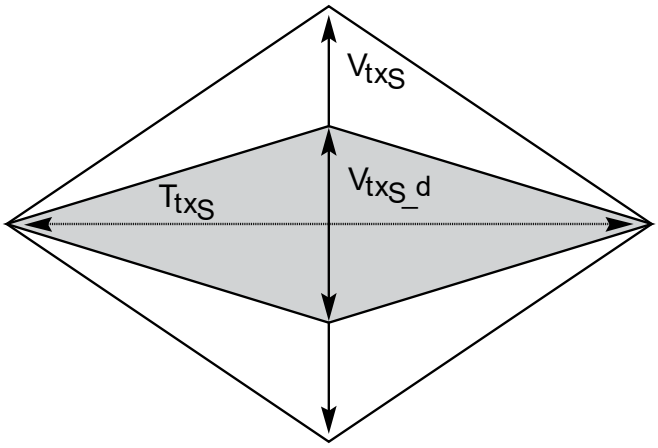


Figure 26: 5.0 GT/s System Board Transmitter Path Composite Compliance Eye Diagram

The system board total jitter for the transmitter, transmitter interconnect and the reference clock must meet the requirements in Table 26 when decomposed into random and deterministic jitter.

Table 26: System Board Jitter Requirements for 5.0 GT/s Signaling

	Max Rj (ps RMS)	Max Dj (ps)	Tj at BER 10^{-12} (ps)
With crosstalk	3.41	57	105
Without crosstalk	3.41	44	92

4.8.12. System Board Transmitter Path Compliance Eye Diagram at 8.0 GT/s

The system board shall pass the eye diagram requirements with at least one of the TX equalization presets defined in the *PCI Express Base Specification*. The eye diagram requirements are evaluated after the behavioral CDR and the behavioral RX Equalization Algorithm defined in the *PCI Express Base Specification*, are applied.

The system board Transmitter path measurements at 8.0 GT/s are made using a two-port measurement methodology. Figure 27 shows a functional block diagram for a system board and Add-in Card that shows the measurement points for the two-port method.

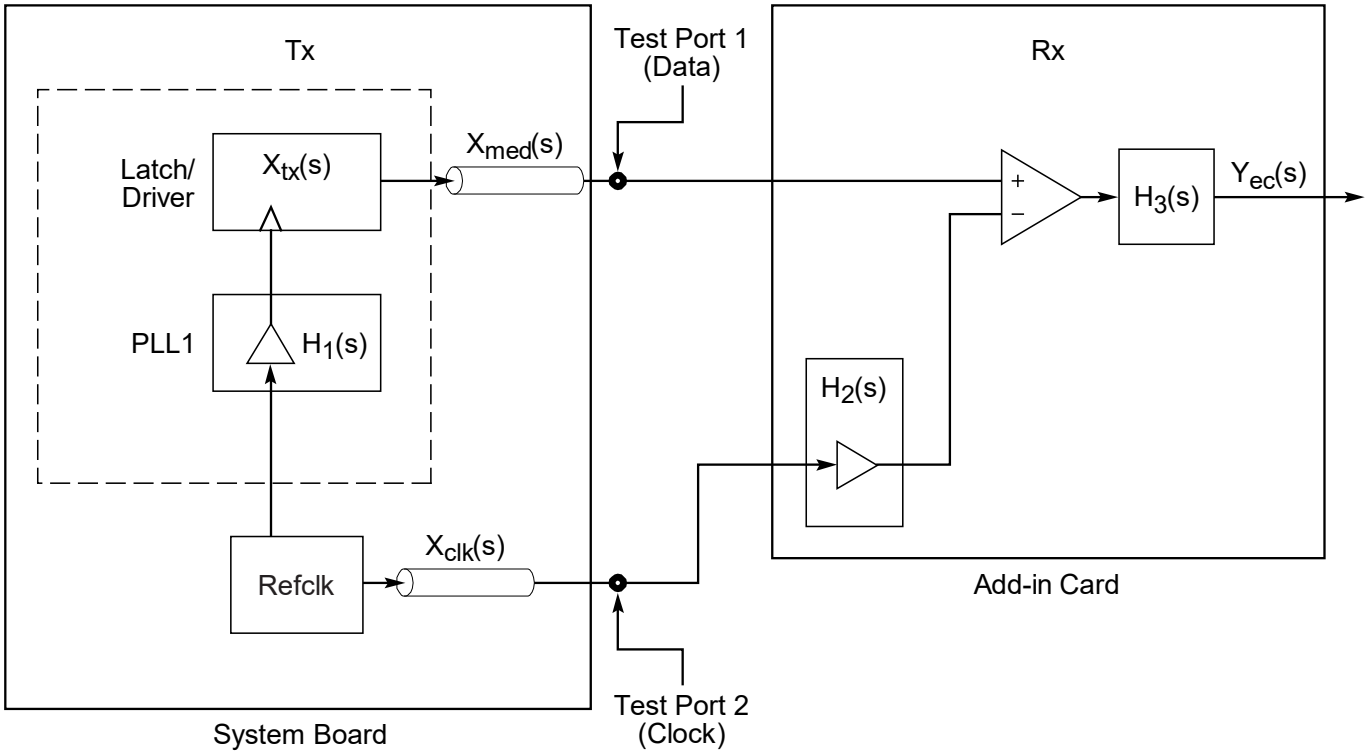


Figure 27: 8.0 GT/s Two Port Measurement Functional Block Diagram

Equations for the jitter at test port 1 and test port 2 and the eye closure at the Add-in Card Receiver from the test port signals are provided as follows:

Data Port Measurement (Test Port 1):

$$\text{Eq.(1)} \qquad X_{dm}(s) = X_{clk}(s)H_1(s)e^{-sT_{d1a}} + X_{tx}(s) + X_{med}(s)$$

Clock Port Measurement (Test Port 2):

$$\text{Eq.(2)} \qquad X_{cm}(s) = X_{clk}(s)e^{-sT_{d1b}}$$

Eye Closure at Receiver Due to Signals at Clock and Data Ports:

Eq.(3) $$Y_{ec}(s) = \{[X_{clk}(s)H_1(s)e^{-sT_{d1a}} + X_{tx}(s) + X_{med}(s)] - [X_{clk}(s)e^{-sT_{d1b}}][H_2(s)e^{-sT_{d2}}]\} \bullet H_3(s)$$

$$= (X_{dm}(s) - X_{clk}(s)H_2(s)e^{-sT_{d2}}) \bullet H_3(s)$$

Where $X_{clk}(s)$ is the reference clock transfer function, T_{d1a} is the delay from the reference clock to the data port, T_{d1b} is the delay from the reference clock to the test port, $X_{tx}(s)$ is the driver/latch transfer function, and $X_{med}(s)$ is the interconnect transfer function. Where the RX PLL transfer function $H_2(s)$, and PI transfer function $H_3(s)$ are the same as those defined in the *PCI Express Base Specification* with parameters that give rise to the largest eye closure $Y_{ec}(s)$. The delay T_{d2} is swept from –3 ns to 3 ns – consistent with the maximum transport delay that can occur in the Add-in Card.

The two-port measurement methodology is performed according to the following steps:

1. Data is gathered from test port 1 and test port 2 to obtain the spectrum Xdm(s) and Xcm(s) or equivalent.
2. The eye closure Yec(s) or Yec (t) is calculated based on equation 3. Td2 is swept from -3 ns to 3 ns. H3(s) is defined in the *PCI Express Base Specification*. H2(s) is one of the following values:

$$H_2(s) = \frac{2\zeta\omega_{n2}s + \omega_{n2}^2}{s^2 + 2\zeta\omega_{n2}s + \omega_{n2}^2}$$

$$where: \zeta = 0.73\ (2\ dB\ PK),\ \omega_{n2} = 6.1\ (2\ MHz\ \ 3dB\ BW)\ \ Mrad/s \text{ or}$$

$$\zeta = 0.73\ (2\ dB\ PK),\ \omega_{n2} = 12.2\ (4\ Mhz\ \ 3dB\ BW)\ Mrad/s \text{ or}$$

$$\zeta = 1.15\ (1\ dB\ PK),\ \omega_{n2} = 11.53\ (5\ Mhz\ \ 3dB\ BW)\ Mrad/s$$

Calculate the eye closure at BER = 10^{-12} based on Y_{ec} (t). The maximum eye closure for any parameters of T_{d2} and $H_2(s)$ in the defined ranges is the total jitter assigned to the system board Transmitter, Transmitter interconnect and the reference clock.

Table 27: System Board Transmitter Path Compliance Eye Requirements at 8.0 GT/s with Ideal Adaptive TX Equalization

Parameter	Min	Max	Unit	Comments
V_{TXS} V_{TXS_d}	34 34	1200 1200	mV	Notes 1, 2, 4 Notes 1, 2, 4
T_{TXS}	41.25		ps	Notes 1, 3, 4

Notes:

1. All Links are assumed active while generating this eye diagram. The eye diagram requires that the compliance pattern in 128b/130b (refer to the *PCI Express Base Specification,* Chapter 4) is being transmitted during the test.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{TXA_d}). V_{TXS} and V_{TXS_d} are minimum differential peak-peak output voltages. The voltage measurements are done at a BER of 10^{-12}. For lab use, an informative voltage limit (V_{TXS} and V_{TXS_d}) at a BER of 10^{-6} is 46 mV.
3. T_{TXS} is the minimum eye width. The recommended sample size for this measurement is at least 10^6 UI. This calculated eye width at BER 10^{-12} must meet or exceed T_{TXS}.
4. The values in Table 27 are referenced to an ideal 100 Ω differential load at the end of an isolated (no crosstalk) test channel consisting of 4.0 inches of 85 Ω trace, followed by a reference receiver package behind a standard PCI Express edge-finger. This channel shall be referenced as the 8.0 GT/s System-Board Test Channel. The s-parameters for the channel are provided with this specification. Additional loss from the measurement set-up must be removed. The System-Board Test Channel is a reference channel for testing and does not represent the worst possible channel that could be implemented on a CEM compliant Add-in Card.

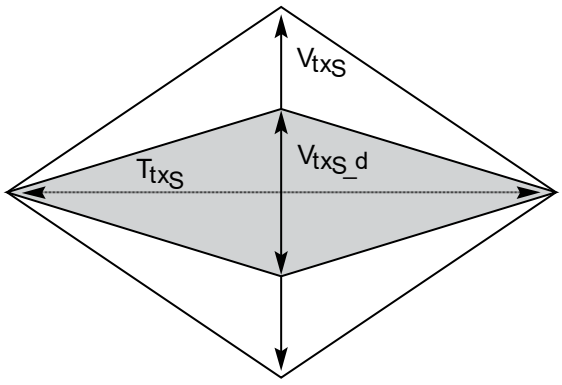


Figure 28: 8.0 GT/s System Board Transmitter Path Composite Compliance Eye Diagram

4.8.13. System Board Transmitter Path Compliance Eye Diagram at 16.0 GT/s

The system board shall pass the eye diagram requirements with at least one of the TX equalization presets defined in the *PCI Express Base Specification*. The eye diagram requirements are evaluated after the behavioral CDR and the behavioral RX Equalization Algorithm defined in the *PCI Express Base Specification* are applied.

The system board Transmitter path measurements at 16.0 GT/s are made using a two-port measurement methodology. Figure 29 shows a functional block diagram for a system board and Add-in Card that shows the measurement points for the two-port method.

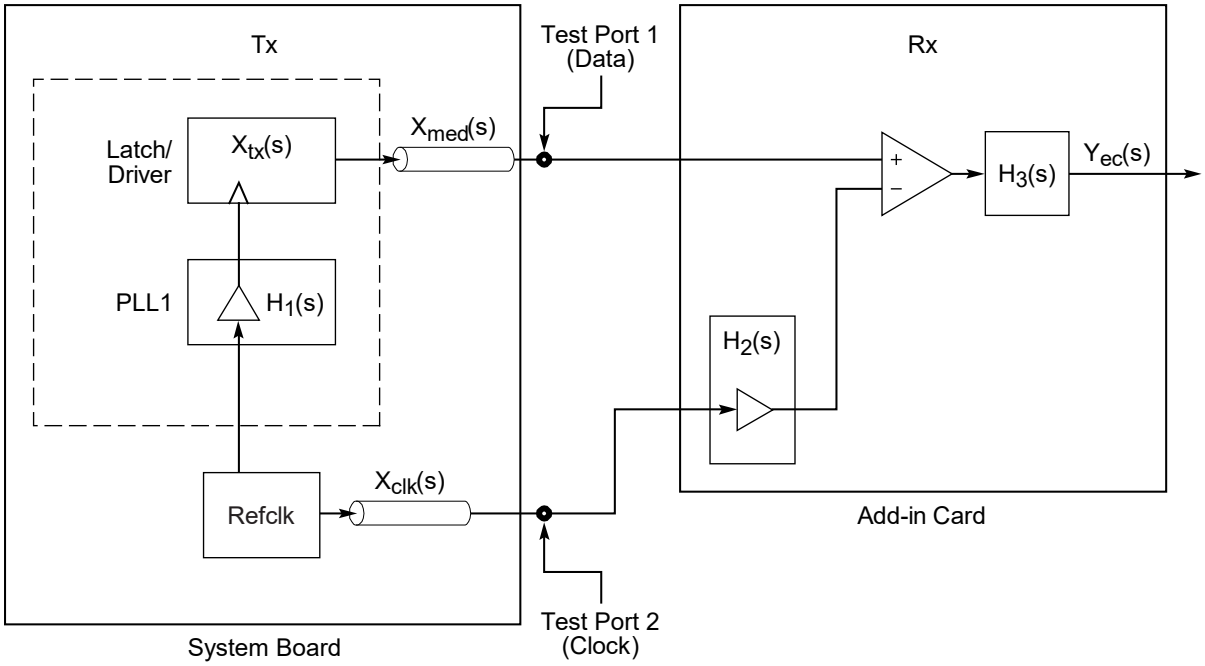


Figure 29: 16.0 GT/s Two Port Measurement Functional Block Diagram

Equations for the jitter at test port 1 and test port 2 and the eye closure at the Add-in Card Receiver from the test port signals are provided as follows:

Data Port Measurement (Test Port 1):

$$\text{Eq.(1)} \qquad X_{dm}(s) = X_{clk}(s)H_1(s)e^{-sT_{d1a}} + X_{tx}(s) + X_{med}(s)$$

Clock Port Measurement (Test Port 2):

$$\text{Eq.(2)} \qquad X_{cm}(s) = X_{clk}(s)e^{-sT_{d1b}}$$

Eye Closure at Receiver Due to Signals at Clock and Data Ports:

$$\text{Eq.(3)} \quad Y_{ec}(s) = \{[X_{clk}(s)H_1(s)e^{-sT_{d1a}} + X_{tx}(s) + X_{med}(s)] - [X_{clk}(s)e^{-sT_{d1b}}][H_2(s)e^{-sT_{d2}}]\} \bullet H_3(s)$$

$$= (X_{dm}(s) - X_{clk}(s)H_2(s)e^{-sT_{d2}}) \bullet H_3(s)$$

Where $X_{clk}(s)$ is the reference clock transfer function, T_{d1a} is the delay from the reference clock to the data port, T_{d1b} is the delay from the reference clock to the test port, $X_{tx}(s)$ is the driver/latch transfer function, and $X_{med}(s)$ is the interconnect transfer function. Where the RX PLL transfer function $H_2(s)$, and PI transfer function $H_3(s)$ are the same as those defined in the *PCI Express Base Specification* with parameters that give rise to the largest eye closure $Y_{ec}(s)$. The delay T_{d2} is swept from –3 ns to 3 ns – consistent with the maximum transport delay that can occur in the Add-in Card.

The two-port measurement methodology is performed according to the following steps:

- Data is gathered from test port 1 and test port 2 to obtain the spectrum $X_{dm}(s)$ and $X_{cm}(s)$ or equivalent.
- The eye closure $Y_{ec}(s)$ or $Y_{ec}(t)$ is calculated based on equation 3. T_{d2} is swept from -3 ns to 3 ns. $H_3(s)$ is defined in Figure 30 of the *PCI Express Base Specification*. $H_2(s)$ is one of the following values:

$$H_2(s) = \frac{2\zeta\omega_{n2}s + \omega_{n2}^2}{s^2 + 2\zeta\omega_{n2}s + \omega_{n2}^2}$$

$$where: \zeta = 0.73\ (2\ dB\ PK),\ \omega_{n2} = 6.1\ (2\ MHz\ \ 3dB\ BW)\ \ Mrad/s \text{ or}$$

$$\zeta = 0.73\ (2\ dB\ PK),\ \omega_{n2} = 12.2\ (4\ Mhz\ \ 3dB\ BW)\ Mrad/s \text{ or}$$

$$\zeta = 1.15\ (1\ dB\ PK),\ \omega_{n2} = 11.53\ (5\ Mhz\ \ 3dB\ BW)\ Mrad/s$$

- Calculate the eye closure at BER = 10^{-12} based on Yec (t). The maximum eye closure for any parameters of Td2 and H2(s) in the defined ranges is the total jitter assigned to the system board Transmitter, Transmitter interconnect and the reference clock.

Table 28: System Board Transmitter Path Compliance Eye Requirements at 16.0 GT/s with Ideal Adaptive TX Equalization

Parameter	Min	Max	Unit	Comments
V_{TXS} V_{TXS_d}	19.0 19.0	1200 1200	mV	Notes 1, 2, 4 Notes 1, 2, 4
T_{TXS}	21.75		ps	Notes 1, 3, 4

Notes:

1. All Links are assumed active while generating this eye diagram. The eye diagram requires that the compliance pattern in 128b/130b (refer to the *PCI Express Base Specification,* Chapter 4) is being transmitted during the test.
2. Transition and non-transition bits must be measured compliance against the de-emphasized voltage level (V_{TXS_d}). V_{TXS} and V_{TXS_d} are minimum differential peak-peak output voltages. The voltage measurements are done at a BER of 10^{-12}. The recommended sample size for this measurement is at least 2 x 10^6 UI.
3. T_{TXS} is the minimum eye width. The recommended sample size for this measurement is at least 2 x 10^6 UI. This calculated eye width at BER 10^{-12} must meet or exceed T_{TXS}.
4. The values in Table 27 are referenced to an ideal 100 Ω differential load at the end of an isolated (no crosstalk) test channel consisting of 5 dB of 85 Ω trace, at 8GHz, followed by a non-root reference package behind a standard PCI Express edge-finger. This channel shall be referenced as the 16.0 GT/s System-Board Test Channel. The s-parameters for the channel are provided with this specification. Additional loss from the measurement set-up must be removed. The System-Board Test Channel is a reference channel for testing and does not represent the worst possible channel that could be implemented on a CEM compliant Add-in Card.

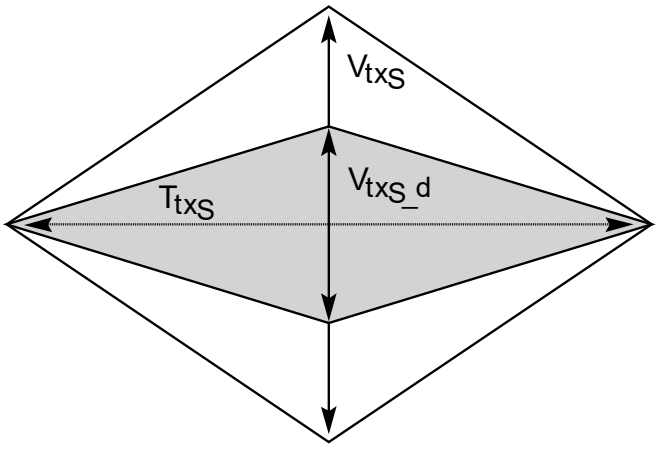


Figure 30: 16.0 GT/s System Board Transmitter Path Composite Compliance Eye Diagram

4.8.14. System Board Minimum Receiver Path Sensitivity Requirements at 2.5 GT/s

The minimum sensitivity values for the system board's Receiver path compliance at 2.5 GT/s are defined in Table 29. A representative eye diagram is shown in Figure 31.

Table 29: System Board Minimum Receiver Path Sensitivity Requirements at 2.5 GT/s

Parameter	Min	Max	Unit	Comments
V_{RXS} V_{RXS_d}	445 312	1200 1200	mV mV	Notes 1, 2, 5 Notes 1, 2, 5
T_{RXS} $J_{RXS\text{-}MEDIAN\text{-}to\text{-}MAX\text{-}JITTER}$	287 56.5		ps ps	Notes 1, 3, 5 Notes 1, 4, 5

Notes:

1. An ideal reference clock without jitter is assumed for this specification. All Links are assumed active while generating this eye diagram.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{RXS_d}). V_{RXS} and V_{RXS_d} are differential peak-peak output voltages.
3. T_{RXS} is the eye width. The sample size for this measurement is 10^6 UI. This value can be reduced to 274 ps for simulation purpose at BER 10^{-12}.
4. $J_{RXS\text{-}MEDIAN\text{-}to\text{-}MAX\text{-}JITTER}$ is the maximum median-to-peak jitter outlier as defined in *the PCI Express Base Specification*. The sample size for this measurement is 10^6 UI. This value can be increased to 63 ps for simulation purpose at BER 10^{-12}.
5. The values in Table 29 are referenced to an ideal 100 Ω differential load at the end of 3-inch 85 Ω differential isolated traces behind a standard connector. The resultant values, when provided to the Receiver interconnect path of the system board, allow for a demonstration of compliance of the overall system board Receiver path. The sensitivity requirements are defined and centered with respect to the jitter median. Exact conditions required for verifying compliance while generating this eye diagram are given in the *PCI Express® Architecture, PHY Test Specification, Revision 4.0* document.

4.8.15. System Board Minimum Receiver Path Sensitivity Requirements at 5.0 GT/s

The minimum sensitivity values for the system board's Receiver path compliance at 5.0 GT/s for a link that operates with 3.5 dB de-emphasis are defined in Table 28. For the system board's Receiver path compliance at 5.0 GT/s for a link that operates with 6.0 dB de-emphasis see Table 29. A representative eye diagram is shown in Figure 31.

Table 30: System Board Minimum Receiver Path Sensitivity Requirements at 5.0 GT/s for a Link that Operates with 3.5 dB De-emphasis

Parameter	Min	Max	Unit	Comments
V_{RXS} V_{RXS_d}	380 380	1200 1200	mV mV	Notes 1, 2, 3 Notes 1, 2, 3
1.5 – 100 MHz RMS Jitter	1.4		ps RMS	
< 1.5 MHz RMS Jitter	3.0		ps RMS	
1.5 – 100 MHz Dj	30		ps PP	
> 100 MHz Dj	27		ps PP	

Notes:

1. All Links are assumed active while generating this eye diagram.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{RXS_d}). V_{RXS} and V_{RXS_d} are differential peak-peak output voltages.
3. The values in Table 30 are calibrated with a reference channel consisting of a 5.0 GT/s System Board Test Channel followed by a 5.0 GT/s Add-in Card Test Channel. After reference calibration, the 5.0 GT/s Add-in Card Test Channel is removed, and a standard PCI Express edge-finger is placed into the PCI Express connector to be tested. The resultant values, when provided to the Receiver interconnect path of the system board, allow for a demonstration of compliance of the overall system board Receiver path. The exact setup and methodology for injecting this signal into the Receiver interconnect path of the system board are not specified. The values in Table 30 may need to be adjusted based on the exact test setup and methodology. For example, if the impedance of the test setup does not create the worst-case mismatch that could be present with a real Add-in Card or the test setup does not provide crosstalk (only a single Lane is tested, etc.), the values in Table 19 must be adjusted accordingly.

Table 31: System Board Minimum Receiver Path Sensitivity Requirements at 5.0 GT/s for a Link that Operates with 6.0 dB De-emphasis

Parameter	Min	Max	Unit	Comments
V_{RXS}	306	1200	mV	Notes 1, 2, 3
V_{RXS_d}	260	1200	mV	Notes 1, 2, 3
1.5 – 100 MHz RMS Jitter	1.4		ps RMS	
< 1.5 MHz RMS Jitter	3.0		ps RMS	
1.5 – 100 MHz Dj	30		ps PP	
> 100 MHz Dj	27		ps PP	

Notes:

1. All Links are assumed active while generating this eye diagram.
2. Transition and non-transition bits must be distinguished to measure compliance against the de-emphasized voltage level (V_{RXS_d}). V_{RXS} and V_{RXS_d} are differential peak-peak output voltages.
3. The values in Table 31 are referenced to an ideal 100 Ω differential load behind 3 inches of isolated 85 Ω trace and a standard PCI Express connector. After reference calibration, the reference fixture is removed, and a standard PCI Express edge finger is placed into the PCI Express connector to be tested. The resultant values, when provided to the Receiver interconnect path of the system board, allow for a demonstration of compliance of the overall system board Receiver path. The exact setup and methodology for injecting this signal into the Receiver interconnect path of the system board are not specified. The values in Table 31 may need to be adjusted based on the exact test setup and methodology. For example, if the impedance of the test setup does not create the worst-case mismatch that could be present with a real Add-in Card or the test setup does not provide crosstalk (only a single Lane is tested, etc.), the values in Table 19 must be adjusted accordingly.

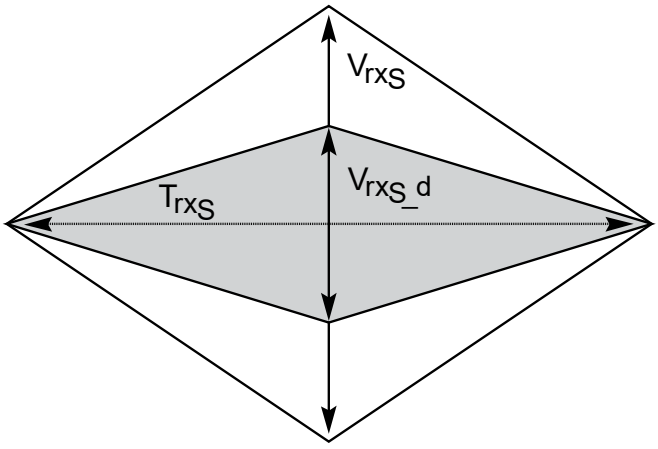


Figure 31: 2.5 GT/s and 5.0 GT/s Representative Composite Eye Diagram for System Board Receiver Path Compliance

4.8.16. System Board Minimum Receiver Path Sensitivity Requirements at 8.0 GT/s

The minimum sensitivity values for the system board Receiver path compliance at 8.0 GT/s are defined in Table 32. The receiver path shall be tested with a worst-case eye to verify that it achieves a BER < 10^{-12}. This worst-case eye is calibrated using TX equalization settings that are optimal with the reference equalizer for the calibration channel. After calibration, the test-generator's equalization settings may be adjusted using the transmitter equalization setting in the required TX equalization space preferred by the device under test, without changing any other parameter of the test signal or recalibrating the test signal.

If the test generator's TX equalization settings are adjusted away from the optimal settings and the test generator is not able to change transmitter equalization without impacting other calibrated parameters – then the other parameters must be adjusted back to the specified values.

If the test is not run in a way that produces the worst-case cross-talk that would be present with all lanes active, the additional cross-talk must be accounted for in some other way.

While the receiver's capacity to adapt its own equalization is part of the test described above, its ability to request the link partner's transmitter to change its equalization settings is tested by applying a signal whose equalization settings are sub-optimal compared to the jitter sensitivity test signal described above. For this signal, the reference receiver would not be able to achieve proper equalization by means of its own CTLE and DFE alone. Such a signal can be defined using the signal resulting from the calibration method described above and adjusting the test-generator equalization. If the RX under test is more capable than the reference (CTLE+DFE) receiver, the RX may not require the TX to change its equalization levels to achieve a BER < 10^{-12}. In any case, equalization settings resulting from this procedure shall be used for the above RX test and, if the RX requires the TX equalization to change, the change accommodates the test set-up used.

A specific methodology for this procedure is outside the scope of this specification.

Table 32: System Board Minimum Receiver Path Sensitivity Requirements at 8.0 GT/s

Parameter	Min	Max	Unit	Comments
$V_{RX\text{-}EH\text{-}8G}$ Eye height	34	34	mV	Notes 1, 2, 4
$T_{RX\text{-}EH\text{-}8G}$ Eye width	.33	.38	UI	Notes 1, 2
Rj (Random Jitter)	3		ps RMS	Notes 5, 6
Sj (Sinusoidal Jitter) 100 MHz	12.5		ps PP	Note 6
Differential Mode Sinusoidal Interference 2.1 GHz	14		mV PP	Note 3

Notes:

1. The system board reference clock is assumed for this specification. The 128/130b compliance pattern must be used during calibration for this test. Modified compliance pattern is used when the receiver test is run. Eye height and width values refer to BER = 10^{-12}.
2. The values in this table are initially calibrated with a reference channel consisting of an 8.0 GT/s System Board Test Channel followed by 8.0 GT/s Add-in Card Test Channel at the TX SMP connectors on the Add-in Card Test Channel. The calibration is done with the same post processing as the Add-in Card 8.0 GT/s TX test. After reference calibration, the 8.0 GT/s Add-in Card Test Channel is removed, and the System Board Test Channel is connected to the System Board to be tested.
3. Eye height and width are specified after the application of the reference receiver. When the optimization of the reference receiver's CTLE and DFE yields an eye height and/or eye width larger than specified, the value for DM-interference is increased.
4. Eye height limits do not account for limitations in test equipment voltage resolution.
5. Rj is applied over the following range. The low frequency limit may be between 1.5 and 10 MHz, and the upper limit is 1.0 GHz. While the nominal value is specified at 3.0 ps RMS, it may be adjusted to meet the value for $T_{RX\text{-}EH\text{-}8G}$ Eye Width.
6. Rj and Sj are measured without post-processing filters.

4.8.17. System Board Minimum Receiver Path Sensitivity Requirements at 16.0 GT/s

The minimum sensitivity values for the system board Receiver path compliance at 16.0 GT/s are defined in Table 33. The receiver path shall be tested with a worst-case eye to verify that it achieves a BER < 10^{-12}. This worst-case eye is calibrated using TX equalization settings that are optimal with the reference equalizer for the calibration channel. After calibration, the test-generator's equalization settings may be adjusted using the transmitter equalization setting in the required TX equalization space preferred by the device under test, without changing any other parameter of the test signal or recalibrating the test signal. This adjustment is done through running the PCI Express training protocol.

If the test generator's TX equalization settings are adjusted away from the optimal settings and the test generator is not able to change transmitter equalization without impacting other calibrated parameters – then the other parameters must be adjusted back to the calibrated values.

If the test is not run in a way that produces the worst-case cross-talk that would be present with all lanes active, the additional cross-talk must be accounted for in some other way.

Table 33: System Board Minimum Receiver Path Sensitivity Requirements at 16.0 GT/s

Parameter	Min	Max	Unit	Comments
$V_{RX-EH-16G}$ Eye height	15	15	mV	Notes 1, 2, 4
$T_{RX-EH-16G}$ Eye width	0.3	0.3	UI	Notes 1, 2
Rj (Random Jitter)	1.0		ps RMS	Notes 5, 6
Sj (Sinusoidal Jitter) 100 MHz	6.25		ps PP	Note 6
Differential Mode Sinusoidal Interference 2.1 GHz	14		mV PP	Note 3

Notes:

1. The system board reference clock is assumed for this specification. The 128/130b compliance pattern must be used during calibration for this test. Modified compliance pattern is used when the receiver test is run. Eye height and width values refer to BER = 10^{-12}.
2. The values in this table are initially calibrated with a reference channel consisting of a 16.0 GT/S System Board Test Channel followed by a 16.0 GT/s Add-in Card Test Channel. After reference calibration, the 16.0 GT/s Add-in Card Test Channel is removed, and the 16.0 GT/s System Board Test Channel is connected to the system board to be tested. The end to end CEM calibration channel must meet the requirements (insertion loss and return loss masks) defined for the 16.0 GT/s calibration channel in the *PCI Express Base Specification*.
3. Eye height and width are specified after the application of the reference receiver. $V_{RX-EH-16G}$ and $T_{RX-EH-16G}$ are adjusted following the same process described in the *PCI Express Base Specification* for calibrating the 16.0 GT/s stressed eye test. When the channel insertion loss is varied as part of the 16.0 GT/s stressed eye calibration process the variation must occur in the 16.0 GT/s System Board Test Channel portion of the channel.
4. Eye height limits do not account for limitations in test equipment voltage resolution.
5. Rj is applied over the following range. The low frequency limit may be between 1.5 and 10 MHz, and the upper limit is 1.0 GHz.
6. Rj and Sj are measured without post-processing filters.

5

5. 150 W, 225 W, and 300 W Add-in Card Power

A PCI Express 150 W Add-in Card must adhere to strict power distribution, power-up, and power consumption requirements to ensure robust operation. Power may only be drawn using two techniques: the standard PCI Express connector and the dedicated 150 W power connector defined in this specification.

It is necessary for a PCI Express 150 W Add-in Card to be seamlessly integrated with a 150 W- capable system to ensure interoperability. To that end, it is required that the 150 W Add-in Card be properly powered in the system. To guarantee proper operation and provide a safe user experience, the following power delivery requirements must be adhered to by a PCI Express 150 W Add-in Card:

- The +12 V delivered from the standard connector and the additional +12 V delivered via the dedicated 2 x 3 connector must be treated as coming from two separate system power supply rails.
- The two +12 V input potentials must not be electrically shorted at any point on a PCI Express 150 W Add-in Card.
- No specific power sequencing between the slot and 2 x 3 connector power can be assumed. A PCI Express 150 W Add-in Card must handle all possible combinations.

IMPLEMENTATION NOTE

Safety Certifications

PCI Express 150 W Add-in Cards and capable systems must adhere to all applicable safety certifications (e.g., UL 240 VA).

A PCI Express 225 W/300 W Add-in Card must adhere to strict power distribution, power-up, and power consumption requirements to ensure robust operation. Power must only be drawn using the three specified connectors: the standard PCI Express connector, the 2 x 4 connector, and the 2 x 3 connector as defined in this specification.

It is necessary for a PCI Express 225 W/300 W Add-in Card to be seamlessly integrated with a 225 W/300 W capable system to ensure interoperability. To that end, it is required that the card be properly powered in the system. To guarantee proper operation and provide a safe user experience, the following power delivery requirements must be adhered to by a PCI Express 225 W/300 W Add-in Card:

- The +12 V delivered from the PCI Express connector and the additional +12 V delivered via the dedicated 2 x 3 and/or 2 x 4 connector(s) must be treated as coming from independent separate system power supply rails.
- The different +12 V input potentials from different connectors must not be electrically shorted at any point on a PCI Express 225 W/300 W Add-in Card.
- The power pins of a single 2 x 3 or 2 x 4 connector can be shorted together.
- No specific power sequencing between the slot, the 2 x 3 connector, and the 2 x 4 connector power can be assumed. A PCI Express 225 W/300 W Add-in Card must handle all possible combinations. A 300 W Add-in Card can receive power by the following methods:
  - 75 W from the PCI Express connector plus 150 W from a 2 x 4 connector plus 75 W from a 2 x 3 connector.
  - 75 W from the PCI Express connector plus 75 W from a first 2 x 3 connector, plus 75 W from a second 2 x 3 connector, plus 75 W from a third 2 x 3 connector.
  - 225 W Add-in Card can receive power by one of the following methods: 75 W from the PCI Express connector plus 150 W from a 2 x 4 connector.
  - 75 W from the PCI Express connector plus 75 W from a 2 x 4 connector plus 75 W from a 2 x 3 connector.
  - 75 W from the PCI Express connector plus 75 W from a first 2 x 3 connector plus 75 W from a second 2 x 3 connector.

IMPLEMENTATION NOTE

Auxiliary Power Connector Configurations for 225 W / 300 W Add-in Cards

PCI Express 225 W/300 W Add-in Cards have a wide variety of power delivery configurations to choose from. This flexibility will lower the cost of migration as certain existing components (e.g., power supply units) can be reused.

- PCI Express 225 W / 300 W Add-in Cards and capable systems must adhere to all applicable safety certifications (e.g., UL 240 VA).

5.1. 150 W Add-in Card Power-Up Sequencing

The following specified power-up sequencing process permits a PCI Express 150 W Add-in Card to sense if the PCI Express 150 W connector is plugged in and then initially draw up to a maximum of 75 W. This methodology allows a PCI Express 150 W Add-in Card to circumvent the 25 W maximum power consumption that is required for all Add-in Cards prior to being enabled for higher power consumption via a Slot Power Limit message.

The system power-up sequencing follows the Slot Power Limit Control mechanism as defined in Chapter 6 of the *PCI Express Base Specification*. An overview of power-up sequencing is shown in Figure 32.

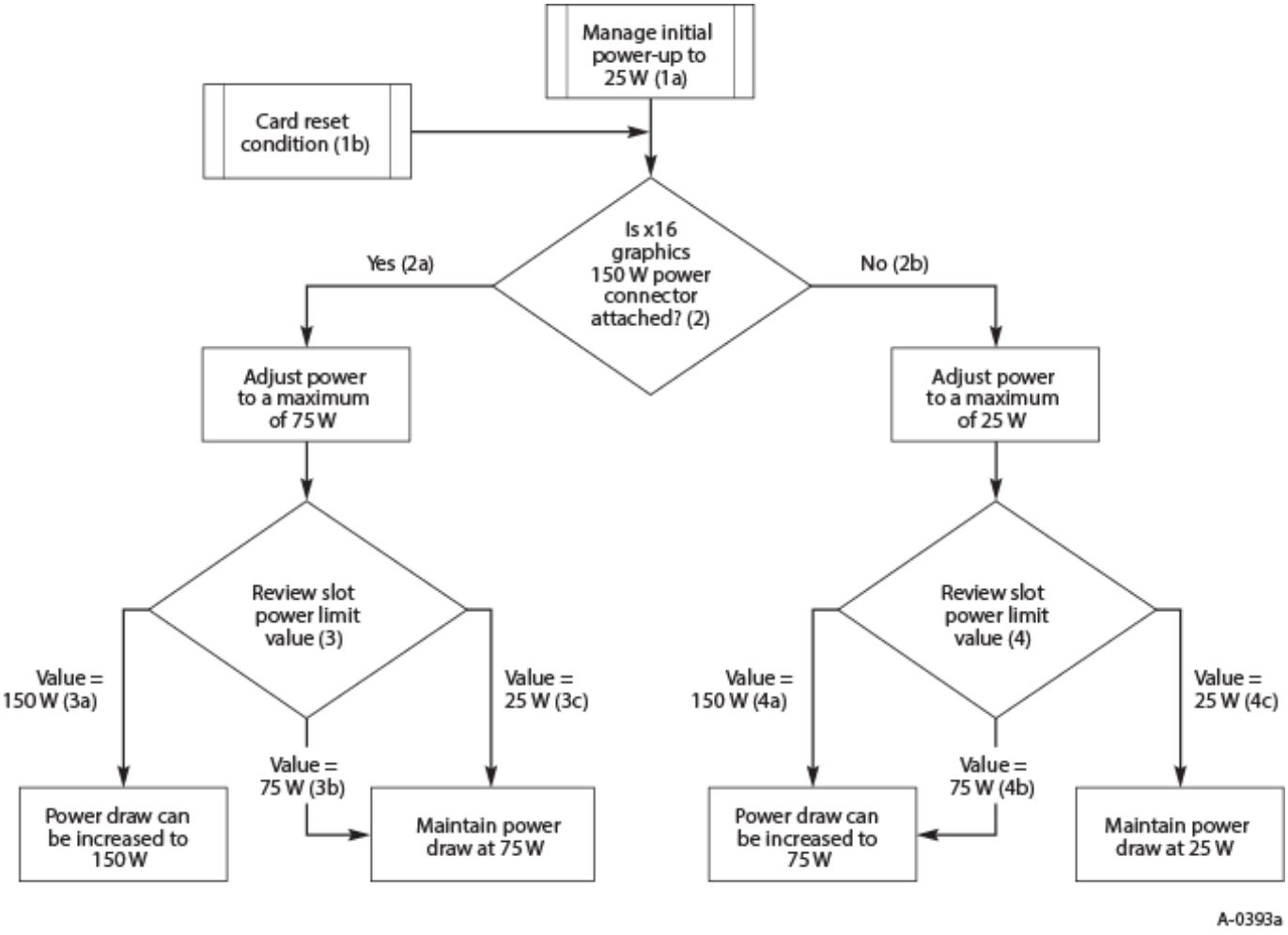


Figure 32: PCI Express 150 W Add-in Card Power-Up Sequence

The following is the system power-up sequence. An overview of the power-up sequence is shown in Figure 32.

1. Initial power-up or reset condition.
   - At initial power-up, manage maximum power to ≤ 25 W maximum for sensing of the PCI Express 150 W power connector.
   - An Add-in Card cannot remember a previous power limit setting through a reset. A card that has been reset must start the process over again as with initial power application. (Total power in this state will be dependent on the Slot Power Limit Value prior to the reset.)
2. Detect if a PCI Express 150 W power connector is plugged into the Add-in Card using the allocated Sense pin.
   - Yes. If the connector is installed, then the PCI Express 150 W Add-in Card can be adjusted to a combined maximum of 75 W of power using the PCI Express 150 W power connector and the PCI Express connector. In this situation, a maximum of 25 W can be drawn from the connector. Proceed to step 3.
   - No. If the PCI Express 150 W power cable is not connected, then power consumption must be adjusted to a maximum of 25 W. Proceed to step 4.
3. Review Slot Power Limit Value. PCI Express 150 W power connector was sensed.
   - Value = 150 W. If the received slot power message indicates 150 W, a PCI Express 150 W Add-in Card can proceed to draw up to a maximum of 150 W. This is a total of 75 W from the PCI Express connector and 75 W via the dedicated PCI Express 150 W power connector.
   - Value = 75 W. If the received slot power message indicates 75 W, power consumption must be maintained at a combined maximum of 75 W of power using the PCI Express x16 150 W power connector and the connector. In this situation, a maximum of 25 W can be drawn from the connector.
   - Value = 25 W. If the received slot power message indicates 25 W or if no slot power message is received, then power consumption must be maintained at a combined maximum of 75 W of power using the PCI Express 150 W power connector and the connector. In this situation, a maximum of 25 W can draw from the connector.
4. Review Slot Power Limit Value. PCI Express 150 W power connector was not sensed.
   - Value = 150 W. If the received slot power message indicates 150 W, power consumption can be increased to a maximum of 75 W via power from the connector.
   - Value = 75 W. If the received slot power message indicates 75 W, power consumption can be increased to a maximum of 75 W via power from the connector.
   - Value = 25 W. If the received slot power message indicates 25 W or if no slot power message is received, total power must be managed to a maximum of 25 W at all times.

Intermediate values, not included in the discrete Slot Power Limit Values listed above, are forbidden.

IMPLEMENTATION NOTE

Power-up Sequencing Configuration Issues

Steps 3b, 3c, 4a, 4b, and 4c above are configurations in the power-up sequencing for a PCI Express 150 W Add-in Card that result in less than the full 150 W of power being available to the Add-in Card. Any operation such as actual display to a connected output device, whether VGA or otherwise, at less than 150 W is not guaranteed and is implementation dependent. However, it is recommended that at least an implementation supplied warning text message be displayed to alert the user of the configuration issue.

Power Distribution and Consumption

PCI Express 150 W Add-in Cards must follow a stringent set of rules for power distribution to the card and power consumption of the card. Drawing power from the system in any way that is not specified is not allowed as is consuming power above the maximum of 150 W.

5.2. 225 W and 300 W Add-in Card Power-Up Sequencing

The following specified power-up sequencing process permits a PCI Express 225 W/300 W Add-in Card to sense if the auxiliary connectors are plugged in and identify the initial power draw limit. This methodology allows a PCI Express 225 W/300 W Add-in Card to circumvent the 25 W maximum power consumption that is required in this specification for an Add-in Card prior to being enabled for higher power consumption via a Slot Power Limit message.

The system power-up sequencing follows the Slot Power Limit Control mechanism as defined in Chapter 6 of the *PCI Express Base Specification.* The power-up sequencing for a 225 W/300 W card is as follows:

Immediately after system reset and before the card has determined which supplemental power connectors are attached, the card power is limited to 25 W which must be drawn from the PCI Express slot.

At system power up, the permitted initial power draw depends on the auxiliary power connector configurations on the card and how many sense pins are detected. Table 34 to Table 38 enumerate the different possibilities.

After system reset is released and the PCI Express Link is up, the card will receive the Slot_Power_Limit message.

- If the Slot_Power_Limit is bigger than or equal to the permitted initial power draw, the card can then draw power up to the Slot_Power_Limit in any order from the PCI Express connector, the 2 x 3 connector (if it exists), and the 2 x 4 connector (if it exists), subject to and limited to the individual power ratings of the respective connectors.
- If the Slot_Power_Limit is smaller than the permitted initial power draw, the card can ignore the Slot_Power_Limit message and continue to draw the same amount of power as permitted at system power up time.

1705 **Table 34: PCI Express 300 W Card (with One 2 x 4 and One 2 x 3 Connector)**
1706 **Permitted Initial Power Draw**

2 x 4 Sense0 Detected?	2 x 4 Sense1 Detected?	2 x 3 Sense Detected?	Power Draw Permitted at System Power Up
N	N	N	25 W available from PCI Express connector
N	N	Y	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from 2 x 3 connector
Y	N	N	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from 2 x 4 connector
Y	N	Y	Total of 125 W is available: 25 W available from PCI Express connector 50 W available from 2 x 3 connector 50 W available from 2 x 4 connector
Y	Y	N	Total of 125 W is available: 25 W available from PCI Express connector 100 W available from 2 x 4 connector
Y	Y	Y	Total of 175 W is available: 25 W available from PCI Express connector 100 W available from 2 x 4 connector 50 W available from 2 x 3 connector

1707

1708 **Table 35: PCI Express 300 W Card (with Three 2 x 3 Connectors)**
1709 **Permitted Initial Power Draw**

First 2 x 3 Sense Detected?	Second 2 x 3 Sense Detected?	Third 2 x 3 Sense Detected?	Power Draw Permitted at System Power Up
N	N	N	25 W available from PCI Express connector
N	N	Y	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from 2 x 3 connector
N	Y	N	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from 2 x 3 connector
Y	N	N	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from 2 x 3 connector
Y	N	Y	Total of 125 W is available: 25 W available from PCI Express connector 50 W available from the first 2 x 3 connector 50 W available from the third 2 x 3 connector

First 2 x 3 Sense Detected?	Second 2 x 3 Sense Detected?	Third 2 x 3 Sense Detected?	Power Draw Permitted at System Power Up
Y	Y	N	Total of 125 W is available: 25 W available from PCI Express connector 50 W available from the first 2 x 3 connector 50 W available from the second 2 x 3 connector
N	Y	Y	Total of 125 W is available: 25 W available from PCI Express connector 50 W available from the second 2 x 3 connector 50 W available from the third 2 x 3 connector
Y	Y	Y	Total of 175 W is available: 25 W available from PCI Express connector 50 W available from the first 2 x 3 connector 50 W available from the second 2 x 3 connector 50 W available from the third 2 x 3 connector

Table 36: PCI Express 225 W Card (with One 2 x 4 Connector) Permitted Initial Power Draw

2 x 4 Sense0 Detected?	2 x 4 Sense1 Detected?	Power Draw Permitted at System Power Up
N	N	25 W available from PCI Express connector
Y	N	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from 2 x 4 connector
Y	Y	Total of 125 W is available: 25 W available from PCI Express connector 100 W available from 2 x 4 connector

Table 37: PCI Express 225 W Card (with Two 2 x 3 Connectors) Permitted Initial Power Draw

First 2 x 3 Sense Detected?	Second 2 x 3 Sense Detected?	Power Draw Permitted at System Power Up
N	N	25 W available from PCI Express connector
N	Y	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from second 2 x 3 connector
Y	N	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from first 2 x 3 connector
Y	Y	Total of 125 W is available: 25 W available from PCI Express connector 50 W available from first 2 x 3 connector 50 W available from second 2 x 3 connector

Table 38: PCI Express 225 W Card (with One 2 x 3 and One 2 x 4 Connector) Permitted Initial Power Draw

2 x 4 Sense0 Detected?	2 x 4 Sense1 Detected?	2 x 3 Sense Detected?	Power Draw Permitted at System Power Up
N	N	N	25 W available from PCI Express connector
N	N	Y	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from 2 x 3 connector
Y	N	N	Total of 75 W is available: 25 W available from PCI Express connector 50 W available from 2 x 4 connector
Y	N	Y	Total of 125 W is available: 25 W available from PCI Express connector 50 W available from 2 x 3 connector 50 W available from 2 x 4 connector
Y	Y	N	Total of 125 W is available: 25 W available from PCI Express connector 100 W available from 2 x 4 connector
Y	Y	Y	Total of 175 W is available: 25 W available from PCI Express connector 100 W available from 2 x 4 connector 50 W available from 2 x 3 connector

For a 225 W/300 W Add-in Card, if the 2 x 3 or 2 x 4 connector is not populated in such a way that results in the full 225 W/300 W power being available to the graphics Add-in Card, any graphics operation and actual display to a connected output device, whether VGA or otherwise, is not guaranteed and is implementation dependent. However, it is preferred that an implementation supplied warning text message is displayed to alert the user of the configuration issue.

6

6. Card Connector Specification

A family of PCI Express vertical edge card connectors supports x1, x4, x8, and x16 Link widths to suit different bandwidth requirements. These connectors support the PCI Express signal and power requirements, as well as auxiliary signals used to facilitate the interface between the system board and Add-in Card hardware. This chapter defines the connector mating interfaces and footprints, as well as the electrical, mechanical, and environmental requirements.

6.1. Connector Pinout

Table 39 shows the pinout definition for the x1, x4, x8, and x16 PCI Express connectors. The auxiliary pins are identified in the shaded areas.

Table 39: PCI Express Connectors Pinout

Pin #	Side B		Side A	
	Name	Description	Name	Description
1	+12V	+12 V power	PRSNT1#	Hot-Plug presence detect
2	+12V	+12 V power	+12V	+12 V power
3	+12V	+12 V power	+12V	+12 V power
4	GND	Ground	GND	Ground
5	SMBCLK	SMBus (System Management Bus) clock	JTAG2	TCK (Test Clock), clock input for JTAG interface
6	SMBDAT	SMBus (System Management Bus) Data	JTAG3	TDI (Test Data Input)
7	GND	Ground	JTAG4	TDO (Test Data Output)
8	+3.3V	+3.3 V power	JTAG5	TMS (Test Mode Select)
9	JTAG1	TRST# (Test Reset) resets the JTAG interface	+3.3V	+3.3 V power
10	+3.3Vaux	+3.3 V auxiliary power	+3.3V	+3.3 V power
11	WAKE#	Signal for Link reactivation	PERST#	Fundamental reset
Mechanical Key				
12	CLKREQ#	Clock Request Signal	GND	Ground
13	GND	Ground	REFCLK+	Reference clock (differential pair)
14	PETp0	Transmitter differential pair, Lane 0	REFCLK-	
15	PETn0		GND	Ground
16	GND	Ground	PERp0	Receiver differential pair, Lane 0
17	PRSNT2#	Hot-Plug presence detect	PERn0	
18	GND	Ground	GND	Ground
End of the x1 Connector				
19	PETp1	Transmitter differential pair, Lane 1	RSVD	
20	PETn1		GND	Ground
21	GND	Ground	PERp1	Receiver differential pair, Lane 1
22	GND	Ground	PERn1	
23	PETp2	Transmitter differential pair, Lane 2	GND	Ground
24	PETn2		GND	Ground

Pin #	Side B		Side A	
	Name	Description	Name	Description
25	GND	Ground	PERp2	Receiver differential pair, Lane 2
26	GND	Ground	PERn2	
27	PETp3	Transmitter differential pair, Lane 3	GND	Ground
28	PETn3		GND	Ground
29	GND	Ground	PERp3	Receiver differential pair, Lane 3
30	PWRBRK#	Emergency Power Reduction	PERn3	
31	PRSNT2#	Hot-Plug presence detect	GND	Ground
32	GND	Ground	RSVD	Reserved
End of the x4 connector				
33	PETp4	Transmitter differential pair, Lane 4	RSVD	Reserved
34	PETn4		GND	Ground
35	GND	Ground	PERp4	Receiver differential pair, Lane 4
36	GND	Ground	PERn4	
37	PETp5	Transmitter differential pair, Lane 5	GND	Ground
38	PETn5		GND	Ground
39	GND	Ground	PERp5	Receiver differential pair, Lane 5
40	GND	Ground	PERn5	
41	PETp6	Transmitter differential pair, Lane 6	GND	Ground
42	PETn6		GND	Ground
43	GND	Ground	PERp6	Receiver differential pair, Lane 6
44	GND	Ground	PERn6	
45	PETp7	Transmitter differential pair, Lane 7	GND	Ground
46	PETn7		GND	Ground
47	GND	Ground	PERp7	Receiver differential pair, Lane 7
48	PRSNT2#	Hot-Plug presence detect	PERn7	
49	GND	Ground	GND	Ground
End of the x8 Connector				
50	PETp8	Transmitter differential pair, Lane 8	RSVD	Reserved
51	PETn8		GND	Ground
52	GND	Ground	PERp8	Receiver differential pair, Lane 8
53	GND	Ground	PERn8	
54	PETp9	Transmitter differential pair, Lane 9	GND	Ground
55	PETn9		GND	Ground
56	GND	Ground	PERp9	Receiver differential pair, Lane 9
57	GND	Ground	PERn9	
58	PETp10	Transmitter differential pair, Lane 10	GND	Ground
59	PETn10		GND	Ground
60	GND	Ground	PERp10	Receiver differential pair, Lane 10
61	GND	Ground	PERn10	
62	PETp11	Transmitter differential pair, Lane 11	GND	Ground
63	PETn11		GND	Ground
64	GND	Ground	PERp11	Receiver differential pair, Lane 11
65	GND	Ground	PERn11	
66	PETp12	Transmitter differential pair, Lane 12	GND	Ground
67	PETn12		GND	Ground
68	GND	Ground	PERp12	Receiver differential pair, Lane 12
69	GND	Ground	PERn12	
70	PETp13	Transmitter differential pair, Lane 13	GND	Ground
71	PETn13		GND	Ground
72	GND	Ground	PERp13	Receiver differential pair, Lane 13
73	GND	Ground	PERn13	
74	PETp14	Transmitter differential pair, Lane 14	GND	Ground
75	PETn14		GND	Ground
76	GND	Ground	PERp14	Receiver differential pair, Lane 14
77	GND	Ground	PERn14	

Pin #	Side B		Side A	
	Name	Description	Name	Description
78	PETp15	Transmitter differential pair, Lane 15	GND	Ground
79	PETn15		GND	Ground
80	GND	Ground	PERp15	Receiver differential pair, Lane 15
81	PRSNT2#	Hot-Plug presence detect	PERn15	
82	RSVD	Reserved	GND	Ground
End of the x16 Connector				

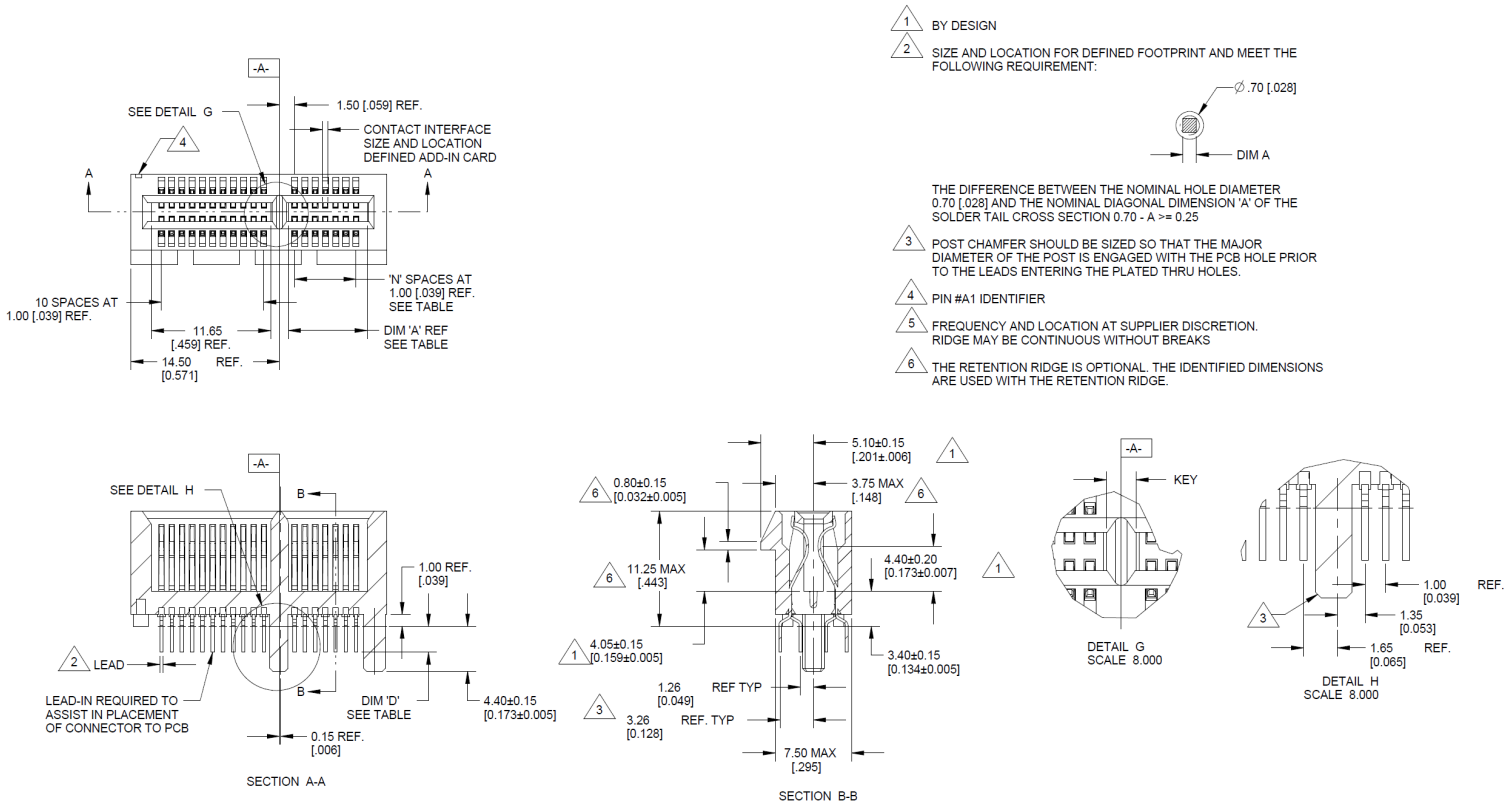
Additional requirements:

- All Add-in Card edge fingers must be present for pins A1/B1 through A82/B82. Depopulating connector pins and AIC edge fingers is never allowed, except for a connector that supports a narrower link width than the mechanical length of the connector slot. For example, a x16 mechanical card edge with a x8 electrical width.
- The pins are numbered as shown in Figure 34 in ascending order from the left to the right, with side A on the top of the centerline and side B on the bottom of the centerline.
- The PCI Express interface pins PETpx, PETnx, PERpx, and PERnx are named with the following convention: "PE" stands for PCI Express *high speed*, "T" for *Transmitter*, "R" for *Receiver*, "p" for *positive* (+), and "n" for *negative* (-).
- By default, PETpx and PETnx pins (the Transmitter differential pair of the connector) must be connected to the PCI Express Transmitter differential pair on the system board, and to the PCI Express Receiver differential pair on the Add-in Card.
- By default, PERpx and PERnx pins (the Receiver differential pair of the connector) shall be connected to the PCI Express Receiver differential pair on the system board, and to the PCI Express Transmitter differential pair on the Add-in Card.
- However, the "p" and "n" connections may be reversed to simplify PCB trace routing and minimize vias if needed. All PCI-Express Receivers incorporate automatic Lane Polarity Inversion as part of the Link Initialization and Training and will correct the polarity independently on each Lane. Refer to the *PCI Express Base Specification*.
- If the component on the system board or Add-in Card does not support the optional PCI Express Lane Reversal functions, they must connect each Transmitter and Receiver Lane to the Add-in Card connector lanes as shown in Table 39. For example, a x4 component must connect Lane 0 to 0, Lane 1 to 1, Lane 2 to 2, and Lane 3 to 3.
- If the component on the system board or Add-in Card supports the optional PCI Express Lane Reversal function, it may connect each Transmitter and Receiver Lane to the Add-in Card connector lanes as shown in Table 39 or it may connect the Transmitter and Receiver lanes using a reversed Lane ordering. Either Lane ordering may be used to simplify PCB trace routing and minimize vias. However, the transmitting and receiving lanes must connected with the same Lane ordering. For example, a x4 component may connect Lane 0 to 0, Lane 1 to 1, Lane 2 to 2, and Lane 3 to 3 or it may connect Lane 0 to 3, Lane 1 to 2, Lane 2 to 1, and Lane 3 to 0.
- The connectors and the Add-in Cards are keyed such that smaller Add-in Cards can be put in larger connectors. For example, a x1 card can be inserted into the x4, x8, and x16 connectors. This is referred to as up-plugging.
- Two ground pins separate adjacent differential pairs to manage the connector crosstalk.
- See Chapter 2 for auxiliary signals description and implementation, except the +3.3Vaux and PRSNT1# and PRSNT2# pins. The requirements for +3.3Vaux are discussed in Chapter 4 and presence detect is discussed in Chapter 3.

- PRSNT1# and PRSNT2# pins are for card presence detect. One presence detect pin at each end of a connector guarantees that at least one of the presence detect pins is last-mate/first-break. Additional PRSNT2# pins in the x4, x8, and x16 PCI Express connectors are for supporting up-plugging. See Chapter 3 for detailed discussions on presence detect.
- The sequential mating for Hot-Plug is accomplished by staggering the edge-fingers on the Add-in Card, as shown in Section 6.2. Detailed requirements on Hot-Plug are covered in Chapter 3.
- Power pins (+3.3V, +3.3Vaux, and +12V) are defined based on the PCI Express power delivery requirements specified in Chapter 4, with the connector contact carrying capability being 1.1 A per pin. The power that goes through the connector shall not exceed the maximum power specified for a given Add-in Card size, as defined in Section 4.2.
- If an optional pin function not implemented, that pin must not be used for any other purpose. Similarly, pins designated as RSVD must not be tasked for any other function.

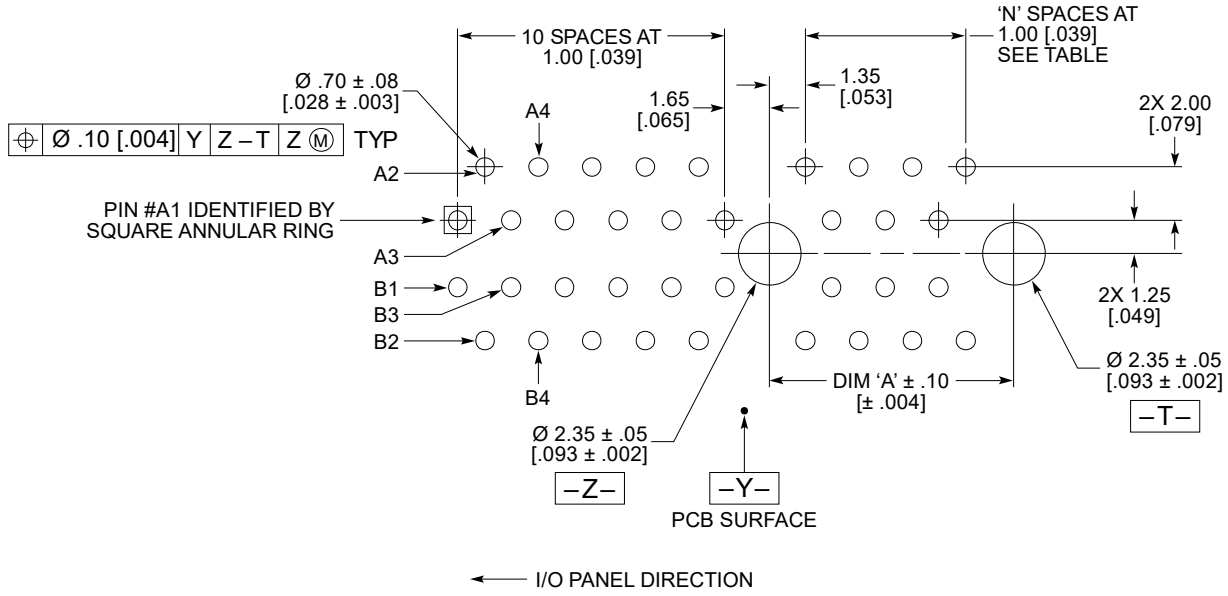
6.2. Connector Interface Definitions

The PCI Express through-hole connector outline and footprint are shown in Figure 33 and Figure 34. For clarity, sentry vias, which are ground placed adjacent to auxiliary and reserved signal pins, are not depicted in Figure 34. Sentry via requirements are detailed in 9.3.1. The surface mount connector outline and footprint are shown in Figure 35 and Figure 36. The Add-in Card edge-finger dimensions are shown in Figure 37. The Add-in Card edge-finger dimensions are independent of the connector mounting style.



CONNECTOR LINK WIDTH	#POS REF	N	DIM 'A'	DIM 'B'	DIM 'C'	PCB THK REF	DIM 'D'
X1	36	6	7.65 [.301]	25.00 [.984]	9.15 [.360]	1.58 [.062]	2.30 +.25/-.13 [.091 +.010/-.005]
X4	64	20	21.65 [.852]	39.00 [1.535]	23.15 [.911]		
X8	98	37	38.65 [1.522]	56.00 [2.205]	40.15 [1.581]	2.36 [.093]	3.10 +.25/-.13 [.122 +.010/-.005]
X16	164	70	71.65 [2.821]	89.00 [3.504]	73.15 [2.880]		

Figure 33: Through-Hole Mount Connector Outline

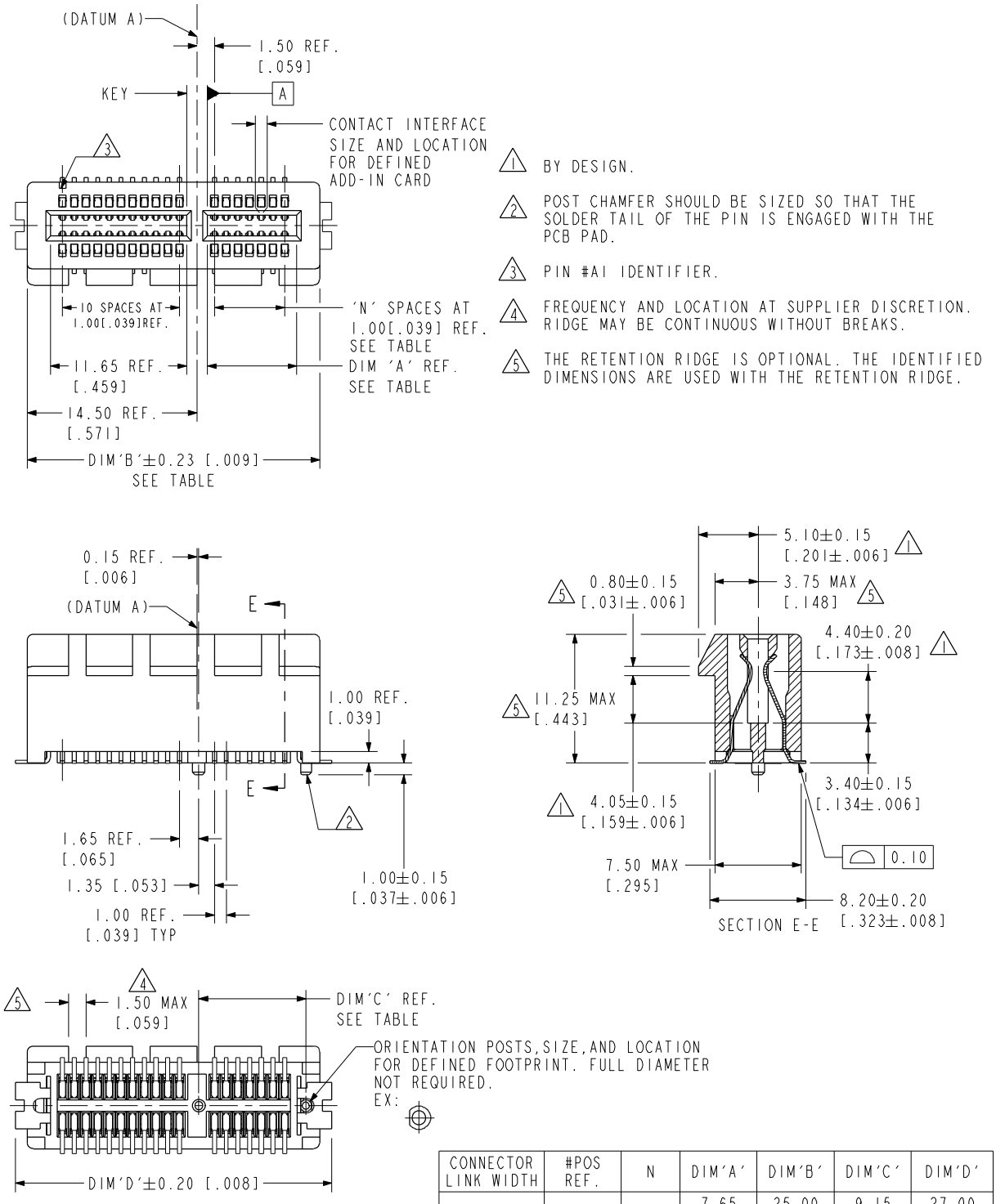


CONNECTOR LINK WIDTH	# POS REF	N	DIM 'A'
X1	36	6	9.15 [.360]
X4	64	20	23.15 [.911]
X8	98	37	40.15 [1.581]
X16	164	70	73.15 [2.880]

A-0900

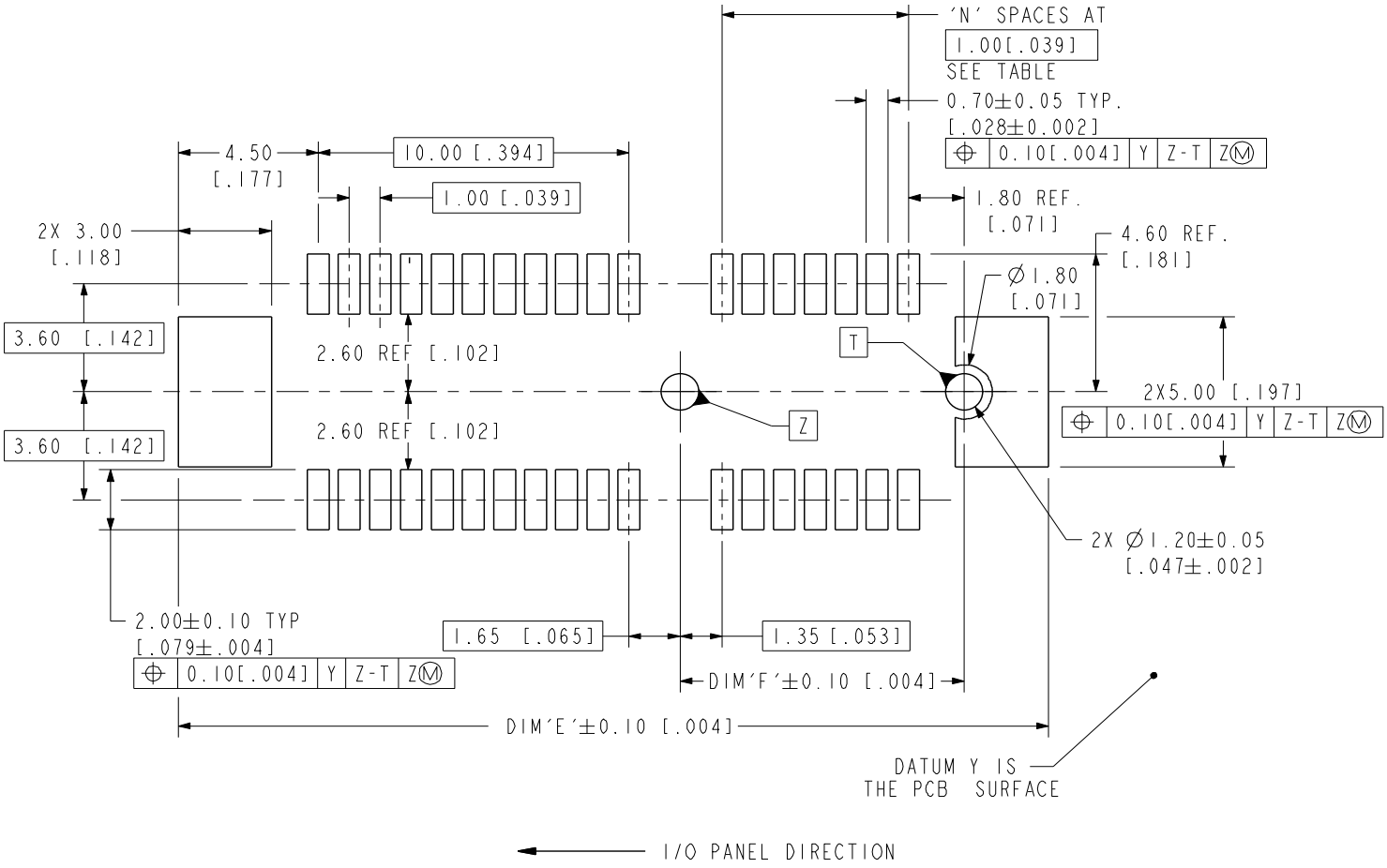
Note: Sentry vias are not shown.

Figure 34: Through-Hole Mount Connector Footprint



CONNECTOR LINK WIDTH	#POS REF.	N	DIM'A'	DIM'B'	DIM'C'	DIM'D'
X1	36	6	7.65 [.301]	25.00 [.984]	9.15 [.360]	27.00 [1.063]
X4	64	20	21.65 [.852]	39.00 [1.535]	23.15 [.911]	41.00 [1.614]
X8	98	37	38.65 [1.522]	56.00 [2.205]	40.15 [1.581]	58.00 [2.283]
X16	164	70	71.65 [2.821]	89.00 [3.504]	73.15 [2.880]	91.00 [3.583]

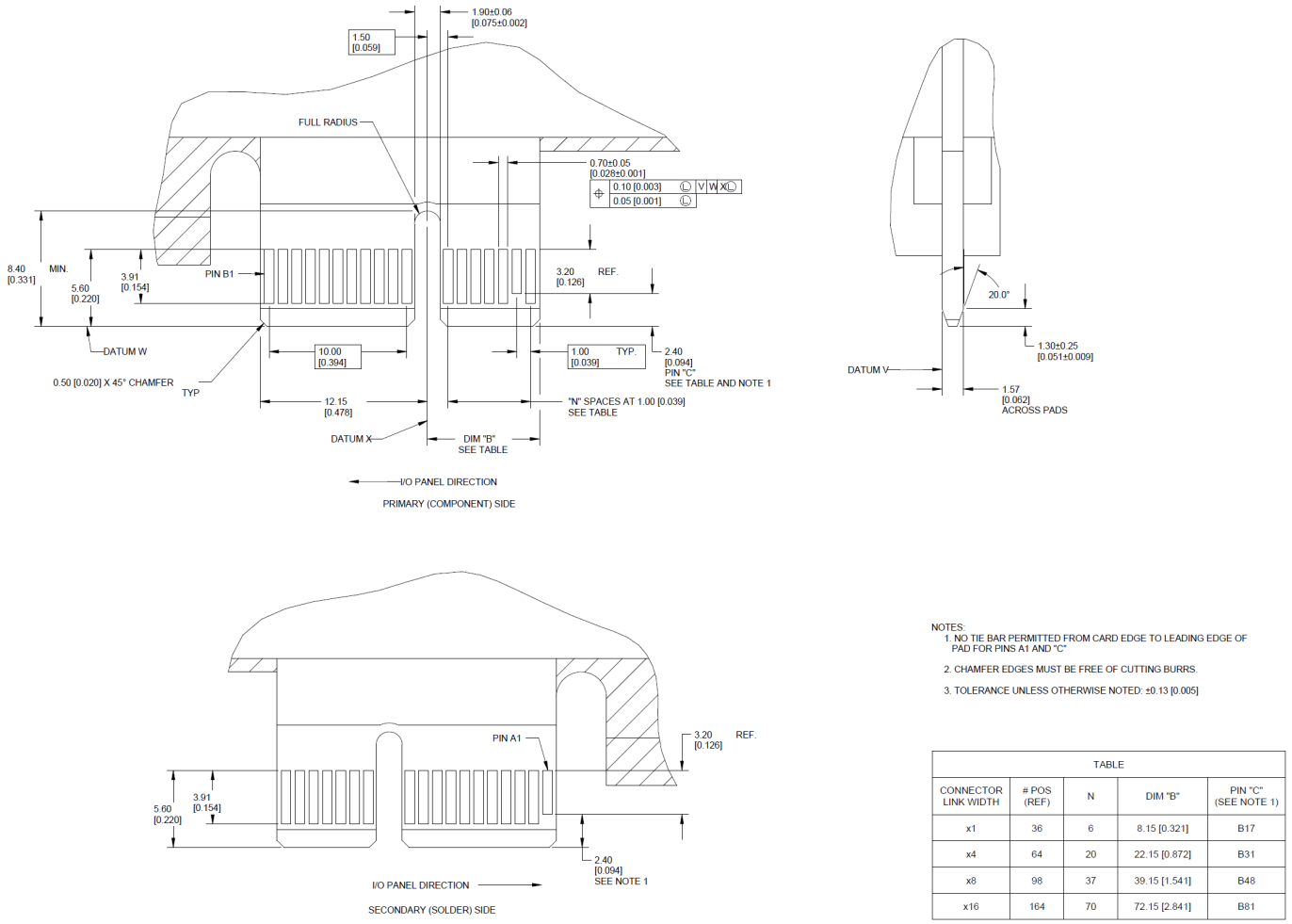
Figure 35: Surface Mount Connector Outline



CONNECTOR LINK WIDTH	#POS REF.	N	DIM'E'	DIM'F'
X1	36	6	28.00 [1.102]	9.15 [.360]
X4	64	20	42.00 [1.654]	23.15 [.911]
X8	98	37	59.00 [2.323]	40.15 [1.581]
X16	164	70	92.00 [3.622]	73.15 [2.880]

NOTE: TOLERANCE UNLESS OTHER NOTED IS ±0.13 [0.005].

Figure 36: Surface Mount Connector Footprint – Alignment holes and mechanical tabs are optional



NOTES:
1. NO TIE BAR PERMITTED FROM CARD EDGE TO LEADING EDGE OF PAD FOR PINS A1 AND "C"
2. CHAMFER EDGES MUST BE FREE OF CUTTING BURRS.
3. TOLERANCE UNLESS OTHERWISE NOTED: ±0.13 [0.005]

TABLE				
CONNECTOR LINK WIDTH	# POS (REF)	N	DIM "B"	PIN "C" (SEE NOTE 1)
x1	36	6	8.15 [0.321]	B17
x4	64	20	22.15 [0.872]	B31
x8	98	37	39.15 [1.541]	B48
x16	164	70	72.15 [2.841]	B81

Figure 37: Add-in Card Edge-Finger Dimensions

Be aware of the following points:

- The connector has a 1.00 mm contact pitch.
- The contact shall be pre-loaded.
- The system PCB through-hole mount connector footprint (Figure 34) requires two 2.35 mm diameter location holes, accepting either plastic or metal pegs/posts or metal board locks. The two 2.35 mm diameter location holes may either be drilled or plated through-holes (PTH). Plated through-holes enable the soldering of a connector with metal guide posts to provide more secure retention for larger/heavier Add-in Cards. Metal board locks are also allowed, although Figure 33 shows only the plastic pegs on the connector housing.
- The surface mount technology connector footprint (Figure 36) requires two 1.20 mm holes, working with either plastic or metal pegs / posts or metal board locks. The two 1.20 mm diameter location holes may either be drilled or plated through-holes. The SMT footprint may omit the pegs for the location holes.
- Figure 37 defines only the mating interface related dimensions. Other Add-in Card dimensions are defined in Chapter 9.
- The PRSNT1# and PRSNT2# edge fingers shown in Figure 37 are 3.20 mm long, 0.71 mm (Reference dimension) shorter than the other fingers. Those pins are designated as A1, B17, B31, B48, and B81, where applicable.

- As shown in Figure 33 and Figure 35, an optional ridge feature is defined on the top of the connector housing on one side. This feature can be used to facilitate card retention. A retention clip may be mounted on an Add-in Card and latched on the ridge.
- Two types of Add-in Cards must be "retention ready":
  – x1, x4, x8, or x16 I/O cards that, in the judgment of the OEM or card manufacturers, have sufficient weight or length that the card may need an additional retention point for stability.
  Retention ready means that the Add-in Card manufacturer must have selected (or created) a retention mechanism and made provisions on the card to facilitate the retention mechanism.
  – The full-length card, 321.00 mm (12.283 inches) long, is considered retention ready. The mounting holes on one end of the full-length card allow the optional PCI card retainer to be installed to secure the card (see Section 9.1).
- Detailed connector contacts and housing designs are up to each connector vendor, as long as the requirements of form, fit, and function are met.
- Straddle mount connectors (connectors that straddle the edge of a circuit board with one set of connections, with the "A" side, connected to pads on the the top of the board and the other set of connections "B" side connected to the bottom of the board) are not explicitly covered in this specification but can be considered similar to surface mount connectors for many purposes such as high speed signaling considerations.

6.3. Signal Integrity Requirements and Test Procedures

6.3.1. Signal Integrity Requirements

The following procedures (outlined in the *ANSI Electronics Industry Alliance (EIA) Standards* documents) shall be followed:

- EIA 364-101 – Attenuation Test Procedure for Electrical Connectors, Sockets, Cable Assemblies or Interconnection Systems
- EIA 364-90 – Crosstalk Ratio Test Procedure for Electrical Connectors, Sockets, Cable Assemblies or Interconnection Systems
- EIA 364-108 – Impedance, Reflection Coefficient, Return Loss, and VSWR Measured in the Time and Frequency Domain Test Procedure for Electrical Connectors, Sockets, Cable Assemblies or Interconnection Systems

6.3.2. Signal Integrity Requirements and Test Procedures for 2.5 GT/s Support

A common electrical test fixture is specified and used for evaluating connector signal integrity. The test fixture will have 0.1524 mm (6.0 mil) wide 50 Ω single ended traces that must be uncoupled. The impedance variation of those traces shall be controlled within ±5%. Refer to the *PCI Express Connector High Speed Electrical Test Procedure* for detailed discussions on the test fixture.

Detailed testing procedures are specified in the *PCI Express Connector High Speed Electrical Test Procedure.* This document must be used in conjunction with the standard test fixture.

For the insertion loss and return loss tests, the measurement shall include 1.2-inch long PCB traces (0.6 inches on the system board and 0.6 inches on the Add-in Card). The edge-finger pad is not counted as Add-in Card PCB trace; it is considered part of the connector interface. The 1.2-inch PCB trace included

in the connector measurement is a part of the trace length allowed on the system board. See Section 4.7 for a discussion of the electrical budget.

Either single ended measurements that are processed to extract the differential characteristics or true differential measurements are allowed. The detailed definition and description of the test fixture and the measurement procedures are provided separately in a document entitled *PCI Express Connector High Speed Electrical Test Procedure*.

An additional consideration for the connector electrical performance is the connector-to-system board and the connector to Add-in Card launches. The connector through-hole pad and antipad sizes shall follow good electrical design practices to minimize impedance discontinuity. On the Add-in Card, the ground and power planes underneath the PCI Express high-speed signals (edge-fingers) shall be removed. Otherwise, the edge-fingers will have too much capacitance and greatly degrade connector performance. A more detailed discussion on the Add-in Card electrical design can be found in the *PCI Express Connector High Speed Electrical Test Procedure*.

Table 40 lists the electrical signal integrity parameters, requirements, and test procedures.

Table 40: Signal Integrity Requirements and Test Procedures for 2.5 GT/s Support

Parameter	Procedure	Requirements
Differential Insertion Loss (DDIL)	EIA 364-101 The EIA standard must be used with the following considerations: 1. The step-by-step measurement procedure is outlined in the *PCI Express Connector High Speed Electrical Test Procedure* (see Note 1 below). 2. A common test fixture for connector characterization shall be used. 3. This is a differential insertion loss requirement. Either true differential measurements must be made or post processing of the single ended measurements must be done to extract the differential characteristics of the connector. The methodology of doing so is covered in the *PCI Express Connector High Speed Electrical Test Procedure* (Note 1).	≤ 1 dB up to 1.25 GHz; ≤ [1.6*(F-1.25) +1] dB for 1.25 GHz < f ≤ 3.75 GHz (for example, ≤5 dB at f = 3.75 GHz)
Differential Return Loss (DDRL)	EIA 364-108 The EIA standard must be used with the following considerations: 1. The step-by-step measurement procedure is outlined in the *PCI Express Connector High Speed Electrical Test Procedure* (Note 1). 2. A common test fixture for connector characterization shall be used. 3. This is a differential return loss requirement. Either true differential measurements must be made or post processing of the single ended measurements must be done to extract the differential characteristics of the connector. The methodology of doing so is covered in the *PCI Express Connector High Speed Electrical Test Procedure* (Note 1).	≤ -12 dB up to 1.3 GHz; ≤ -7 dB for 1.3 GHz < f ≤ 2 GHz; ≤ -4 dB for 2 GHz < f ≤ 3.75 GHz

Parameter	Procedure	Requirements
Intra-pair Skew	Intra-pair skew must be achieved by design; measurement not required.	5 ps max
Differential Near End Crosstalk: DDNEXT	EIA 364-90 The EIA standard must be used with the following considerations: 1. The crosstalk requirement is with respect to all the adjacent differential pairs including the crosstalk from opposite sides of the connector, as illustrated in Figure 38. This is reflected in the measurement procedure. 2. The step-by-step measurement procedure is outlined in the *PCI Express Connector High Speed Electrical Test Procedure*. 3. A common test fixture for connector characterization shall be used. 4. This is a differential crosstalk requirement between a victim differential signal pair and all of its adjacent differential signal pairs. Either true differential measurements must be made, or post processing of the single ended measurements must be done to extract the differential crosstalk of the connector. The methodology of doing so is covered in the *PCI Express Connector High Speed Electrical Test Procedure* (see Note 1).	≤ -32 dB up to 1.25 GHz; ≤ -[32-2.4*(F-1.25)] dB for 1.25 GHz < f ≤ 3.75 GHz (for example, ≤ -26 dB at f = 3.75 GHz)
Jitter	By design; measurement not required.	10 ps max

Notes:

1. The *PCI Express Connector High Speed Electrical Test Procedure* is available separately.
2. A typical approach to making these measurements is with a network analyzer or a TDR oscilloscope. Differential measurements require the use of a two port (or a four port) instrument to measure the connector. The differential parameters may be measured directly if the equipment supports “True” differential excitation (“True” differential excitation is the simultaneous application of a signal to one line of the pair and a 180-degree phase shifted version of the signal to the second line of the pair). If single ended measurements are made, the differential connector parameters must be derived from the single ended measurements as defined in *the PCI Express Connector High Speed Electrical Test Procedure*.
3. The connector shall be targeted for a 100 Ω differential impedance.

In Figure 38, pairs marked as 11-9, 5-7, 15-13, and 17-19 are the adjacent pairs with respect to the victim pair 1-3.

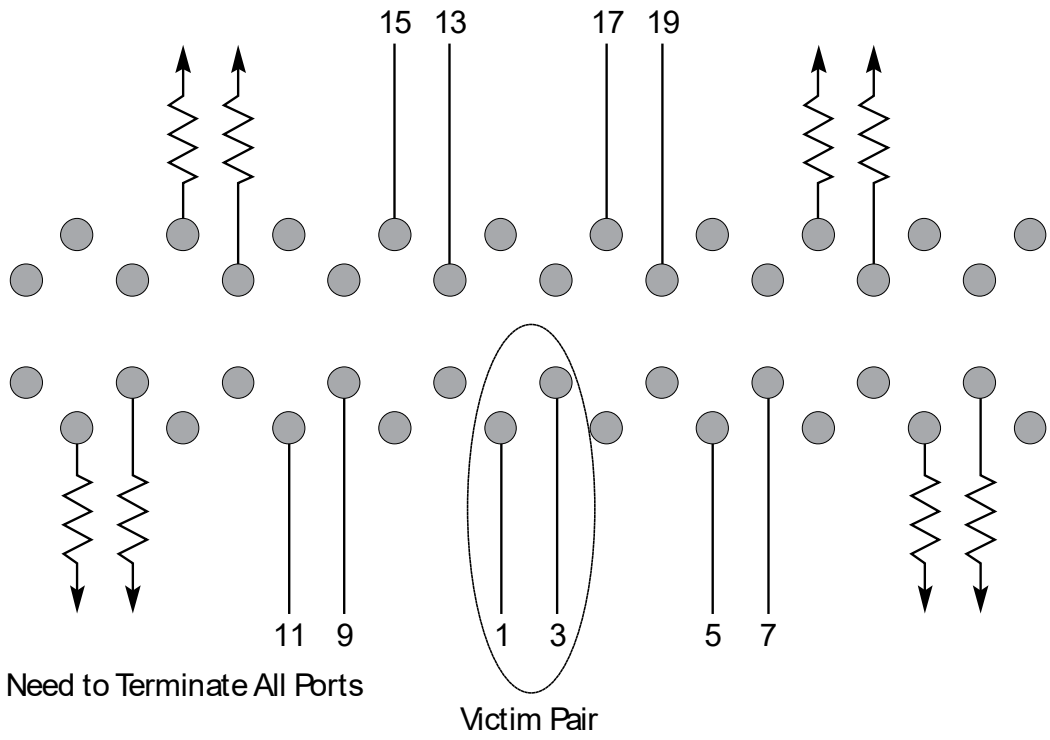


Figure 38: Illustration of Adjacent Pairs

6.3.3. Signal Integrity Requirements and Test Procedures for 5.0 GT/s Support

An electrical test fixture must be used for evaluating connector signal integrity. The test fixture effects, not including the connector via, are deembedded from measurements. A section is provided with test fixture requirements and recommendations.

Table 41 lists the electrical signal integrity parameters, requirements, and test procedures.

Table 41: Signal Integrity Requirements and Test Procedures for 5.0 GT/s Support

Parameter	Procedure	Requirements
Differential Insertion Loss (DDIL)	EIA 364-101 The EIA standard shall be used with the following considerations: 1. The measured differential S parameter shall be referenced to an 85 Ω differential impedance. 2. The test fixture shall meet the test fixture requirement defined in Section 6.3.3.1. 3. The test fixture effect shall be removed from the measured S parameters. See Note 1.	≥ -0.5 dB up to 2.5 GHz; ≥ -[0.8*(f-2.5)+0.5] dB for 2.5 GHz < f ≤ 5 GHz (for example, ≥ -2.5 dB at f = 5 GHz); ≥ -[3.0*(f-5)+2.5] dB for 5 GHz < f ≤ 7.5 GHz (for example, ≥-10 dB at f = 7.5 GHz)
Differential Return Loss (DDRL)	EIA 364-108 The EIA standard shall be used with the following considerations: 1. The measured differential S parameter shall be referenced to an 85 Ω differential impedance. 2. The test fixture shall meet the test fixture requirement given in Section 6.3.3.1. 3. The test fixture effect shall be removed. See Note 1.	≤ -15 dB up to 3 GHz; ≤ -5 dB for 3 GHz < f ≤ 5 GHz; ≤ -1 dB for 5 GHz < f ≤ 7.5 GHz
Intra-pair Skew	Intra-pair skew is achieved by design; measurement not required.	5 ps max
Differential Near End Crosstalk (DDNEXT)	EIA 364-90 The EIA standard must be used with the following considerations: 1. The crosstalk requirement is with respect to all the adjacent differential pairs including the crosstalk from opposite sides of the connector, as illustrated in Figure 38. 2. This is a differential crosstalk requirement between a victim differential signal pair and all its adjacent differential signal pairs. The measured differential S parameter shall be referenced to an 85 Ω differential impedance.	≤ -32 dB up to 2.5 GHz; ≤ -26 dB for 2.5 GHz < f ≤ 5 GHz; ≤ -20 dB for 5 GHz < f ≤ 7.5 GHz

Notes:

1. The specified S parameters requirements are for connector only, not including the test fixture effect. While the TRL calibration method is recommended, other calibration methods are allowed.

6.3.3.1 Test Fixture Requirements

The test fixture for connector S-parameter measurement must be designed and built to the following requirements:

- The test fixture shall be an FR4-based PCB of the microstrip structure; the dielectric thickness or stackup shall be approximately 0.102 mm (4 mils).
- The total thickness of the test fixture PCB shall be 1.57 mm (62 mil) and the test Add-in Card must be a break-out card fabricated in the same PCB panel for the fixture.
- The measurement signals shall be launched into the connector from the top of the test fixture, capturing the through-hole stub effect.
- Traces between the connector and measurement ports (SMA or microprobe) must be uncoupled.
- The trace lengths between the connector and measurement port shall be minimized. The maximum trace length shall not exceed 45.72 mm (1800 mil). The trace lengths between the connector and measurement port on the test baseboard and Add-in Card shall be equal. The edge-finger pad is not counted as Add-in Card PCB trace; it is considered part of the connector interface.
- All the traces on the test board and Add-in Card must be held to a characteristic impedance of 50 Ω with a tolerance of ±7%.
- The test Add-in Card edge-finger pads shall be fabricated per mechanical specification defined in Figure 37. The ground plane immediately underneath the edge-finger pads must be removed.
- The through-hole on the test board shall have the following stackup: 0.711 mm (28 mil) finished hole, 1.067 mm (42 mil) pad, and 1.473 mm (58 mil) antipad.
- Use of SMA connectors is recommended. The SMA launch structure shall be designed to minimize the connection discontinuity from SMA to the trace. The impedance range of the SMA seen from a TDR with a 60 ps rise time is recommended to be within 50 ±7 Ω.
- If a fixture with other characteristics is used, the fixture effects must be reliably removed and must not impact measurement accuracy.

6.3.4. Signal Integrity Requirements and Test Procedures for 8.0 GT/s Support

An electrical test fixture must be used for evaluating connector signal integrity. The test fixture effects, not including the connector via, are deembedded from measurements. A section is provided with test fixture requirements and recommendations.

Table 42 lists the electrical signal integrity parameters, requirements, and test procedures.

Table 42: Signal Integrity Requirements and Test Procedures for 8.0 GT/s Support

Parameter	Procedure	Requirements
Differential Insertion Loss (DDIL)	EIA 364-101 The EIA standard shall be used with the following considerations: 1. The measured differential S parameter shall be referenced to an 85 Ω differential impedance. 2. The test fixture shall meet the test fixture requirement defined in Section 6.3.4.1. 3. The test fixture effect shall be removed from the measured S parameters. See Note 1.	≥ -0.5 dB up to 2.5 GHz; ≥ -[0.8*(f-2.5)+0.5] dB for 2.5 GHz < f ≤ 5 GHz (for example, ≥ -2.5 dB at f = 5 GHz); ≥ -[3.0*(f-5)+2.5] dB for 5 GHz < f ≤ 12 GHz (for example, ≥ -10 dB at f = 7.5 GHz)
Differential Return Loss (DDRL)	EIA 364-108 The EIA standard shall be used with the following considerations: 1. The measured differential S parameter shall be referenced to an 85 Ω differential impedance. 2. The test fixture shall meet the test fixture requirement in Section 6.3.4.1. 3. The test fixture effect shall be removed. See Note 1.	≤ -15 dB up to 3 GHz; ≤ 5*f – 30 dB for 3 GHz < f ≤ 5 GHz; ≤ -1 dB for 5 GHz < f ≤ 12 GHz
Intra-pair Skew	Design must achieve intra-pair skew; measurement not required.	5 ps max
Differential Near End Crosstalk (DDNEXT)	EIA 364-90 The EIA standard must be used with the following considerations: 1. The crosstalk requirement is with respect to all the adjacent differential pairs including the crosstalk from opposite sides of the connector, as illustrated in Figure 38. 2. This is a differential crosstalk requirement between a victim differential signal pair and all of its adjacent differential signal pairs. The measured differential S parameter shall be referenced to an 85 Ω differential impedance.	≤ -32 dB up to 2.5 GHz; ≤ -26 dB for 2.5 GHz < f ≤ 5.0 GHz; ≤ -20 dB for 5 GHz < f ≤ 10 GHz; < -10 dB for 10 GHz < f ≤ 12 GHz

Notes:
1. The specified S-parameters requirements are for connector only, not including the test fixture effect. While the TRL calibration method is recommended, other calibration methods are allowed.

6.3.4.1 Test Fixture Requirements

The test fixture for connector S-parameter measurement must be designed and built to the following requirements:

- The test fixture shall be an FR4-based PCB of the microstrip structure; the dielectric thickness or stackup shall be approximately 0.102 mm (4 mil).
- The total thickness of the test fixture PCB shall be 1.57 mm (0.062") and the test Add-in Card must be a break-out card fabricated in the same PCB panel for the fixture.
- The measurement signals shall be launched into the connector from the top of the test fixture, capturing the through-hole stub effect.
- Traces between the connector and measurement ports (SMA or microprobe) must be uncoupled.
- The trace lengths between the connector and measurement port shall be minimized. The maximum trace length shall not exceed 46 mm (1800 mil). The trace lengths between the connector and measurement port on the test baseboard and Add-in Card shall be equal. The edge-finger pad is not counted as Add-in Card PCB trace; it is considered part of the connector interface.
- All traces on the test board and Add-in Card must be held to a characteristic impedance of 50 Ω with a tolerance of ±7%.
- The test Add-in Card edge-finger pads shall be fabricated per mechanical specification defined in Figure 37. The ground plane immediately underneath the edge-finger pads must be removed.
- The through-hole on the test board shall have the following stackup: 0.711 mm (28 mil) finished hole, 1.067 mm (42 mil) pad, and 1.473 mm (58 mil) antipad.
- Use of SMA connectors is recommended. The SMA launch structure shall be designed to minimize the connection discontinuity from SMA to the trace. The impedance range of the SMA seen from a TDR with a 30 ps rise time is recommended to be within 50 ±7 Ω.
- If a fixture with other characteristics is used, the fixture effects must be reliably removed and must not impact measurement accuracy.

6.3.5. Signal Integrity Requirements and Test Procedures for 16.0 GT/s Support

An electrical test fixture must be used for evaluating connector signal integrity. The test fixture effects, not including the connector via, are deembedded from measurements. Test fixture requirements and recommendations are provided.

Table 43 lists the electrical signal integrity parameters, requirements, and test procedures.

Table 43: Signal Integrity Requirements and Test Procedures for 16.0 GT/s Support

Parameter	Procedure	Requirements
Differential Insertion Loss (DDIL)	EIA 364-101 The EIA standard shall be used with the following considerations: 1. The measured differential S parameter shall be referenced to an 85 Ω differential impedance. 2. The test fixture shall meet the test fixture requirement defined in Section 6.3.5.1. 3. The test fixture effect shall be removed from the measured S parameters. See Note 1.	≥ -0.5 dB up to 4 GHz; ≥ [-0.25*f +0.5] dB for 4 GHz < f < 8 GHz (for example -1.5 dB at 8 GHz); ≥ [-0.75*f+4.5] dB for 8 GHz< f < 10 GHz (for example: -3.0 dB at 10 GHz)
Differential Return Loss (DDRL)	EIA 364-108 The EIA standard shall be used with the following considerations: 1. The measured differential S parameter shall be referenced to an 85 Ω differential impedance. 2. The test fixture shall meet the test fixture requirement in Section 6.3.5.1. 3. The test fixture effect shall be removed. See Note 1.	≤ -15 dB up to 3 GHz; ≤ [5*f – 30] dB for 3 < f < 4.4 GHz; (for example: -10 dB at 4 GHz); ≤ -8 dB from 4.4 to 10 GHz
Intra-pair Skew	Intra-pair skew must be achieved by design; measurement not required.	5 ps max
Differential Near End Crosstalk (DDNEXT)	EIA 364-90 The EIA standard must be used with the following considerations: 1. The crosstalk requirement is with respect to all the adjacent differential pairs including the crosstalk from opposite sides of the connector, as listed in Table 44. 2. This is a differential crosstalk requirement between a victim differential signal pair and all its adjacent differential signal pairs. The measured differential S parameter shall be referenced to an 85 Ω differential impedance.	≤ -32 dB up to 8 GHz and -20 dB from 8 GHz to 10 GHz

Notes:

1. The specified S-parameters requirements are for connector only, not including the test fixture effect. While the TRL calibration method is recommended, other calibration methods are allowed.

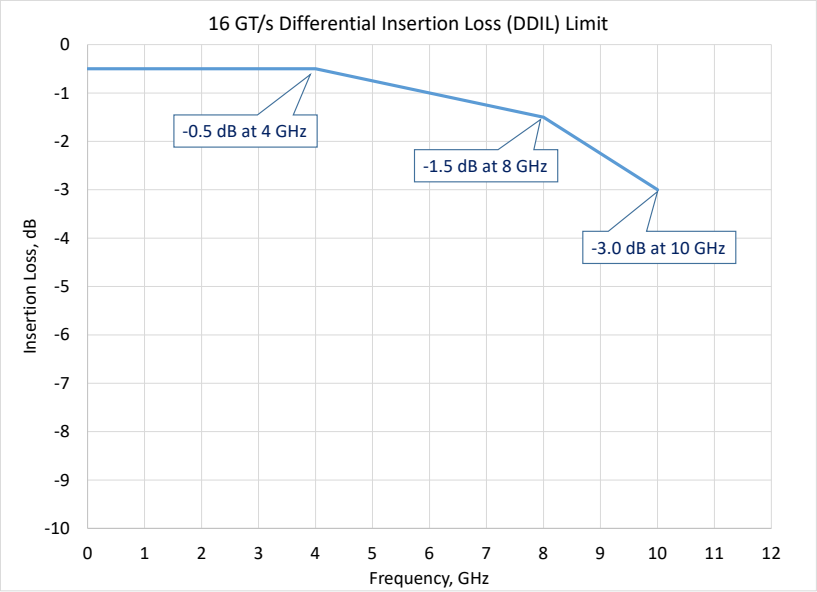


Figure 39. Differential Insertion Loss Limits for 16.0 GT/s Operation

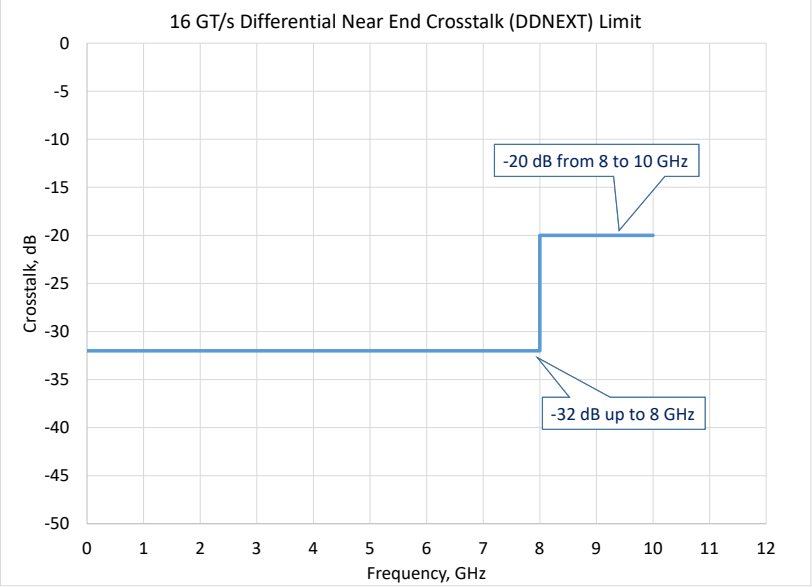


Figure 40. Differential Near End Crosstalk Limits for 16.0 GT/s operation

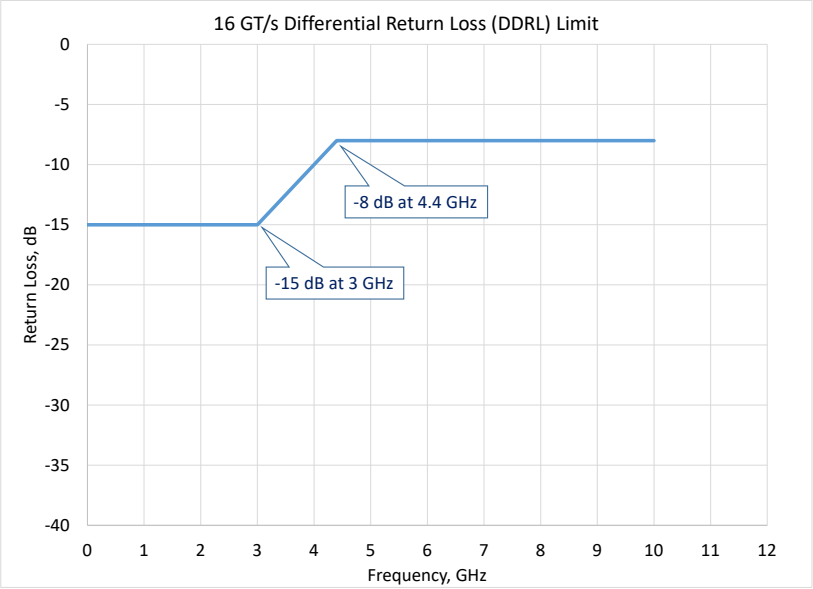


Figure 41. Differential Return Loss Limits for 16.0 GT/s operation

6.3.5.1 Test Fixture Requirements

A test fixture for connector S-parameter measurement must be designed and built to the following:

- The test fixture used for measuring S-parameters will comprise a baseboard and mating Add-in Card fabricated from the same PCB panel. The total thickness of the boards, measured across the Add-in Card edge fingers, must be 1.57 mm (062 mil).
- The PCB test fixture must be an FR-4 based material, or of a lower loss material with a relative permittivity of 3.6 or greater. Dielectric loss factor is not specified.
- The test PCB must have a microstrip structure; the microstrip's dielectric thickness or stackup are recommended to be approximately 0.102 mm (4 mil).
- The interconnect traces on all boards must be routed uncoupled (single ended) where possible. Some method of mitigating fiber weave effects must be applied. This can include off-axis routing or board rotation on the PCB panel.
- The trace lengths between the connector and measurement port must be minimized. The maximum trace length must not exceed 48 mm (1.9 inches). The trace lengths between the connector and measurement port on the test baseboard and Add-in Card must be equal within 0.5 mil. The edge-finger pad is not counted as Add-in Card PCB trace; it is considered part of the connector interface.
- Separate PCB structures must be included to support deembedding of the feeds to isolate the performance of the connector interface. These structures may support Thru-Reflect-Line, the 2x thru procedure, or a similar deembedding method. The deembedding structures' signal launch and traces must match those of the test fixture.
- The baseboard, and Add-in Card must be on the same PCB panel during fabrication, and the deembedding structures must lie on one or both test boards, or on a third, adjacent PCB card. Silkscreen serialization of the test cards during manufacturing may aid in tracking adjacent PCB sets.
- The pinfield must replicate the pin assignments of a x4 connector interface. The pin pairs measured correspond to high speed pairs Tx0, Tx1, and Tx2, as well as Rx0 and Rx1, as shown in Table 44. This pinfield will require a x4 connector and x4 card. A baseboard mounting a connector longer than x4 or an Add-in Card longer than x4 may be used but are not required.

- Pins A1/B1 to A11/B11, which lie below the key notch on both sides of the card, may be terminated with an open, short, or an arbitrary impedance. If the Add-in Card is up-plugged into a longer edge connector, such as x8 or x16, the pins beyond A32/B32 may be arbitrarily terminated as well.
- Scattering parameters must be obtained over a range spanning 100 MHz to 10 GHz, with a frequency spacing of no greater than 10 MHz.

Table 44: Pin Connectivity for the 16.0 GT/s Connector Characterization Board

Pin Number	Signal Assignment	Baseboard Termination	Add-in Card Termination
B12	CLKREQ#	OPEN	R-C TERM
B14	Tx0p	MEASURE	MEASURE
B15	Tx0n	MEASURE	MEASURE
B17	PRSNT2#	OPEN	R-C TERM
B19	Tx1p	MEASURE	MEASURE
B20	Tx1n	MEASURE	MEASURE
B23	Tx2p	MEASURE	MEASURE
B24	Tx2n	MEASURE	MEASURE
B27	Tx3p	42.5 Ω	42.5 Ω
B28	Tx3n	42.5 Ω	42.5 Ω
B30	PWRBRK#	OPEN	R-C TERM
B31	PRSNT2#	OPEN	R-C TERM
A13	REFCLK+	50 Ω	OPEN
A14	REFCLK-	50 Ω	OPEN
A16	Rx0p	MEASURE	MEASURE
A17	Rx0n	MEASURE	MEASURE
A19	Reserved	OPEN	R-C TERM
A21	Rx1p	MEASURE	MEASURE
A22	Rx1n	MEASURE	MEASURE
A25	Rx2p	42.5 Ω	42.5 Ω
A26	Rx2n	42.5 Ω	42.5 Ω
A29	Rx3p	42.5 Ω	42.5 Ω
A30	Rx3n	42.5 Ω	42.5 Ω
A32	Reserved	OPEN	R-C TERM

- The high-speed pins in Table 44 labeled 42.5 Ω, such as Tx3, must be terminated with 42.5 +/- 2 Ω resistors to emulate the termination of an operating high-speed pair. The trace between the high-speed edge finger or baseboard pin and the termination must have a characteristic impedance of 42.5 Ω
- The clock pair, pins A13 and A14, must be terminated single-ended with resistors whose values are 50 +/- 2 Ω. This termination is applied on the baseboard side only; the Add-in Card REFCLK nets are left open-circuited at the end of the edge fingers.
- Compression-fit (bolt-on) PCB mount coaxial connectors are recommended, but not required, for the PCB test ports. The signal launch of the test port connectors must be optimized for lowest return loss across the band of interest.
- Via stubs, both in the test port feeds and in the pinfield, must be avoided.
- Test port feeds marked "MEASURE" in the Table 44, must be optimized to a characteristic impedance of either 42.5 Ω or 50 Ω. All of the traces on the test board and Add-in Card must be held to the specified characteristic impedance 42.5 or 50 Ω with a tolerance of ±7%.
- For a baseboard mounting press-fit or soldered through-hole mount connectors:
  - The measurement signals shall be launched into the connector pinfield from the bottom of the test fixture baseboard, to prevent any through-hole via stub effects for the connector pins.
  - The connector pinfield through-hole vias must have a 0.70 mm (28 mil) finished hole diameter.
  - The pad (annular ring) must be circular, with a diameter of 1.0 mm (40 mil). For positions representing high speed Tx and Rx signal pairs, the antipad must be 1.5 mm (59 mil) and circular.
  - For positions representing Auxiliary (sideband) or Reserved signals, including CLKREQ#, PRSNT2#, and PWRBRK#; the antipads must be circular, with a diameter of 1.22 mm (48 mil).
  - The traces for the through-hole connector deembedding structures must lie on the back side of the board, to represent the feed traces on the baseboard and one side of the Add-in Card. An optional second set of deembedding structures may be placed on the top of the board, to better represent the corresponding feed traces on the both sides of the Add-in Card.
  - The measurement signals must be launched into the connector from the bottom of the test fixture baseboard.
  - Two sentry vias (ground vias) must bracket each sideband signal. They must have a drill size of approximately 0.254 mm (10 mil). They must be 180 degrees apart, across the axis of auxiliary signal via. They must lie within 30° to 45° of the direction of the fiber weave, with the via center as the axis, to mitigate conductive anodic filament (CAF) formation between the ground and sideband vias.
- For a baseboard mounting a Surface Mount (SMT) connector:
  - The measurement signals shall be launched into the connector pinfield through topside microstrip on the test fixture baseboard, with no signal vias in the pinfield region.
  - For convenience, to prevent crossed cables during measurement, the SMT baseboard feeds is permitted to lie on the back side of the baseboard PCB. This will require a well-designed through-hole via, located at least 25 mm (98 mil) from the pinfield.
  - Adjacent ground vias must be placed at both ends of each baseboard ground pad.

- For the Add-in Card (AIC):
  - The feed structures must emulate those on the baseboard or have separate deembedding structures to remove their effects.
  - Mechanical fixtures or other means must be used to ensure full insertion of the card into the slot, and alignment to 90° with the baseboard.
  - Via stubs must be avoided. This may require test port feeds on both sides of the Add-in Card, since both Tx and Rx signals will be characterized.

6.4. Connector Environmental and Other Requirements

6.4.1. Environmental Requirements

Connector environmental tests shall follow EIA-364-1000.01, Environmental Test Methodology for Assessing the Performance of Electrical Connectors and Sockets Used in Business Office Applications. The test groups/sequences and durations shall be derived from the following requirements:

- Durability (mating/unmating) rating of 50 cycles
- Field temperature: 65 °C
- Field life: seven years

Since the connector defined in Section 6.2 has far more than 0.127 mm wipe length, Test Group 6 in EIA-364-1000.01 is not required. Test Group 7 in EIA-364-1000.01 is optional since the durability cycles is ≤ 50. The temperature life test duration and the mixed flowing gas test duration values are derived from EIA 364-1000.01 based on the field temperature, using simple linear interpolation. Table 45 lists these values.

Table 45: Test Durations

Test	Duration/Temperature
Temperature Life	168 hours at 105 °C
Temperature Life (preconditioning)	92 hours at 105 °C
Mixed Flowing Gas	10 days

The low-level contact resistance (LLCR) is required to be 30 mΩ or less, initially. The contact resistance measurement points shall include the solder tail and the contact-mating interface, as illustrated in Figure 42. The resistance change, which is defined as the change in LLCR between the reading after stress and the initial reading, shall not exceed the value that is to be specified by each OEM to best suit their needs.

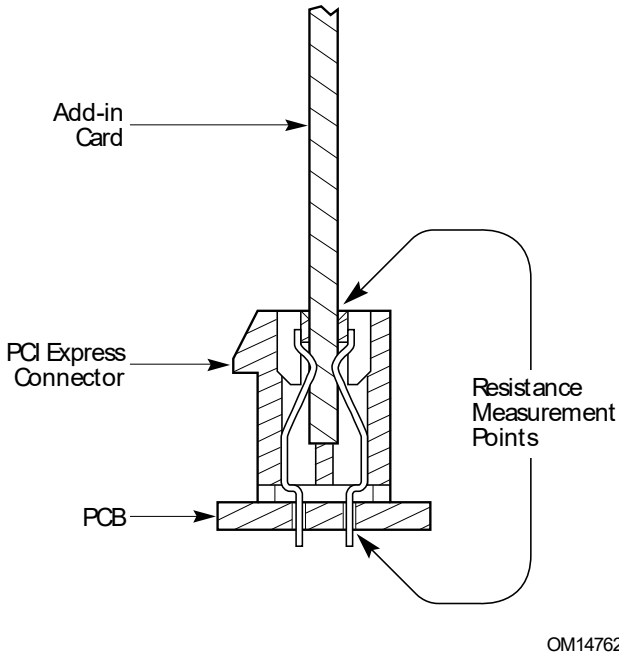


Figure 42: Contact Resistance Measurement Points

To be sure that the environmental tests measure the stability of the connector, the Add-in Cards used shall have edge-finger tabs with a minimum plating thickness of 30 microinches of gold over 50 microinches of nickel *for the environmental test purpose only*. Furthermore, it is highly desirable that testing gives an indication of the stability of the connector when Add-in Cards at the lower and upper limit of the card thickness requirement are used. In any case, both the edge tab plating thickness and the card thickness shall be recorded in the environmental test report.

6.4.2. Mechanical Requirements

Table 46 lists the mechanical parameters and requirements. The sample size follows Section 2.2.1 of *EIA-364-1000.01*.

Table 46: Mechanical Test Procedures and Requirements

Test Description	Procedure	Requirement
Visual and dimensional inspections	EIA 364-18 Visual, dimensional, and functional per applicable quality inspection plan	Meets product drawing requirements
Insertion force	EIA 364-13 Measure the force necessary to mate the connector assemblies at a maximum rate of 12.5 mm (0.492 inches) per minute, using a steel gauge 1.70 mm thick with a tolerance +0.00, - 0.01 mm.	1.15 N maximum per contact pair
Removal force	EIA 364-13 Measure the force necessary to unmate the connector assemblies at maximum rate of 12.5 mm (0.492 inches) per minute, using a steel gauge 1.44 mm thick with a tolerance +.001, - 0.00 mm.	0.15 N minimum per contact pair

6.4.3. Current Rating Requirement

Table 47 lists the contact current rating requirement and test procedure.

Table 47: End of Life Current Rating Test Sequence

Test Order	Test	Procedure	Condition	Requirement
1	Contact current rating	EIA 364-70 method 2 The sample size is a minimum of three mated connectors. The sample shall be soldered on a PC board with the appropriate footprint. Wire the eight power pins (B1, B2, B3, A2, A3, B8, A9, and A10) and the eight nearest ground pins (A4, B4, B7, A12, B13, A15, B16, and B18) in a series circuit. The mated Add-in Card is included in this circuit. The Add-in Card shall have 1 oz. copper traces and its mating geometry shall conform to the applicable PCI Express drawings. A thermocouple of 30 AWG or less shall be placed on the card edge-finger pad (pins B2 and A9) as close to the mating contact as possible. Conduct a temperature rise vs. current test.	Mated	1.1 A per pin minimum The temperature rise above ambient shall not exceed 30 °C. The ambient condition is still air at 25 °C.

6.4.4. Additional Considerations

Table 48 lists the additional requirements.

Table 48: 6-9: Additional Requirements

Parameter	Procedure	Requirement
Flammability	UL94V-1 minimum	Material certification or certificate of compliance required with each lot to satisfy the Underwriters Laboratories follow-up service requirements.
Lead-free soldering		Connector must be compatible with lead free soldering process.

This specification does not attempt to define the connector requirements that are considered application-specific. It is up to the users and their connector suppliers to determine if additional requirements shall be added to satisfy the application needs. The system level shock and vibration tests are considered application-specific because results will depend on card weight and size, chassis stiffness, and retention mechanisms, as well as the connector. Therefore, those tests are not specified in the connector specification. It will be up to each system OEM to decide how the shock and vibration tests shall be done.

7

7. PCI Express 2 x 3 Auxiliary Power Connector Definition

This chapter defines the PCI Express 2 x 3 auxiliary connector and cable assembly to support 150 W Add-in Cards .

7.1. 6-Position Power Connector System Performance Requirements

The power connector system performance requirements are as follows:

- **Current Rating:** 8.0 amperes per pin/position maximum to a 30 °C T-Rise above ambient temperature conditions at +12 VDC, all six contacts energized
- **Mated Connector Retention:** 30.00 N minimum when plug pulled axially

7.2. 6-Position PCB Header

7.2.1. 6-Position R/A Thru-Hole PCB Header Assembly

Figure 43 shows the details of a 6-position, R/A through-hole PCB header assembly.

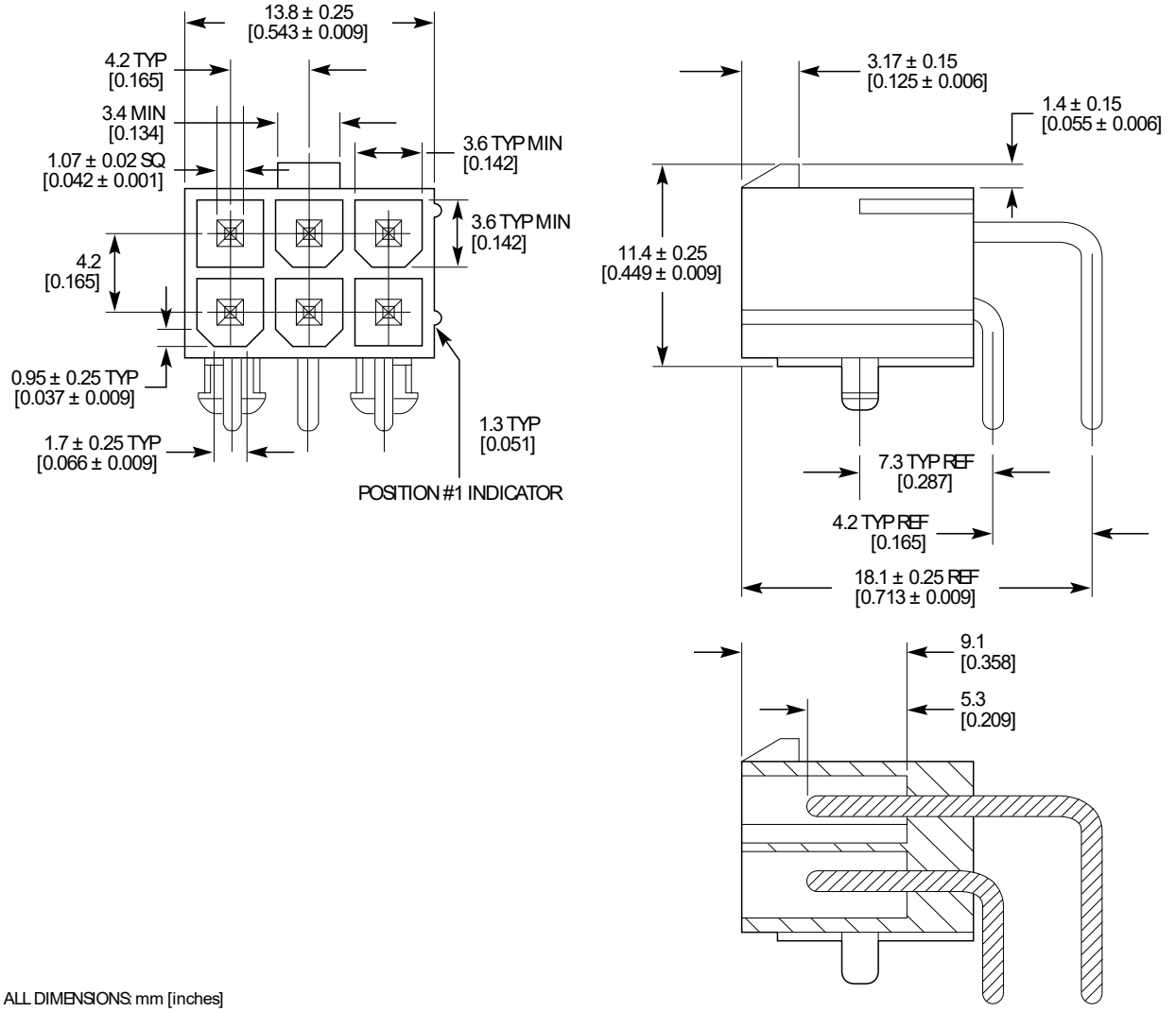


Figure 43: 6-Position R/A Thru-Hole PCB Header Assembly

6-Position R/A Thru-Hole PCB Header Assembly:

1. Housing Material: Thermoplastic
2. Pin Contact Base Material: Brass alloy or equivalent
3. Pin Contact Plating: Sn alloy
4. Connector Polarization: Per Figure 43

7.2.2. 6-Position R/A Thru-Hole Header Recommended PCB Footprint

Figure 44 shows the recommended PCB footprint for a 6-position, R/A through-hole header.

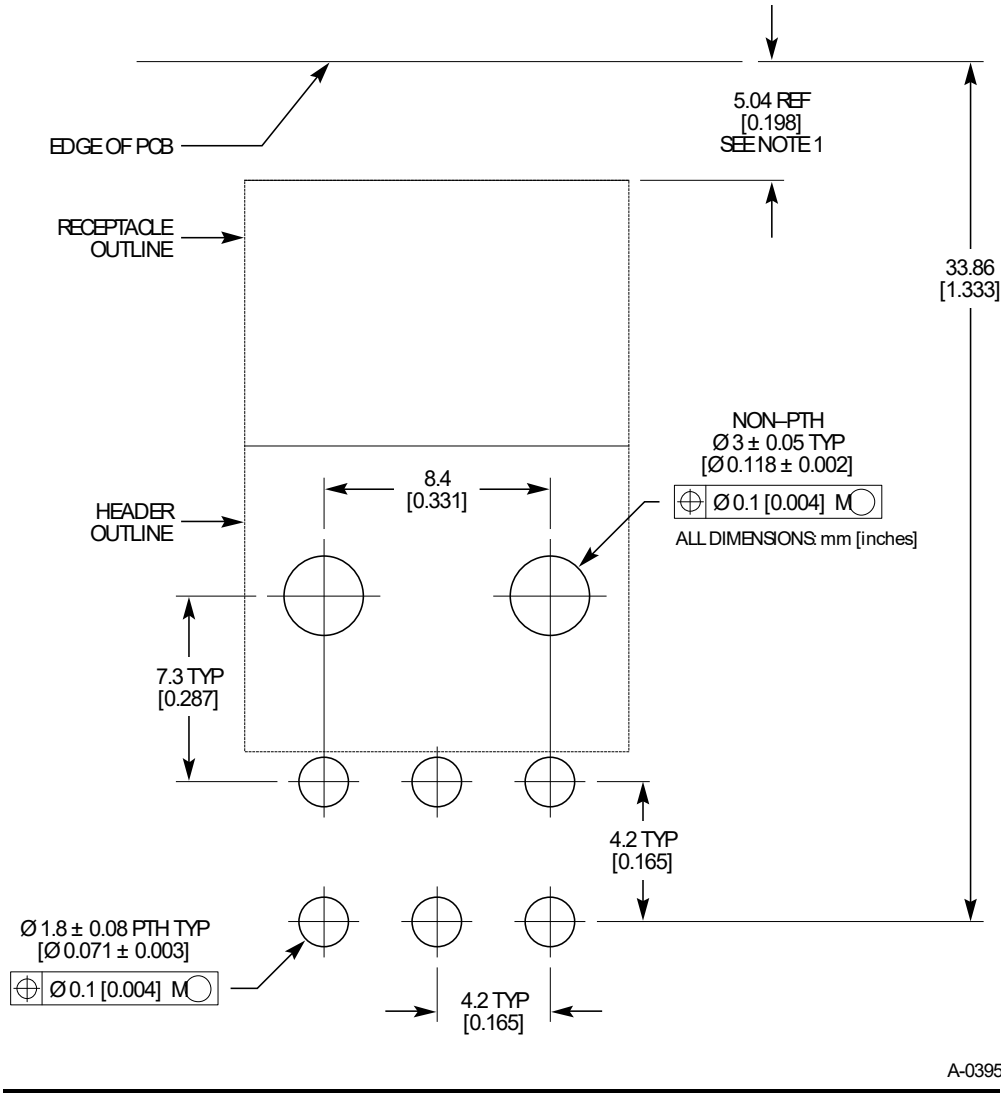


Figure 44: 6-Position R/A Thru-Hole Header Recommended PCB Footprint

7.2.3. 6-Position R/A SMT PCB Header Assembly

Figure 45 shows the details of a 6-position, R/A SMT header assembly.

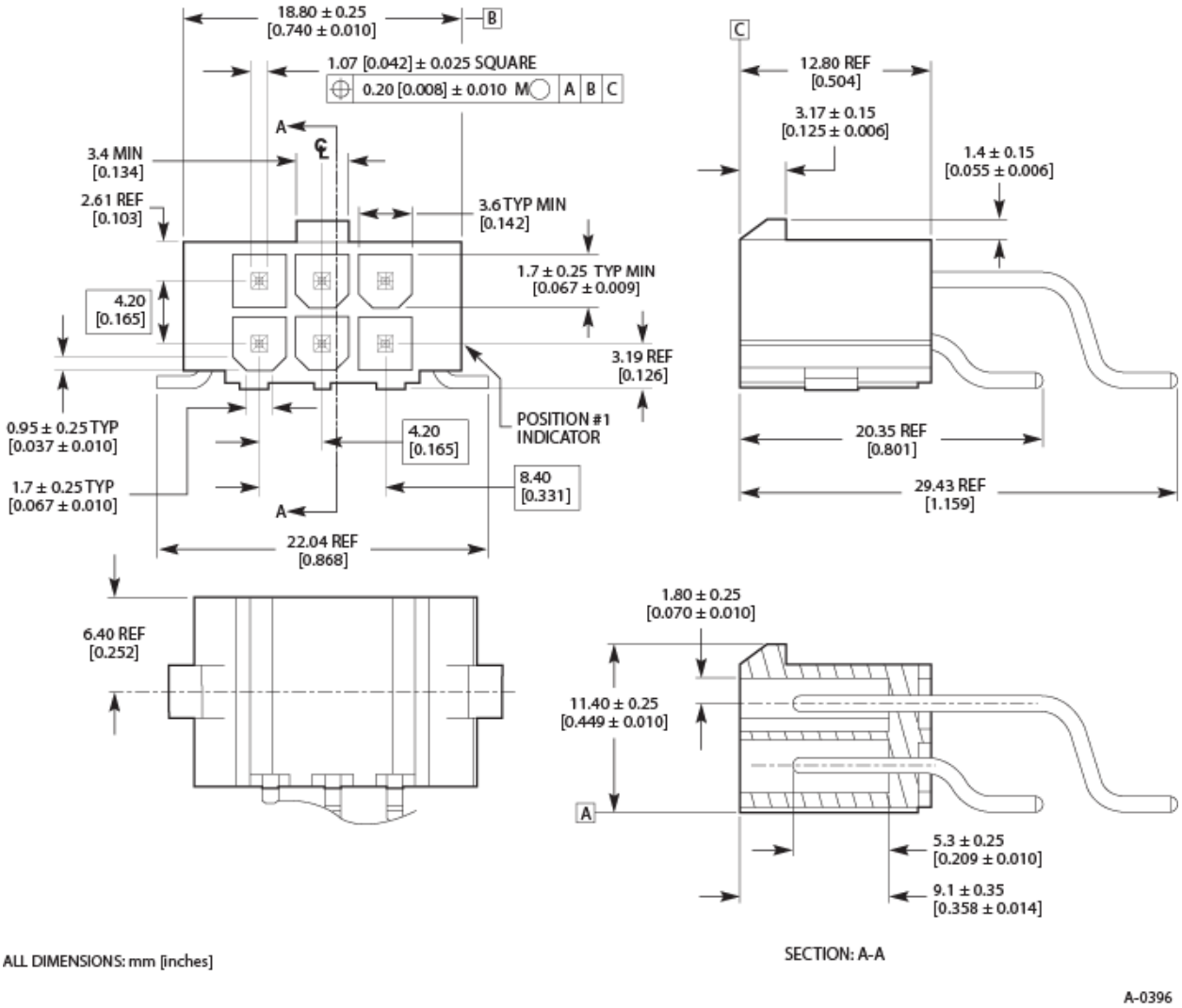


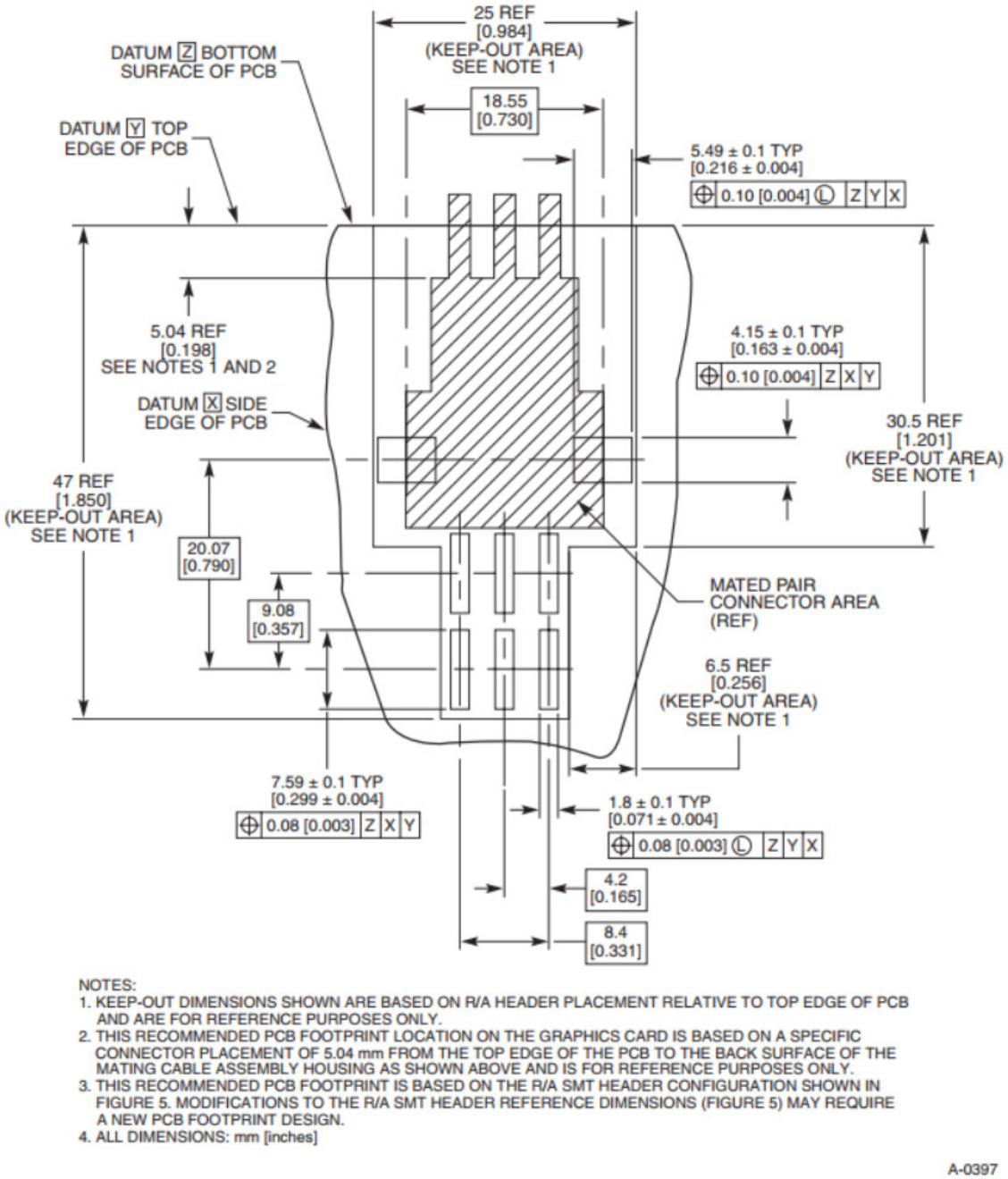
Figure 45: 6-Position R/A SMT PCB Header Assembly

6 Position R/A SMT Header Assembly:

1. Housing Material: Thermoplastic
2. Pin Contact Base Material: Brass alloy or equivalent
3. Pin Contact Plating: Sn alloy
4. Connector Polarization: See Figure 45

7.2.4. 6-Position R/A SMT Header Recommended PCB Footprint

Figure 46 shows the recommended PCB footprint for a 6-position, R/A SMT header.



For Header configuration (Note 3), see Figure 45.

Figure 46: SMT Header Recommended PCB Footprint

7.3. 6-Position Cable Assembly

Figure 47 shows the cable connector housing.

Cable Assembly Housing Details:

- Housing Material: Thermoplastic, special polarization per Figure 47
- Pin Contact Base Material: Brass alloy or equivalent
- Pin Contact Plating: Sn alloy

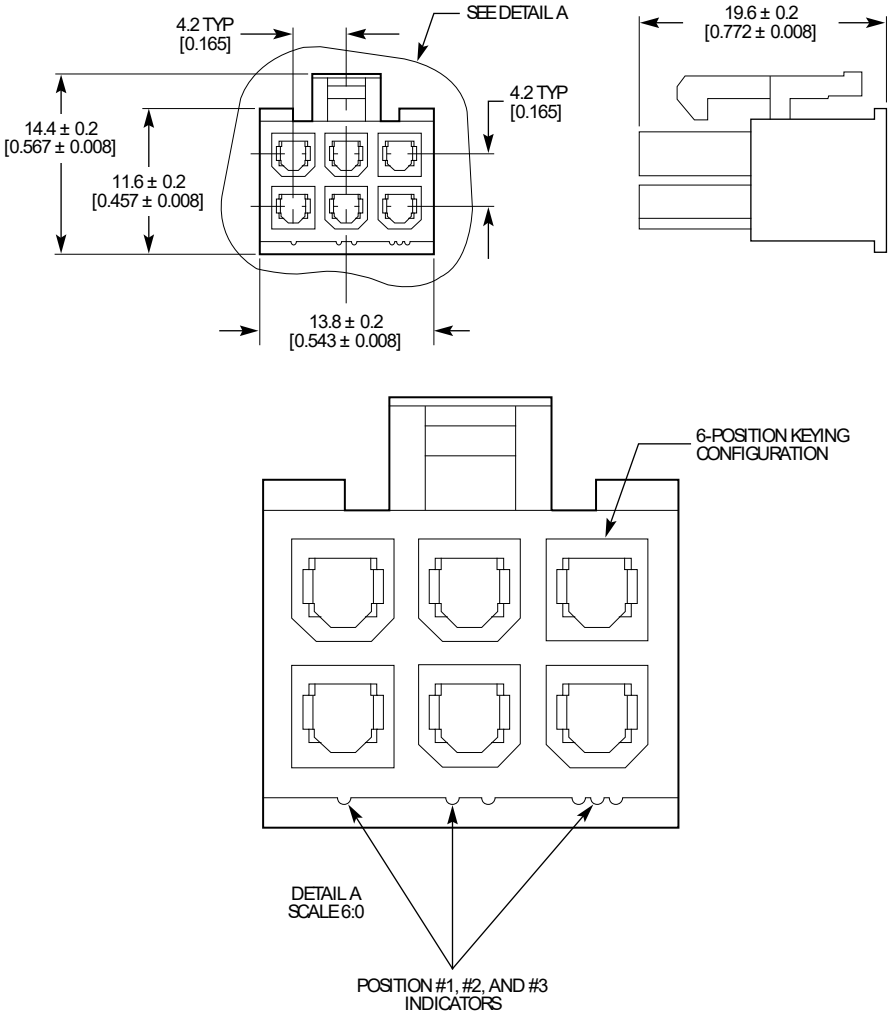


Figure 47: Cable Connector Housing

Cable Assembly Contact and Wire Details:

- Wire Size: 18 AWG
- Cable Bend Radius: 1xR minimum

7.4. Connector Mating-Unmating Keepout Area (Latch Lock Release)

The connector mating-unmating keepout area is specified in Figure 48.

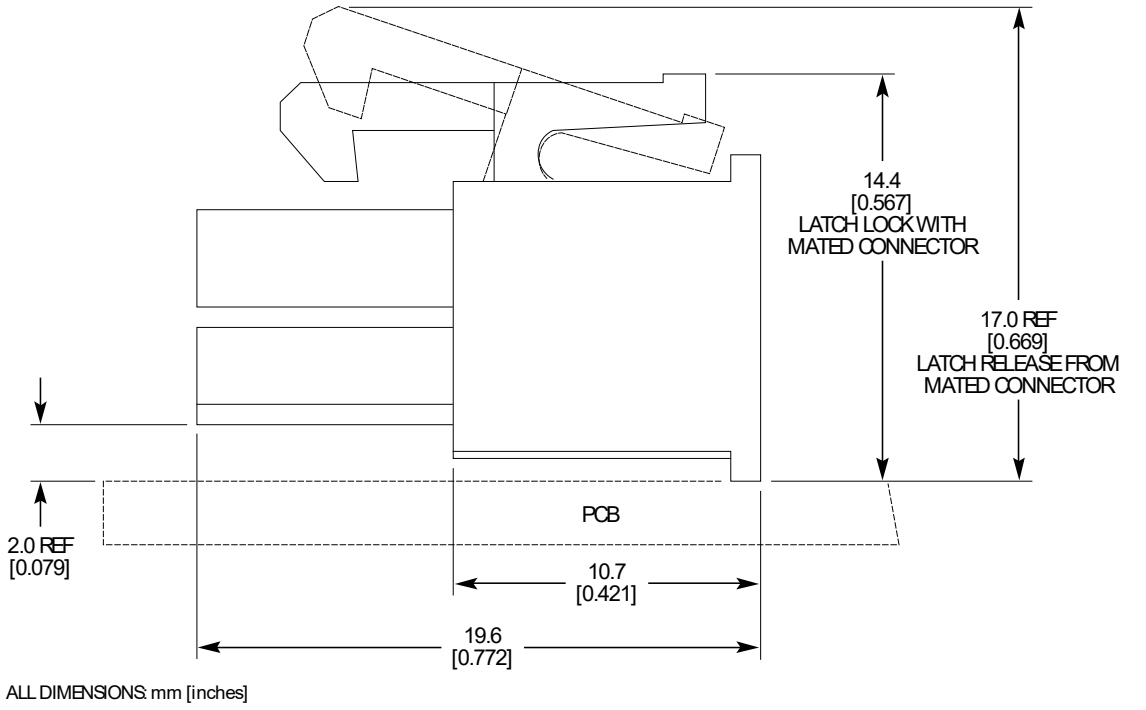


Figure 48: Connector Mating-Unmating Keepout Area (Latch Lock Release)

7.5. 6-Position Power Connector System Pin Assignment

Figure 49 and Table 49 show the pin-out for the PCI Express 150 W power connector.

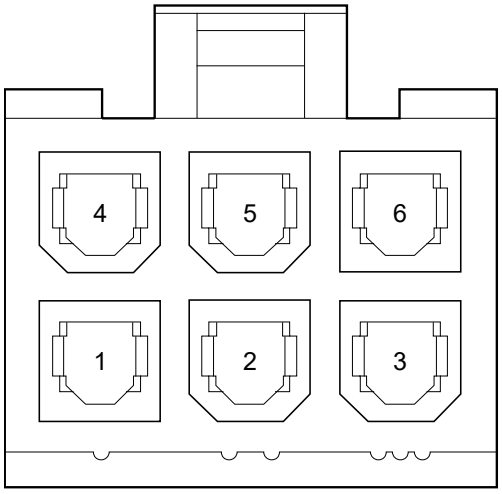


Figure 49: 150 W Power Connector

Table 49: 150 W Power Connector Pin-out

Pin	Signal
1	+12 V
2	+12 V
3	+12 V
4	Ground
5	Sense
6	Ground

IMPLEMENTATION NOTE

PCI Express 150 W Add-in Card Power Connector Sense Pin

The Sense pin on the PCI Express 150 W power connector must be connected to ground either directly in the power supply or via a jumper to an adjacent ground pin in the connector. This pin is used by a PCI Express 150 W Add-in Card to detect if the PCI Express 150 W power connector is plugged.

7.6. Additional Considerations

Table 50 lists the additional requirements for the PCI Express 150 W power connector.

Table 50: PCI Express 150 W Power Connector Additional Requirements

Parameter	Procedure	Requirement
Flammability	UL94V-1 minimum	Material certification or certificate of compliance is required with each lot to satisfy the Underwriters Laboratories follow-up service requirements.
Lead-free soldering		Connector must be compatible with lead free soldering process.
Connector Color		The color of the connector must be black. Exceptions will be made for color coding schemes that call for a different color of this connector.

8

8. PCI Express 2 x 4 Auxiliary Power Connector Definition

This chapter defines the PCI Express 2 x 4 auxiliary power connector and cable assembly.

For backward compatibility, the 2 x 3 power connector plug can be inserted into the 2 x 4 connector receptacle. The 2 x 4 receptacle is keyed such that the 2 x 3 connector plug needs to be properly aligned to plug in. Based on the sense codings in the 2 x 4 plug, a 225 W/300 W card with a 2 x 4 receptacle can detect if a 2 x 4 or a 2 x 3 plug is inserted. The 225 W/300 W card can then draw the appropriate power correspondingly.

The 2 x 4 connector plug must not be inserted into the 2 x 3 connector receptacle and is physically prevented from doing so. A dongle must be used for this purpose.

Figure 50, Figure 52, and Figure 52 show the described auxiliary power connector mating scenarios.

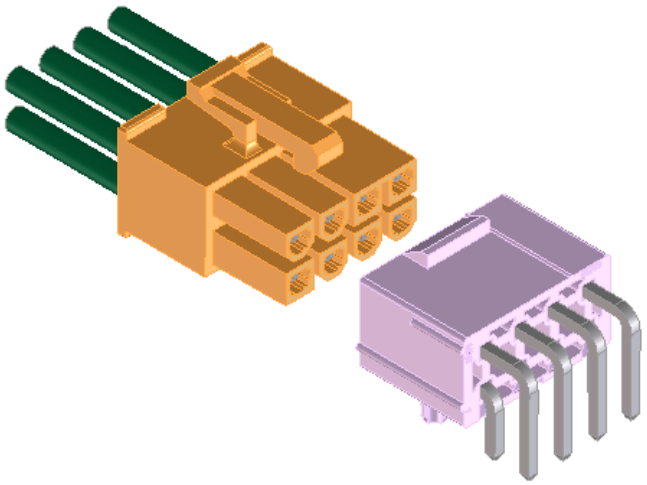
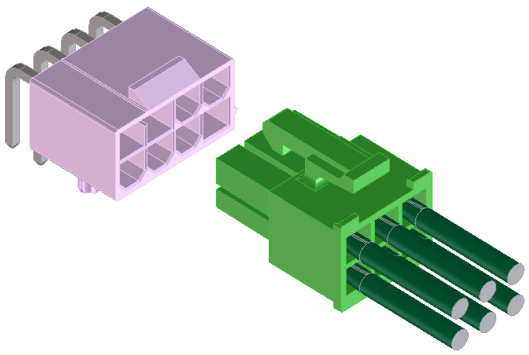


Figure 50: 2 x 4 Plug Mating with a 2 x 4 Receptacle



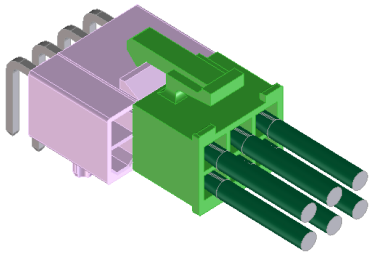


Figure 51: 2 x 3 Plug Mating with a 2 x 4 Receptacle

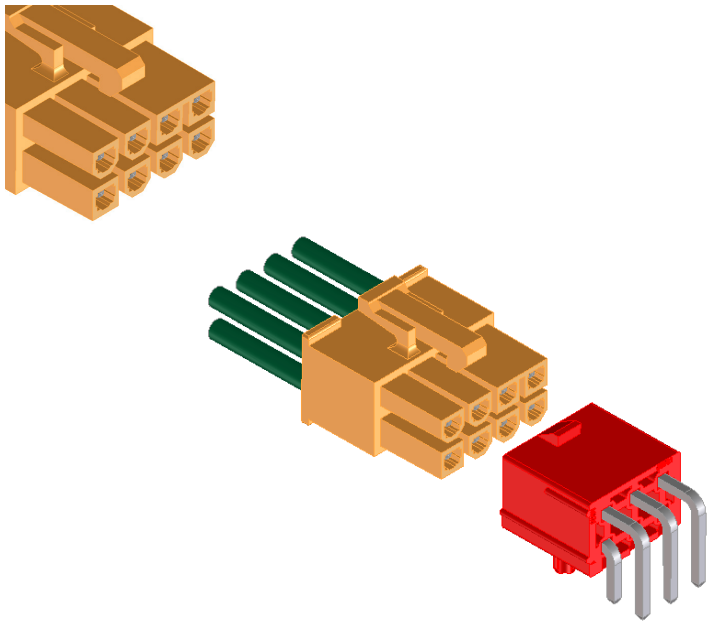


Figure 52: 2 x 4 Plug is Physically Prevented from Mating with a 2 x 3 Receptacle

8.1. 2 x 4 Auxiliary Power Connector Performance Requirements

The auxiliary power connector performance requirements are as follows:

- **Current Rating:** 7.0 A per pin/position maximum to a 30 °C T-Rise above ambient temperature conditions at +12 VDC with all eight contacts energized
- **Mated Connector Retention:** 30.00 N minimum when plug pulled axially

IMPLEMENTATION NOTE

Auxiliary Power Connector Current Rating

System integrators should ensure that the contacts used in an auxiliary power connector are of the correct rating to meet the 7.0 A requirement. Appropriate derating practices should be used.

8.2. 2 x 4 Receptacle

8.2.1. Connector Drawing

Figure 53 shows the details of a 2 x 4 (eight-position), right-angle (R/A) through-hole connector.

2 x 4 Receptacle:

- Housing Material: Thermoplastic
- Pin Contact Base Material: Brass Alloy or equivalent
- Pin Contact Plating: Sn Alloy
- An alignment rib is defined (detail A) to help guide the mating with a 2 x 3 plug.
- Though not defined in this specification, a vertical receptacle, in which the mating cable plug is perpendicular to the Add-in Card, is also allowed. Add-in Card manufacturers can work with their connector vendors to enable such a connector.
- All dimensions are in mm [inches].

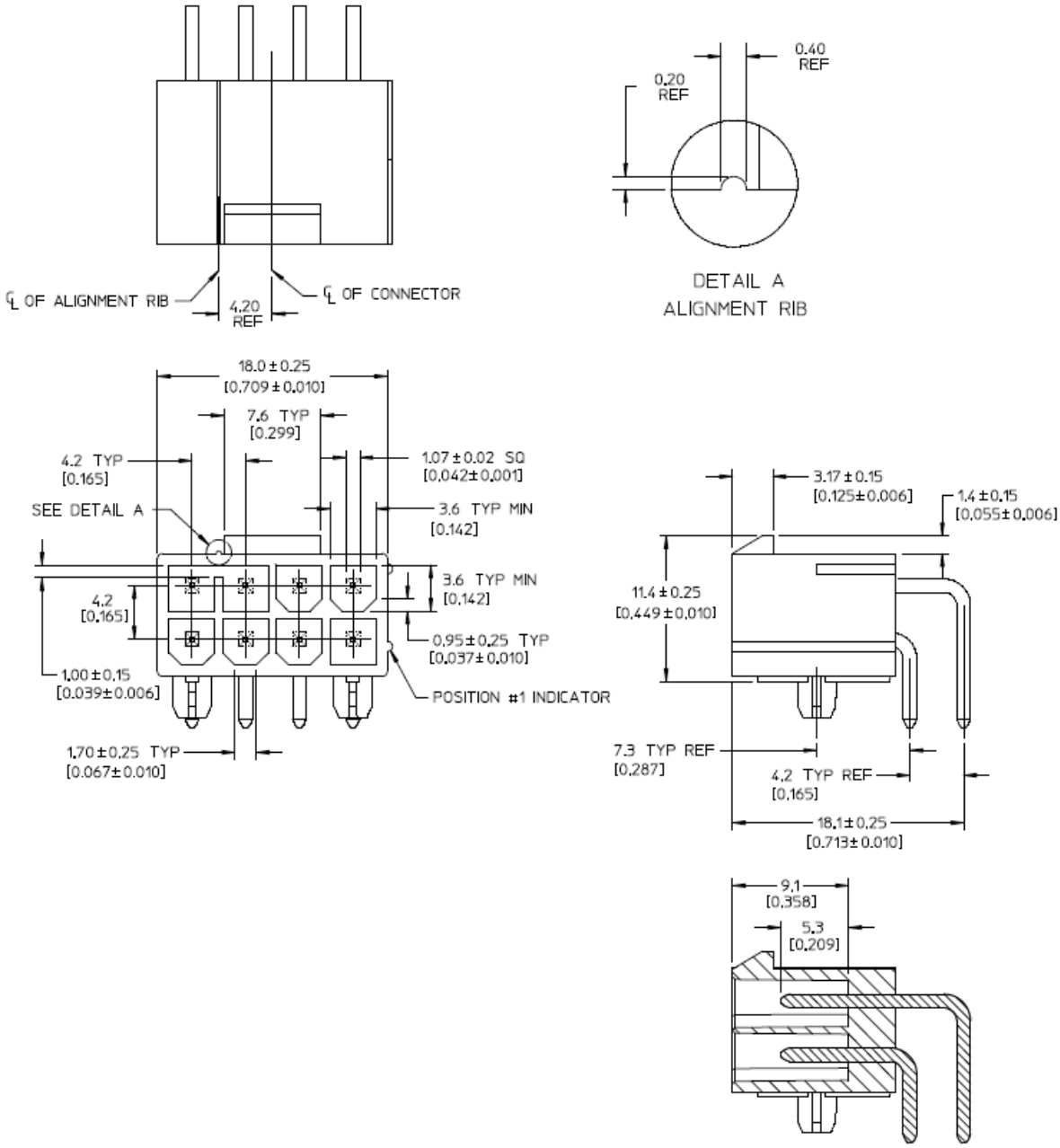


Figure 53: 2 x 4 R/A Through-Hole Receptacle Drawing

8.2.2. PCB Footprint

Figure 54 shows the recommended PCB footprint for the 2 x 4 R/A receptacle.

All dimensions are in mm [inches].

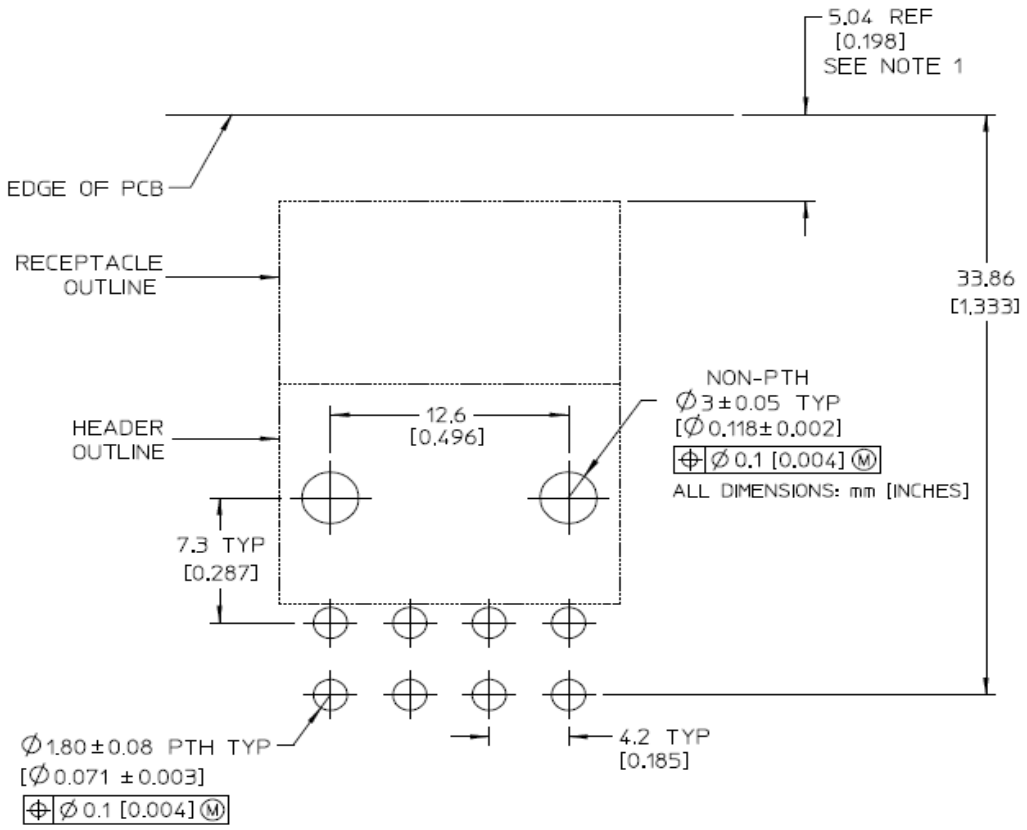


Figure 54: 2 x 4 R/A Through-Hole Receptacle Recommended PCB Footprint

8.3. Cable Assembly

Figure 55 shows the cable plug connector housing.

All dimensions are in mm [inches].

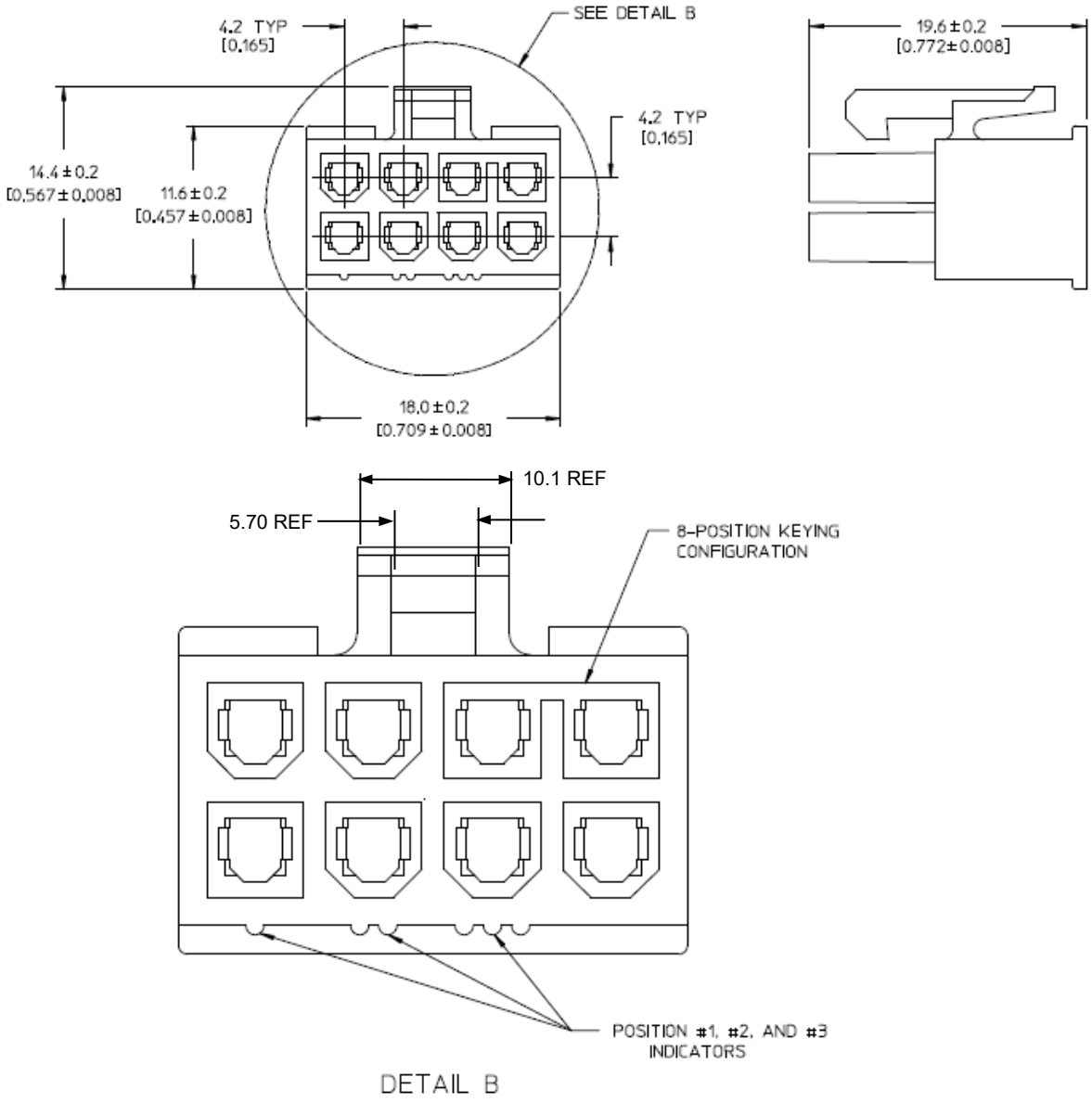


Figure 55: Cable Plug Connector Housing

Cable Assembly Contact and Housing Details:

- Housing Material: Thermoplastic; special polarization per Figure 55
- Pin Contact Base Material: Brass alloy or equivalent
- Pin Contact Plating: Sn alloy

Wire Details:

- Wire Size: 18 AWG
- Cable Bend Radius: 1xR minimum

IMPLEMENTATION NOTE

Modular Plug Connector Assembly

A 2 x 4 plug connector can be designed with a 2 x 3 plug module and a 2 x 1 plug module to form a 2 x 4 modular plug connector such that it can be plugged into a 2 x 4 or 2 x 3 receptacle. Cable assembly vendors should design the Latch Lock Hook and Release Handle with the dimensions defined in Figure 56 to ensure that the connector locks securely when plugged into a 2 x 4 or a 2 x 3 receptacle. The rest of the dimensions are the same as shown in Figure 55.

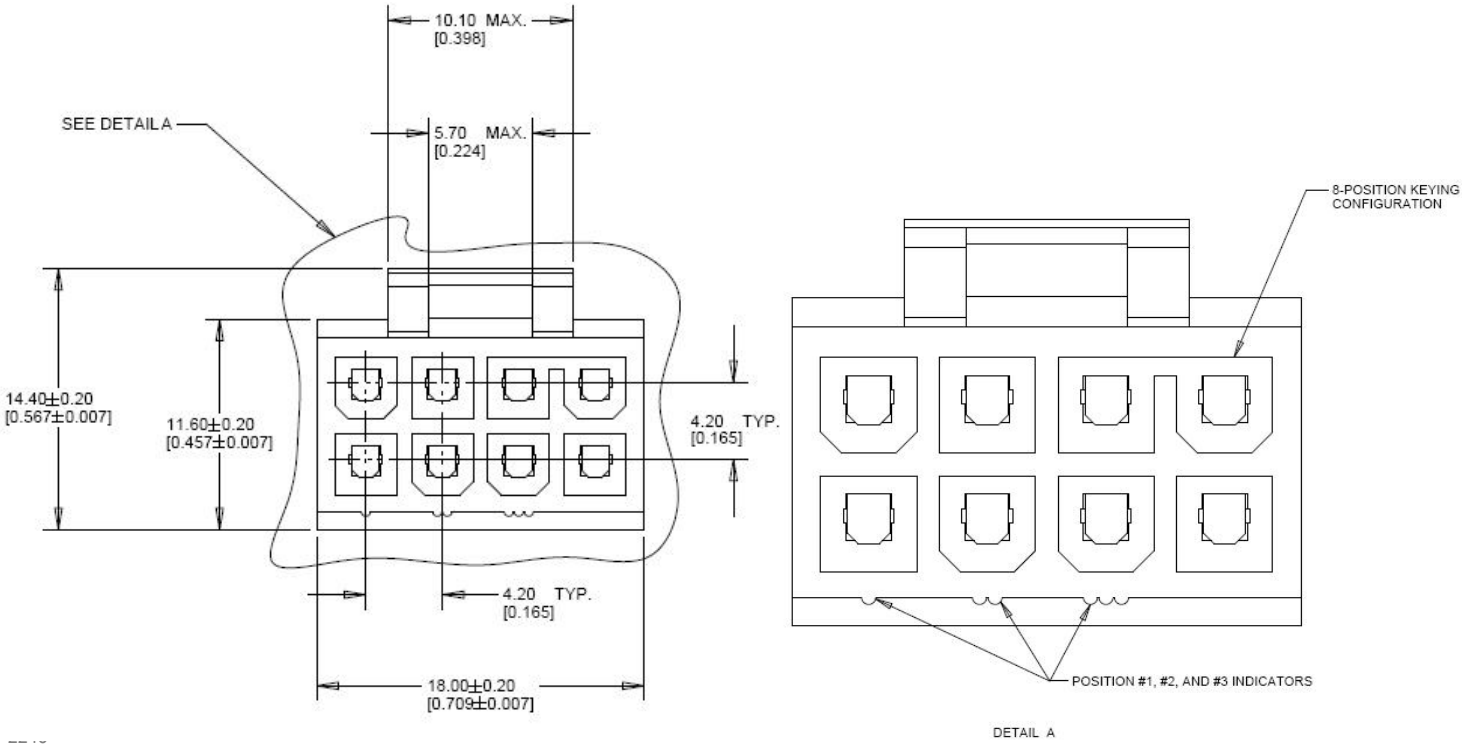


Figure 56: Modular Plug Connector Housing (All Dimensions in mm [Inches])

8.4. Connector Mating-Unmating Keepout Area (Latch Lock Release)

The connector mating-unmating keepout area is specified in Figure 57.

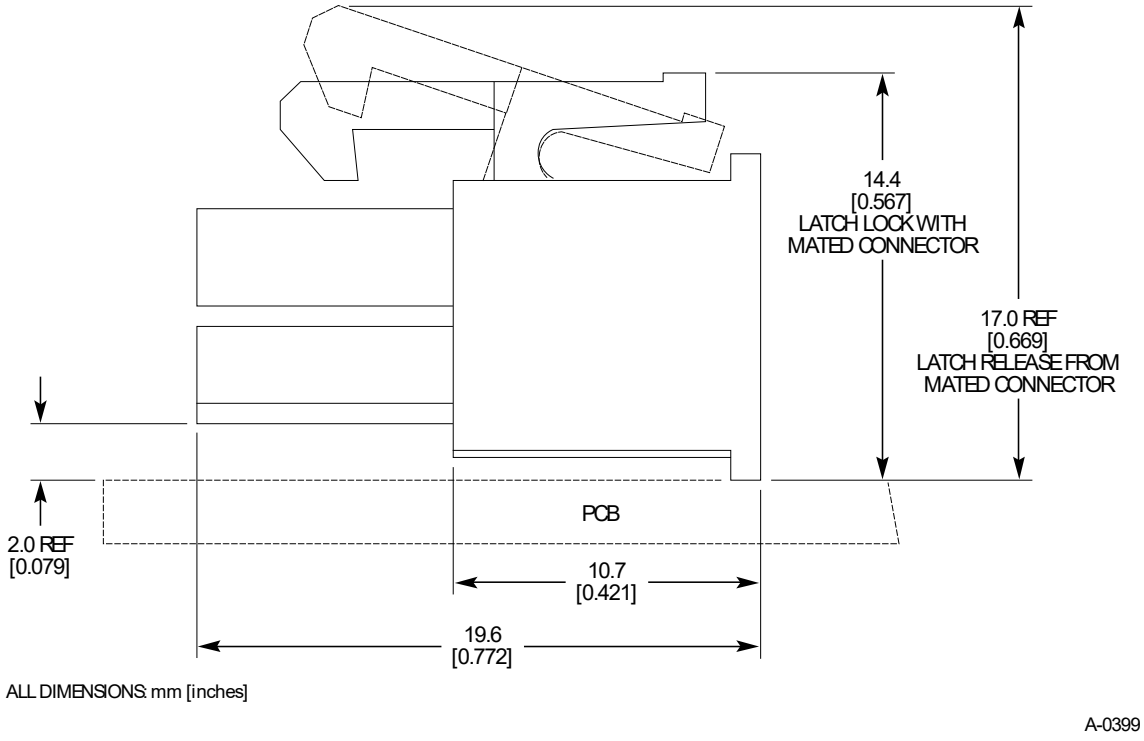


Figure 57: Connector Mating-Unmating Keepout Area (Latch Lock Release)

8.5. 2 x 4 Auxiliary Power Connector System Pin Assignment

Figure 58 and Figure 59 show the pin-out for the 2 x 4 auxiliary power connector.

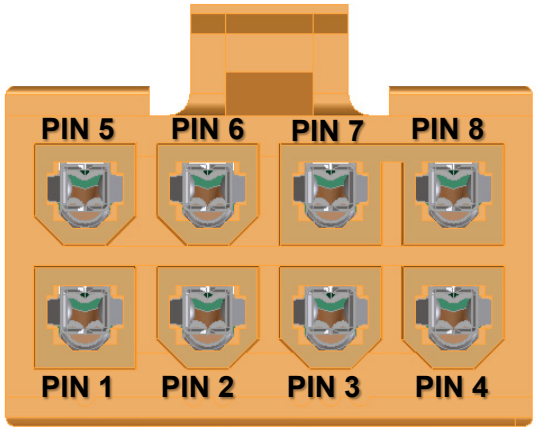


Figure 58: 2 x 4 Auxiliary Power Connector Plug Side Pin-out

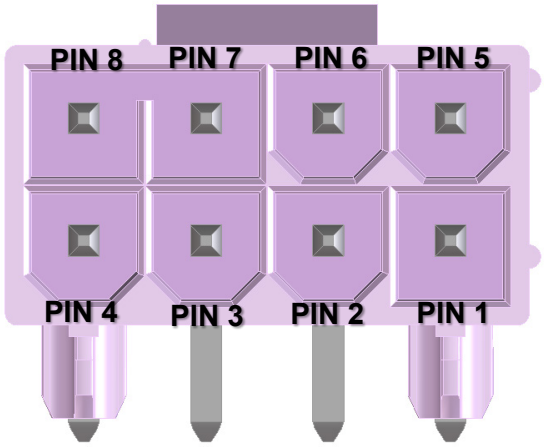


Figure 59: 2 x 4 Auxiliary Power Connector Receptacle Side Pin-out

Table 51 and Table 52 show the 2 x 4 pin-out assignments. A 225 W/300 W card with a 2 x connector receptacle, decodes the sense coding to determine how much power to draw from the 2 x 4 auxiliary power connector.

Table 51: 2 x 4 Auxiliary Power Connector Pin-out Assignment

Pin	Signal
1	+12 V
2	+12 V
3	+12 V
4	Sense1
5	Ground
6	Sense0
7	Ground
8	Ground

Table 52: Sense Pins Decoding by a Graphics Card

Sense1	Sense0	Comment
Ground	Ground	A 2 x 4 connector is plugged into the card. The card can draw up to 150 W from the auxiliary power connector.
Ground	Open	Reserved
Open	Ground	A 2 x 3 connector is plugged into the card. The graphics card can only draw up to 75 W from the auxiliary power connector.
Open	Open	No auxiliary power connector is plugged in.

For a sense pin that needs to be grounded, it must be connected to ground either directly in the power supply or via a jumper to an adjacent ground pin in the connector. A PCI Express 225 W/300 W card use sense pins to detect how much power to draw from the 2 x 3 or 2 x 4 connector.

A 2 x 4 auxiliary power connector plug from the power supply unit must not use the 75 W sense coding (Sense1=Open and Sense0=Ground) to avoid end-user confusion.

For informational purposes, Figure 60 shows the 2 x 3 connector pin-out. Table 53 shows how the pins are mapped when a 2 x 3 plug is inserted into a 2 x 4 receptacle.

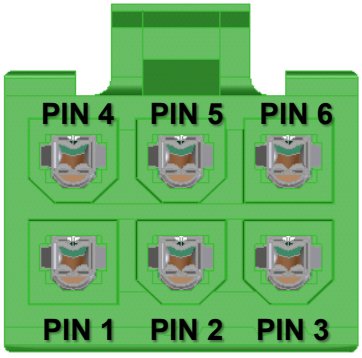


Figure 60: 2 x 3 Connector Pin-out

2277 **Table 53: 2 x 3 Plug to 2 x 4 Receptacle Pin Mapping**

2 x 3 Plug	2 x 4 Receptacle	Signal
1	1	+12 V
2	2	+12 V
3	3	+12 V
NA	4	Sense1
4	5	Ground
5	6	Sense0
6	7	Ground
NA	8	Ground

2278

2279 # 8.6. Additional Considerations

2280 Table 54 lists the additional requirements for the PCI Express 2 x 4 auxiliary power connector.

2281 **Table 54: Additional Requirements**

Parameter	Procedure	Requirement
Flammability	UL94V-1 minimum	Material certification or certificate of compliance required with each lot to satisfy the Underwriters Laboratories follow-up service requirements.
Lead-free soldering		Connector must be compatible with lead free soldering process.
Connector Color		Color of the connector must be black. Exceptions will be made for color coding schemes that call for a different color of this connector.

2282

9

9. Add-in Card Form Factors and Implementation

9.1. Add-in Card Form Factors

To enable the reuse of existing chassis slots, the PCI Express Add-in Cards are similar to the PCI Add-in Card form factor. Two PCI Express Add-in Card heights are defined: the standard height of 111.28 mm (4.376 inches) maximum and the low profile of 68.90 mm (2.731 inches) maximum. The card height is measured from the bottom of the edge-finger to the top of the card (see Figure 61 and Figure 64). A PCI Express DUAL-SLOT Add-in Card has the same dimensions as a standard height full length card, except the component side height restriction is reduced to 34.80 mm. A TRIPLE-SLOT Add-in Card has the same dimensions as a standard height full length card, except the component side height restriction is 55.12 mm. Table 55 lists the Add-in Card sizes.

Table 55: Add-in Card Sizes

Add-in Card	Height	Length[1]
Standard height	111.28 mm (4.381 inches) maximum	See Figure 61.
Low profile	68.90 mm (2.731 inches) maximum	See Figure 66.

The maximum length specifies what the system design must accommodate. An Add-in Card can be any length up to the maximum for a length interval. For example, a standard height card with a 177.80 mm (7.00 inch) length can be installed in a system that accommodates 241.30 mm (9.5 inches) maximum length cards, but a system that only accommodates 167.65 mm (6.6 inches) maximum length cards will not support this card.

IMPLEMENTATION NOTE

PCI Express Card Length

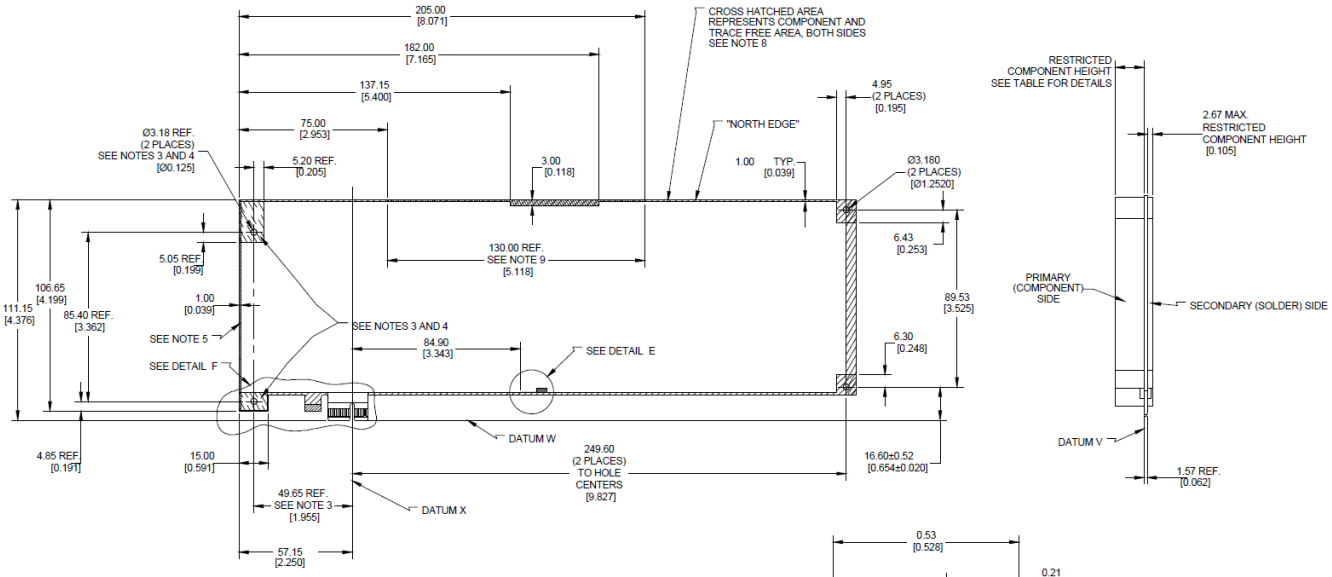
Not all system designs will support 312 mm full length cards. It is strongly recommended that PCI Express Add-in Cards be designed with a 241.30 mm (9.5 inches) maximum length. This applies to SINGLE-SLOT, DUAL-SLOT, and TRIPLE-SLOT Add-in Card designs.

Figure 61 and Figure 63 show the standard PCI Express card form factor without and with the I/O bracket, respectively.

The following notes apply to Figure 61 through Figure 64:

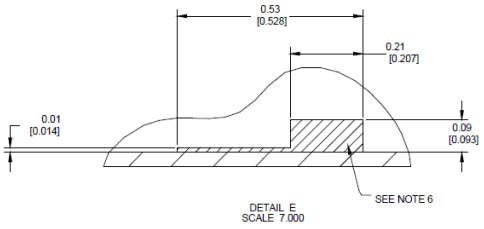
[1] Not all system designs will support this length of Add-in Card. It is strongly recommended that standard height Add-in Cards be designed with a 241.30 mm (9.5 inches) maximum length.

- The mounting holes illustrated in Figure 61 are required only on the right end of the full-length card (312.00 mm). Those holes may be needed to install an optional PCI Add-in Card retainer.
- The mounting holes and keepout zones around them marked as note 3 in Figure 61 may be used on those cards in which the I/O bracket is mounted to the card directly and are for reference purposes only. The purpose of this keepout is to ensure that the card cannot short out on the I/O bracket. Add-in Card providers must ensure that their card cannot short out the I/O bracket. On full-length cards, a keepout of 5.08 mm is required to prevent card components from being damaged by the system's card guides (see Figure 61).
- All graphics cards are required to be retention ready as defined in Section 9.2. This retention ready requirement may also apply to x1, x4, x8, or x16 I/O cards at each OEM, or Add-in Card manufacturer's discretion. See Section 9.2 for more information.
- Special attention shall be given to high mass Add-in Cards. This specification defines the additional feature and keepouts for high-mass cards for card retention shown in Figure 64. This retention feature is not limited to higher-mass cards and may be used by any card.



NOTES:
1. TOLERANCE UNLESS OTHERWISE SPECIFIED: ±0.13 [0.005]
2. THIS FEATURE IS TO PREVENT THE PCI EXPRESS CARD FROM BEING PLUGGED INTO PCI CONNECTORS
3. THESE MOUNTING HOLES AND THE KEEP-OUT AROUND THEM ARE REQUIRED ONLY WHEN THE I/O BRACKET IS MOUNTED TO THE CARD DIRECTLY. FURTHERMORE, THESE ARE CHASSIS KEEPOUTS AREAS, ARE INCLUDED IN THE ADD-IN CARD VOLUME, AND MUST ABIDE BY THE RESTRICTED COMPONENT HEIGHT, BOTH SIDES.
4. THESE MOUNTING HOLES MAY BE LOCATED DIFFERENTLY THAN AS SHOWN. ADDITIONALLY, THE SIZE OF THE KEEP-OUTS AROUND THESE HOLES ARE AT THE DISCRETION OF THE ADD-IN CARD PROVIDER.
5. CROSS HATCHED AREA REPRESENTS AN EXPOSED SIGNAL/POWER COMPONENT, FEATURE, AND TRACE FREE AREA, SECONDARY SIDE (SOLDER SIDE) ONLY. HOWEVER, NON-CONDUCTIVE FEATURES (PLASTIC LOCATION PINS, ETC.), GROUNDED FEATURES (BOARDLOCKS, GROUND PINS AND VIAS, ETC.) AND NON-EXPOSED TRACES ARE ALLOWED TO RESIDE IN THIS AREA
6. CROSS HATCHED AREA REPRESENTS COMPONENT FREE AREA, BOTH SIDES
7. NO COPPER OR SOLDER MASK IS ALLOWED IN CROSS HATCHED AREA, BOTH SIDES
8. UNLESS OTHERWISE SPECIFIED AND ALONG "NORTH EDGE" ONLY, EXTERNALLY-MATING CONNECTORS, INCLUDING BUT NOT LIMITED TO POWER CONNECTORS, CARD-TO-CARD EDGE OR BRIDGE CONNECTORS, SPDIF CONNECTORS, ETC. MAY ENCROACH INTO THIS AREA. INTRUSION BY SELF-CONTAINED COMPONENTS AND EXPOSED TRACES ARE PROHIBITED.
9. NO COMPONENTS OR SURFACE TRACES ALLOWED IN THIS AREA. IN ADDITION, ITEMS INCLUDING BUT NOT LIMITED TO HEATSINKS, DAUGHTER CARDS, OR MATING CONNECTORS (IN WHOLE OR IN PART) ARE NOT ALLOWED TO EXTEND INTO NOR ABOVE THE CARD EDGE IN THIS AREA. THIS KEEPOUT APPLIES TO BOTH SIDES OF THE CARD. THIS KEEPOUT ESTABLISHES A CONSISTENT REGION FOR SUPPLEMENTAL MECHANICAL SUPPORT OF THE ADD-IN CARD BY THE SYSTEM.
10. SEE FIGURE 92 FOR ADDITIONAL KEEPOUT DESCRIPTIONS

TABLE	
CONFIGURATION	PRIMARY SIDE HEIGHT RESTRICTION
SINGLE SLOT	14.47 MAX [0.570]
DUAL SLOT	34.80 MAX [1.370]
TRIPLE SLOT	55.12 MAX [2.170]



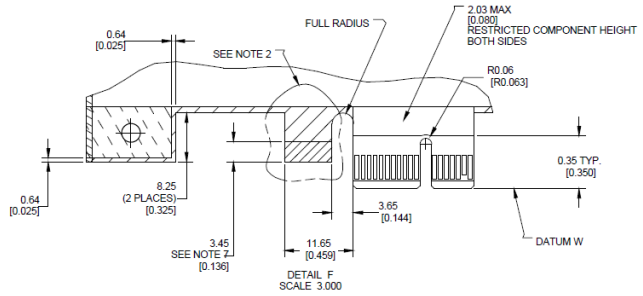
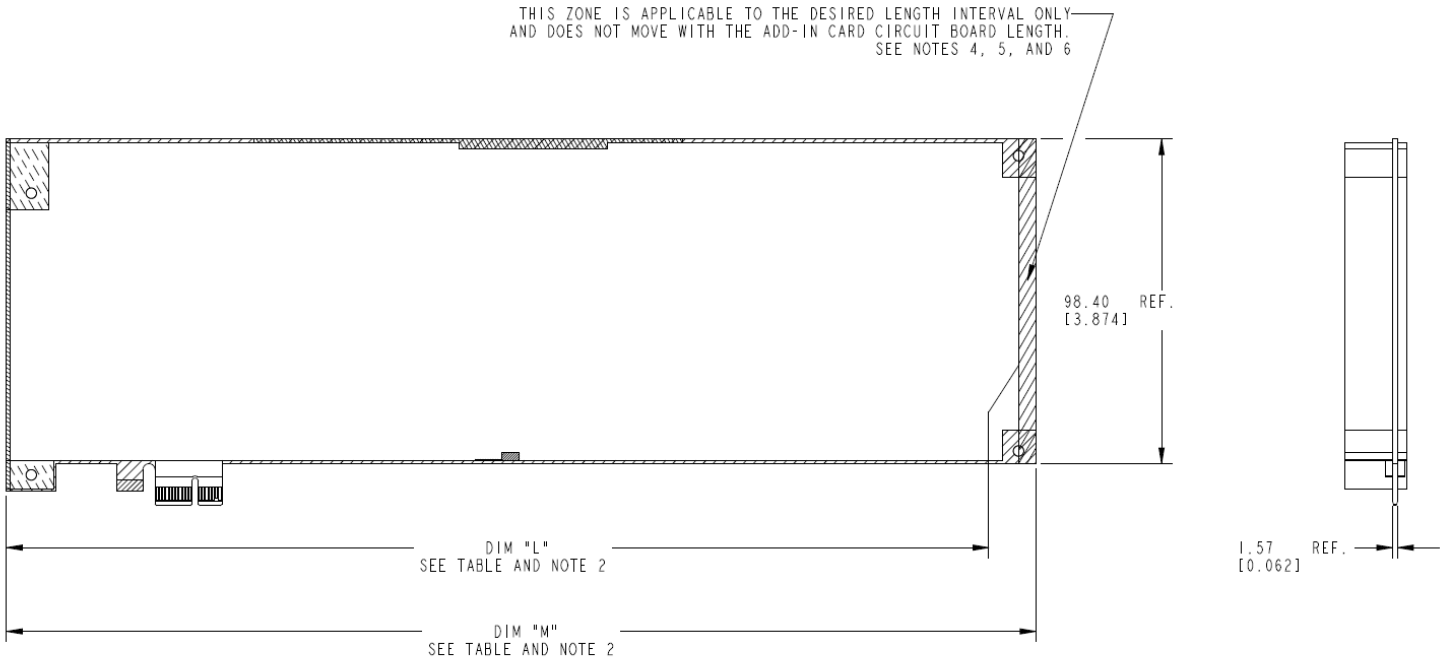


Figure 61: Standard Height PCI Express Add-in Card without the I/O Bracket

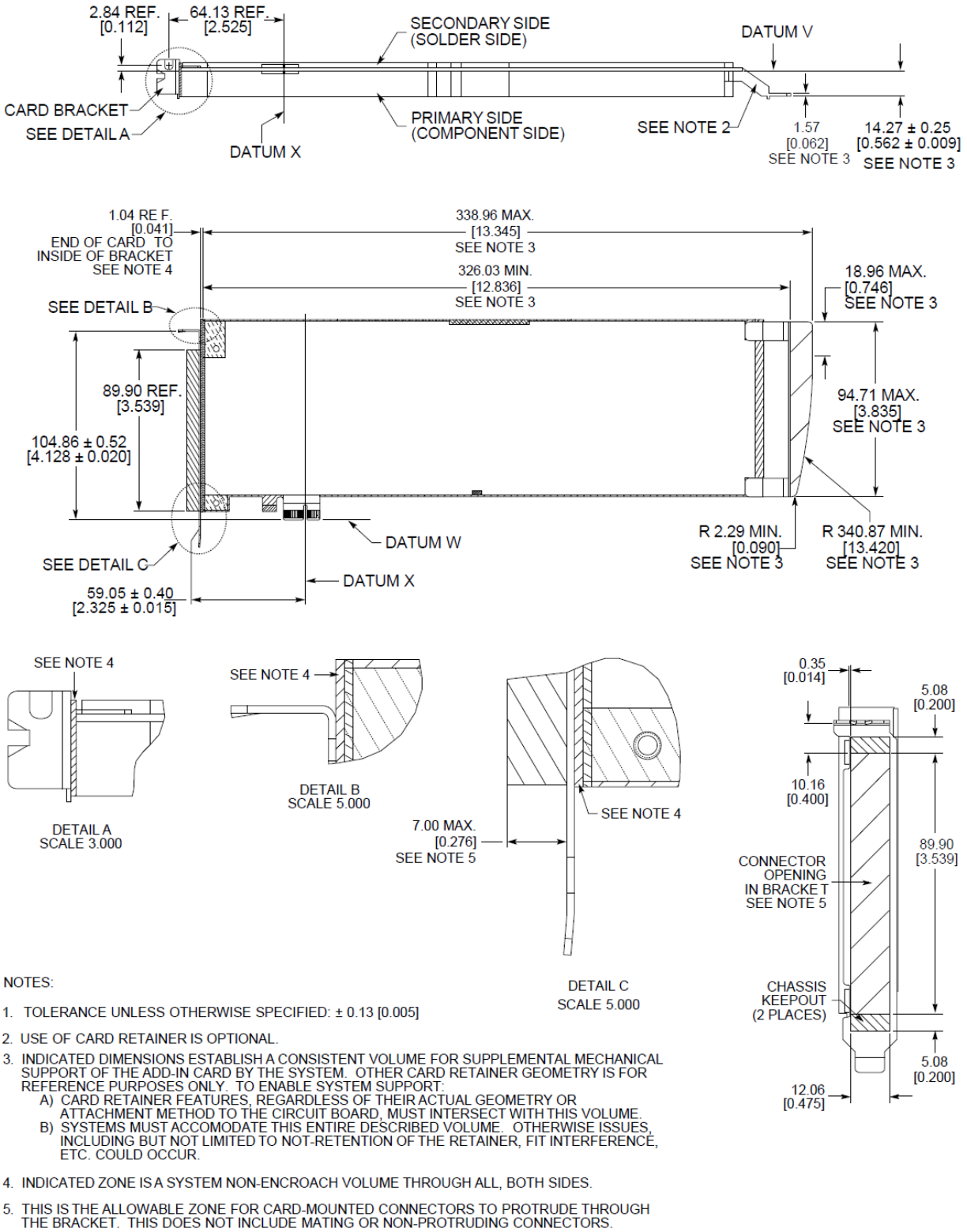


NOTES:

1. TOLERANCE UNLESS OTHERWISE SPECIFIED: ±0.13 [0.005]
2. DIMENSIONS ESTABLISH A CONSISTENT VOLUME FOR END CARD MECHANICAL SUPPORT
3. FOR EACH LENGTH INTERVAL, DIMENSION "M" ALSO DESCRIBES THE MAXIMUM OVERALL LENGTH OF THE ADD-IN CARD ASSEMBLY
4. FOR EACH DESIRED LENGTH INTERVAL, FEATURES OF THE ADD-IN CARD ASSEMBLY MUST INTERSECT WITH THIS VOLUME. IF PART OF THE ADD-IN CARD CIRCUIT BOARD, THIS MUST BE A COMPONENT AND SURFACE TRACE FREE AREA, BOTH SIDES.
5. FOR EACH DESIRED LENGTH INTERVAL, SYSTEMS MUST ACCOMODATE THE ENTIRE DESCRIBED VOLUME. OTHERWISE, ISSUES INCLUDING BUT NOT LIMITED TO NON-RETENTION OF ADD-IN CARD, FIT INTERFERENCE, ETC. COULD OCCUR.
6. FOR THE FULL LENGTH INTERVAL ONLY, ITEMS INCLUDING BUT NOT LIMITED TO HEATSINKS, DAUGHTER CARDS, OR MATING CONNECTORS (IN WHOLE OR IN PART) ARE NOT ALLOWED TO EXTEND INTO THIS AREA. THIS KEEPOUT APPLIES TO BOTH SIDES OF THE CARD. THESE ADDITIONAL COMPONENT AND TRACE RESTRICTIONS ARE DESIRED BUT NOT REQUIRED FOR THE HALF-LENGTH AND THREE-QUARTER LENGTH INTERVALS.

TABLE		
LENGTH INTERVAL	DIM "L"	DIM "M"
HALF LENGTH	162.57 [6.400]	167.65 MAX [6.600]
THREE-QUARTER LENGTH	248.92 [9.800]	254.00 MAX [10.000]
FULL LENGTH	306.92 [12.083]	312.00 MAX [12.283]

Figure 62: Chassis Interface Zones on Right/East Edge of Add-in Card



NOTES:

1. TOLERANCE UNLESS OTHERWISE SPECIFIED: ± 0.13 [0.005]
2. USE OF CARD RETAINER IS OPTIONAL.
3. INDICATED DIMENSIONS ESTABLISH A CONSISTENT VOLUME FOR SUPPLEMENTAL MECHANICAL SUPPORT OF THE ADD-IN CARD BY THE SYSTEM. OTHER CARD RETAINER GEOMETRY IS FOR REFERENCE PURPOSES ONLY. TO ENABLE SYSTEM SUPPORT:
   A) CARD RETAINER FEATURES, REGARDLESS OF THEIR ACTUAL GEOMETRY OR ATTACHMENT METHOD TO THE CIRCUIT BOARD, MUST INTERSECT WITH THIS VOLUME.
   B) SYSTEMS MUST ACCOMODATE THIS ENTIRE DESCRIBED VOLUME. OTHERWISE ISSUES, INCLUDING BUT NOT LIMITED TO NOT-RETENTION OF THE RETAINER, FIT INTERFERENCE, ETC. COULD OCCUR.
4. INDICATED ZONE IS A SYSTEM NON-ENCROACH VOLUME THROUGH ALL, BOTH SIDES.
5. THIS IS THE ALLOWABLE ZONE FOR CARD-MOUNTED CONNECTORS TO PROTRUDE THROUGH THE BRACKET. THIS DOES NOT INCLUDE MATING OR NON-PROTRUDING CONNECTORS.

A-0904a

Figure 63: Standard Height PCI Express Add-in Card with the I/O Bracket and Card Retainer

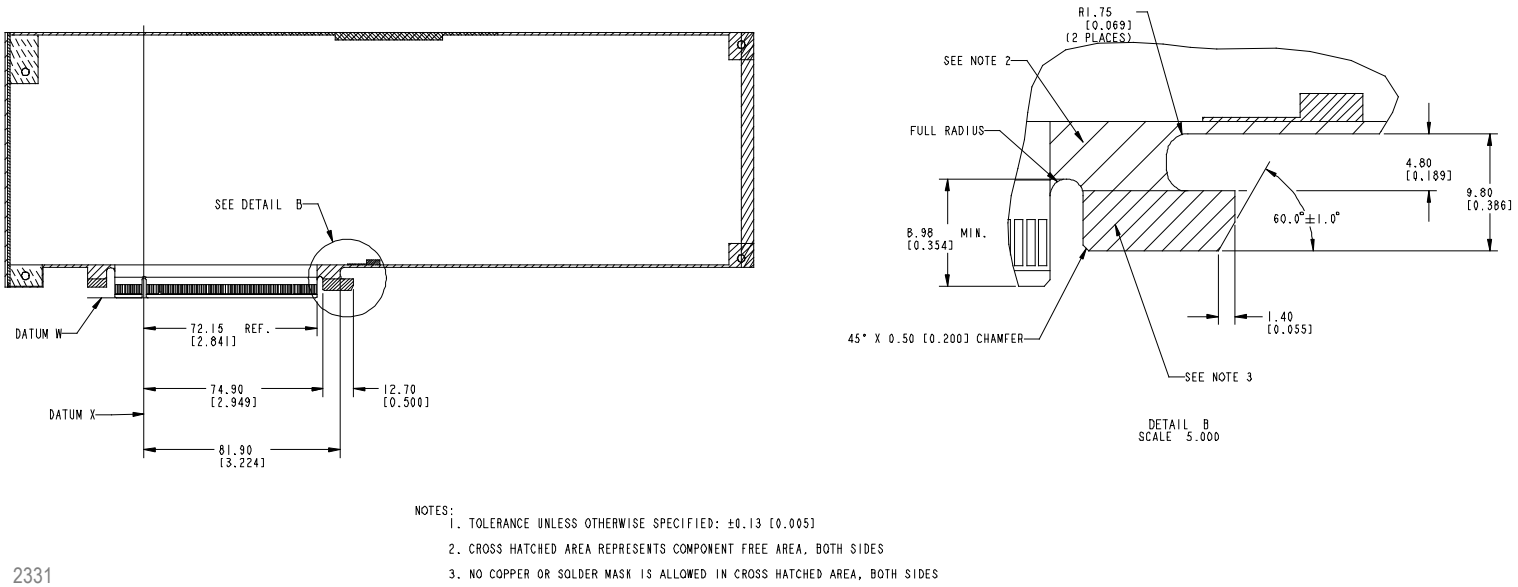


Figure 64: Additional Feature and Keepouts for a High Mass Card

The 3.0 mm keepout on the top of the card is to accommodate system or chassis-level card retention solutions at each OEM's discretion. To facilitate a chassis level retention solution, the height of the standard height graphics card is required to be fixed: 111.15 mm ±0.13 mm. The "hockey stick" shaped feature and keepout defined on the bottom of the card is to allow retention mechanisms either mounted directly on the system board or integrated into the connector. If present, the position (relative to Datum X in Figure 9-4) of the "hockey stick" must remain the same, regardless of the length of the connector/edge fingers. This feature and keepout are also required for the low-profile graphics card.

All retention mechanisms that are intended for high mass cards must use the feature/keepout defined in Figure 64. However, the specific retention mechanism design left to the system manufacturers' choice. Figure 65 shows the standard PCI Express I/O bracket, which is the same as the PCI bracket. The mounting tabs of the bracket shown in Figure 65 are to be mounted onto the secondary side of the card, as illustrated in Figure 63. However, a user also has the option to have a bracket with the mounting tabs mounted onto the primary side of the card. Exact locations of contact between the bracket and the Add-in Card PCB (and the associated keepout zones) are at the discretion of the Add-in Card provider and must not be assumed to be fixed by the system integrator for additional card retention. Any dimensions in figures which describe geometry for "PCB attach" are REFERENCE.

The detailed Add-in Card edge-finger dimensions are defined in Section 6.2, which describes the connector mating interface. The edge-finger portions of the PCI Express cards are required to have bevels or chamfers as defined in Figure 37.

Figure 66 and Figure 68 show, respectively, the low-profile PCI Express Add-in Card form factor without and with the bracket, while Figure 69 shows the low-profile Add-in Card I/O bracket. When mounting a low-profile card into a full height PCI slot, the standard I/O bracket must be modified to add a stiffening flange. Figure 70 shows the modified full height I/O bracket for low profile cards.

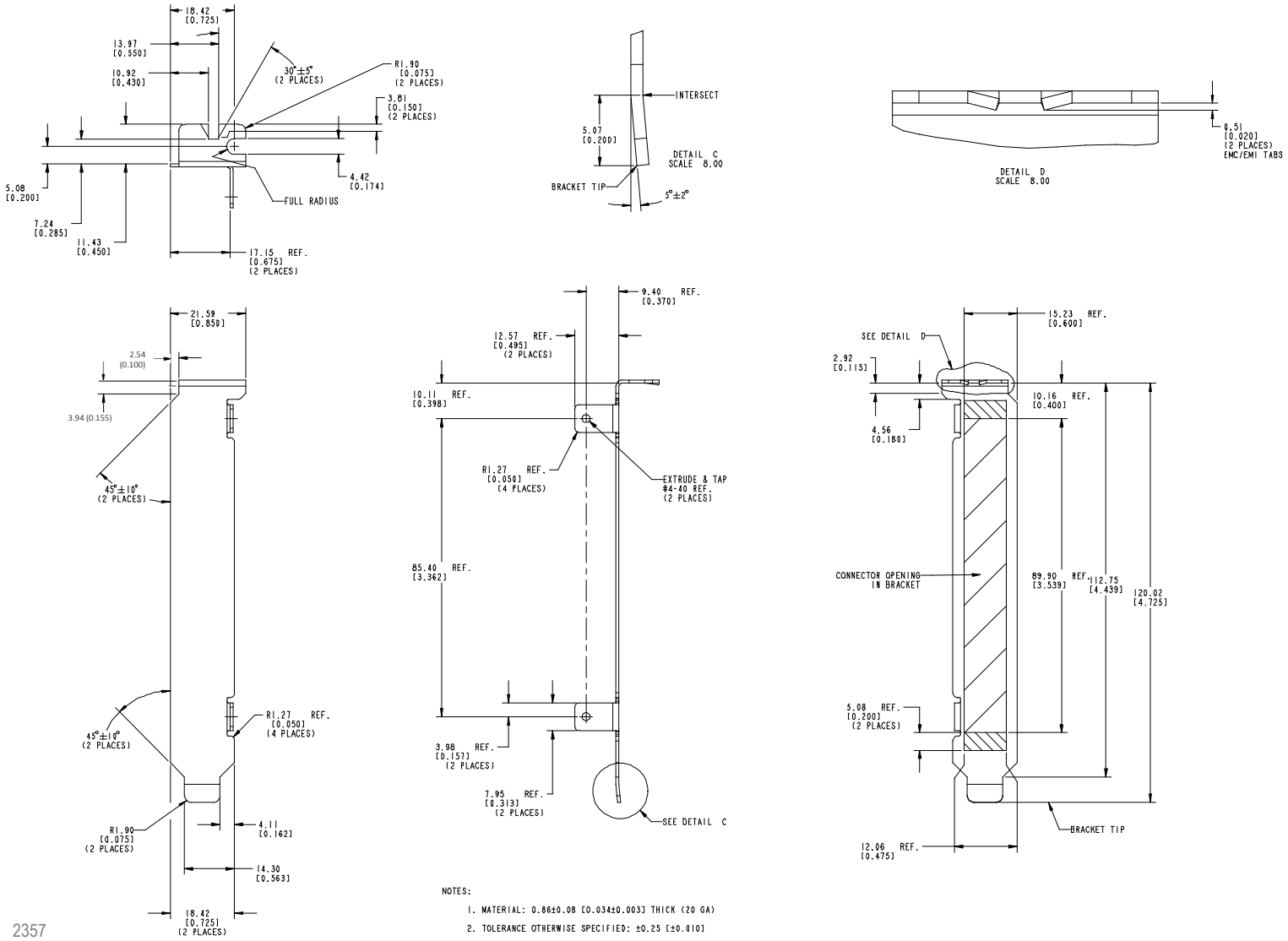
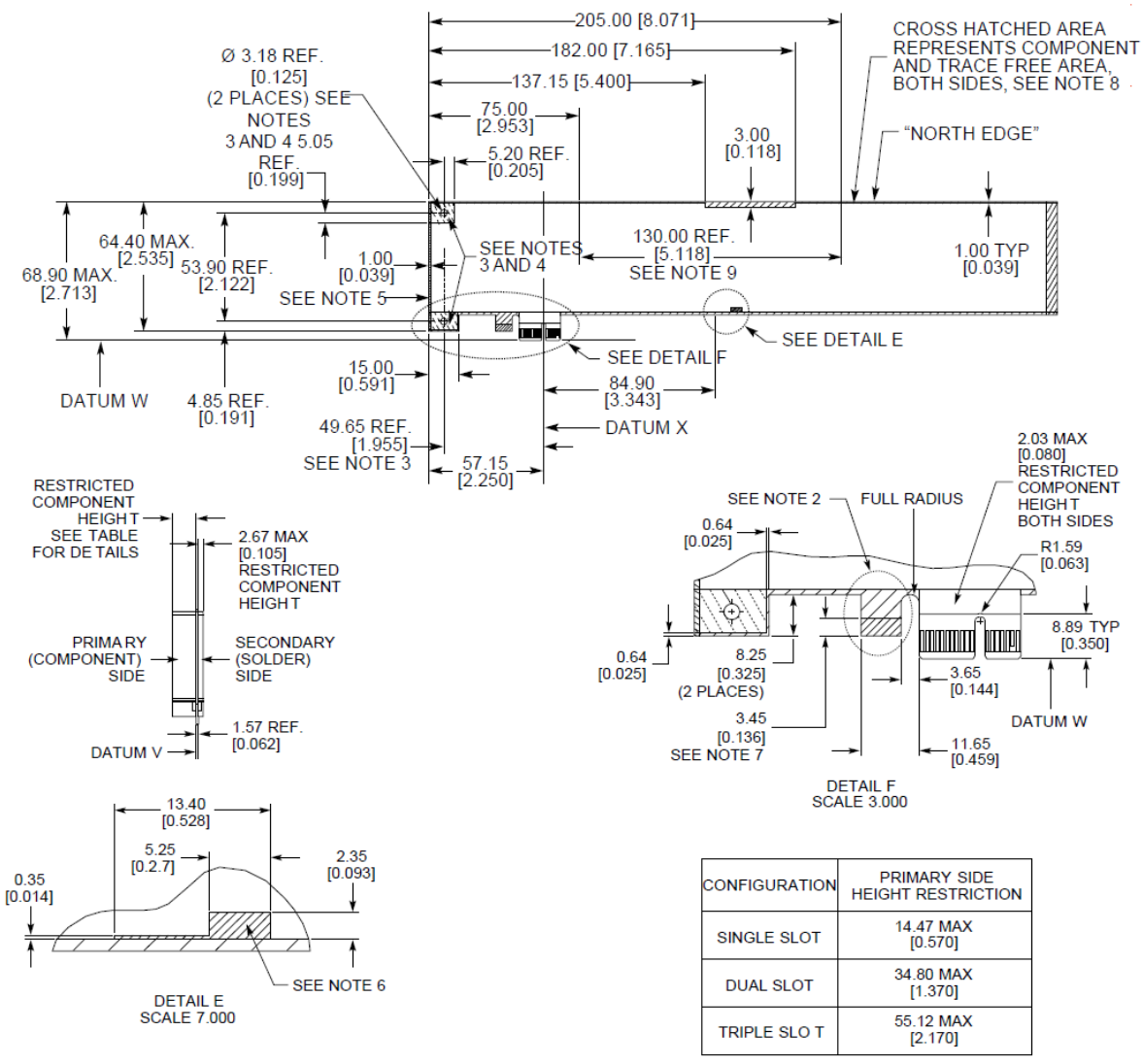


Figure 65: Standard Add-in Card I/O Bracket



CONFIGURATION	PRIMARY SIDE HEIGHT RESTRICTION
SINGLE SLOT	14.47 MAX [0.570]
DUAL SLOT	34.80 MAX [1.370]
TRIPLE SLO T	55.12 MAX [2.170]

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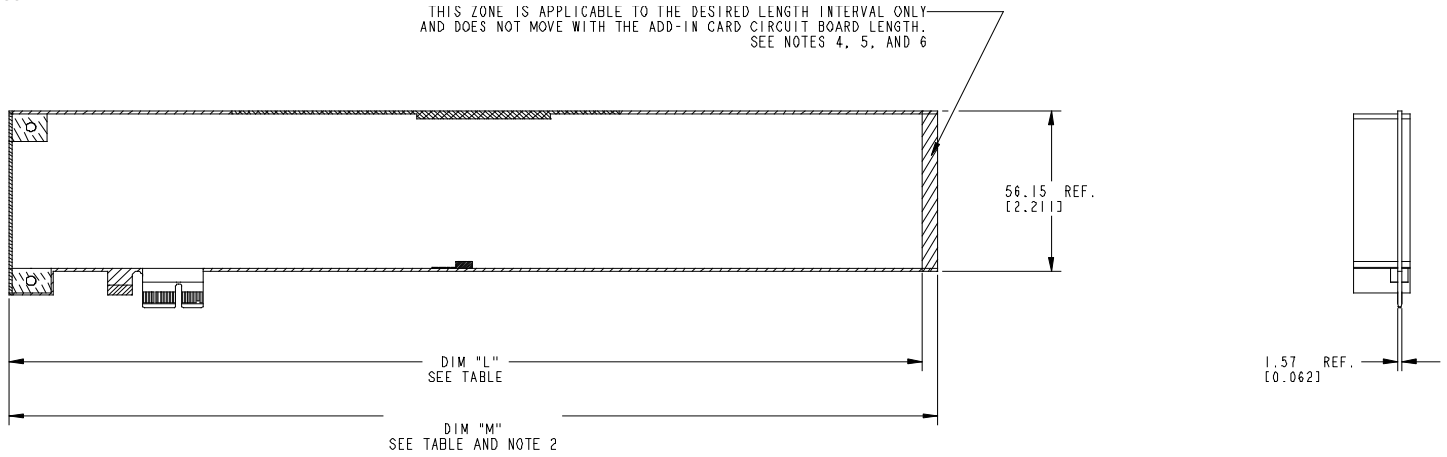
NOTES:

1. TOLERANCE UNLESS OTHERWISE SPECIFIED: ± 0.13 [0.005]
2. THIS FEATURE IS TO PREVENT THE PCI EXPRESS CARD FROM BEING PLUGGED INTO PCI CONNECTORS.
3. THESE MOUNTING HOLES AND THE KEEP-OUT AROUND THEM ARE REQUIRED ONLY WHEN THE I/O BRACKET IS MOUNTED TO THE CARD DIRECTLY. FURTHERMORE, THESE ARE CHASSIS KEEPOUT AREAS, ARE INCLUDED IN THE ADD-IN CARD VOLUME, AND MUST ABIDE BY THE RESTRICTED COMPONENT HEIGHT, BOTH SIDES.
4. THESE MOUNTING HOLES MAY BE LOCATED DIFFERENTLY THAN AS SHOWN. ADDITIONALLY, THE SIZE OF THE KEEP-OUTS AROUND THESE HOLES ARE AT THE DISCRETION OF THE ADD-IN CARD PROVIDER.
5. CROSS HATCHED AREA REPRESENTS AN EXPOSED SIGNAL/POWER COMPONENT, FEATURE, AND TRACE FREE AREA, SECONDARY SIDE (SOLDER SIDE) ONLY. HOWEVER, NON-CONDUCTIVE FEATURES (PLASTIC LOCATION PINS, ETC.), GROUNDED FEATURES (BOARDLOCKS, GROUND PINS AND VIAS, ETC.) AND NON-EXPOSED TRACES ARE ALLOWED TO RESIDE IN THIS AREA.
6. CROSS HATCHED AREA REPRESENTS COMPONENT FREE AREA, BOTH SIDES.
7. NO COPPER OR SOLDER MASK IS ALLOWED IN CROSS HATCHED AREA, BOTH SIDES.
8. UNLESS OTHERWISE SPECIFIED AND ALONG "NORTH EDGE" ONLY, EXTERNALLY-MATED CONNECTORS, INCLUDING BUT NOT LIMITED TO POWER CONNECTORS, CARD-TO-CARD EDGE OR BRIDGE CONNECTORS, S/PDIF CONNECTORS, ETC. MAY ENCROACH INTO THIS AREA. INTRUSION BY SELF-CONTAINED COMPONENTS AND EXPOSED TRACES ARE PROHIBITED.
9. NO COMPONENTS OR SURFACE TRACES ALLOWED IN THIS AREA. IN ADDITION, ITEMS INCLUDING BUT NOT LIMITED TO HEATSINKS, DAUGHTER CARDS, OR MATING CONNECTORS (IN WHOLE OR IN PART) ARE NOT ALLOWED TO EXTEND INTO NOR ABOVE THE CARD EDGE IN THIS AREA. THIS KEEPOUT APPLIES TO BOTH SIDES OF THE CARD. THIS KEEPOUT ESTABLISHES A CONSISTENT REGION FOR SUPPLEMENTAL MECHANICAL SUPPORT OF THE ADD-IN CARD BY THE SYSTEM.
10. SEE FIGURE 62 FOR ADDITIONAL KEEPOUT DESCRIPTIONS

2361 **Figure 66: Low Profile PCI Express Add-in Card without the I/O Bracket**

2362



NOTES:

1. TOLERANCE UNLESS OTHERWISE SPECIFIED: ±0.13 [0.005]
2. DIMENSIONS ESTABLISH A CONSISTENT VOLUME FOR END CARD MECHANICAL SUPPORT
3. FOR EACH LENGTH INTERVAL, DIMENSION "M" ALSO DESCRIBES THE MAXIMUM OVERALL LENGTH OF THE ADD-IN CARD ASSEMBLY
4. FOR EACH DESIRED LENGTH INTERVAL, FEATURES OF THE ADD-IN CARD ASSEMBLY MUST INTERSECT WITH THIS VOLUME. IF PART OF THE ADD-IN CARD CIRCUIT BOARD, THIS MUST BE A COMPONENT AND SURFACE TRACE FREE AREA, BOTH SIDES.
5. FOR EACH DESIRED LENGTH INTERVAL, SYSTEMS MUST ACCOMODATE THE ENTIRE DESCRIBED VOLUME. OTHERWISE, ISSUES INCLUDING BUT NOT LIMITED TO NON-RETENTION OF ADD-IN CARD, FIT INTERFERENCE, ETC. COULD OCCUR.
6. FOR THE FULL LENGTH INTERVAL ONLY, ITEMS INCLUDING BUT NOT LIMITED TO HEATSINKS, DAUGHTER CARDS, OR MATING CONNECTORS (IN WHOLE OR IN PART) ARE NOT ALLOWED TO EXTEND INTO THIS AREA. THIS KEEPOUT APPLIES TO BOTH SIDES OF THE CARD. THESE ADDITIONAL COMPONENT AND TRACE RESTRICTIONS ARE DESIRED BUT NOT REQUIRED FOR THE HALF-LENGTH AND THREE-QUARTER LENGTH INTERVALS.

TABLE		
LENGTH INTERVAL	DIM "L"	DIM "M"
HALF LENGTH	166.65 [6.561]	167.65 MAX [6.600]
THREE-QUARTER LENGTH	248.92 [9.800]	254.00 MAX [10.000]
FULL LENGTH	306.92 [12.083]	312.00 MAX [12.283]

2363

2364 **Figure 67: Chassis Interface Zone on Right/East Edge of Low-Profile Add-in Card**

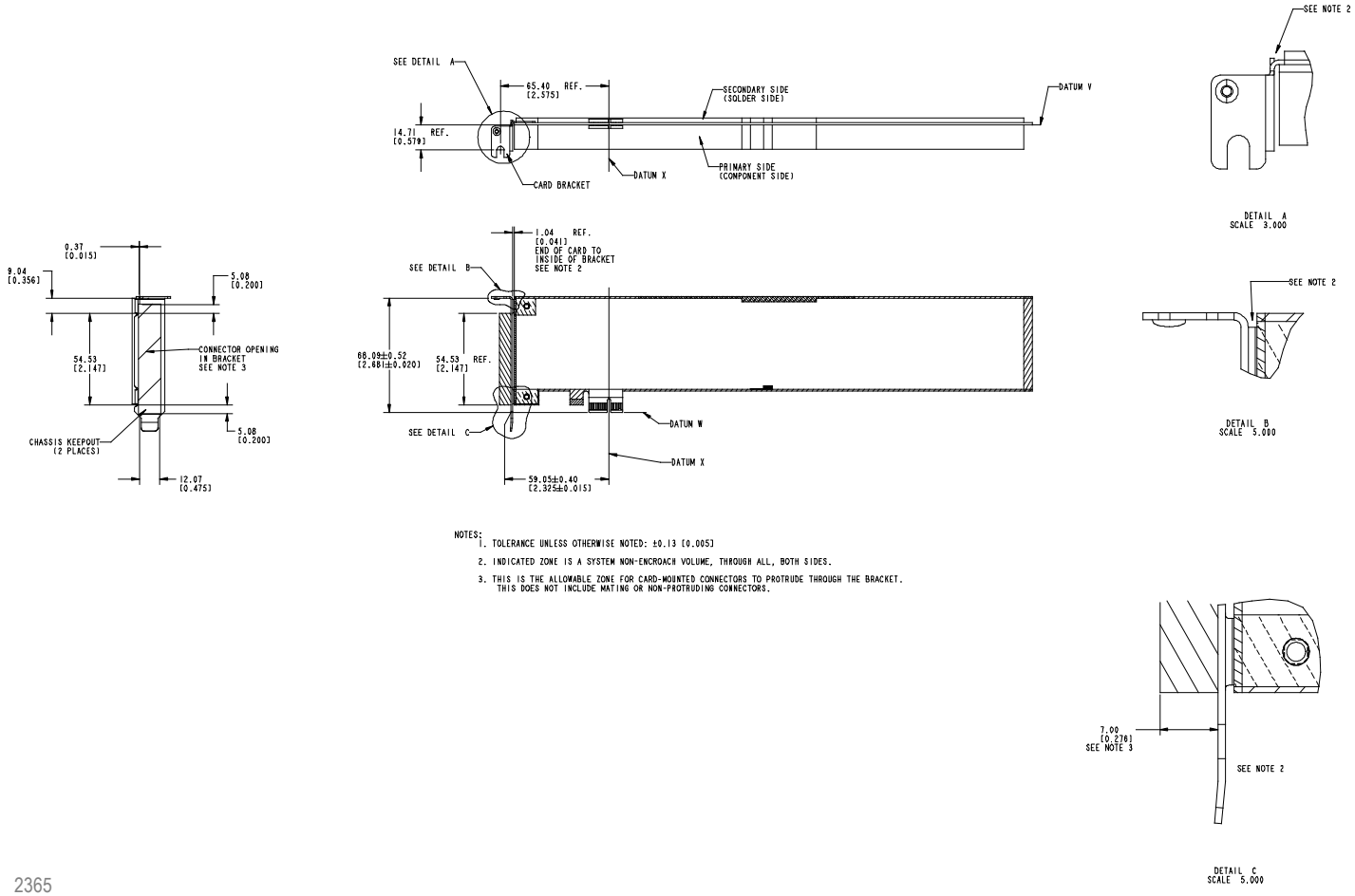
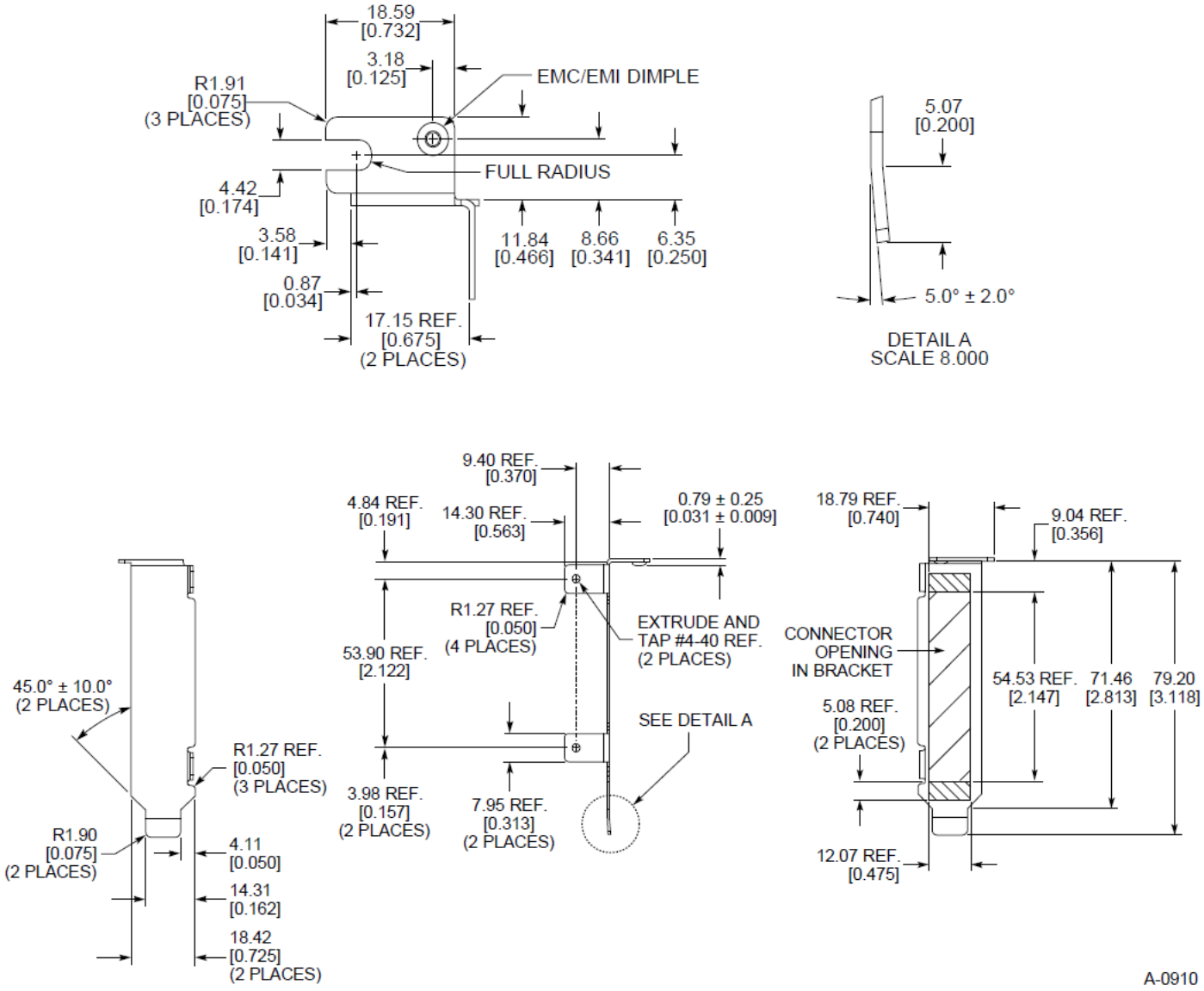


Figure 68: Low Profile PCI Express Add-in Card with the I/O Bracket

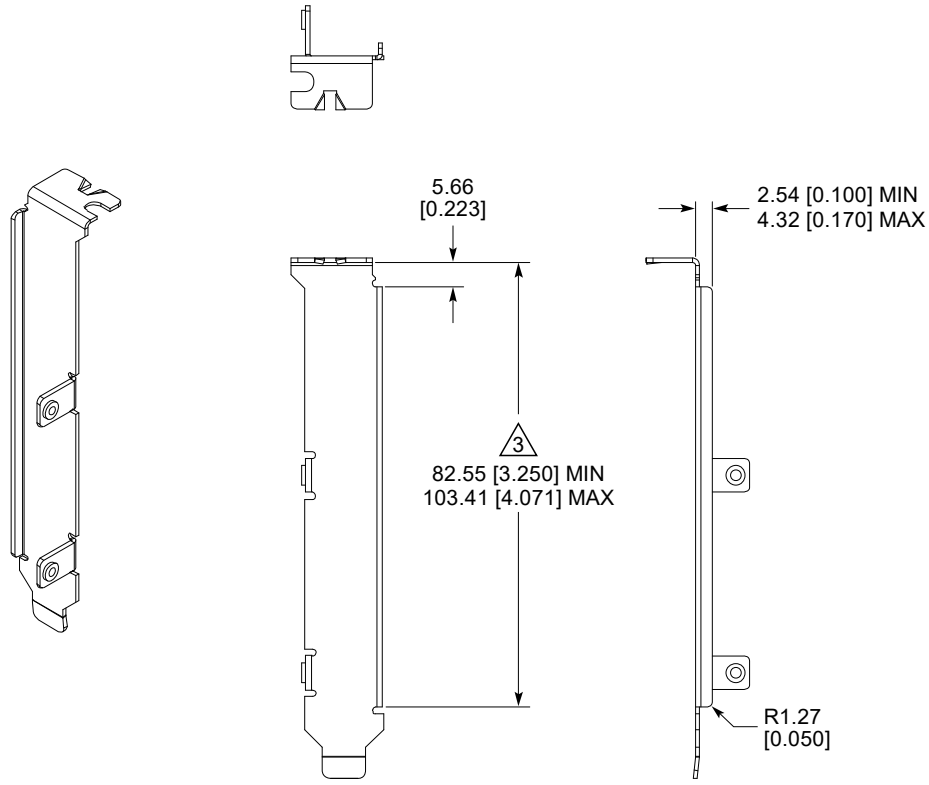


NOTES:

1. MATERIAL: 0.86 ± 0.08 [0.034 ± 0.003] THICK (20 GA)
2. TOLERANCE UNLESS OTHERWISE SPECIFIED: ± 0.25 [± 0.010]

2368

Figure 69: Low Profile I/O Bracket



NOTES:
1. STIFFENING FLANGE IS REQUIRED WHEN MOUNTING A LOW PROFILE CARD TO A FULL HEIGHT BRACKET.
2. STIFFENING FLANGE IS OPTIONAL WHEN MOUNTING A FULL HEIGHT CARD.
3. THIS DIMENSION PROVIDES FOR CLEARANCE BETWEEN THE FLANGE AND COMPONENTS ON THE MOTHERBOARD.
4. THIS DRAWING SHOWS THE DIMENSIONS OF THE STIFFENING FLANGE ONLY. SEE FIGURE 9-5 FOR DIMENSIONS OF THE REMAINING FEATURES.
5. TOLERANCE UNLESS OTHERWISE NOTED: ± 0.25 [± 0.010]

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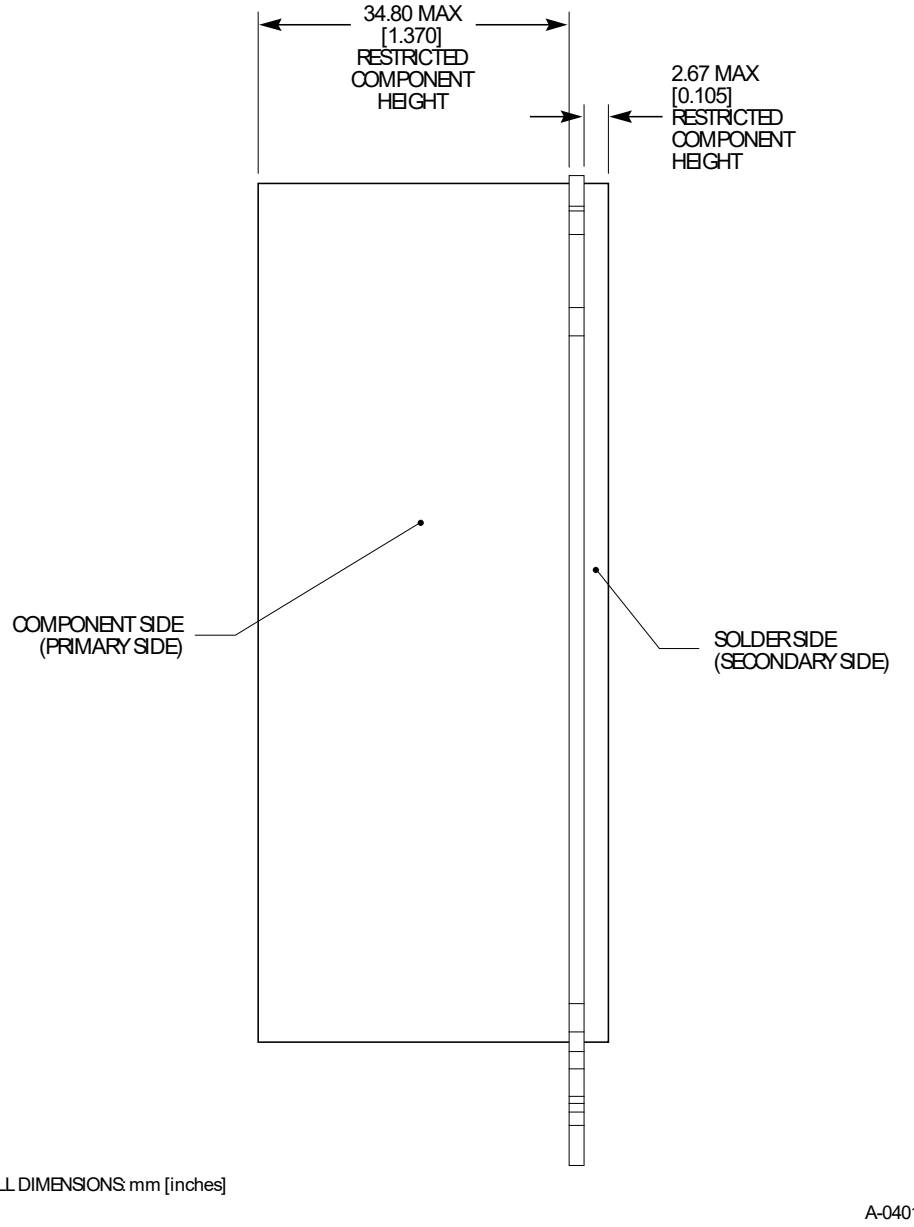
Figure 70: Full Height I/O Bracket for Low Profile Cards

2372 The form factor dimensions for a PCI Express DUAL-SLOT Add-in Card are shown in Figure 71.



2373

2374 **Figure 71: PCI Express DUAL-SLOT Add-in Card Dimensional Drawing**

The form factor dimensions for a PCI Express TRIPLE-SLOT Add-in Card are shown in Figure 72. The only difference from standard height full length cards is the additional spacing of the restricted component height on the primary side of the card.

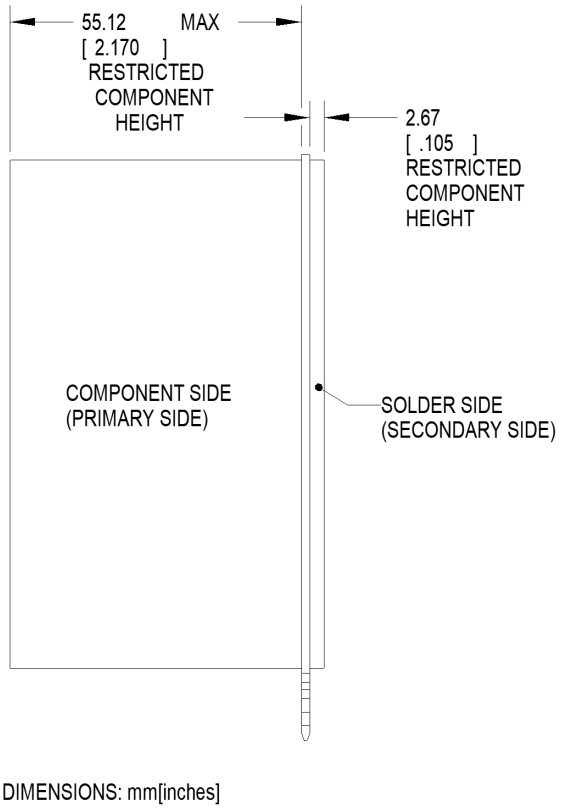


Figure 72: PCI Express TRIPLE-SLOT Add-in Card Dimensional Drawing

A PCI Express DUAL-SLOT Add-in Card may utilize a two slot I/O bracket to accommodate adequate thermal management.

Figure 73 is a detailed drawing of a two-slot I/O bracket design. Figure 74 is an isometric view of the two-slot I/O bracket with an area for graphics card venting. The size and number of any holes in the bracket follow proper EMI and thermal design guidelines.

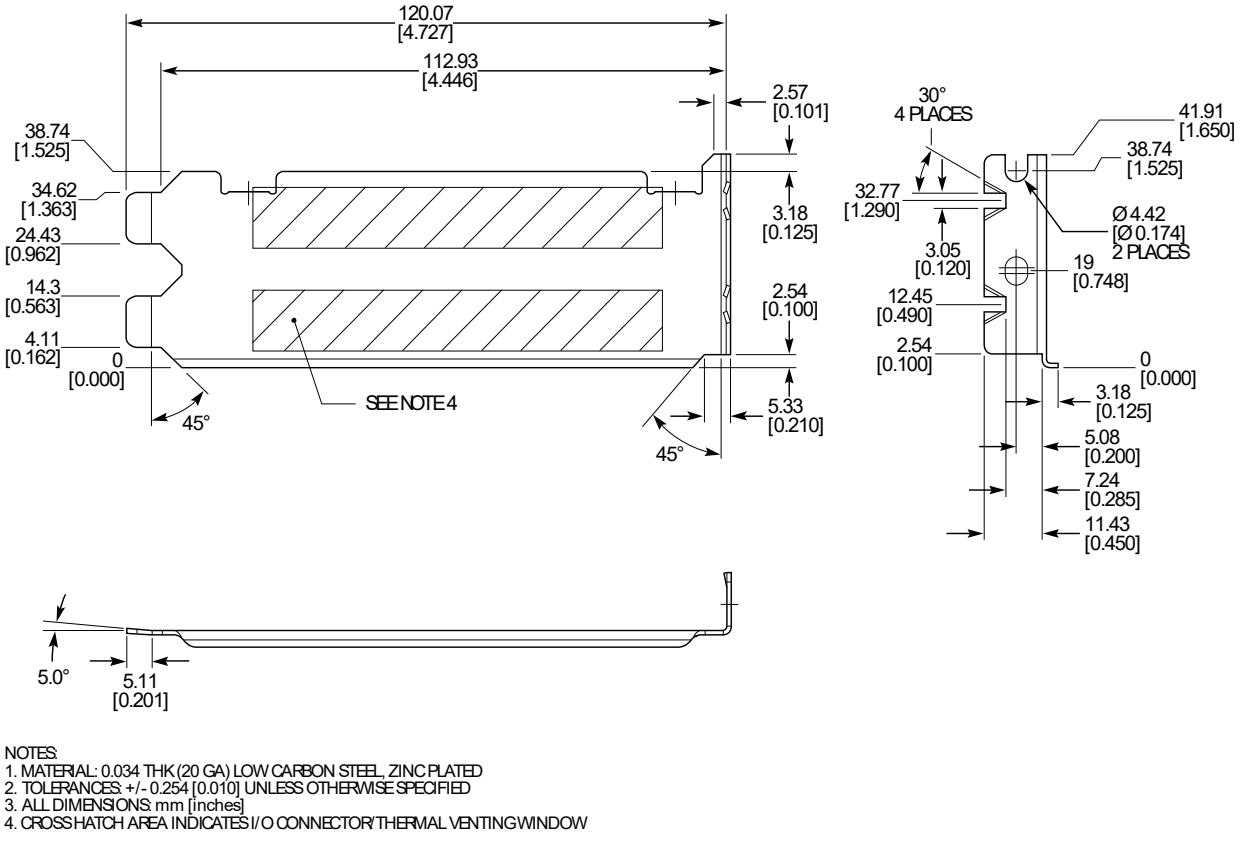


Figure 73: Detailed Two-Slot I/O Bracket Design

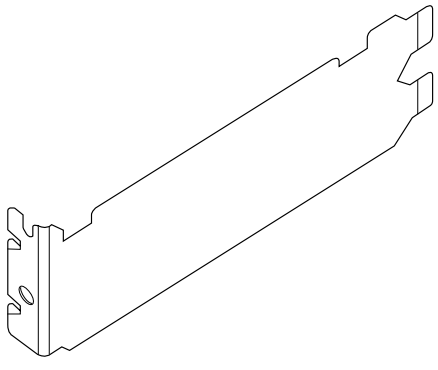
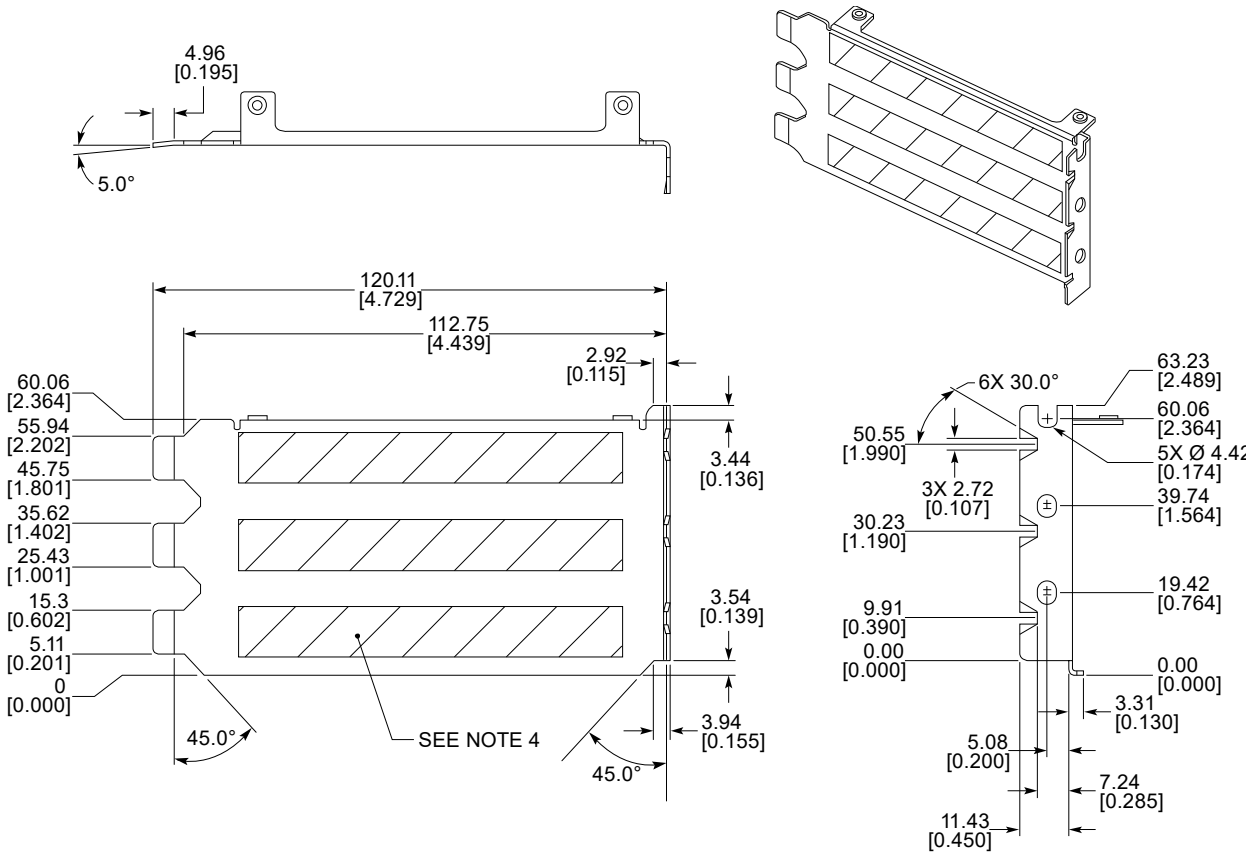


Figure 74: Two-Slot I/O Bracket Example (Isometric View)

A PCI Express TRIPLE-SLOT Add-in Card may utilize a three slot I/O bracket to accommodate adequate thermal management.

Figure 75 is a detailed drawing of a three-slot I/O bracket design. Figure 76 is an isometric view of the three-slot I/O bracket with an area for graphics card venting. The size and number of any holes in the bracket follow proper EMI and thermal design guidelines.



NOTES:
1. MATERIAL: 0.034 THICK (20 GA) LOW CARBON STEEL, ZINC PLATED.
2. TOLERANCE UNLESS OTHERWISE SPECIFIED: ± 0.254 [0.010]
3. ALL DIMENSIONS: MM [INCHES].
4. CROSS HATCH AREA INDICATES I/O CONNECTOR/THERMAL VENTING WINDOW.

Figure 75: Detailed Three-Slot I/O Bracket Design

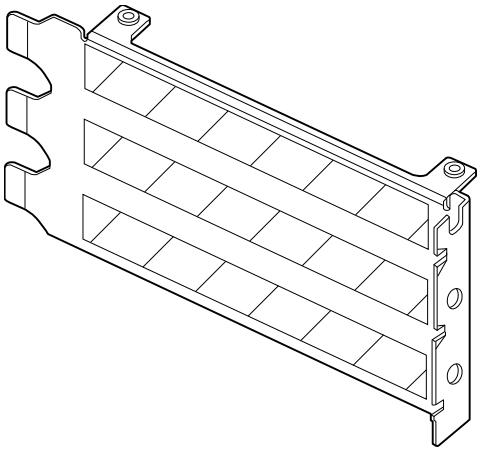


Figure 76: Three-Slot I/O Bracket Example (Isometric View)

PCI Express Add-in Cards require additional card retention and support for cards that are greater than 350 grams in mass. Testing has shown that using the connector retention mechanism alone for cards over 350 grams will cause connector and/or card damage.

Additionally, use of the "hockey stick" retention feature defined in this specification with certain Add-in Card thermal solutions makes access to and disengagement of the connector retention mechanism difficult without special tools. As a result, the "hockey stick" feature is optional for a PCI Express Add-in Card.

IMPLEMENTATION NOTE

PCI Express Usage of the "Hockey Stick" Feature

The hockey stick feature is optional for a PCI Express Add-in Card design. The actual board design used to omit this feature is implementation dependent, but the resultant layout cannot exceed any CEM outline measurement.

This specification defines keepouts and features on any PCI Express Add-in Card to be used for card retention. Detailed retention mechanism design, however, is considered implementation specific and it is up to system OEMs to work with card vendors.

The following guidelines must be observed when designing retention mechanism for high mass Add-in Cards:

The use of the "hockey stick" feature alone is unlikely to be sufficient because of the high card mass allowed in this specification (1.5 kg maximum). The use of the keepout area to hold the card in place is strongly recommended. This mechanism may be necessary to prevent excessive deformation of the card during shock and vibration.

The bracket is part of the card retention mechanism. It must have sufficient mechanical strength to withstand system-level shock and vibration. Deformation of card brackets has been one of the major failure mechanisms in the past.

All cards shall be enabled for a full-length Add-in Card retainer. Partial length cards shall have means of being extended to full length and equipped with the retainer. The card features used for extending partial length cards to full length are the card vendor's option; they may include component keepouts and holes similar to those shown in Figure 61.

All cards shall be enabled for a full-length stiffener to minimize card flexure during dynamic events. When included, the stiffener must be located within the card component keep-in volume as defined in Figure 71 and Figure 72. Implementation details are the card vendor's option.

A PCI Express card shall not exceed 1.5 kilograms in mass. To support such a mass, attention must be paid to bracket, chassis strengths, and retention mechanism designs. Card manufacturers must make efforts to minimize the card mass.

9.2. Add-in Card Layout Requirements and Recommendations for 16.0 GT/s Operation

Operating at a data rate of 16.0 GT/s places additional requirements on the Add-in Card layout specifically with respect to the edge-fingers.

9.2.1. Voiding and Planes Under Edge-fingers

For an Add-in Card that supports 16.0 GT/s, there must be no inner-layer conductors of any kind, including ground or power planes, beneath the edge-fingers (for a distance of 15 mil). Any conductors in this region increase capacitance with respect to the high-speed signal lines, which degrades insertion loss and increases return loss.

Inner plane layers may be added beneath any of the edge fingers if they extend no more than 2-mm into the edge finger region from the main routing area of the board and are at a depth of least 15 (0.38 mm) beneath the edge finger copper pads on the surface of the PCB. See Figure 77.

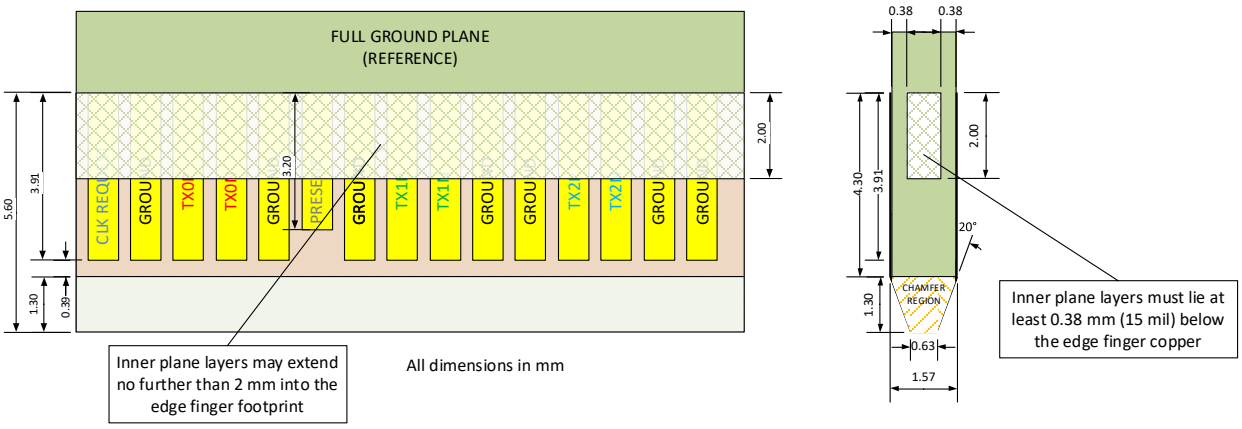


Figure 77: Add-in Card Edge-finger Regions, with the Allowed Inner Layer Plane Volume Indicated (crosshatched area)

9.2.2. No Add-in Card Depopulated or Floating Edge-fingers

Edge fingers must be present in every pin position in the high-speed region comprising pins A12/B12 and beyond, even if the signals are not used on the Add-in Card or system board. This permits the implementation of the AC sideband termination on the Add-in Card. Therefore, every edge finger must be present and connected to either a high-speed Tx/Rx pair, a ground, or a sideband termination network. This requirement applies to edge fingers assigned to ground, even if two ground fingers are adjacent. One exception to this would be cards whose electrical length is smaller than the mechanical board outline.

For example, a card having a x4 electrical width, but having a x16 mechanical length that fully engages a x16 slot, can mount edge fingers only in those positions required for a x4 card. Edge fingers in positions A12 to A32, and B12 to B32, would all be present and connected, with no depopulated fingers among them. Positions A33 to A82 and B33 to B82 may be depopulated. The uppermost PRSNT2# pad must be connected, in accordance with section 3.2.

9.2.3. Edge-finger Length and Outer Layer Keepout

Edge-fingers are 3.91 mm (154.0 mil) in length with the top of the edge-finger located 5.6 mm (220.0 mil) above the bottom edge of the Add-in Card edge. This creates a nominal 0.39 mm gap between the edge finger and chamfer region. This edge finger length is a reduction from the legacy 4.30 mm dimension specified in PCIe Gen 1. Small amounts of residual surface metal are permitted in the region extending 0.13 mm beyond the lower end of the edge finger. Any active PRSNT1# or PRSNT2# pins must have shorter, 3.20 mm edge fingers. Non-functional PRSNT2# edge fingers may be either shorter or full-length.

All dimensions in mm

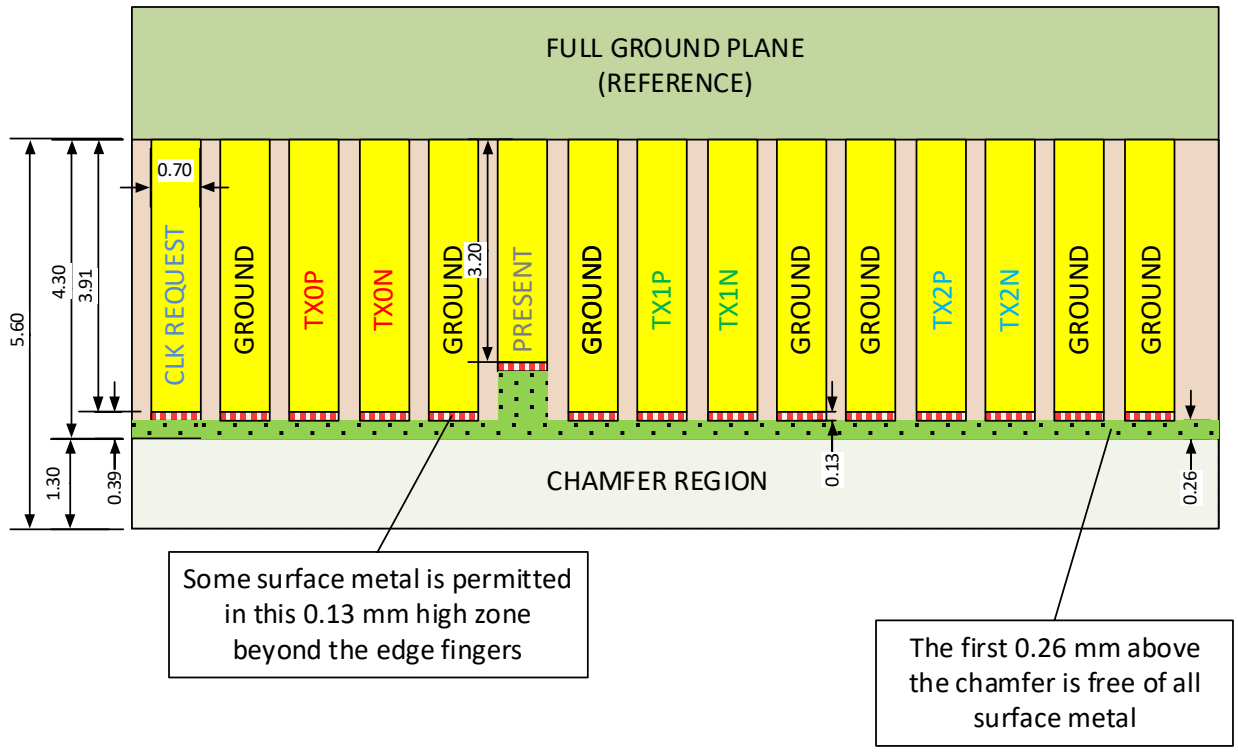


Figure 78: Add-in Card Edge-fingers Indicating Edge-finger Length and Surface Metal Keepout Areas

9.2.4. Add-in Card Adjacent Edge-finger Ground Vias

Add-in Card ground vias serving edge finger ground conductors must be center-aligned with the gap between adjacent edge-fingers, to reduce obstruction to signals routed from non-ground edge fingers. The distance between a horizontal line across the top edge ground fingers and a horizontal line across the bottom edge of the ground via pads must not exceed 15 mil. The edge fingers shall be connected to the ground via with a length of trace whose width matches or exceeds the via pad diameter to minimize the inductance of the ground connection (see Figure 79). Ground vias may be shared by edge fingers assigned as ground pins on the front and back of the Add-in Card.

This requirement improves signal integrity by increasing the frequency of a pathological ground resonance present in the ground conductors.

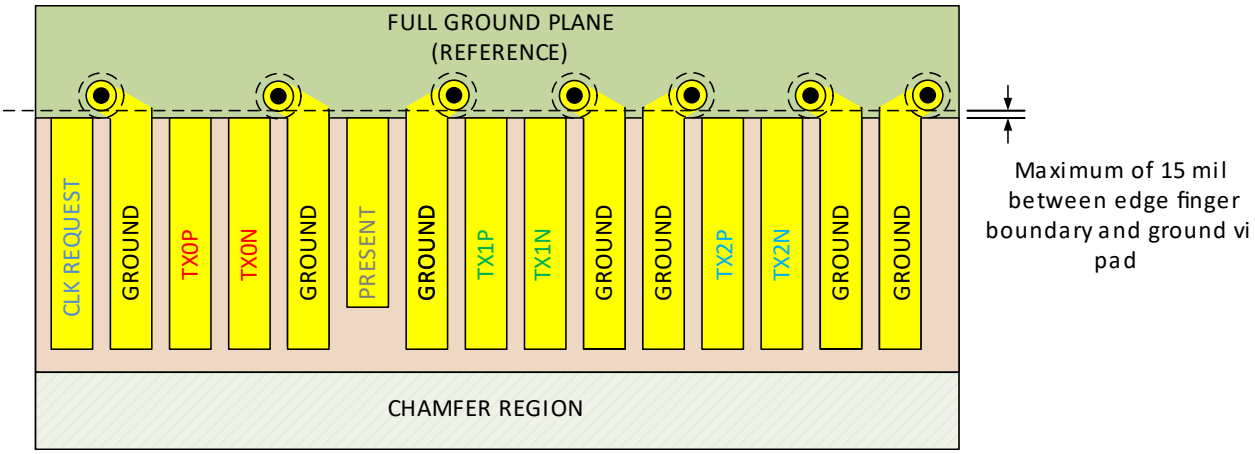


Figure 79: Add-in Card Edge-fingers Indicating Adjacent Ground Vias.
(For the sake of clarity, joined edge finger ground vias, which are also required, are not shown)

9.2.5. Joined Edge-finger Ground Vias

Many of the ground edge-fingers are double grounds (two ground edge fingers adjacent to each other on the same Add-in Card surface). In these cases, joining the adjscent edge-fingers at the lowered via location is required to provide additional improvement in the ground resonance. Through-hole ground vias can also be shared by ground edge-fingers on opposing sides of the Add-in Card.

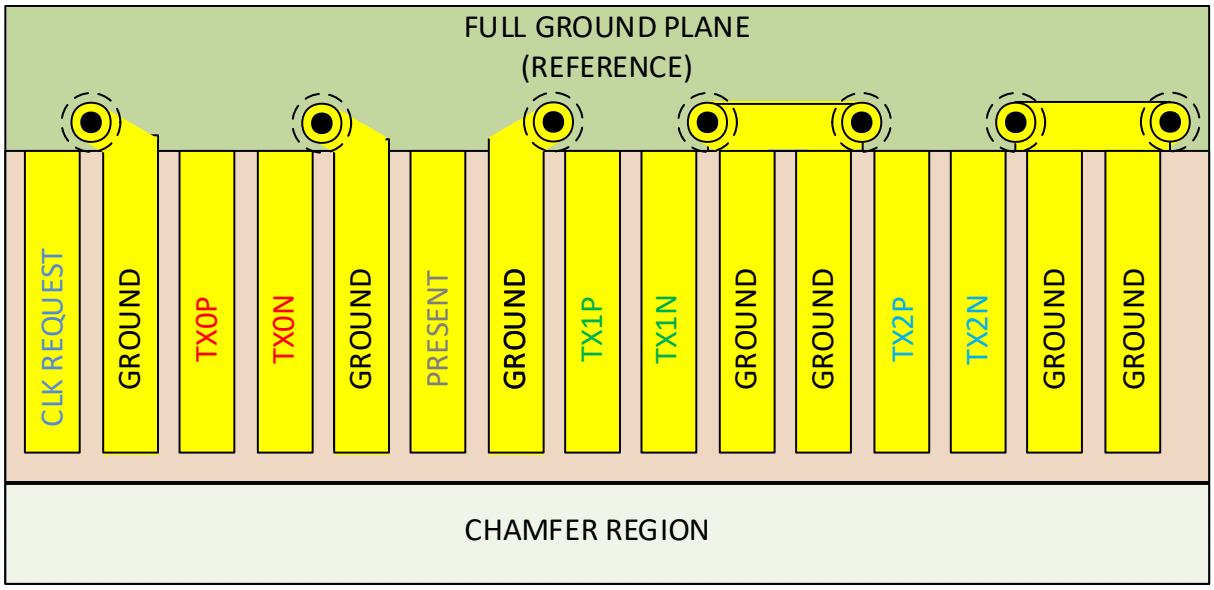


Figure 80: Add-in Card Edge-fingers Indicating Adjacent and Joined Ground Vias

9.2.6. Auxiliary Signal Conductor AC Match Termination

Several Auxiliary (sideband) signals lie among high speed Tx/Rx pairs and ground conductors in the range of pins A11/B11 to A82/B82.

Within this section of the connector pinfield and the corresponding Add-in Card edge-finger region, many of the auxiliary signals, such as CLKREQ#, PWRBRK#, are used; while others, such as RESERVED, are unused. In all cases, these conductors are naturally terminated in a mismatched impedance at each end, which may present a short, an open, or a high impedance, unless explicit matching is applied. Poorly terminated pins allow resonances that degrade insertion loss and markedly increases crosstalk for the adjacent high-speed Tx/Rx signal pairs. This may potentially interfere with the assigned function of the sideband pin.

This resonance results from the conductive structure comprising the baseboard via (or SMT pad), the connector contact, and the Add-in Card edge finger. The resonance effectively couples energy to and from the high-speed lanes and the sideband lanes.

Add-in Card Terminating these conductors through a 42.5 Ω impedance to ground eliminates this resonance and the resulting high frequency crosstalk. To avoid compromising any low frequency signaling on these auxiliary conductors a DC blocking capacitor must be added to the termination. To effect the required termination, all conductors carrying auxiliary signals are terminated by an appropriate resistance (nominally 42.5 Ω +/- 5%) in series with an appropriate capacitance (nominally 1.0 pF +/-10%) to ground. This is required for Add-in Cards and recommended for system boards.

The ground via for the termination network must lie within 0.5 mm (20 mil) of the resistor component.

Following is a list of the auxiliary signals to be terminated:

- A **x1** Add-in Card or connector requires two auxiliary signals be terminated:
  - B12 CLKREQ#
  - B17 PRSNT2#
- A x4 Add-in Card or connector requires four additional auxiliary signals be terminated:
  - A19 RSVD
  - A32 RSVD
  - B30 PWRBRK#
  - B31 PRSNT2#
- A x8 Add-in Card or connector requires two more auxiliary signals be terminated:
  - A33 RSVD
  - B48 PRSNT2#
- A x16 add in card or connector requires three additional auxiliary signals be terminated
  - A50 RSVD
  - B81 PRSNT2#
  - B82 RSVD#

The trace length from the top of an auxiliary signal or unused edge-finger to the termination circuit must be as short as practicable and never exceed 500 mil. Schematic connectivity for the B-side pins is shown for a x16 Add-in Card in Figure 81. A-side connectivity is required but is not shown.

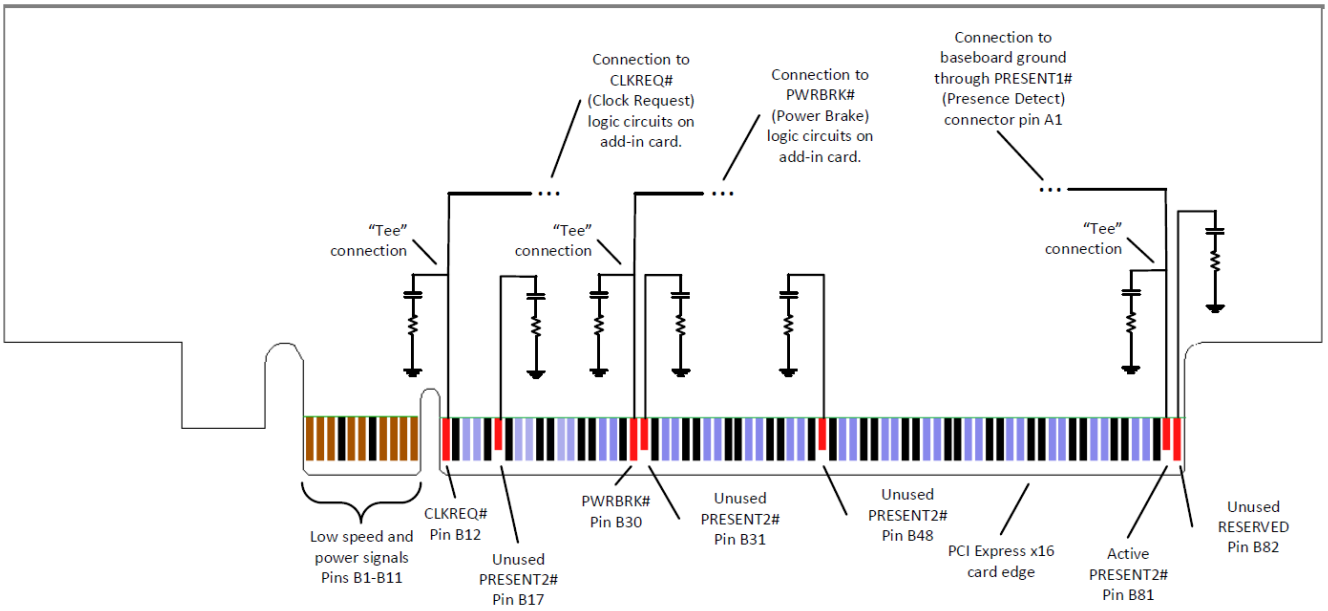


Figure 81: Add-in Card with AC Terminations on All Auxiliary and Reserved Signal Conductors. Only the B-side is shown.

The AC sideband termination provides a matched termination to ground for floating conductors such as RESERVED and some PRESENT2# pins. Other auxiliary pins effectively have a tee connection. The path between the PRESENT1# and PRESENT2# pad B81, is one example of a sideband signal that will have a tee connection to the AC termination.

9.3. System Board Requirements for 16.0 GT/s Operation

The system board must be updated to improve operation at 16.0 GT/s as well. For system boards supporting 16.0 GT/s, all the requirements in this section must be met. System boards that do not support 16.0 GT/s, may optionally implement any or all of these requirements. These 16.0 GT/s requirements for the system board are compatible with all the 16.0 GT/s Add-in Card requirements.

9.3.1. Sentry Ground Vias Adjacent to Auxiliary Signal Vias

This requirement applies only to the system boards mounting through-hole/press-fit connectors. It does not apply to Add-in Cards or system boards mounting surface mount connectors.

Due to the irregular signal assignment within the PCIe pinfield, markedly higher crosstalk and degraded insertion loss are observed among high speed Tx and Rx signal pairs adjacent to auxiliary signal pins. This crosstalk stems chiefly from the distribution of signal, ground, and sideband vias in the system boards' pinfield.

To mitigate this effect, small diameter through-hole ground vias "sentry vias" must be placed adjacent to each auxiliary signal pin via on the system baseboard, in the range A12/B12 to A82/B82. For ease of routing other signals laterally through the pinfield, the via drill diameter should be small, e.g. 0.25-0.30 mm (10-12 mil).

Two, three, or four vias shall be used for each auxiliary signal via. The vias must be placed adjacent to the auxiliary signal via, within the limits of the PCB fabrication technology used to construct the system board.

Figure 82a illustrates a x4 PCIe connector pinfield with three or four sentry vias flanking each auxiliary signal. Note that this implementation exceeds the minimum sentry via requirement; as few as two sentry vias per pin may be used, as shown in Figure 82b.

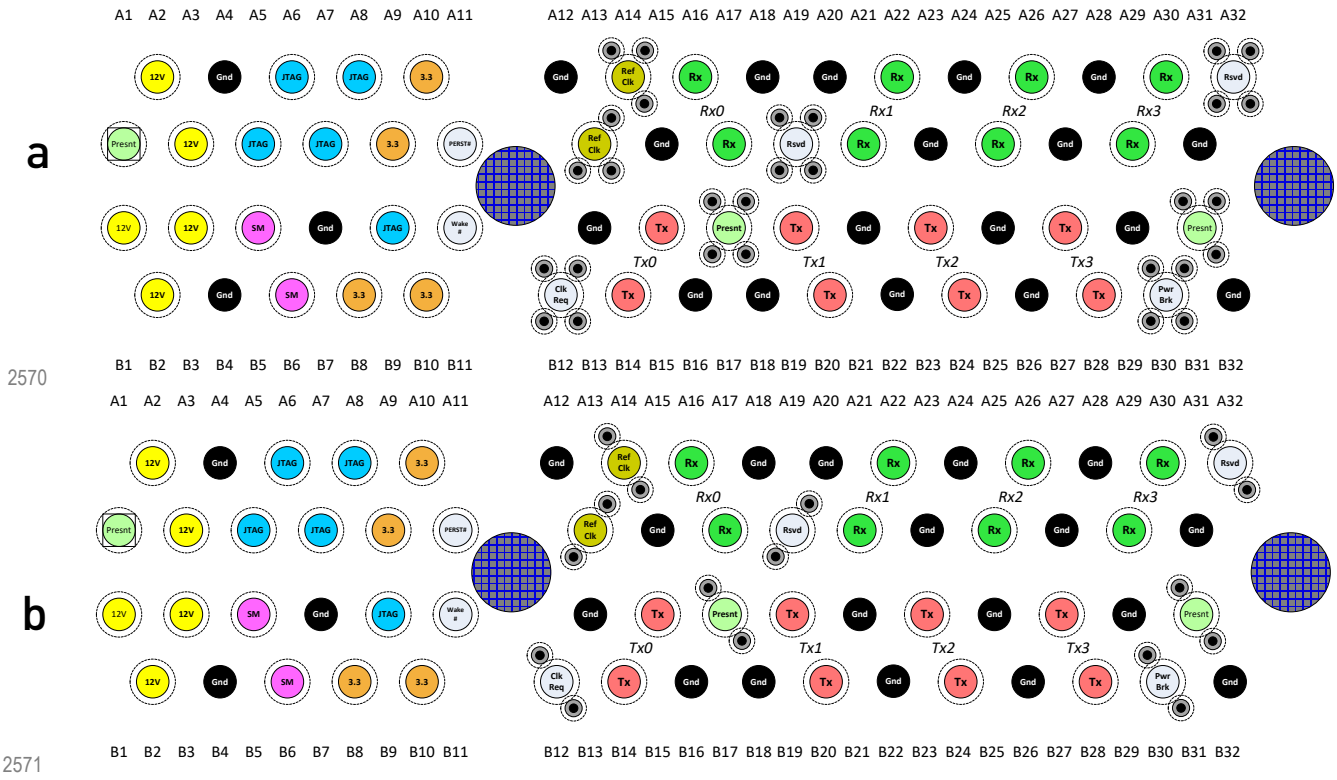


Figure 82: System Board with Sentry Vias on All Auxiliary Connector Vias for a x4 system board. a) Four sentry vias per pin. b) Two sentry vias per pin

A x1 connector requires four auxiliary signals be isolated with Sentry vias:
CLKREQ# (pin B12)
REFCLK+ (pin A13)
REFCLK- (pin A14)
PRSNT2# (pin B17)

A x4 connector requires four more auxiliary signals be isolated:
RSVD (pin A19)
RSVD (pin A32)
PWRBRK# (pin B30)
PRSNT2# (pin B31).

A x 8 connector requires two more auxiliary signals be isolated:
RSVD (pin A33)
PRSNT2# (pin B48)

A x16 connector requires three more auxiliary signals be isolated
RSVD (pin A50)
PRSNT2# (pin B81)
RSVD (pin B82)

Sentry vias must be present on these pins, regardless of whether the auxiliary pin is in use. In general, any auxiliary pins that are in use operate at such low data rates that any bandwidth-limiting effects of adjacent ground vias will not affect the assigned function of the pin. Sentry vias must not be applied to the highspeed Tx and Rx pinfield vias, since this will markedly degrade performance. Sentry vias need not be applied to grounds. Surface mount connectors do not require sentry vias.

Baseboards supporting only PCIe generation 3.0 or below, may benefit from sentry vias, but to a lesser extent. Sentry vias will not adversely affect PCIe generations 1.0 through 3.0.

9.4. Connector and Add-in Card Locations

Figure 83 shows an example of a typical desktop system (microATX form factor). The Add-in Card slots contain the PCI and AGP Add-in Card connectors.

The PCI Express Add-in Cards use the space allocated for those Add-in Card slots to take advantage of the existing chassis infrastructure. This requirement dictates that the PCI Express connectors must use the slots that coincide with the locations of the present PCI and AGP slots/connectors.

Figure 84 illustrates the introduction of a PCI Express connector in a microATX system, co-existing with the PCI connectors. In this case, the PCI Express connector is introduced by replacing the AGP connector.

Like the PCI Add-in Card, the components on a PCI Express Add-in Card face away from the CPU, or the core area.

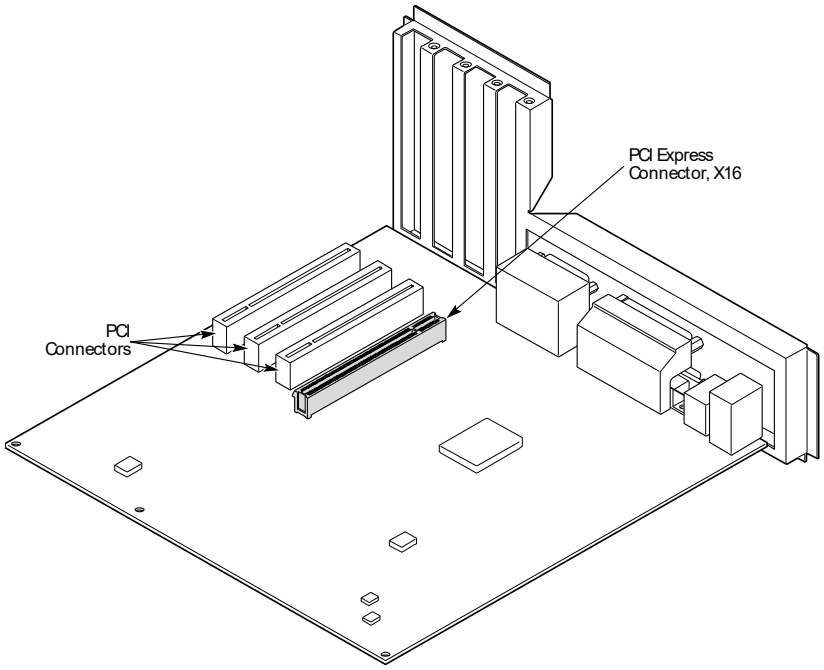


Figure 83: Example of a PC System in microATX Form Factor

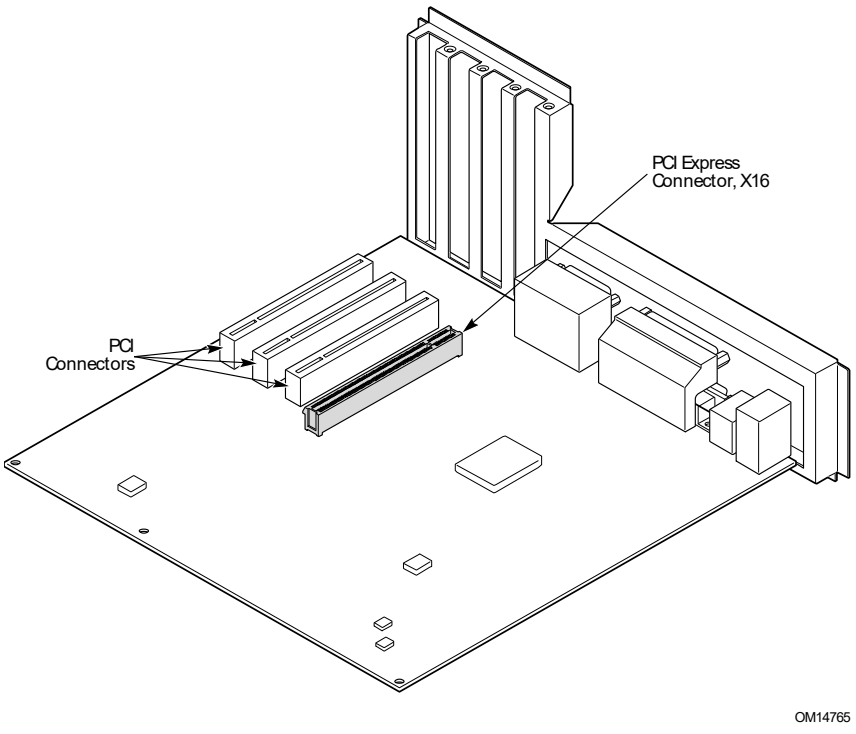


Figure 84: Introduction of a PCI Express Connector in a microATX System

Over time, more PCI Express connectors are going to be used on the system board. Figure 85 shows a situation where a basic bandwidth PCI Express connector replaces a PCI connector (x1) and a high bandwidth (x16) PCI Express connector replaces the AGP connector.

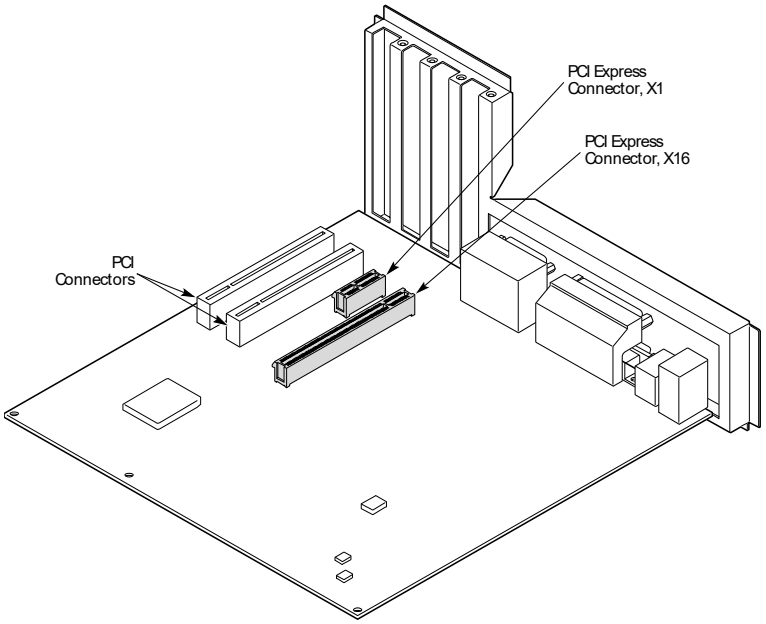
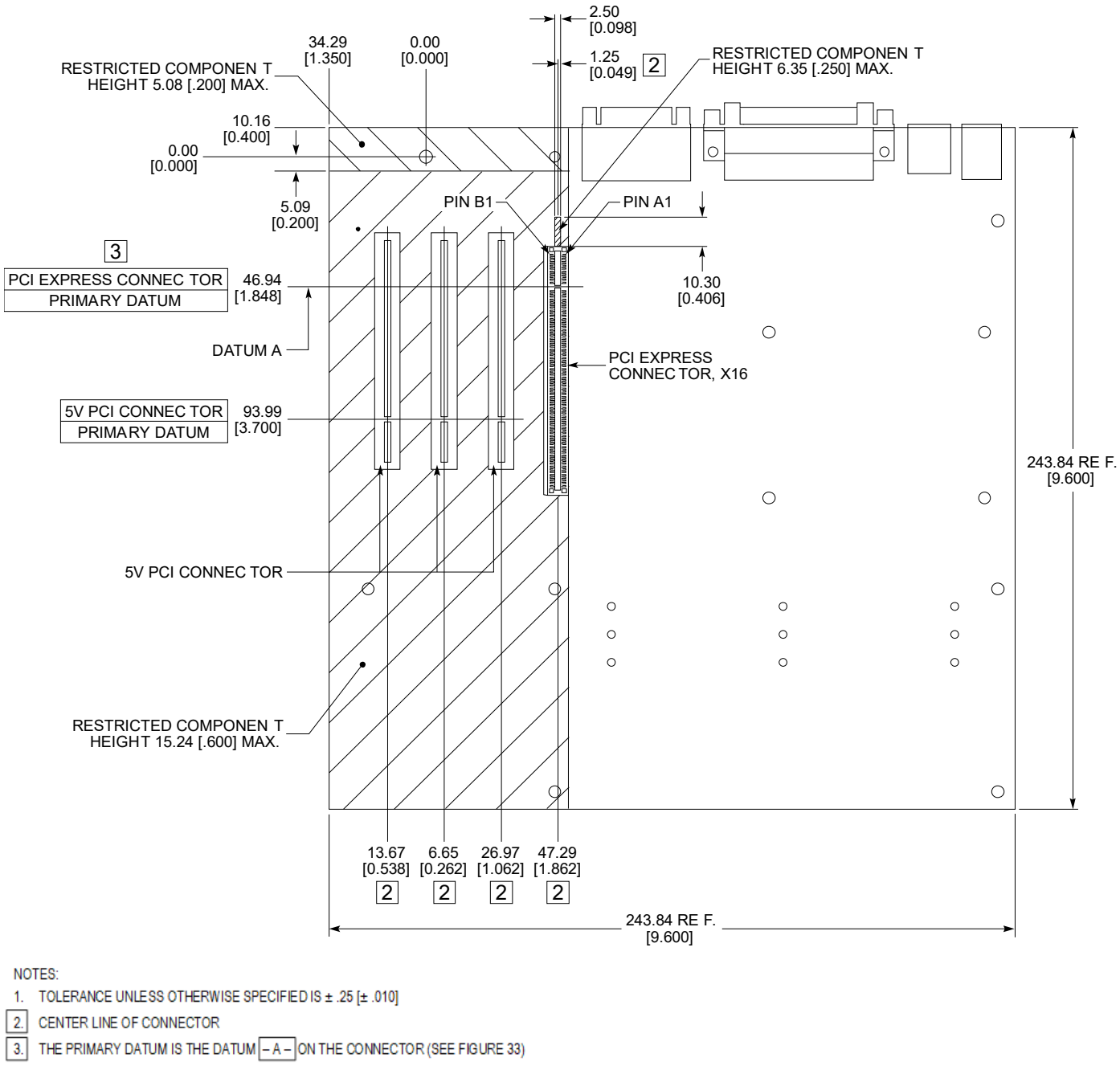


Figure 85: More PCI Express Connectors are Introduced on a microATX System Board

Figure 86 shows the PCI Express connector location, as well as the component height restriction zones. In this case, a x16 PCI Express connector replaces the AGP connector. When more PCI Express connectors are introduced, the height restriction zones will grow accordingly. This is depicted in Figure 87, where an additional x1 PCI Express connector is introduced along with the x16 connector. The 5.08 mm (0.200 inches) maximum and the 15.24 mm (0.600 inches) maximum height restriction zones are identical to the PCI requirements. But the additional, small height restriction zones of 6.35 mm (0.250 inches) max are unique to PCI Express.

There is a slight offset between PCI and PCI Express connector locations. The PCI Express connectors are located slightly further away from the rear of the chassis. The PCI Express Add-in Cards contain features (see Note 2 in Figure 61 and Figure 66) to prevent them from being mistakenly inserted into a PCI slot. Such features require the additional height restriction zones of 6.35 mm (0.250 inches) maximum.

The card retention clip requires additional height restrictions. Such restrictions depend on the retention clip design and location, which may vary from user to user. Because retention clip designs vary, they are not specified here as a requirement. However, in the design guideline, a reference retention clip design and implementation is given, together with the keepout and height restriction zones. See Figure 88 and Figure 89 for standard height and low profile connector openings in the chassis. See Figure 90

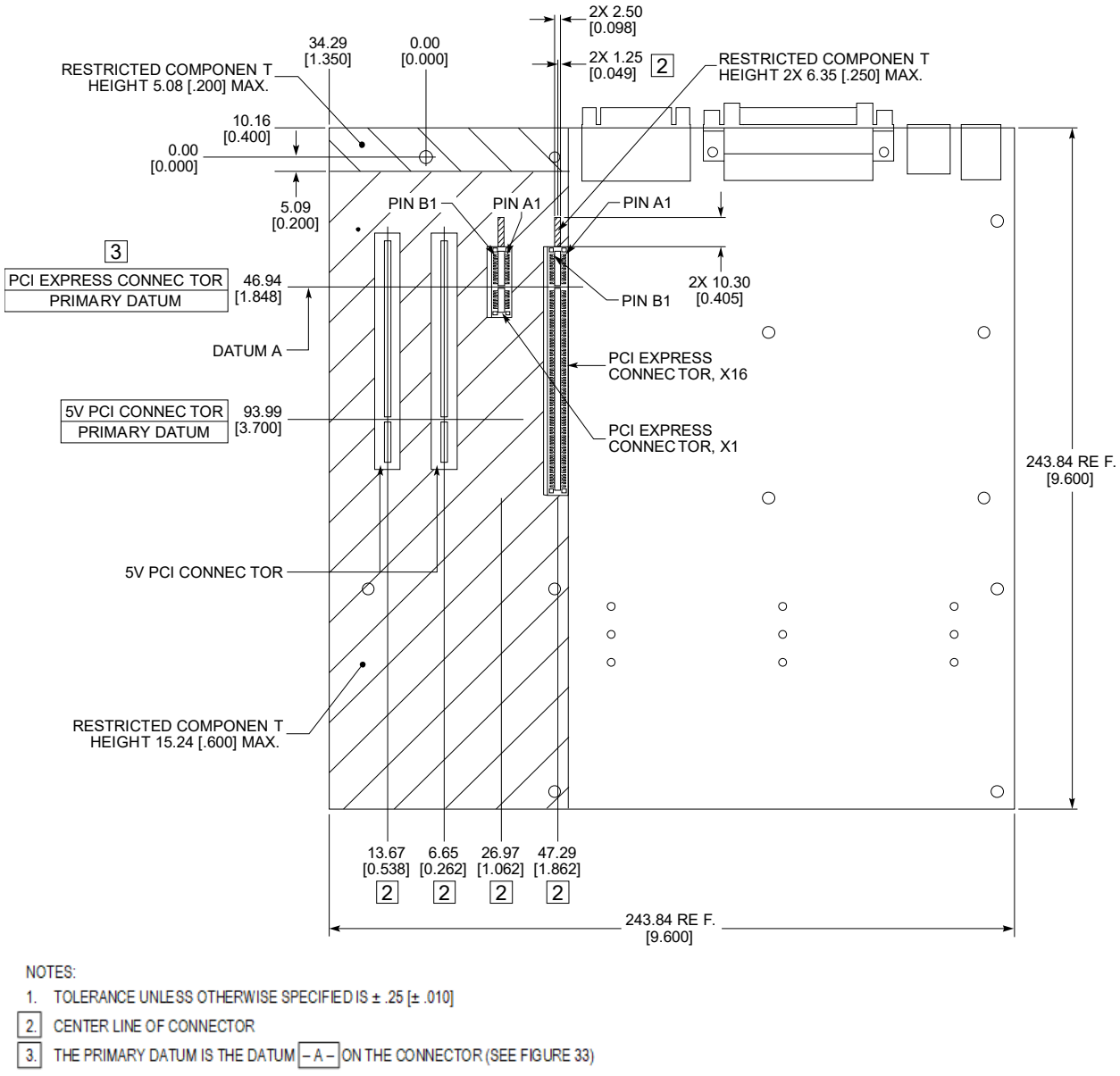


NOTES:

1. TOLERANCE UNLESS OTHERWISE SPECIFIED IS ± .25 [± .010]
2. CENTER LINE OF CONNECTOR
3. THE PRIMARY DATUM IS THE DATUM – A – ON THE CONNECTOR (SEE FIGURE 33)

A-0913

Figure 86: PCI Express Connector Location in a microATX System with One PCI Express Connector

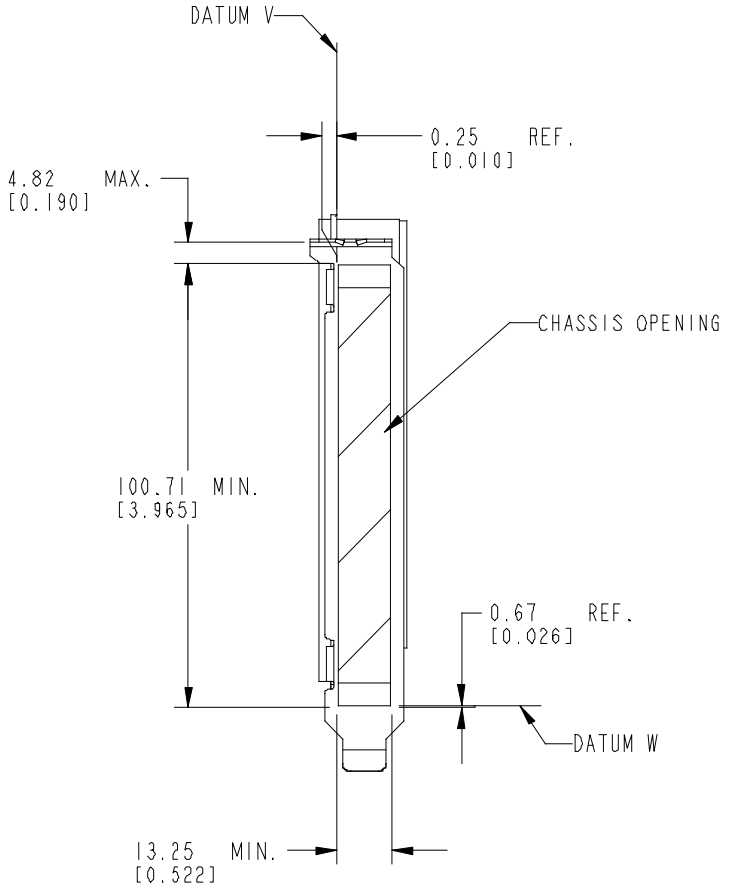


NOTES:

1. TOLERANCE UNLESS OTHERWISE SPECIFIED IS ± .25 [± .010]
2. CENTER LINE OF CONNECTOR
3. THE PRIMARY DATUM IS THE DATUM – A – ON THE CONNECTOR (SEE FIGURE 33)

A-0914

Figure 87: PCI Express Connector Location in a microATX System with Two PCI Express Connectors



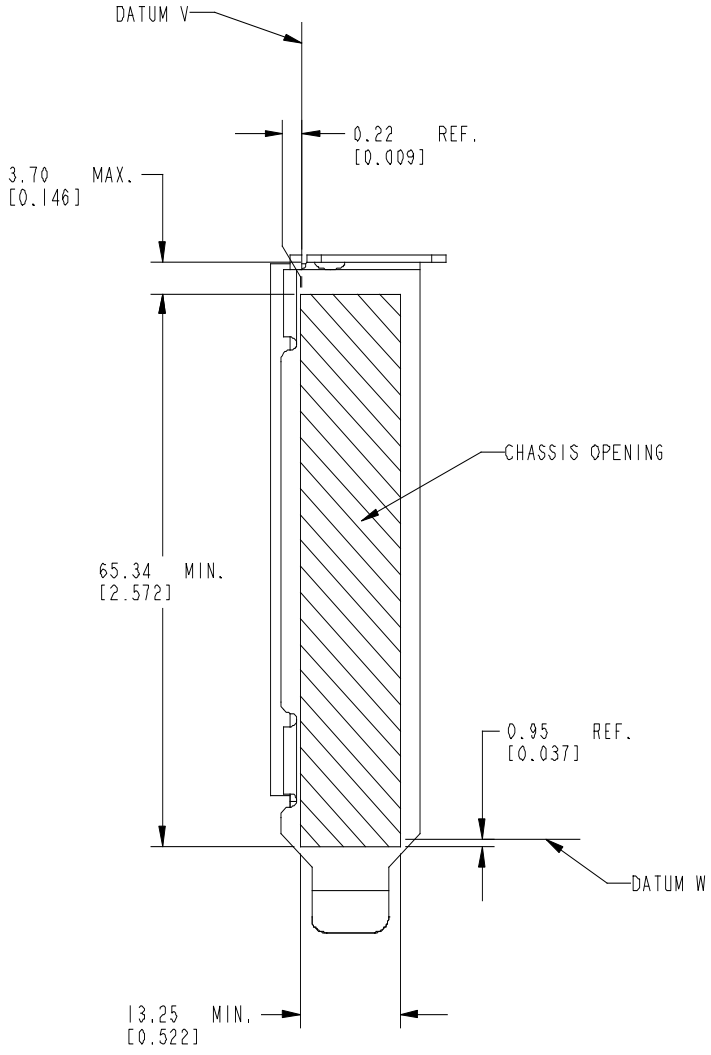
NOTES:

1. CHASSIS OPENING IS THE MINIMUM REQUIRED APERTURE, TAKING INTO ACCOUNT REFERENCE SYSTEM LEVEL TOLERANCES. ACTUAL DIMENSIONS WILL VARY BASED ON SYSTEM IMPLEMENTATION.

2. THE SIZE OF THIS CHASSIS OPENING MUST INCLUDE SYSTEM ACCOMODATIONS, INCLUDING BUT NOT BE LIMITED TO: PROTRUDING CONNECTORS ON THE ADD-IN CARD, INSERTION AND REMOVAL OF THE ADD-IN CARD FROM THE SYSTEM, ETC.

3. I/O CONNECTORS MATING TO THE CARD CAN HAVE OVERMOLDS EXTENDING IN ALL DIRECTIONS AROUND THIS OPENING. THIS WILL LIMIT THE EFFECTIVE THICKNESS OF THE CHASSIS NEAR THIS REGION.

Figure 88: Standard Height Connector Opening in Chassis



NOTES:

1. CHASSIS OPENING IS THE MINIMUM REQUIRED APERTURE, TAKING INTO ACCOUNT REFERENCE SYSTEM LEVEL TOLERANCES. ACTUAL DIMENSIONS WILL VARY BASED ON SYSTEM IMPLEMENTATION.
2. THE SIZE OF THIS CHASSIS OPENING MUST INCLUDE SYSTEM ACCOMODATIONS, INCLUDING BUT NOT LIMITED TO: PROTRUDING CONNECTORS ON THE ADD-IN CARD, INSERTION AND REMOVAL OF THE ADD-IN CARD FROM THE SYSTEM, ETC.
3. I/O CONNECTORS MATING TO THE CARD CAN HAVE OVERMOLDS EXTENDING IN ALL DIRECTIONS AROUND THE OPENING. THIS WILL LIMIT THE EFFECTIVE THICKNESS OF THE CHASSIS NEAR THIS REGION.

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2646 **Figure 89: Low Profile Connector Opening in Chassis**

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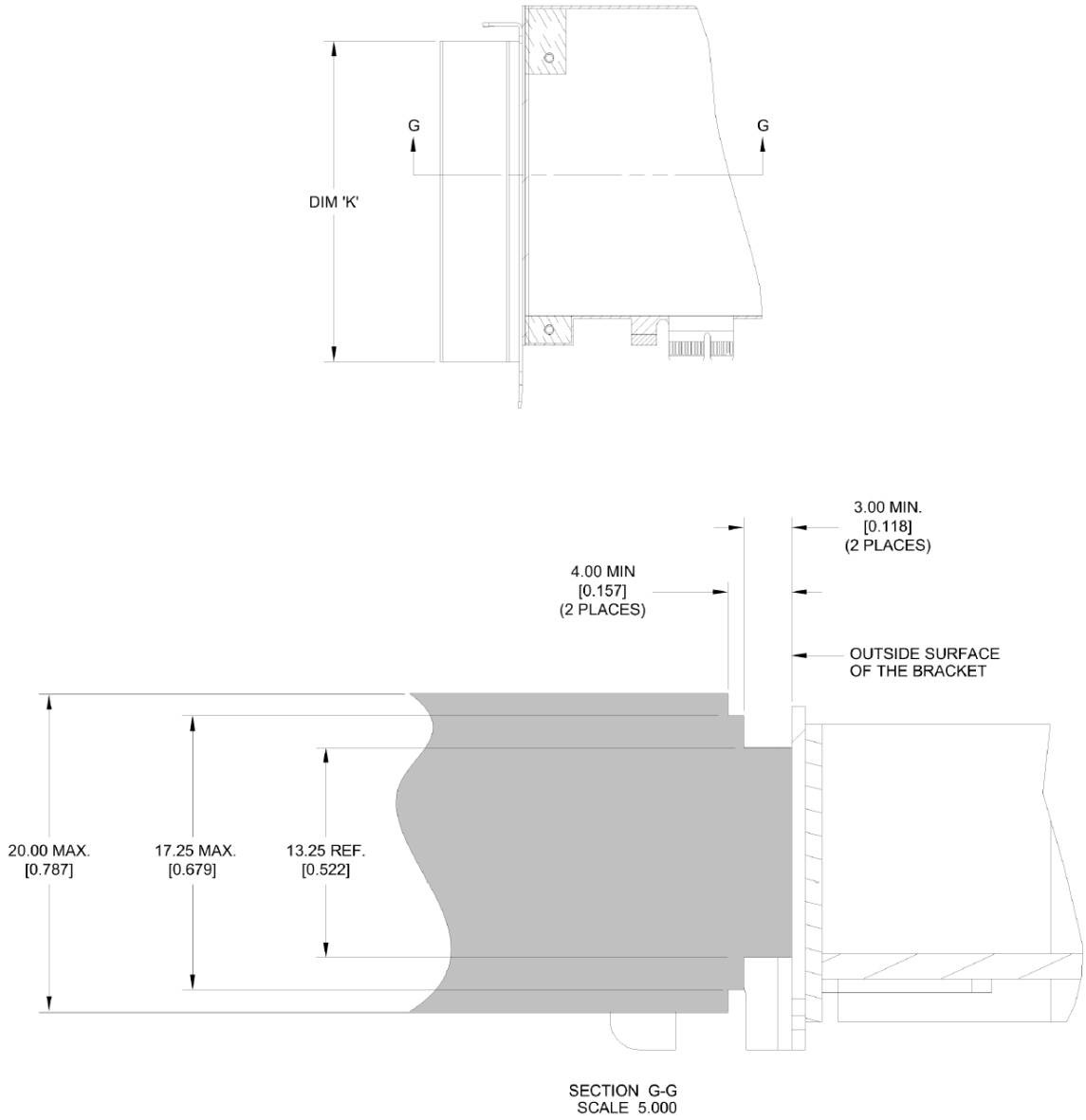

TABLE	
CARD HEIGHT	DIM 'K'
STANDARD HEIGHT (SEE FIGURE 61)	100.71 REF. [3.965]
LOW PROFILE (SEE FIGURE 66)	65.34 REF. [2.572]

NOTES:

1. THE VOLUMETRIC CHASSIS KEEPOUT SHOWN REPRESENTS THE CLEARANCE REQUIRED TO ENABLE FULL MATING OF CABLE ASSEMBLIES TO I/O CONNECTORS ON THE ADD-IN CARD.
2. THE DESCRIBED VOLUME IS THE MINIMUM REQUIRED. ACTUAL DIMENSIONS WILL VARY BASE ON SYSTEM IMPLEMENTATION.

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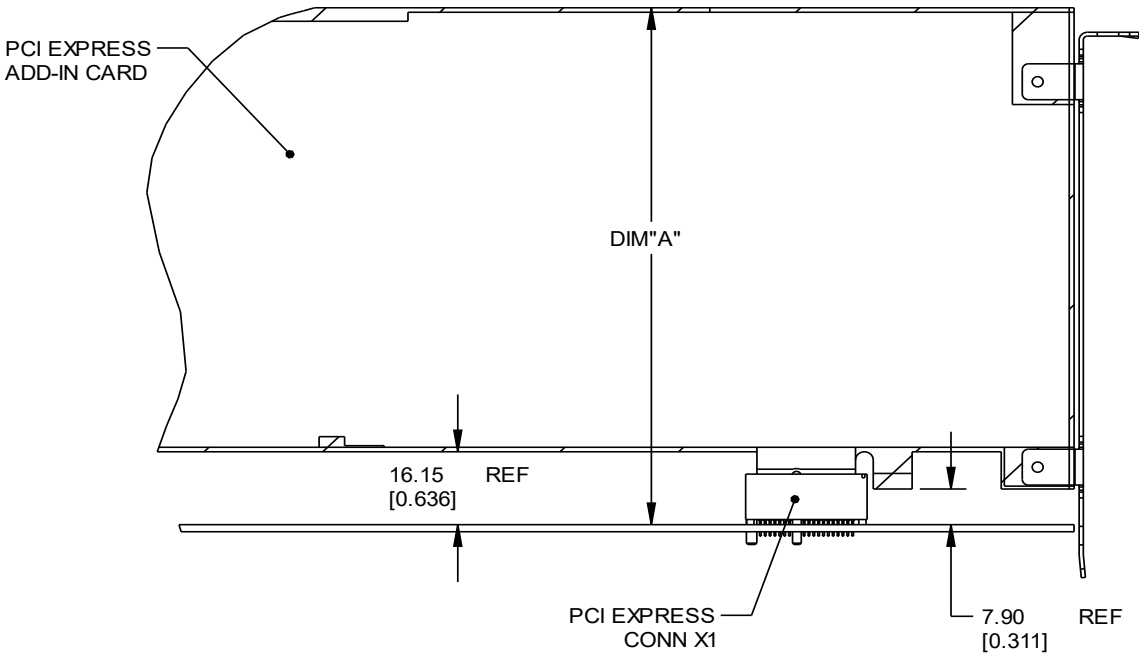
Figure 90: Chassis I/O Cable Keepout

Figure 91 and Figure 92 and shows examples of structure shapes that could affect cable attachment. Chassis wall thickness greater than the ATX wall thickness and the use of structural shapes formed in the chassis wall between slots (as shown) also affect cable attachment.



DIM "A" MAX	
STANDARD HEIGHT	114.83 [4.521]
LOW PROFILE	72.45 [2.852]

Figure 91: Impact of Structural Shapes

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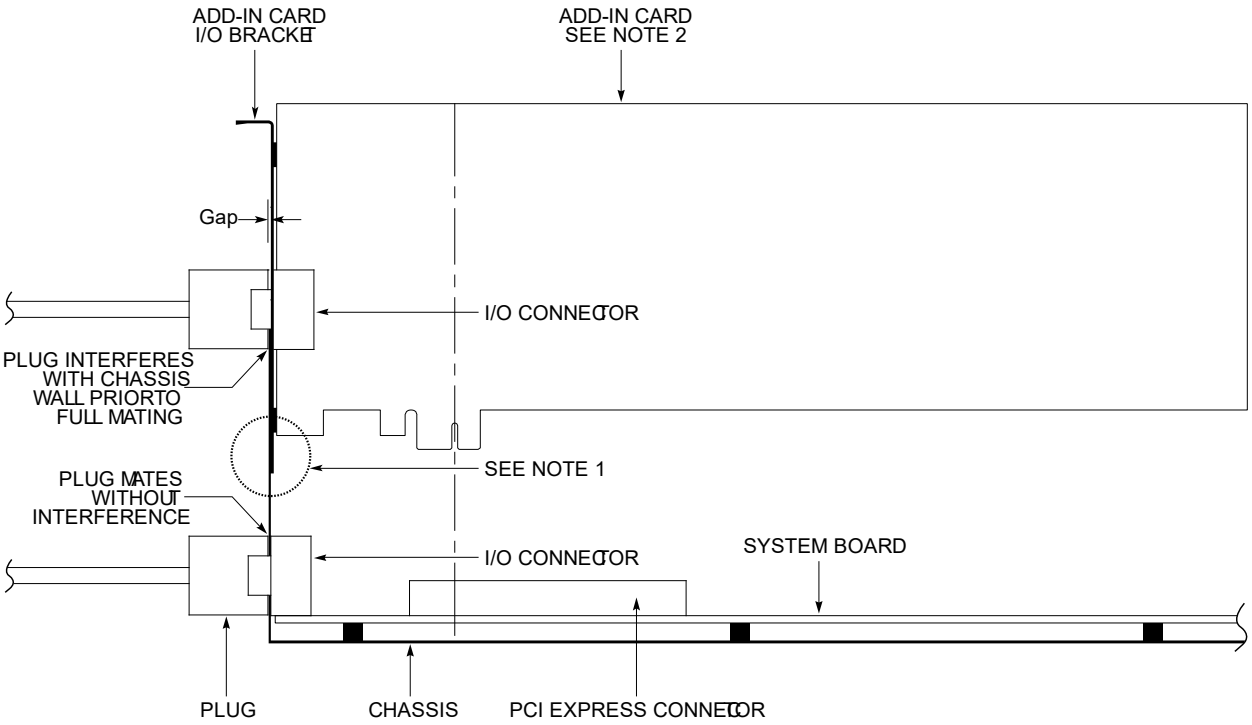

NOTES:

1. AS THE ADD-IN-CARD BRACKET RESIDES BEHIND THE CHASSIS WALL WHEN INSTALLED IN THE SYSTEM BOARD CONNECTOR, THE RESULTING DOUBLE WALL THICKNESS REDUCES THE PROTRUTION OF THE I/O CONNECTOR AUCH THAT THE CABLE PLUG MAY NOT FULLY MATE. SEE FIGURE 88 AND FIGURE 89 FOR MINIMUM CHASSIS CLEARANCE GUIDANCE. SEE FIGURE 90 FOR CHASSIS KEEPOUT/VCABLE + PLUG KEEP-IN VOLUMETRIC DEFINITION.
2. ADDITIONAL TOLERANCE FROM OTHER SOURCES (PCI EXPRESS CONNECTOR-TO-SYSTEM BOARD, ETC.).
3. ADD-IN-CARDS ARE UNIVERSAL. THEREFORE ADD-IN-CARD DESIGNERS MUST ASSUME THAT ADEQUATE CLEARANCE FOR I/O MATING CABLE PLUGS WILL BE PROVIDED IN THE SYSTEM. SEE FIGURE 88, FIGURE 89, AND FIGURE 90 FOR ADDITIONAL DETAILS ON THE NEEDED CLEARANCE.

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Figure 92: Impact of Structural Shapes in the System

9.5. Card Interoperability

PCI Express cards and connectors exist with a variety of Link widths. The interoperability of cards and connectors is summarized in Table 56.

Table 56: Card Interoperability

	Connector			
Card	**x1**	**X4**	**X8**	**x16**
x1	Required	Required	Required	Required
x4	No	Required	Required	Required
x8	No	No	Required	Required
x16	No	No	No	Required

The connectors refer to the receptacle connectors mounted on a system board (see Chapter 5). The shaded area in Table 56 represents up-plugging, while the remaining represents down-plugging. Be aware of the following:

- Down-plugging, i.e., plugging a larger edge size card into a smaller connector, is not allowed and is physically prevented.
- Up-plugging, i.e., plugging a smaller edge size card into a larger connector, is supported.
- All PCI Express Add-in Cards must be able to negotiate and operate in all smaller Link widths from the full Link width down to x1. The x2 and x12 Link widths are optional.
- The upstream PCI Express components on a system board must be able to negotiate and operate in all smaller Link widths from the full Link width down to x1. The x2 and x12 Link widths are optional.

9.6. 10 W/25 W/75 W/150 W Thermal Characterization

To ensure robust system operation and reliability, adapter Add-in Cards must undergo thermal characterization. The following guidelines must be used when performing thermal characterization for Add-in Cards up to 150 W that do not support Thermal Reporting Vital Product Data. If dynamic system cooling response or detailed information for thermal operation or flow impedance is desired, Thermal Reporting Vital Product Data and associated testing must be utilized instead.

- The design of the test system or fixture, including appropriate slot airflow, is left to the discretion of the Add-in Card vendor.
- The Add-in Card must be operated to its rated TDP level using a vendor-specific exercise procedure.
- The test must be performed in a thermal chamber such that the card's ambient temperature is brought to the card's rated operational temperature.
- The test must be performed with an empty slot or equivalent empty space on each side of the card.

For cards with an integrated air mover:

- Ambient temperature is defined as the average air temperature at the fan inlet. Because the fan location may vary for different cards, engineering judgment must be utilized to determine the exact number and location of the inlet temperature measurements.
- Any airflow (CFM) exiting the rear I/O bracket is of great interest and value to system builders. When requested, card vendors must work directly with system builders on the details of how to measure the CFM.

For cards without an integrated air mover:

- Ambient temperature is defined as the average air temperature 1" (25 mm) upstream of the leading edge of the card. This corresponds to the location of incoming air over the card in a typical ATX-based system.
- Card airflow (LFM) must be recorded in the same location as the temperature measurement for thermal characterization and must be reported alongside temperature ratings. For example, thermal characterization performed in a system or fixture with 600 LFM of airflow over the slot may yield substantially different results than the same test with 50 LFM over the slot. The LFM that was used when qualifying a card to a rated temperature is valuable information for system integration.

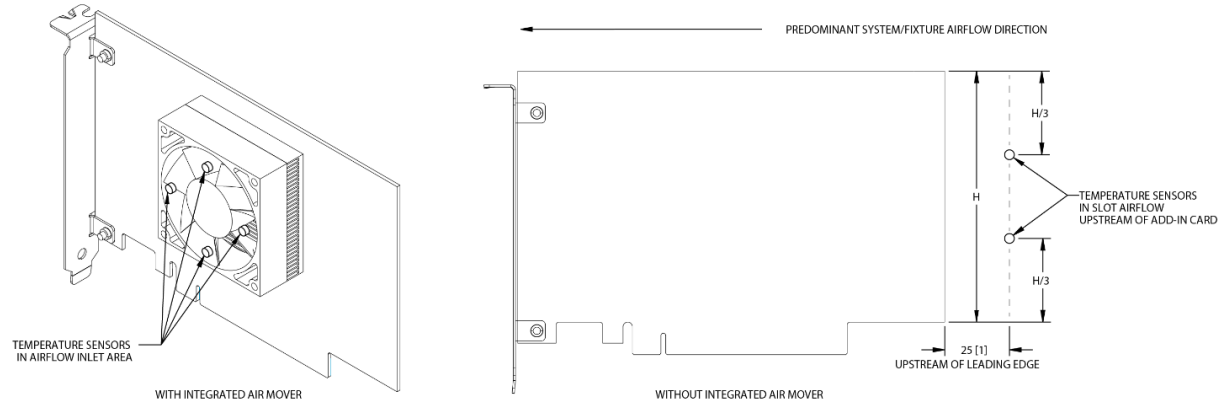

Figure 93. Thermal Characterization

9.7. 150 W Thermal Management

Increasing power has a corresponding impact on the thermal management solutions of both the PCI Express 150 W Add-in Card and the platforms that support them. To guarantee robust system operation and reliability, the card and system must work together to dissipate the additional thermal load the 150 W Add-in Card puts on the system. It is recommended that the card manage its exhaust flow with respect to the system enclosure. For most ATX systems, it is recommended that the card exhaust heat to the outside of the system enclosure. This type of card thermal solution has the least impact on systems that use typical ATX chassis designs.

For other 150 W Add-in Card thermal designs, it is recommended that the card manufacturer and chassis designer or system integrator work closely together to insure the card, chassis, and system components work together so that performance and component reliability are not impacted.

10

10. PCI Express 225 W/300 W Add-in Card Thermal and Acoustic Management

Increasing card power has a corresponding impact on the thermal (for example, inlet temperature and airflow) and acoustic management solutions of the PCI Express 225 W/300 W high power Add-in Cards and the platforms that support them. To ensure robust system operation and reliability, the high-power cards and systems must work together to dissipate the additional thermal load the card puts on the system.

10.1. Inlet Temperature

Inlet temperature is defined as the average temperature at the card thermal solution's fan inlet. Since the fan location may vary for different cards, engineering judgment must be utilized to determine the exact locations for the inlet temperature sensors placement. Figure 94 illustrates an example showing the temperature sensor placement at the thermal solution inlet; one may consider the averaged temperature measured by the different sensors as the inlet temperature.

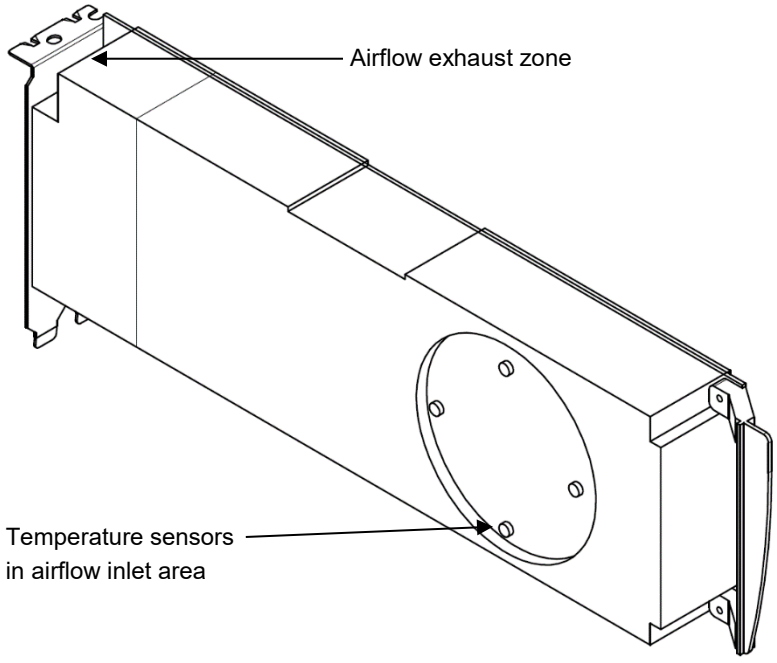

Figure 94: Example of High-Power Card Showing Temperature Sensor Placements at the Thermal Solution Inlet

The procedure described in Section 10.2 must be used as a guideline for characterizing the high-power Add-in Card. The Add-in Card inlet temperature must be controlled at 45 °C for both 300 W and 225 W cards.

For cards with a forced convection thermal solution, the rear bracket shall include vents for airflow exhaust to the outside of the system. Any airflow exhaust inside the system must be located at the rear end of the card as shown in Figure 94. It is recommended that any airflow exhaust inside the system should be located within 2.0 inches of the rear bracket.

10.2. Card Thermal Characterization Procedure

The following method must be used to carry out thermal characterization of 225 W/300 W high power Add-in Card:

The measurement must be carried out on a 225 W/300 W high-power Add-in Card with an open bench test setup system as shown in Figure 95 to Figure 97. Figure 95 illustrates a setup to test a DUAL-SLOT card. Dimensions in Figure 95 apply to other fixture versions shown in
Figure 96 and Figure 97, except where indicated otherwise. The fixture may be made of ¼ inch thick polycarbonate plastics, simulating full-length adjacent cards and a standard rear chassis panel.

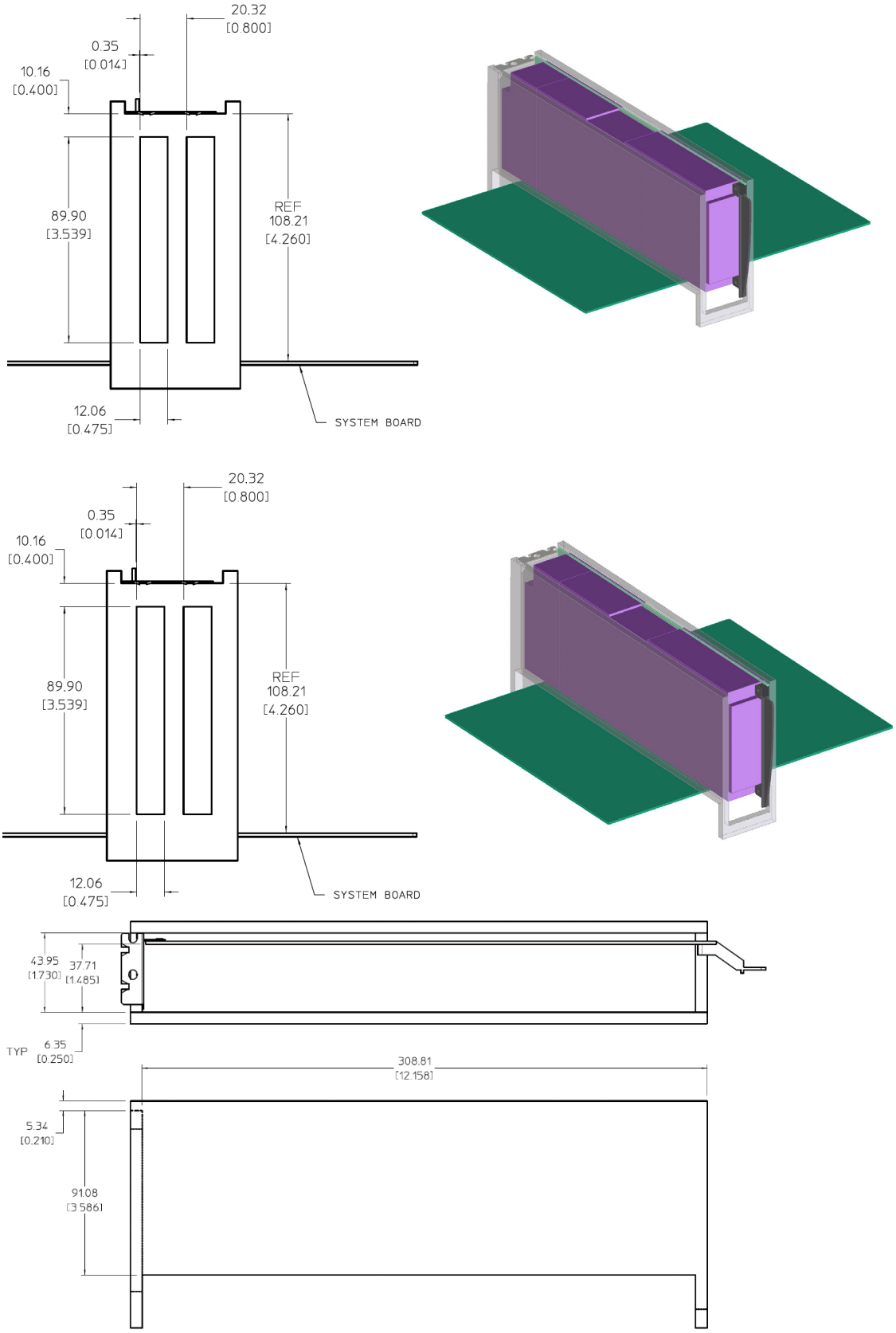

Figure 95: Thermal Characterization Fixture – DUAL-SLOT Version

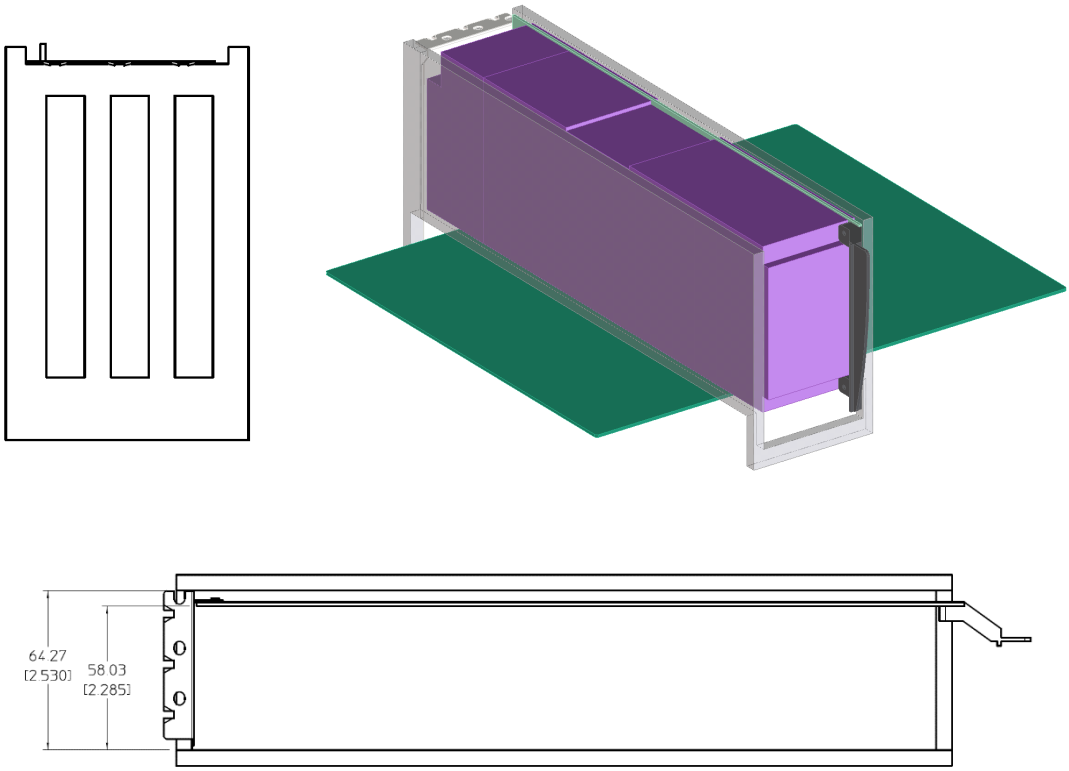

Figure 96: Thermal Characterization Fixture – TRIPLE-SLOT Version

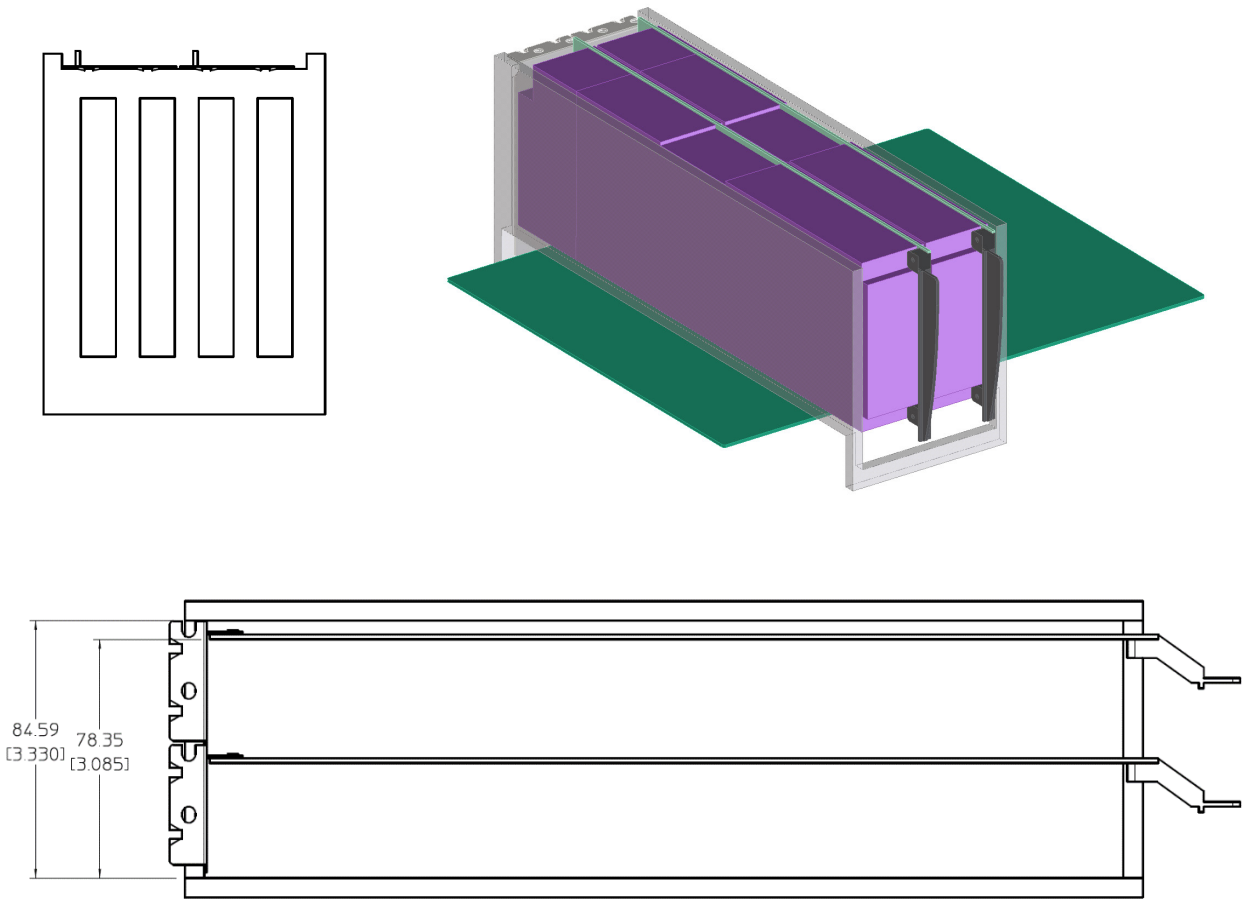

Figure 97: Thermal Characterization Fixture – Tandem DUAL-SLOT Version

Use the following test procedure:

1. Install the card under test in one of the test setups or fixtures shown in Figure 95 to Figure 97 according to the card volumetrics.
2. Place the test setup in a thermal chamber and adjust the chamber temperature such that the card's inlet temperature is 45 °C (for both 300 W and 225 W cards).
3. Thermal characteristic measurements listed below must be carried out with the card in idle and full power states. The "idle" and "full power" states are defined by the Add-in Card vendor and are to be recorded as condition under which the thermal characterization is performed.
   - Critical component temperatures
   - Critical temperature limits
   - Inlet temperature
   - Exhaust temperature
   - Fan speed

   Airflow (CFM) exiting the rear I/O bracket is of great interest and value to system builders. When requested, card vendors must work directly with system builders on the details of how to measure the CFM.

10.3. Acoustic Management

The acoustic emission of a system is increasingly important for computer systems. This is becoming more challenging with higher power systems. The acoustic noise sources in a system are typically the cooling fans, the power supply fan, the graphics card fan, the hard drive, and the optical drives.

The high-power card manufacturers, the chassis designers, and the system integrators must work closely together to deliver a reasonable solution, such that the end user experience is not impacted.

10.3.1. Background and Scope

The acoustic noise generated by high power PCI Express cards can be a significant contributor to overall system noise and, in fact, can be the loudest single component in the computer system. Card and system vendors will need to work together to make sure the acoustic emissions meet end-user requirements, contractual requirements, and/or government-mandated acoustic standards.

This specification does not define acoustic requirements for card compliance. Instead, this specification lists a few general guidelines and defines a standardized method for measuring card acoustics. This standardized method is intended to help system and card vendors to understand acoustic performance of the cards and to work together more efficiently and reduce acoustic emissions.

10.3.2. Card Acoustic Characterization Procedure

The following method uses an industry-standard method, ISO 3744, to measure acoustic emissions and adapts it to the constraints associated with PCI Express cards. This method uses the "idle" and "full power" fan speed data gathered in the Card Thermal Characterization Procedure (see Section 10.2).

1. Measurement and test setup must be as defined in ISO 3744, Acoustics – Determination of Sound Power Levels of Noise Sources Using Sound Pressure – Engineering Method in an Essentially Free Field Over a Reflecting Plane.
2. Place the card in the acoustic chamber by itself, in free air, without the system board or any other system components. The card under test must be suspended by some type of "bungee cords" to avoid any fixturing effect on acoustics. The detailed implementation of the "bungee cords" is up to each card manufacturer.
3. It is not necessary to fully power or operate the card. Instead, it is necessary to operate only the fan; this can be accomplished with an external power source and fan control circuit.
4. Measure and/or calculate the following acoustic emissions at both the "idle" and "full power" fan speeds.
   - Sound pressure, L_{PA}
   - Sound power, L_{WA}
   - 1/3-octave acoustic spectral content

IMPLEMENTATION NOTE

Acoustic Characterization

Any equipment used for fan power and control must be located outside the acoustic chamber or be sufficiently quiet so as not to contribute to the acoustic measurements.

The particular circuit (i.e., waveform) used to control the fan may have a significant effect on the acoustic results, especially at low fan speeds.

10.3.3. Acoustic Recommendations and Guidelines

In addition to minimizing the overall acoustic levels, the following points should be considered:

- The acoustic emissions should not include any prominent tones.
- Certain frequencies are more objectionable to humans than others.
- The card's fan(s) should be dynamically controlled to minimize noise over the complete range of expected operational and environmental conditions.
- The card's fan(s) should be controlled such that there are no abrupt changes or noticeable oscillations in acoustic levels or quality.
- The chassis should be designed to minimize coupling of vibrations and acoustic noise from the card to the chassis.
- The card should be designed to minimize coupling of vibrations from the card's fan to the card.

11

11. Adapter Add-in Card Thermal Reporting

Adapter Add-in Card are influenced by the temperature and airflow velocity and volume present across these cards. To enable enclosure management to comprehend whether a given adapter Add-in Card without integrated air movers to be adequately cooled based on its dynamic operating conditions, an adapter is permitted to communicate its operating requirements over a range of environmental conditions through Vital Product Data (VPD). For adapter Add-in Cards with a Multi-Function Device that support Thermal Reporting data using VPD, the data must be present in Function 0. For multi-device adapter Add-in Cards, the data must be present in only one of the PCI Express devices on the adapter Add-in Card,

Platform software reads these values to determine whether an adapter Add-in Card can be supported based on the adapter Add-in Card's thermal characteristics as well as to determine how to optimize cooling mechanisms to ensure correct operation without expending excessive power.

Adapter Thermal Reporting uses three graph sets that each define up to 15 operating curves. Each curve corresponds to one numeric value communicated by the corresponding VPD field. Values associated with unspecified curves are treated as Reserved.

11.1. Airflow Impedance (AFI) Level

The intent of Airflow Impedance Level information is to identify adapter Add-in Cards which, if in the same airflow path as other platform features to be cooled, may contribute to a total airflow impedance that impacts the cooling for the platform. Also, the installation of higher impedance adapter Add-in Cards, especially if multiple such adapter Add-in Cards are installed, in a platform may exceed the capabilities for a given platform fan's performance curve. Through testing, platform developers determine what adapter Add-in Card AFI Levels the platform supports.

Impedance is categorized as one of N levels communicated by the Air Flow Impedance (AFI) Level field. Each level corresponds to one of the curves illustrated in Figure 98. The level is assigned based on the highest AFI level number which is still below the measured adapter Add-in Card AFI throughout the range of air flows. The AFI Level field is set to a value of one through nine. All other values are currently Reserved.

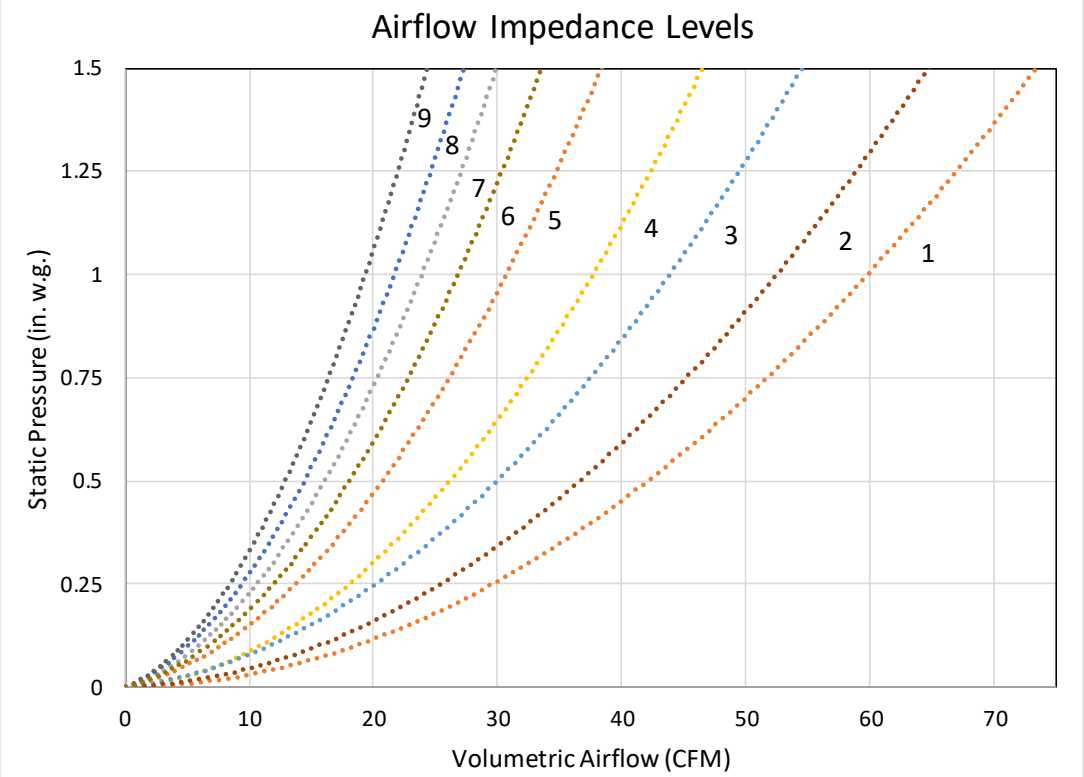

Figure 98. AFI Levels

An adapter Add-in Card is to be rated to it's appropriate AFI Level by comparing its measured impedance, in 0.25-inch water increments through the static pressure range of 0.25 to 1.25 in.w.g., to the AFI Level equations listed in Table 57. The lowest AFI Level which always has higher volumetric airflow for a given static pressure relative to the adapter Add-in Card's measured impedance shall be listed as the adapter Add-in Card's AFI Level.

The airflow impedance testing for an adapter Add-in Card begins at 0.25 in.w.g. to lessen the potential for error at low flowrates.

Table 57. AFI Level Equations

AFI Level	Equation (X=volumetric airflow [CFM]; Y=static pressure [in.w.g.])
0	Reserved
1	Y = 0.0003 * X^2 + 0.0003 * X
2	Y = 0.0003 * X^2 + 0.0012 * X
3	Y = 0.0004 * X^2 + 0.0035 * X
4	Y = 0.0006 * X^2 + 0.0023 * X
5	Y = 0.0008 * X^2 + 0.0066 * X
6	Y = 0.0011 * X^2 + 0.078 * X
7	Y = 0.0014 * X^2 + 0.0091 * X
8	Y = 0.0016 * X^2 + 0.0117 * X
9	Y = 0.0020 * X^2 + 0.078 * X
10-15	Reserved

11.2. Maximum Thermal (MaxTherm) Level

The intent of the Maximum Thermal (MaxTherm) Level information is to define the minimum airflow required at a given air temperature for which an adapter Add-in Card, when stressed to its TDP level limit, will operate within its component's reliability limits and without degraded adapter Add-in Card performance.

Once an adapter Add-in Card's thermal performance profile is established (see Appendix C), the Maximum Thermal (MaxTherm) Level is determined. MaxTherm is the lowest curve in Figure 99 which is entirely above the adapter Add-in Card's quantified thermal performance curve throughout the range of approach ambient temperatures – also referred to as local ambient temperatures – shown on the X-axis ranging from 25 °C up to 65 °C.

Note that the curves shown in Figure 98 and Figure 99 are for reference only. Compare measured readings against the equations defined in Table 58. Note that Thermal Levels 2, 3, and 4 have a low limit for their approach air speed of 100 LFM, meaning their Thermal Levels do not require an adapter Add-in Card to support less than 100 LFM.

It is suggested, but not required, that adapter Add-in Card developers strive to offer solutions that can operate within the shaded recommended design space envelope shown in Figure 98 to maximize the number of systems that can support such conditions.

The MaxTherm field is defined for a value of 1 through 8 (inclusive). All other values are Reserved. See Figure 99 for encodings. Platform software must treat a Reserved MaxTherm value as if MaxTherm reporting was not supported.

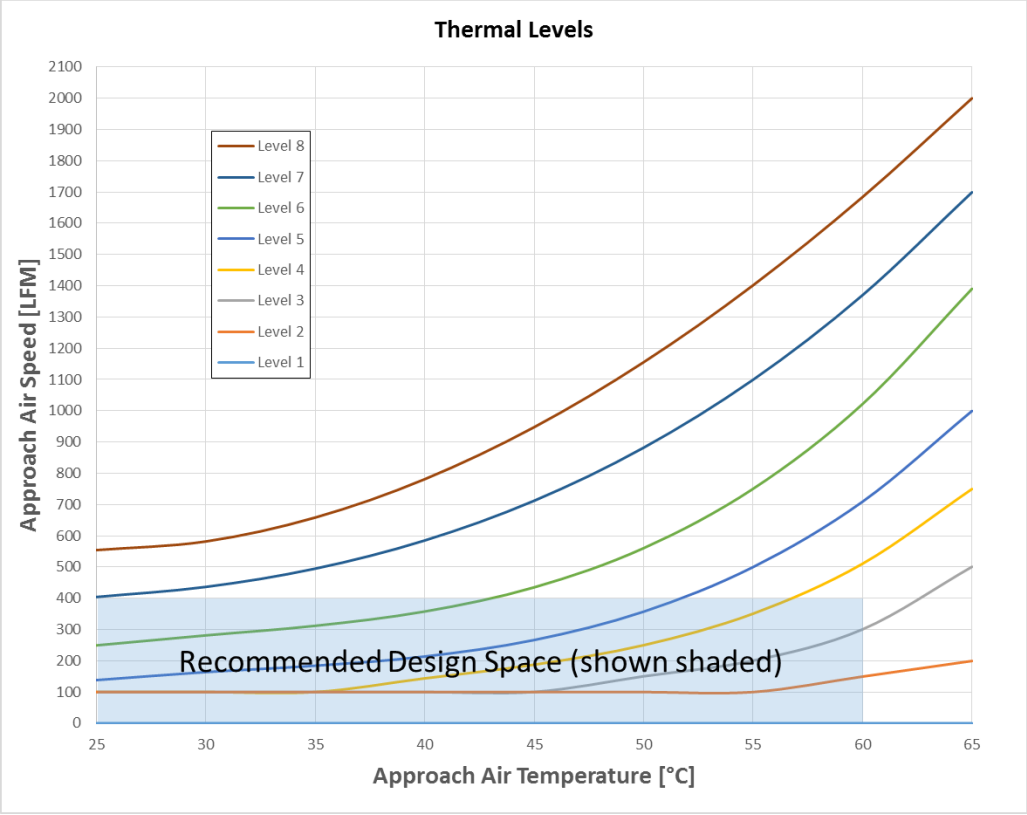

Figure 99. MaxTherm and DTherm Levels

No lower air speeds shall be presumed for approach air temperatures below 25 °C.

For example, Figure 100 illustrates the curve of a hypothetical adapter Add-in Card that has been tested. Given this profile, the MaxTherm Level for the unit under test (UUT) adapter Add-in Card would be set to six if it wished to support the entire temperature range up through 65 °C. The highlight circle in the figure shows it exceeds MaxTherm Level 5 above an approach air temperature of 52 °C.

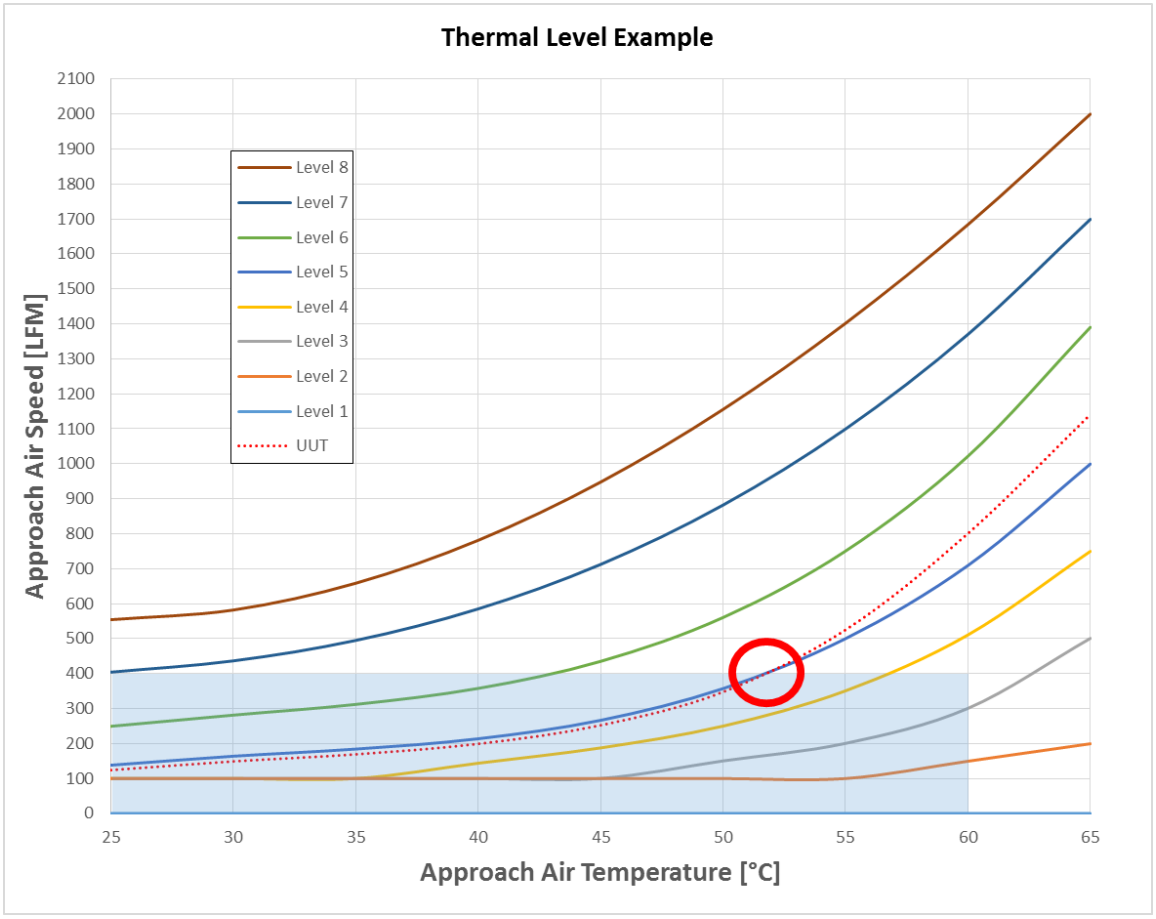

Figure 100. Example Adapter Add-in Card Thermal Profile

Table 58. Thermal Level Equations

Thermal Level	Equation (X=approach air temperature [Celsius]; Y= approach airflow speed [LFM])
0	Reserved
1	Y = 0
2*	Y = -0.00093 * X^3 + 0.16705 * X^2 – 250.92807
3*	Y = 0.06667 * X^3 – 10.0000 * X^2 + 508.33333 * X – 8600.00000
4*	Y = 0.02700 * X^3 – 3.27605 * X^2 + 140.74670 * X – 1972.30735
5	Y = 0.01915 * X^3 – 1.82974 * X^2 + 62.21147 * X – 572.75974
6	Y = 0.02201 * X^3 – 2.00909 * X^2 + 66.82862 * X – 509.54545
7	Y = 0.00717 * X^3 – 0.11926 * X^2 – 3.31674 * X + 449.64286
8	Y = –0.00340 * X^3 + 1.28248 * X^2 – 57.26411 * X + 1237.37229
9-15	Reserved

Note: * Approach air speed values for indicated Thermal Levels shall not be less than 100 LFM.

11.3. Degraded Thermal (DTherm) Level

The intent of the Degraded Thermal (DTherm) Level information is to determine the minimum airflow required at a given air temperature for which an adapter Add-in Card, when provided the same stress application as it was for MaxTherm, will operate within its component's reliability limits but at a degraded adapter Add-in Card performance level. Typically, this is accomplished by the adapter Add-in Card's self-initiated thermal protection schemes, such as throttling. This is potentially of interest for platforms unable to provide sufficient cooling, such as due to the loss of a cooling fan which reduces the platform's cooling capacity. The reduced cooling capacity in such a case may be below the adapter's MaxTherm Level.

If an adapter Add-in Card can operate at a reduced performance level to protect itself thermally and this translates into a reduced Adapter Thermal Profile then that established for MaxTherm, then DTherm is not equal to MaxTherm. DTherm is calculated using the same curves and process as MaxTherm, however, the adapter Add-in Card's profile is created using the adapter Add-in Card's most reduced performance operating level at which it is still on and providing useful work that is not less than 10% of its maximum sustained performance noted in MaxTherm testing. The DTherm field is defined for a value of one through eight (inclusive). All other values are Reserved. Platform software must treat a Reserved DTherm value as if the adapter Add-in Card is not capable of operating at a reduced performance level (i.e., platform software must use only MaxTherm value).

11.4. MaxAmbient

Some adapter Add-in Cards may not be thermally viable up to an approach air temperature of 65 °C, regardless of the air speed involved. Or, even if the adapter Add-in Card could be thermally viable at high temperature extremes, the airflow requirements to do so may require it to operate at a higher thermal challenge level, potentially reducing the number of systems able to supply the needed airflow. In either circumstance, the adapter Add-in Card may opt to have its upper approach air temperature limit be less than 65 °C. This approach air temperature upper threshold is referred to as MaxAmbient. MaxAmbient must be a value between 50 and 65 inclusive. The number represents a temperature in degrees Celsius and is entered as a whole number. It applies to the full operating potential MaxTherm condition.

For the example of establishing a MaxTherm Level for an adapter Add-in Card, as previously illustrated in Figure 98, if it was desired by the adapter Add-in Card's developer to report less than a MaxTherm Level of 6, then a MaxAmbient value of 34h (representing 52 °C) could have been used by the adapter Add-in Card's developer instead of 41h (representing 65 °C). In such a case, declaring a MaxTherm Level of 5 with a MaxAmbient of 34h would have been acceptable. If MaxAmbient is unsupported, then these bits must be set to 00h. Platform software must treat a Reserved MaxAmbient value as if MaxAmbient reporting was not supported (i.e., MaxTherm value applies up to 65 °C).

Appendix 0 describes the thermal test set up and procedure to evaluate an adapter Add-in Card's thermal performance.

APPENDIX A. INSERTION LOSS VALUES (VOLTAGE TRANSFER FUNCTION) (INFORMATIONAL ONLY)

The maximum loss values in dB (decibels) are specified for the system board and the Add-in Card. The insertion loss values are defined as the ratio of the voltage at the ASIC package pin (Transmitter/Receiver) and the voltage at the PCI Express connector interface, terminated by 100 Ω differential termination, realized as two 50 Ω resistances. These resistances are referenced to ground at the interface (see Figure 101).

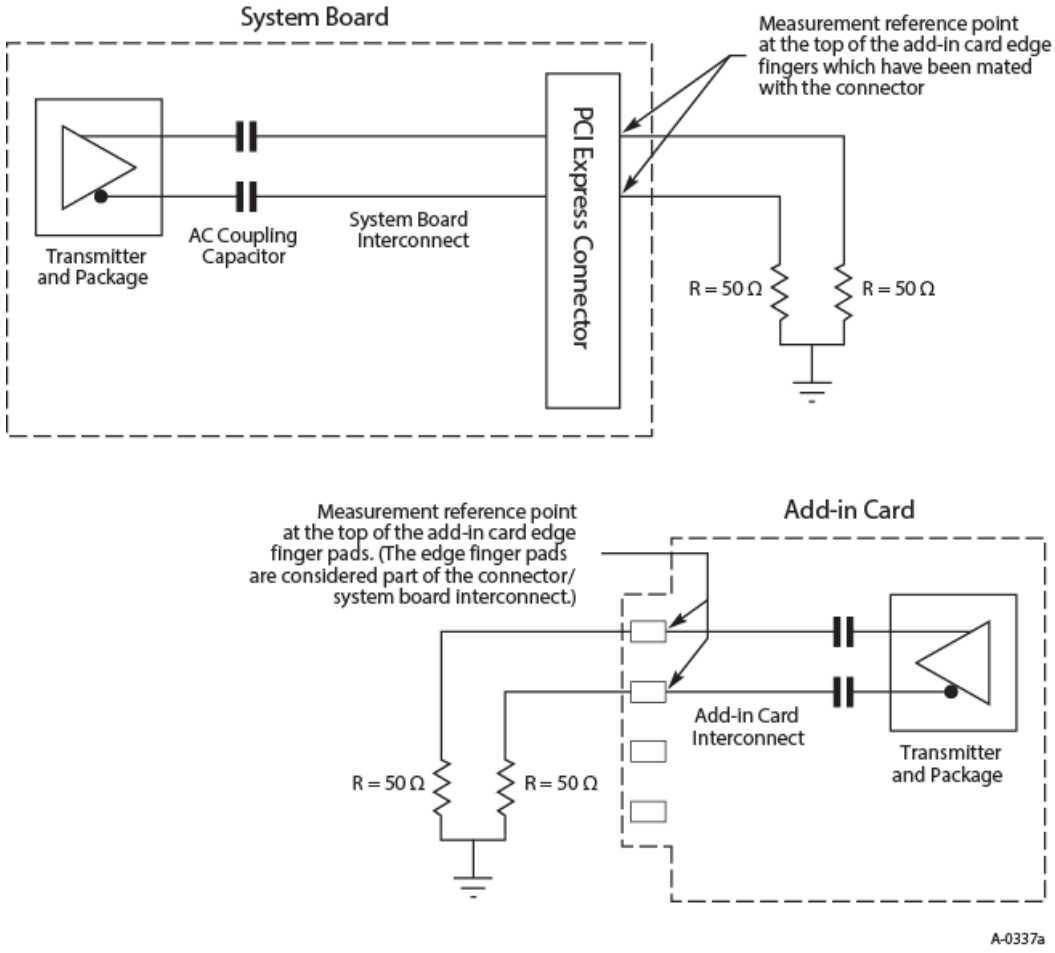

Figure 101 Example Interconnect Terminated at the Connector Interface

All PCI Express differential trace pairs are required to be referenced to the ground plane (Figure 102). The loss values associated with any riser card interface and adjoining connector implementation must collectively meet the system board loss budget allocations and associated eye diagrams (Table 59).

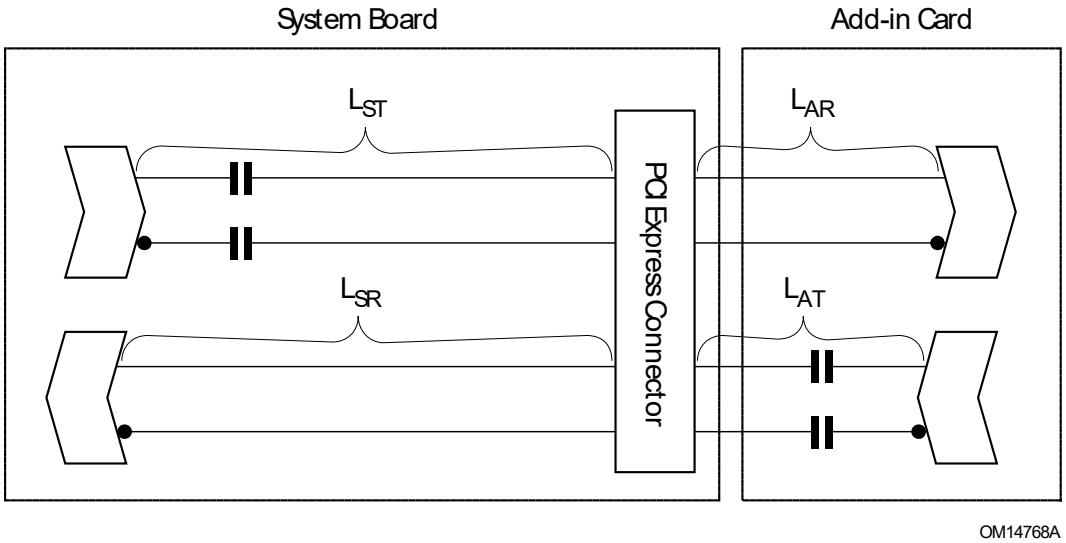

Figure 102. Insertion Loss Budgets

Table 59: Allocation of Interconnect Path Insertion Loss Budget for 2.5 GT/s Signaling

Loss Parameter	Loss Budget Value at 1.25 GHz (dB)		Loss Budget Value at 625 MHz (dB)		Comments
PCI Express Add-in Card	L_{AR} < 2.65	L_{AT} < 3.84	L_{AR} < 1.95	L_{AT} < 2.94	Notes 1, 2
System Board and Connector	L_{ST} < 9.30	L_{SR} < 8.11	L_{ST} < 6.00	L_{SR} < 5.01	Notes 1, 3
Guard Band	1.25		1.25		Note 1
Total Loss	L_T < 13.2		L_T < 9.2		

Notes:

1. All values are referenced to 100 Ω, realized as two 50 Ω resistances. The loss budget values include all possible crosstalk impacts (near-end and far-end) and potential mismatch of the actual interconnect with respect to the 100 Ω reference load.
2. The *PCI Express Base Specification, Revision 4.0* allows an interconnect loss of 13.2 dB for 1.25 GHz (non de-emphasized) signals and 9.2 dB for 625 MHz (de-emphasized) signals. From this, a total of 1.25 dB is held in reserve as guard band to allow for any additional attenuation that might occur when the Add-in Card and system board are mated. The allocated loss budget values in the table directly correlate to the eye diagram voltages in Section 4.8. Tradeoffs in terms of attenuation, crosstalk, and mismatch can be made within the budget allocations specified.
3. As a guide for design and simulation, the following derivation of the budgets may be assumed for 1.25 GHz signals: 5.2 dB is subtracted from 13.2 dB to account for near-end crosstalk and impedance mismatches. Out of this, the 1.25 dB is reserved as guard band. The following loss allocations are then assumed per differential pair: L_{AR} = 1.4 dB; L_{AT} = 1.8 dB; L_{SR} = 6.2 dB; L_{ST} = 6.6 dB. These allocation assumptions must also include any effects of far-end crosstalk. 625 MHz values may be derived in a similar manner.

4. The Add-in Card budget does not include the Add-in Card edge-finger or connector. However, it does include potential AC coupling capacitor attenuation on the Transmitter (TX) interconnect on Add-in Card. The budget allocations generally allow for a maximum of 4-inch trace lengths for differential pairs having an approximate 5-mil trace width. No specific trace geometry, however, is explicitly defined in this specification. The subscripts of the symbol designators, T and R, represent the Transmitter and Receiver respectively.
5. The system board budget includes the PCI Express connector and assumes it is mated with the card edge-finger. Refer to Section 0 for specifics on the standalone connector budget. The system board budget includes potential AC coupling capacitor attenuation on the Transmitter (TX) interconnect on the system board. The subscripts of the symbol designators, T and R, represent the Transmitter and Receiver respectively.

IMPLEMENTATION NOTE

Insertion Loss Budget

The insertion loss budget distributions above are used to derive the eye diagram heights as described in Section 4.8. However, they are provided here only as a design guideline. Compliance measurements must actually be verified against the eye diagrams themselves as defined in Section 4.8.

The *PCI Express Base Specification* provides design guidelines for channels designed to support 5.0 GT/s signaling.

APPENDIX B. TEST CHANNEL SCATTERING PARAMETERS

8.0 GT/s Test Channels

The 12-port S-parameters for the System-Board Test Channel with and without a standard connector/edge-finger model are distributed with this specification in the following files:

- system_board_test_channel_with_connector_8 G.s12p
- system_board_test_channel_without_connector_8 G.s12p

The 12-port S-parameters for the Add-in Card Test Channel with and without a standard connector/edge-finger model are distributed with this specification in the following file:

- add_in_card_test_channel_with_connector.s12p

16.0 GT/s Test Channels

The 12-port S-parameters for the System-Board Test Channel with connector/edge-finger model are distributed with this specification in the following files:

- system_board_test_channel_with_connector_16G.s12p

The 12-port s-parameters for the Add-in Card Test Channel without a standard connector/edge-finger model are distributed with this specification in the following file:

- Add_in Card_test_channel_with_connector.s12p

C

APPENDIX C. THERMAL DATA COLLECTION AND TEST PROCEDURE

This appendix describes the thermal test set-up and procedure to evaluate an adapter Add-in Card's thermal performance. Thermal performance is communicated via the following four VPD fields:

- AFI Level
- MaxTherm Level
- DTherm Level
- MaxAmbient

The values of these fields are determined using a custom test fixture. Details regarding the dimensions and construction of the test fixture are provided in the associated CAD files (refer to the PCI-SIG website) for the thermal challenge and airflow impedance tester.

The test fixture is intended to be attached to an AMCA 210-99/ASHRAE 51-1999 compliant airflow chamber, which can quantify both static pressure as well as volumetric airflow. The tester is attached to the airflow chamber such that air blows toward the PCIe adapter Add-in Card and exits the tester at the adapter's I/O bracket.

For MaxTherm and DTherm level testing, the airflow impedance plates (shown as orange in color in Figure 103) must be removed. For AFI Level testing, where the desire is to understand the relative airflow impedance of the adapter Add-in Card, the use of the airflow impedance plates (two when testing SINGLE-SLOT adapter Add-in Cards; one when testing DUAL-SLOT adapter Add-in Cards) is required.

The adapter Add-in Card to be tested is installed in the test fixture, which is positioned above an operational platform IO board's PCIe x16 connector. Any cables needed to fully exercise the adapter Add-in Card are attached to the adapter Add-in Card to be tested. The test fixture's lid is then attached, and the test fixture is checked to ensure air flow is not leaking through its joints.

The adapter Add-in Card is operated to its rated TDP level using a vendor-specific exercise procedure. The adapter Add-in Card's manufacturer is responsible for providing sufficient detail - including full descriptions of all software, firmware, and hardware needed - such that others could recreate the same results if provided the same adapter Add-in Card.

See the associated CAD file information for details of the tester's construction and size. Figure 103 shows an exploded view of the tester, with the lid, its mounting screws, the AFI blocks (shown in orange for illustration purposes only), and adapter Add-in Card under test (in green) shown suspended above the tester housing.

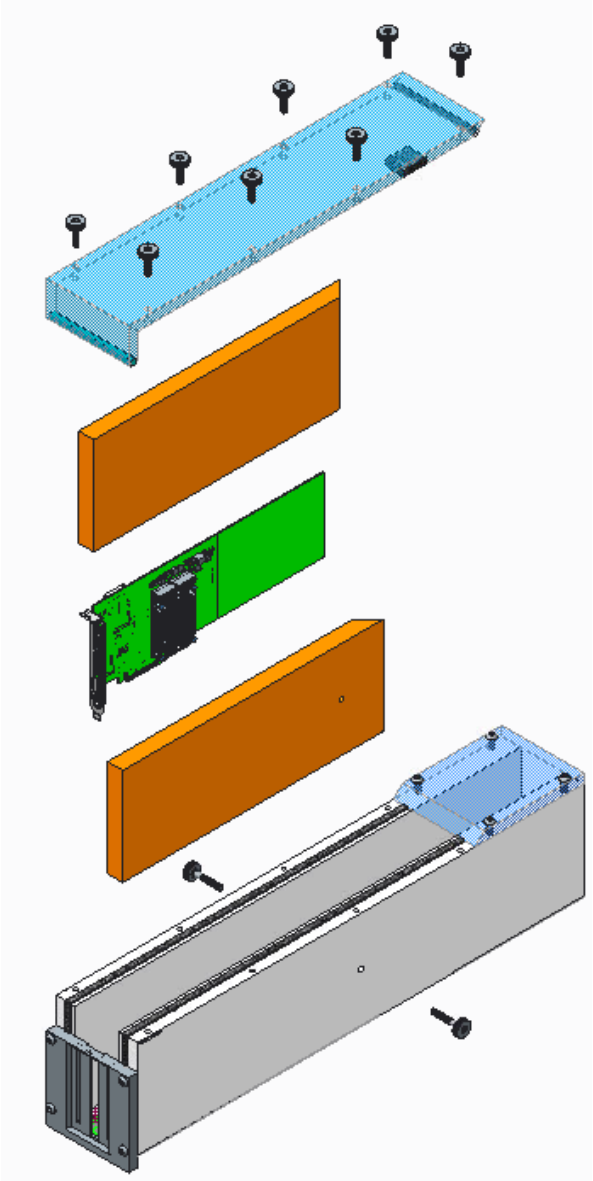

Figure 103. Tester isometric exploded view: {Lid, AFI Block, Add-in Card, AFI Block}

During Thermal Level testing for MaxTherm and DTherm data, the AFI blocks (shown in orange in Figure 103) are not used in the tester as shown in Figure 104. The tester is connected to a flow bench which provides quantifiable volumetric airflow and static pressure.

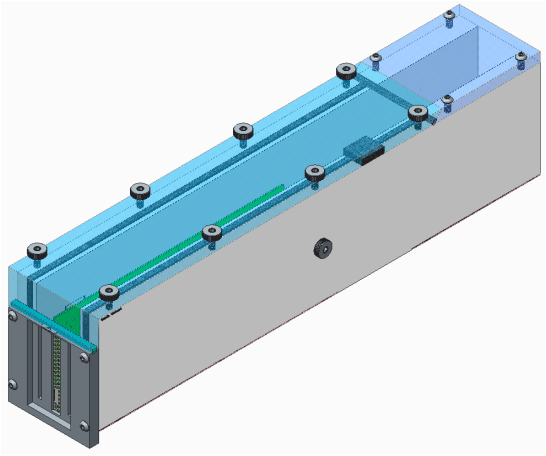

Figure 104. Tester isometric view in MaxTherm and DTherm Testing Configuration

During Thermal Level testing for AFI Level data, the AFI blocks (shown in orange in Figure 103) are used in the tester (two AFI blocks when testing SINGLE-SLOT adapter Add-in Cards as shown in Figure 105; one AFI block when testing DUAL-SLOT adapter Add-in Cards as shown in Figure 106.

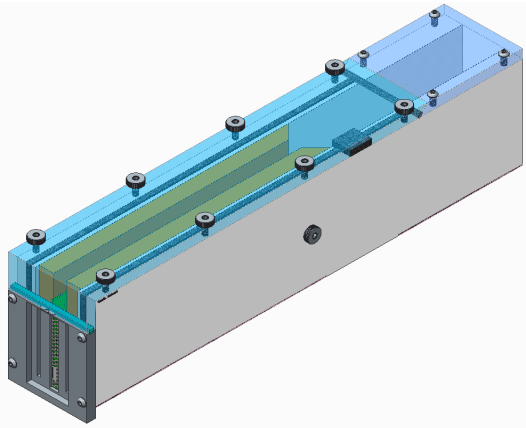

Figure 105. Tester isometric view in SINGLE-SLOT Adapter Add-in Card AFI testing configuration

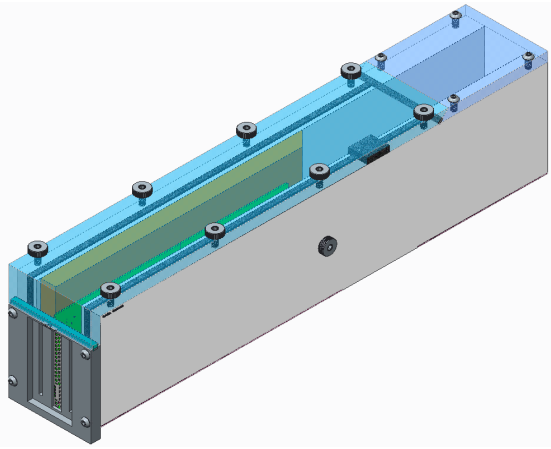

Figure 106. Tester isometric view in DUAL-SLOT Adapter Add-in Card AFI Testing Configuration

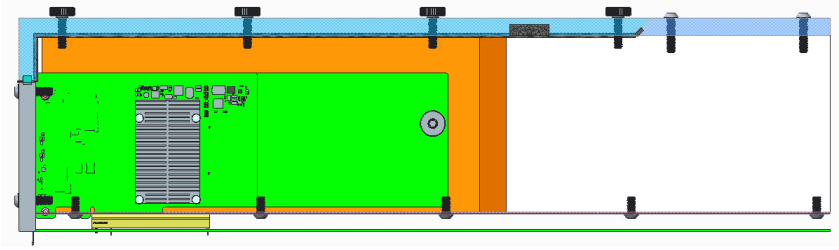

Figure 107. Side view in DUAL-SLOT adapter Add-in Card AFI testing configuration (Side wall removed for viewing illustration only)

A system board with at least one x16 PCI slot capable of operating at the adapter Add-in Card's maximum link width and maximum link speed is needed for the testing. The PCIe slot must be able to send a Set_Slot_Power_Limit Message value that allows the adapter Add-in Card to operate at its higher performance level. The platform power supply must be able to supply the power required for both the system board and the adapter Add-in Card to run at their highest performance levels, including any additional adapter Add-in Card power cables (if used).

For MaxTherm and DTherm testing, the quantified volumetric airflow is divided by the cross-sectional area of the duct to establish the average velocity of air entering the test fixture:
velocity (FT/min) = volume flow (ft^3/min) / tester's inner area (ft^2) perpendicular to airflow.
Hot-wire anemometer must be placed at the center of tester's air channel, within 50 mm downstream of the tester's air entrance opening. The anemometer data must be collected for reference only. At least one thermocouple sensor is required to be placed at this same location to collect inlet air temperature data, unless also using the anemometer's local ambient temperature reading. Figure 108 shows an example test setup connected to a flow bench.

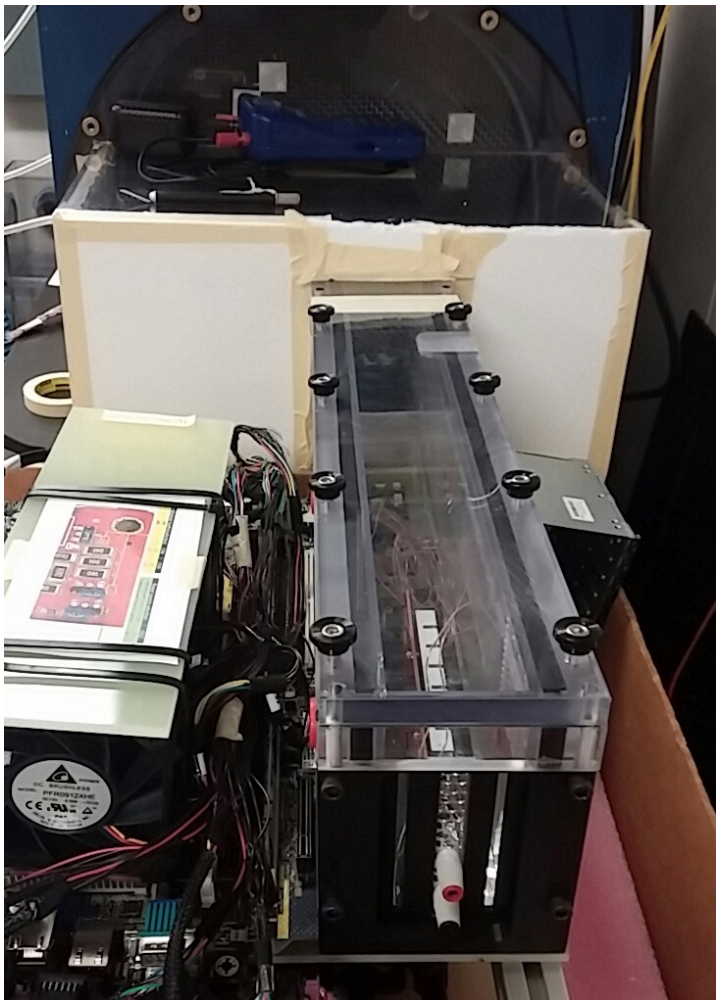

Figure 108. Actual Thermal Level Test Fixture Set-up

The target output is the air speed (LFM, or FT / min) required to cool the adapter Add-in Card under test at projected (or actual) air temperatures while the adapter Add-in Card is being stressed to its TDP level. The adapter Add-in Card component's minimum temperature margin at various air speeds are collected, while also noting the air temperature entering the test fixture. The adapter Add-in Card's minimum temperature margin is added to the tester's air inlet temperature to arrive at a projection as to what would be the zero-temperature margin ambient for given air speeds. With the exception of adapter Add-in Cards meeting the requirements of Thermal Level 1, no less than six data points, regularly spaced from a project approach ambient of 25 °C to at least 50 °C (65 °C preferred), are to be collected. These projected approach ambients and approach air speeds are then compared against the Thermal Levels shown in Figure 108.

For example, a hypothetical fabric adapter Add-in Card was profiled for its thermal levels using an airflow chamber, such as the one shown in Figure 109, at various air speeds.

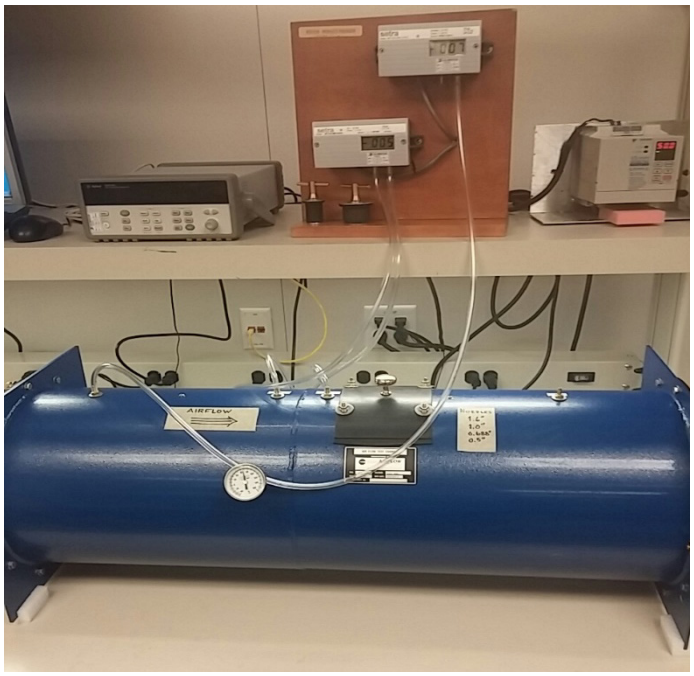

Figure 109. An Example of an Airflow Chamber

Several measurement points are made to enable a good curve fit across the range of interest. The components with the least temperature margin are monitored using either temperature sensors that are part of the adapter Add-in Card's design or added thermocouples. An optical transceiver plug, technically not a part of the adapter Add-in Card, but being integral for its intended usage, is included in this adapter Add-in Card's characterization. The results for this example adapter Add-in Card are given in Table 60.

Table 60. Hypothetical Fabric Adapter Add-in Card Thermal Level Measurements

	Test Run								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Approach Ambient Temperature (°C)	26	26	26	26	25	25	25	25	25
Measured CFM	49	41	32	27	23	18.5	15	12	7.5
VR Temperature (thermocouple reading: 100C max allowed) (°C)	39.3	40	41	42	44	47	56	65	76
QSFP Temperature (adapter Add-in Card sensor reading: 70C max allowed) (°C)	31	34	38	41	43	47	52	56	68
ASIC Temperature (adapter Add-in Card sensor reading: 105C max allowed) (°C)	54.5	55	56	58	60	64	78	92	105

From these measurements the average air speed in LFM (linear feet per minute) can be calculated by dividing the volumetric airflow in CFM (cubic feet per minute) by the tester's inner channel area. The tester's inner dimensions are 4.724 inches in height by 2.337 inches in width. Table 61 shows the results of the calculated LFM.

Table 61. Hypothetical Fabric Adapter Add-in Card's Calculated Approach LFM

	Test Run								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Approach Ambient Temperature (°C)	26	26	26	26	25	25	25	25	25
Measured CFM	49	41	32	27	23	18.5	15	12	7.5
Tester's inner channel height (IN)	4.724	4.724	4.724	4.724	4.724	4.724	4.724	4.724	4.724
Tester's inner channel width (IN)	2.337	2.337	2.337	2.337	2.337	2.337	2.337	2.337	2.337
Calculated LFM (CFM/tester's channel area)	**639.1**	**534.8**	**417.4**	**352.2**	**300.0**	**241.3**	**195.7**	**156.6**	**97.8**

The temperature margins at the different air speeds measured are calculated by subtracting the measured temperature for each component from its maximum allowed temperature for reliability and data integrity, sometimes referred to as the component's maximum continuous operating temperature, or MCOT. No additional temperature margin or safety factor must be used in these calculations.

By adding the test run's actual measured approach ambient to the least temperature margin for the adapter Add-in Card's components, the result is the maximum approach ambient supportable for that air speed. Note in this example how under different air speeds, different components may have the least temperature margin for the adapter Add-in Card.

Following the above described steps, the approach temperature to plot against the calculated LFM for this example adapter Add-in Card may be determined, as shown in Table 62

Table 62. Example Fabric Adapter Add-in Card's Calculated Approach Air Temperature

	Test Run								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Approach Ambient Temperature (°C)	26	26	26	26	25	25	25	25	25
VR margin to 100 °C (°C)	50.7	50	49	48	46	43	34	25	14
QSFP margin to 70 °C (°C)	**39**	**36**	**32**	**29**	**27**	**23**	**18**	14	2
ASIC margin to 105 °C (°C)	50.5	50	49	47	45	41	27	**13**	**0**
Max Approach Temperature at Calculated LFM [Approach Ambient + Least Margin Component] (°C)	**65**	**62**	**58**	**55**	**52**	**48**	**43**	**38**	**25**

Plotting the resulting max approach level against the calculated LFM graphically displays how the adapter Add-in Card compares to the various Thermal Levels, as shown in Figure 110.

Note that this adapter Add-in Card's plot never exceeds Thermal Level 5. Even though it is under Thermal Level 4 when above approach air temperatures of approximately 57 °C, its MaxTherm Level would be 5 (to cover the mandatory range below 50 °C. Since it could operate up through an approach air temperature of 65 °C, it would specify a MaxAmbient value of 41h. Using a lower MaxAmbient value would not allow this adapter Add-in Card the advantage of using a lower Thermal Level, so it must declare the maximum ambient it could support, up to the limit of 65 °C.

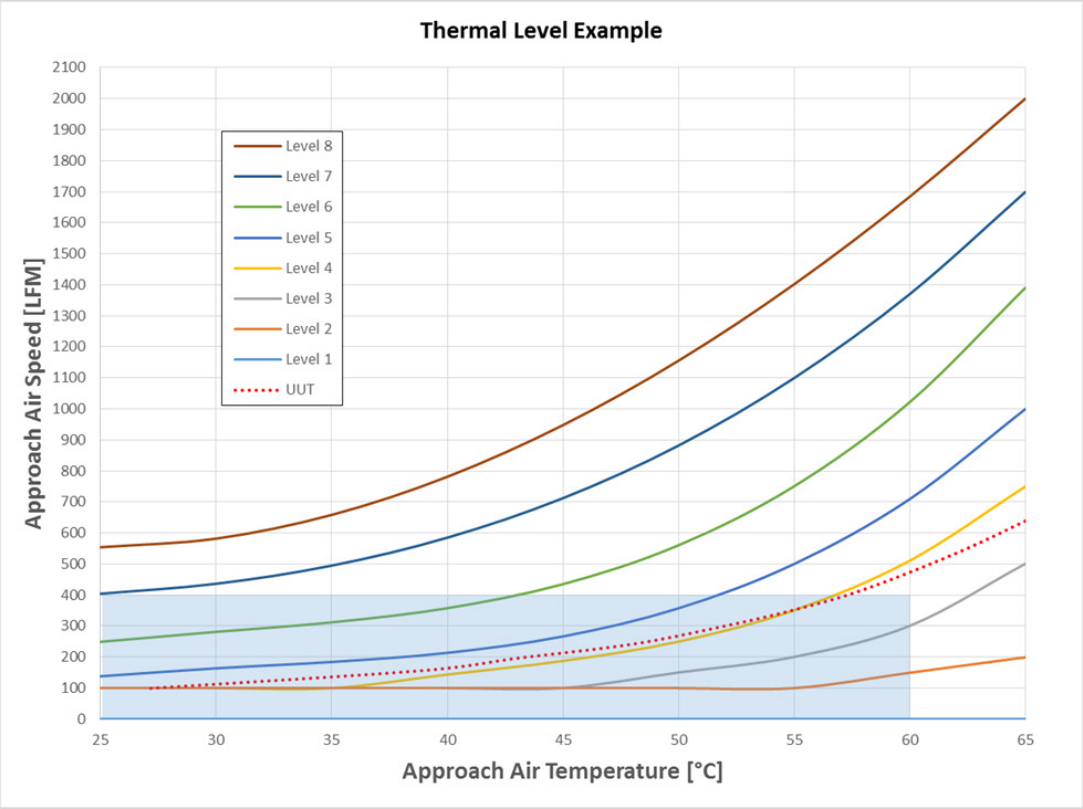

Figure 110. Example Adapter Add-in Card's Thermal Level

Since this example adapter Add-in Card does not support lowered power levels/lowered performance when under adverse environments, its DTherm Level is the same as its MaxTherm Level.

APPENDIX D. ACKNOWLEDGEMENTS

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[2] Company affiliation listed is at the time of specification contributions.

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