

## PCI Express for Software Engineers

### Training

#### Let MindShare Bring “PCI Express for Software Engineers” To Life For You

MindShare's PCI Express for Software Engineers course starts with a high-level view of the technology to provide the big-picture context of PCIe protocol. The course then describes configuration space and the enumeration process. The most important registers are described including those related to error and interrupt handling.

The course describes registers added with each generation of specification from PCIe specification 1.1 to the latest 5.0. There are a large number of features and optional behaviors described in the PCIe spec. MindShare can customize the course to cover the topics that are most important for your group. Use the course outline below as a guide to request topics you want covered or removed.

#### You Will Learn:

- PCI Express features and capabilities
- The definition and responsibilities of each of the layers in the interface
- Overview of the PCIe packet-based transaction protocol
- The error detection, reporting and possible correction mechanisms
- The address space and packet-routing methods used
- How the various power management techniques work
- The details of the configuration registers that provide control and status visibility to software
- Software enumeration process
- Overview of the equalization necessary to operate at 8.0GT/s and higher speeds
- Overview the LTSSM including the concepts important for each state
- Essential features added to Gen3, Gen4 and Gen5 specifications

For SRIOV and ATS related topics, which are incorporated into the PCIe 5.0 spec, please request our 3-day [IO Virtualization for Intel Platforms](#) or [IO Virtualization for ARM Platforms](#) as these topics are **NOT** covered in this standard 5-day PCIe course. Additionally, PIPE 6.0 spec related topics are not covered but can be added upon request. Some of the ECNs listed below are covered upon request.

#### Who Should Attend?

This course is suitable for software engineers because the configuration registers used to control the hardware are covered in detail. Firmware and device driver coders will benefit from understanding the enumeration process and learning the function of the most important PCIe registers.

**Course Length:** 3 Days (but customizable to shorter or longer duration)

#### Course Outline:

	Hands-On 5-day Class	Software 3-day Class
<b>PCI Architecture Background Foundation</b>		
PCI concepts important for understanding PCI Express	X	X
Physical Address Spaces	X	X
Traffic Types (System Memory, PIO and DMA)	X	X
Typical System Transactions (NVMe Example)	X	X

	Hands-On 5-day Class	Software 3-day Class
<b>PCI Express Features and Architecture Overview</b>		
Layered Architecture	X	X
ARM example topology	X	X
TLP, DLLP and Ordered Set Packet Format Overview	X	X
Protocol Overview	X	X
<b>Configuration Overview</b>		
Legacy and Enhanced Configuration Access Mechanism (ECAM)	X	X
Type 0 and Type 1 Headers, Capability and Extended Capability Structures	X	X
Bus Enumeration	X	X
<b>HANDS-ON ARBOR LAB:</b> Scan your system and determine topology	X	X
<b>Address Space and Transaction Routing</b>		
Clarification of Memory space	X	X
System memory vs MMIO	X	X
Prefetchable vs Non-prefetchable	X	X
IO space	X	X
Setting up the BARs as well as the Base and Limit registers	X	X
Switch Routing Mechanism	X	X
<b>HANDS-ON ARBOR LAB:</b> Debug problem with address mapping	X	X
<b>TLP Format Details</b>		
Normal TLP fields	X	overview
TLP Prefixes	X	
Lightweight Notification and TPH / Steering Tags	X	
10-bit Tags	X	overview
PCI-SIG Vendor-Defined Messages	X	
<b>Quality of Service and Arbitration</b>		
TC/VC Mapping	X	overview
VC Arbitration	X	overview
Port Arbitration	X	overview
Multi-function Arbitration	X	overview
<b>Flow Control</b>		
Flow Control Protocol	X	overview
Scaled Flow Control	X	overview
Link Feature Exchange	X	overview
Flow Control Initialization	X	overview
Runtime Flow Control Update Mechanism	X	overview

	Hands-On 5-day Class	Software 3-day Class
<b>Transaction Ordering</b>		
Simplified Ordering Table	X	X
Relaxed and ID-Based Ordering	X	X
<b>DLLP Format Details</b>		
DLLPs	X	
NOP & Data Link Feature DLLPs	X	
<b>ACK / NAK Protocol</b>		
TLP Error Recovery Mechanism	X	overview
Simplified Replay Timer	X	X
Examples of Numerous Error Scenarios	X	
Nullified Packets and Cut-Through Mode Switches	X	overview
<b>Physical Layer Logic (2.5GT/s and 5.0GT/s)</b>		
Block Diagram	X	overview
Ordered Sets	X	
Byte Striping/Unstriping	X	
Scrambling/Unscrambling	X	
8b/10b Encoding/Decoding	X	
Serializing/Deserializing	X	
<b>Physical Layer Logic (8.0GT/s, 16.0GT/s and 32.0GT/s)</b>		
128b/130b Encoding/Decoding	X	overview
Control SKPs	X	
Ordered-Set Blocks and Data Blocks	X	
Data Streams and Packet Framing	X	
Data Parity Checking	X	overview
16.0 & 32.0 GT/s Data Parity Checking	X	overview
Precoding	X	overview
<b>Physical Layer Electrical (all speeds)</b>		
Differential Tx / Rx	X	
2.5GT/s and 5.0GT/s De-emphasis	X	overview
8.0GT/s, 16.0GT/s and 32.0GT/s Equalization Concept	X	overview
Rx Equalization	X	
Electrical Conditions for different Link States	X	
Spread Spectrum Clocking (SSC)	X	
Separate Refclk Independent SSC (SRIS)	X	

	Hands-On 5-day Class	Software 3-day Class
<b>Link Initialization and Training (LTSSM)</b>		
Detect, Polling, Configuration, L0 States	X	overview
Recovery: Link Speed Change	X	overview
Recovery: Equalization Process	X	overview
16.0 GT/s Equalization and Config Structures	X	overview
Negotiation for skipping parts or all of Tx Equalization	X	overview
32.0 GT/s Equalization and Config Structures	X	overview
Recovery: Link Width Change		
L0s, L1, L2, Hot Reset, Link Disable and Loopback States	X	overview
Modified TS1 / TS2s and Alternate Protocol Negotiation	X	overview
<b>Interrupt Support</b>		
Legacy Interrupt Handling		
MSI Interrupts	X	X
32-bit MSI Data	X	X
MSI-X Interrupts	X	X
<b>HANDS-ON ARBOR LAB:</b> Investigate source of MSI(-X) interrupt and delivery	X	X
<b>Error Detection and Handling</b>		
Correctable, Non-Fatal and Fatal Errors	X	X
Advisory Non-Fatal Errors	X	X
Error Subclass field for Correctable Error Messages		
Advanced Error Reporting (AER)	X	X
<b>HANDS-ON ARBOR LAB:</b> Determine source and error reporting mechanism	X	X
<b>Power Management</b>		
Device Power States	X	X
Link Power States	X	X
L1 Substates	X	overview
Link Activation		
Active State Power Management (ASPM) - hardware controlled	X	overview
Software Controlled Power Management	X	overview
Power Management Events (PME, Beacon and #WAKE)	X	
Dynamic Power Allocation (DPA)		
Optimized Buffer Flush Fill (OBFF)		
Latency Tolerance Reporting (LTR)	X	X
<b>System Resets</b>		
Conventional Reset Mechanisms: Cold, Warm and Hot Reset	X	X
Function Level Reset (FLR)	X	X

	<b>Hands-On 5-day Class</b>	<b>Software 3-day Class</b>
<b>Features Introduced with PCIe 4.0</b>		
Retimers	overview	overview
Lane Margining	overview	overview
Flattening Portal Bridge (FPB)	overview	overview
Hierarchy ID Reporting		
Designated Vendor-Specific Extended Capability (DVSEC)	overview	X
Enhanced Allocation		
Emergency Power Reduction State		
<b>Features Introduced with PCIe 5.0</b>		
System Firmware Intermediary Support	overview	overview
<b>Other PCIe Features (ECNs)</b>		
Hot Plug		
Power Budgeting		
Multi-Casting		
Protocol Multiplexing (PMUX)		
Resizable BARs		
Downstream Port Containment (DPC) and Enhanced DPC (eDPC)		
Lightweight Notification (can be used for lightweight cache coherency)		
Process Address Space ID (PASID)		
Precision Time Measurement (PTM)		
Device Readiness Status (DRS) and Function Readiness Status (FRS)		

### Recommended Prerequisites:

A basic understanding of digital bus architectures such as PCI is recommended.

### Course Material:

- 1) [PCI Express Technology eBook](#) (or hardcopy on request) by Mike Jackson and Ravi Budruk
- 2) Downloadable PDF version of the presentation slides
- 3) Add-On MindShare [Arbor software tool](#), used for student labs in the class (discounted pricing applies)
- 4) Add-On [Comprehensive PCI Express eLearning course](#) (discounted pricing applies)