Thunderbolt™ 3 Technology and USB-C

Jeff Bake – Thunderbolt Product Manager, Intel Corporation
Dinesh Jain – Senior Product Engineer, Intel Corporation
Jacob Ontiveros – Senior Applications Engineer, Texas Instruments

HSTS004
Agenda

• USB-C Introduction
• Thunderbolt™ 3 Technology Overview
• Key User Experiences
• Thunderbolt Device Development
• USB-C Alternate Mode and Power Delivery
• Summary
Agenda

• USB-C Introduction

• Thunderbolt™ 3 Technology Overview

• Key User Experiences

• Thunderbolt Device Development

• USB-C Alternate Mode and Power Delivery

• Summary
USB-C Cables and Connectors

• Symmetric and Flip-able/Reversible
• Power delivery up to 100W of power - 20V at 5A
• Supports Alternate Modes – DisplayPort*, Thunderbolt™, Audio etc.

Thunderbolt 3 is bringing Thunderbolt to USB-C
More Speed

• **40Gbps** Thunderbolt™ 3
  - Bi-directional, PCI Express® and DisplayPort*
  - Four lanes of PCI Express **Gen 3**
  - Eight lanes of DisplayPort 1.2
• Native **USB 3.1** (10Gbps)
• Native DisplayPort 1.2
Thunderbolt™ 3 Brings Thunderbolt to USB-C

The USB-C that does it all.

- More Protocols
- More Speed: 40 Gbps – fastest connection
- More Pixels: Dual 4K displays, 60hz
- More Power: 100W charging, 15W device
Not all USB-C Computer **Ports** Will be Equal

<table>
<thead>
<tr>
<th>USB 2.0</th>
<th>USB 3.1 5 Gb/s</th>
<th>USB 3.1 10 Gb/s</th>
<th>DisplayPort™ Multi-Function 5 (or) 10 Gb/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>480 Mb/s</td>
<td>PD Enabled</td>
<td>PD Enabled</td>
<td>PD Enabled</td>
</tr>
<tr>
<td>PD Enabled</td>
<td>PD Enabled</td>
<td>PD Enabled</td>
<td>PD Enabled</td>
</tr>
</tbody>
</table>

Thunderbolt™ 3 the USB-C that does it all

40 Gb/s and PD Enabled
Agenda

• USB-C Introduction

• Thunderbolt™ 3 Technology Overview

• Key User Experiences

• Thunderbolt Device Development

• USB-C Alternate Mode and Power Delivery

• Summary
More Protocols

More protocols than any other I/O controller

Connect *any* dock, device or display, including billions of USB devices

Thunderbolt™ Technology
Thunderbolt™ 3 - Host Mode

• Connected through PCI Express® (PCIe) switch to Host PCIe bus
• Always functions as a Host USB controller
  – Appears in host Device Manager even if located in a dock or device
Thunderbolt™ 3 – Thunderbolt Host Mode

![Diagram of Thunderbolt™ 3 architecture](image)

- **PCI Express® (PCIe) Switch**
- **PCIe Phy**
- **xHCI Controller**
- **Link Controller**
- **Active Block**
- **Inactive Block**
- **Active Path**
- **Inactive Path**

**Key Components:**
- **Thunderbolt Switch**
- **DP In Phy**
- **DP In**
- **Host DMA**
- **Thunderbolt Phy**
- **Thunderbolt 3**

**Connections:**
- **2x DP In (x4)**
- **1.2 in (x4)**
- **DP In Phy**
- **PCIe x4 Gen 3**

**Technology:**
- Thunderbolt™ Technology
- DisplayPort™ (DP)
Thunderbolt™ 3 – USB 3.1 Host Mode

- PCIe x4 Gen 3
- 2x DP 1.2 in (x4)
- PCI Express® (PCIe) Switch
- xHCI Controller
- Thunderbolt Phy
- USB 3.1

Active Block
Inactive Block
Active Path
Inactive Path
Thunderbolt™ 3 – Thunderbolt/USB 3.1 Host Mode

Each Thunderbolt port is configured independently.
Thunderbolt™ 3 DisplayPort* Host Mode

- **PCI Express® (PCIe) Switch**
- **xHCI Controller**
- **Host DMA**
- **Thunderbolt Switch**
- **Link Controller**
- **Thunderbolt Phy**
- **DP Phy**

**Connections:**
- PCIe x4 Gen 3
- 2x DP 1.2 in (x4)
- DP Phy

**Active and Inactive Blocks:**
- Active Block
- Inactive Block
- Active Path
- Inactive Path

**DisplayPort**
- *1.2

**Technologies:**
- Thunderbolt™ Technology
- DisplayPort™ (DP)
Large displays with amazing detail

- Twice the video bandwidth of any other cable
- Single-cable connection for two 4K 60Hz or a 5K 60Hz display
- 2 streams (eight lanes) of DisplayPort* 1.2
More Power

100W System Charging
For single-cable docking

15W to bus-powered devices
• Higher speed and capacity storage
• Portable displays
• High-performance adapters
Daisy-chain up to six Thunderbolt devices

Open Thunderbolt port operates the same as computer port and supports Thunderbolt, USB, or DisplayPort* devices
Agenda

• USB-C Introduction
• Thunderbolt™ 3 Technology Overview
• Key User Experiences
• Thunderbolt Device Development
• USB-C Alternate Mode and Power Delivery
• Summary
Key User Experiences

4K Video

Single-cable Docking

External Graphics

Thunderbolt™ Networking
Thunderbolt™ 3 Delivers Best Docking over USB-C

Bandwidth for more and faster IO

100W PC Charging

Single-Cable Docking
• 40Gbps Data + 4K Video + 100W PC Charging
• Only way to get 4K + data from one USB-C connection
• Two uncompressed 4K displays
Thunderbolt™ 3 External Graphics

External graphics solution that supports hot plug & surprise removal of cable on dedicated PC-device

• External graphics can connect to external monitor, or be routed back to notebook screen

Graphics Dock

- USB 3.0, GbE, Discrete Graphics with HDMI®, VGA

Standalone Graphics

- 150-200W discrete graphics card for premium gaming

All information related to future Intel products and plans is preliminary and subject to change at any time, without notice.
Thunderbolt™ Networking with Thunderbolt 3

- Peer-to-Peer communication between computers
- Bridging or routing between multiple computers
- Behaves as if systems were connected with Ethernet
  - Uses existing OS network and sharing infrastructure
    - File, print, share internet connection, etc…
- Connect Mac*/PC/Linux* to Mac/PC/Linux

Only PC I/O to offer 20Gbps network data transfer speed
Agenda

• USB-C Introduction
• Thunderbolt™ 3 Technology Overview
• Key User Experiences
• Thunderbolt Device Development
• USB-C Alternate Mode and Power Delivery
• Summary
Thunderbolt™ 3 Peripheral Device Targets

Device Categories

- Docks
- Displays
- Storage
- Cables
  - Thunderbolt™ 20Gbps and 40Gbps
  - USB-C to USB Type-B, Type-A and Micro-B, DisplayPort®, mDP, HDMI®
- Adapters
  - Thunderbolt 3 to legacy Thunderbolt (based on mDP)
  - Dual video and more
- Audio/Video
- NAS
Thunderbolt™ 3 Dock – Connect to PC with One Cable

- Connect to PC with One Cable
- Showing max bandwidth for each protocol listed - many other protocols are possible depending on dock configuration (eSATA*, card slots, Firewire*, HDMI*, WiGig*)

Source of performance measurement: Intel testing in Intel lab. Other developers may receive different results. Diagrams for marketing purposes only, see IBL for specific details. All products, designs, computer systems, dates and figures specified are preliminary based on current expectations, and are subject to change without notice.
**Full x4 PCI Express® Gen 3 Bandwidth to Device**

- **Intel SSD 730 Series SATA**
- **Intel SSD 750 Series (PCI Express®)**

<table>
<thead>
<tr>
<th>MB/s</th>
<th>Intel SSD 730 Series SATA*</th>
<th>Intel SSD 750 Series (PCI Express®)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td>~450MB/s</td>
<td>~700MB/s</td>
</tr>
<tr>
<td>1000</td>
<td>~1200MB/s</td>
<td>~2400MB/s</td>
</tr>
<tr>
<td>2000</td>
<td>~2400MB/s</td>
<td>~700MB/s</td>
</tr>
<tr>
<td>2500</td>
<td>~2400MB/s</td>
<td>~2400MB/s</td>
</tr>
</tbody>
</table>

Source of performance measurement: Intel testing in Intel lab. Other developers may receive different results. Diagrams for marketing purposes only, see IBL for specific details. All products, designs, computer systems, dates and figures specified are preliminary based on current expectations, and are subject to change without notice.

Thunderbolt™ Technology
Diagrams for marketing purposes only, see IBL for specific details. All products, designs, computer systems, dates and figures specified are preliminary based on current expectations, and are subject to change without notice.
Thunderbolt™ Cables

• Passive lower cost cables will support Thunderbolt™ at 20Gb/s
  - Low cost cables will be adequate for many Thunderbolt devices
  - Lengths up to 2.0m

• Thunderbolt active cables will support Thunderbolt at 40Gb/s
  - Needed for high-performance docking with 4K displays and storage, and enthusiast-level external graphics
  - Lengths up to 2.0m

• Optical Cables will support Thunderbolt at 40Gb/s
  - Targeted for 2016 with lengths up to 60m
How to Become a Thunderbolt™ Developer

• Visit
  thunderbolttechnology.net

• Submit Application Form
  thunderbolttechnology.net/developers
Agenda

• USB-C Introduction

• Thunderbolt™ 3 Technology Overview

• Key User Experiences

• Thunderbolt Device Development

• USB-C Alternate Mode and Power Delivery

• Summary
USB Power Delivery Contract Example

Scope Capture w/ TPS65982 Firmware
(One DFP as a Dock & One UFP as a Notebook)

- DFP & UFP establish a PD power contract
- DFP send source capabilities and UFP will send back sink capabilities
- PD contract established VBUS changes to 20V
- DFP enters Discovery Mode
TPS65982 Handles HV Charging

System Concerns – Charging from VBUS

- System power must meet the positive voltage transition spec
  - Dip is allow at the beginning of the transition
    - Must not drop vSrcValid (min) USB 2.0/3.1
    - Must be monotonic when transitioning

- System power must meet the negative voltage transition spec
  - Dip is allow at the end of the transition
    - Must not drop vSrcValid (min) USB 2.0/3.1
    - Must be monotonic when transitioning
  - Pull down circuit may be implemented for negative slew rate
TPS65982 | USB-C Port Power Switch with USB-PD Controller & HS Mux

Features

- Supports all USB-C High Current Modes
  - Integrated Port Power Switches up to 20V @ 3A
  - Supports bi-directional external power NMOS FETs
- Fully compliant USB PD Baseband modem per USB PD2.x
  - BMC encoder/decoder
  - Physical Layer with CRC
  - Policy and Policy Engine
- Performs all CC pin functions
  - Cable Detection and Cable Orientation
- Integrated HS Mux
  - CC/2, SBU1/2, USB TP/TN, USBBP/BN
    - DisplayPort, Thunderbolt™
- Flexible system interfaces
  - I2C Slave/Master, SPI, Simple connection to HD3SS460 SS Mux for Display Port/USB3.0
- Easy to use 6 x 6 mm uBGA ZQZ 96pin, 0.5mm pitch

Applications

- Notebook / Desktop Computers
- Dock / Camera / Storage / Tablet / TV/ Monitor
- Power Management System

Benefits

- Fully Integrated USB-C and PD Solution
  - No additional discrete components needed for full CC Function
  - No additional components needed for Power Paths up to 20V @ 3A
- Compliant to the USB-C 1.x and USB PD 2.x Specifications
- Configurable as either a Downward Facing Port, Upward Facing Port or Dual Role Port
- Integrated USB Endpoint
- Industry’s smallest solution size

Available Now
Agenda

• USB-C Introduction
• Thunderbolt™ 3 Technology Overview
• Key User Experiences
• Thunderbolt Device Development
• USB-C Alternate Mode and Power Delivery
• Summary
Summary

- Thunderbolt™ 3 is a premium I/O controller that supports 3rd Gen Thunderbolt, USB 3.1 and DisplayPort* 1.2

- Thunderbolt 3 will adopt the USB-C connector as the Thunderbolt connector for future generation designs
  - Small form factor, standard, and high volume
  - One connector for charging, power delivery, USB, video, and Thunderbolt

- Key user experiences are 4K video, single wire docking, Thunderbolt networking and external graphics

- Texas Instruments provides a complete power delivery solution
Additional Sources of Information

• A PDF of this presentation is available from our Technical Session Catalog: www.intel.com/idfsessionsSF. This URL is also printed on the top of Session Agenda Pages in the Pocket Guide.

• Come and see our demos in the Intel Computing Innovation Exhibit located on the 2nd floor concourse

• Additional info in the Thunderbolt™ Community – Booth #’s 931-942

• More web based info: www.thunderbolttechnology.net

• Learn More About Thunderbolt: http://learn.thunderbolttechnology.com/
Legal Notices and Disclaimers

Intel technologies' features and benefits depend on system configuration and may require enabled hardware, software or service activation. Learn more at intel.com, or from the OEM or retailer.

No computer system can be absolutely secure.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase. For more complete information about performance and benchmark results, visit http://www.intel.com/performance.

Cost reduction scenarios described are intended as examples of how a given Intel-based product, in the specified circumstances and configurations, may affect future costs and provide cost savings. Circumstances will vary. Intel does not guarantee any costs or cost reduction.

This document contains information on products, services and/or processes in development. All information provided here is subject to change without notice. Contact your Intel representative to obtain the latest forecast, schedule, specifications and roadmaps.

Statements in this document that refer to Intel's plans and expectations for the quarter, the year, and the future, are forward-looking statements that involve a number of risks and uncertainties. A detailed discussion of the factors that could affect Intel's results and plans is included in Intel's SEC filings, including the annual report on Form 10-K.

The products described may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request.

No license (express or implied, by estoppel or otherwise) to any intellectual property rights is granted by this document.

Intel does not control or audit third-party benchmark data or the web sites referenced in this document. You should visit the referenced web site and confirm whether referenced data are accurate.

Intel, Thunderbolt, and the Intel logo are trademarks of Intel Corporation in the United States and other countries.

*Other names and brands may be claimed as the property of others.

© 2015 Intel Corporation.
Risk Factors

The above statements and any others in this document that refer to plans and expectations for the second quarter, the year and the future are forward-looking statements that involve a number of risks and uncertainties. Words such as "anticipates," "expects," "intends," "plans," "believes," "seeks," "estimates," "may," "will," "should" and their variations identify forward-looking statements. Statements that refer to or are based on projections, uncertain events or assumptions also identify forward-looking statements. Many factors could affect Intel's actual results, and variances from Intel's current expectations regarding such factors could cause actual results to differ materially from those expressed in these forward-looking statements. Intel presently considers the following to be important factors that could cause actual results to differ materially from the company's expectations. Demand for Intel's products is highly variable and could differ from expectations due to factors including changes in business and economic conditions; consumer confidence or income levels; the introduction, availability and market acceptance of Intel's products, products used together with Intel products and competitors' products; competitive and pricing pressures, including actions taken by competitors; supply constraints and other disruptions affecting customers; changes in customer order patterns including order cancellations; and changes in the level of inventory at customers. Intel's gross margin percentage could vary significantly from expectations based on capacity utilization; variations in inventory valuation, including variations related to the timing of qualifying products for sale; changes in revenue levels; segment product mix; the timing and execution of the manufacturing ramp and associated costs; excess or obsolete inventory; changes in unit costs; defects or disruptions in the supply of materials or resources; and product manufacturing quality/yields. Variations in gross margin may also be caused by the timing of Intel product introductions and related expenses, including marketing expenses, and Intel's ability to respond quickly to technological developments and to introduce new products or incorporate new features into existing products, which may result in restructuring and asset impairment charges. Intel's results could be affected by adverse economic, social, political and physical/infrastructure conditions in countries where Intel, its customers or its suppliers operate, including military conflict and other security risks, natural disasters, infrastructure disruptions, health concerns and fluctuations in currency exchange rates. Results may also be affected by the formal or informal imposition by countries of new or revised export and/or import and doing-business regulations, which could be changed without prior notice. Intel operates in highly competitive industries and its operations have high costs that are either fixed or difficult to reduce in the short term. The amount, timing and execution of Intel's stock repurchase program could be affected by changes in Intel's priorities for the use of cash, such as operational spending, capital spending, acquisitions, and as a result of changes to Intel's cash flows or changes in tax laws. Product defects or errata (deviations from published specifications) may adversely impact our expenses, revenues and reputation. Intel's results could be affected by litigation or regulatory matters involving intellectual property, stockholder, consumer, antitrust, disclosure and other issues. An unfavorable ruling could include monetary damages or an injunction prohibiting Intel from manufacturing or selling one or more products, precluding particular business practices, impacting Intel's ability to design its products, or requiring other remedies such as compulsory licensing of intellectual property. Intel's results may be affected by the timing of closing of acquisitions, divestitures and other significant transactions. A detailed discussion of these and other factors that could affect Intel's results is included in Intel's SEC filings, including the company's most recent reports on Form 10-Q, Form 10-K and earnings release.
Backup
# New Thunderbolt™ 3 Branding

<table>
<thead>
<tr>
<th>Name</th>
<th>Logo</th>
<th>Icon</th>
<th>Port Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thunderbolt™ 3</td>
<td><img src="image" alt="Logo" /></td>
<td><img src="image" alt="Icon" /></td>
<td><img src="image" alt="Port Placement" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generation Rev</th>
<th>No change</th>
</tr>
</thead>
</table>
USB-C & Thunderbolt™ Lane Bonding

• USB-C connectors provide 4 high-speed differential signal paths clockable up to 20 Gbps each

• Thunderbolt™ 3 controllers bond two lanes in each direction at 10 Gbps or 20 Gbps to create either two 20 Gbps or 40 Gbps links, enabling high-speed data transfers in each direction simultaneously