Intel Thunderbolt 4.0

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Outline

Outline

Introduction

What is Thunderbolt ?

A high-speed protocol that delivers power, data, and a video signal at the same time, also can dynamically adjust data and video bandwidth depending on the device and/or application.

- It's now the basis of the USB4 protocol specification.
- Thunderbolt 4 and USB4 products will use the same underlying protocol specification to improve compatibility for USB-C based products

Introduction

- **History**

Version	Year Introduced	Peak Rated Throughput	Connector Type
Thunderbolt 1	2011	10Gbps	mini DisplayPort
Thunderbolt 2	2013	20Gbps	mini DisplayPort
Thunderbolt 3	2015	40Gbps	USB Type-C
Thunderbolt 4	2020	40Gbps	USB Type-C

Thunderbolt 1   Thunderbolt 2   Thunderbolt 3   Thunderbolt 4

Mini DisplayPort on a MacBook Pro

Introduction

- **A decade of Thunderbolt innovation**

2010
Combined high-speed **video and data** onto a single connector **(10Gb/s)**

2013
Speed increase **(20Gb/s)**

2015
Combined high-speed video and data with power onto a **USB-C** connector **(40Gb/s)**

2017
Native Windows support for Thunderbolt

2019
Thunderbolt protocol **specification contributed** by Intel to be used in USB4

Ice Lake with **integrated** Thunderbolt 3

2020
Tiger Lake with integrated Thunderbolt 4 NEW

Thunderbolt 4 offers the **most complete** version of USB-C NEW

Thunderbolt 4 **certification includes** USB4 testing NEW

Introduction

- **Key Features**
  - Thunderbolt™ ports provide high bandwidth for connecting high-speed devices.
  - Thunderbolt™ cables help to ensure a quality connection between the device and a PC.
  - Thunderbolt™ accessories make it easy to expand the capabilities of your PC with docking options and external devices.

Outline

- **Introduction**
- **Technology Analysis**
- **Comparison**
- **Industrial Analysis**
- **Conclusion**
- **References**

Technology Analysis

Thunderbolt Protocol Architecture

- **Connector and Cable**
  - A Thunderbolt connector is capable of providing two full duplex channels
  - Thunderbolt cables may be electrical or optical

- **Electrical/Optical Layer**
  - Responsible for link maintenance including hot-plug detection, and data encoding to provide highly efficient data transfer.
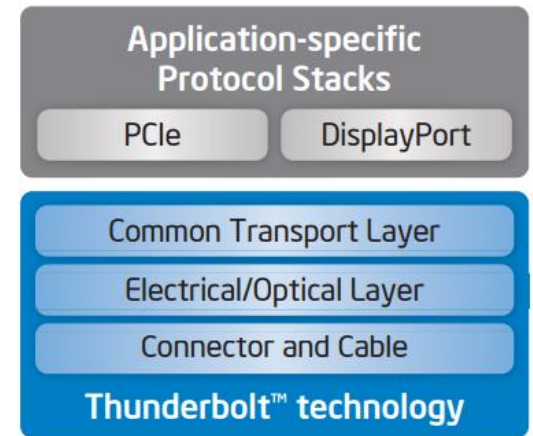

Figure 2. Thunderbolt™ Technology Architecture.

Technology Analysis

Thunderbolt Protocol Architecture

- **Common Transport Layer**
  - A high-performance, low-power, switching architecture
  - Allows PCI Express transactions with DisplayPort communication on the same link.
  - A time synchronization protocol
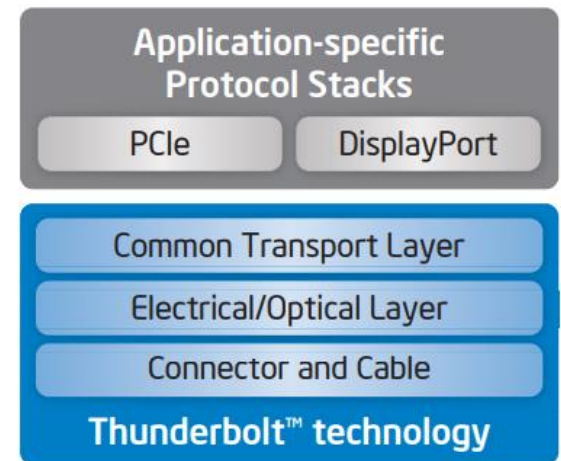- **DisplayPort and PCI Express protocols are mapped onto the transport layer.**

Figure 2. Thunderbolt™ Technology Architecture.

Technology Analysis

Thunderbolt Controller Block diagram

- **Intel's upcoming mobile PC processors, code-named "Tiger Lake," will be the first to integrate Thunderbolt 4.**

- **Intel® 8000 series Thunderbolt 4 controllers**
  - JHL8540 and JHL8340 host controllers for computer makers
  - JHL8440 device controller for accessory makers
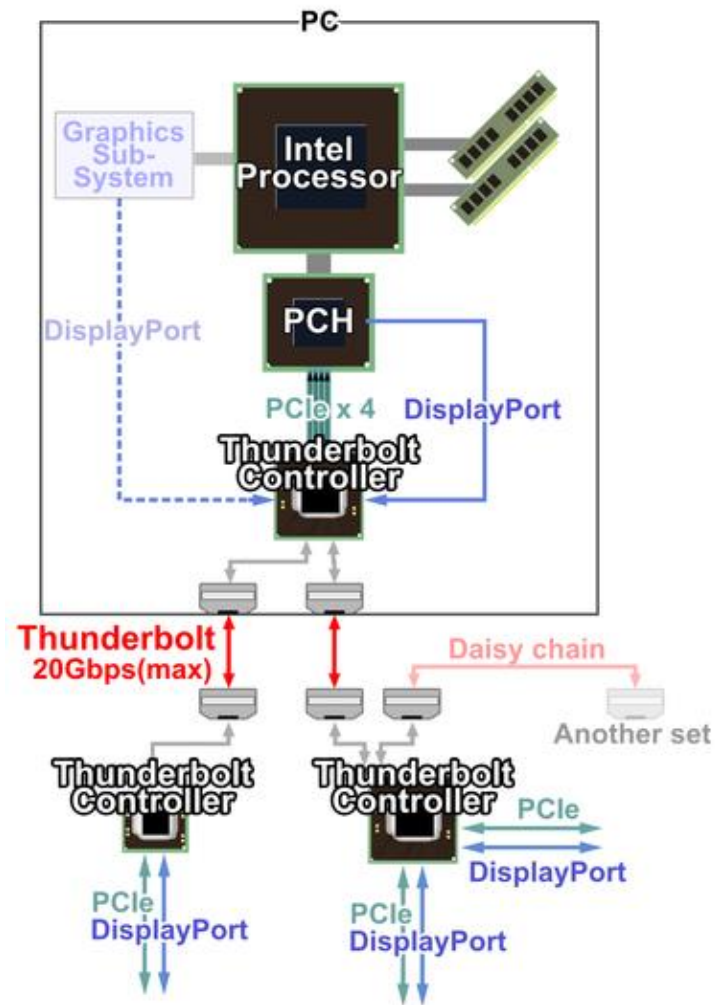
Technology Analysis

■ **Intel® 8000 Series Thunderbolt 4 Controller Technical Specifications**

Intel Thunderbolt controllers

Ver. ⬍	Model ⬍	Ch. ⬍	Size (mm) ⬍	Power (W) ⬍	Family ⬍	Release date ⬍	Features ⬍
4	JHL8340[176]†	1	?	?	Maple Ridge	2H 2020	40 Gbit/s speed, USB4 compliant
4	JHL8540[177]†	2	10.7 × 10.7	?	Maple Ridge	Q4 2020	40 Gbit/s speed, USB4 compliant
4	JHL8440[178]*	4	10.7 × 10.7	?	Goshen Ridge	Q3 2020	40 Gbit/s speed, USB4 compliant (peripheral only), with 4x Thunderbolt 4 ports for branching hub topology. Tunnelling of DP1.4, USB 3 (10G), PCIe (32G). Has PCIe 3.0 x1 and USB 3 (10G) native interfaces.

Technology Analysis

Features

- ### Data Transfer and Video Display

  - High bandwidth : Always 40Gbps
  - Video: Support for two 4K displays or one 8K display
  - Data: PCIe at 32 Gb/s

| | | | | | 40 Gb/s |
| USB 2.0 | USB 3.2 | USB 3.2 | USB 3.2 | USB4 40
USB4 20 | Thunderbolt™ 4
Thunderbolt™ 3 |
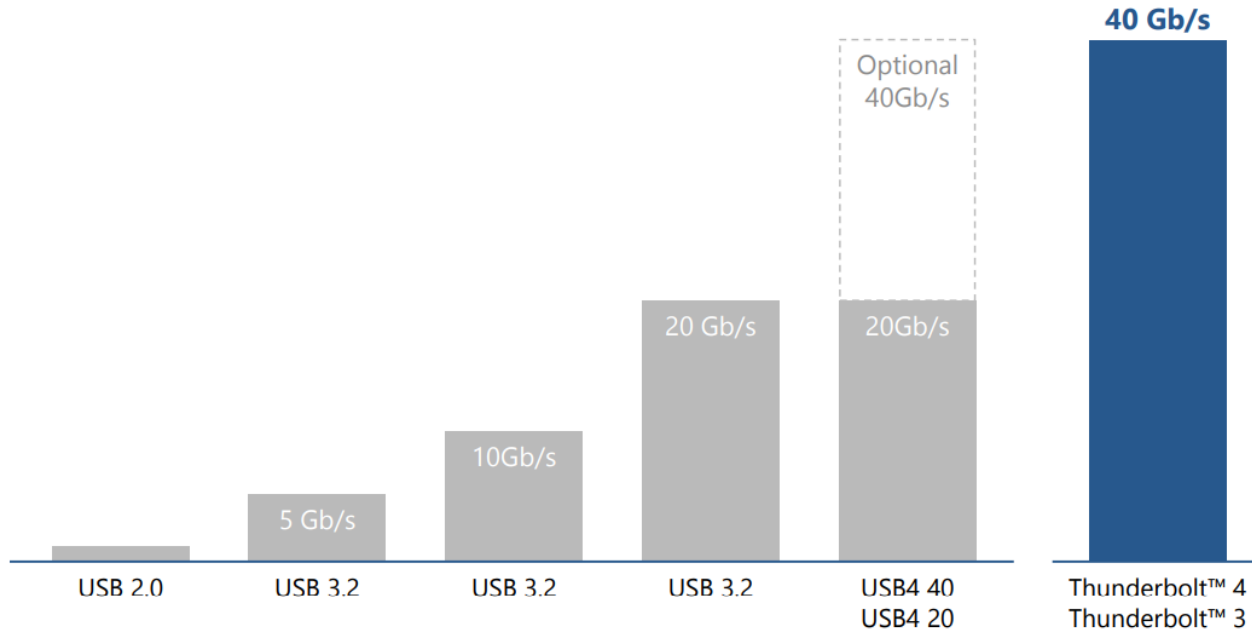
Technology Analysis

Features

- **Quick Charging**
  - Up to 100W of power for laptop charging (at least one computer port)
  - Up to 15W for computer-powered accessories charging
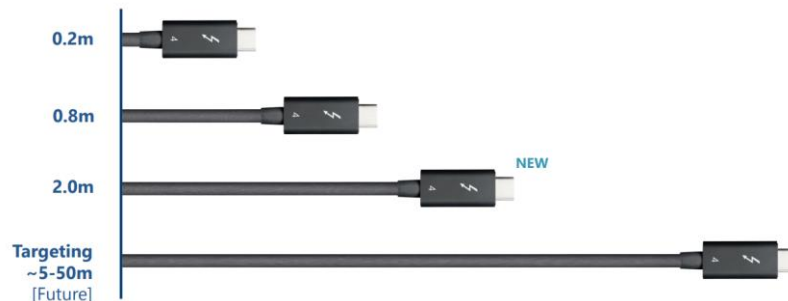
- **Enhanced Security**
  - Intel VT-d based direct memory access (DMA) protection

- **Supports up to four Thunderbolt ports per accessory**

- **Wake from Sleep Mode**
  - PC wake from sleep when computer is connected to a Thunderbolt dock

- **Universal 40Gb/s cables up to 2 meters in length**

Technology Analysis

Features

■ More protocols

- ■ USB4 Specification Compliant
- ■ 4 lanes of PCI Express Gen 3
- ■ DisplayPort 2.0

■ Backward Compatibility

Thunderbolt™ 4

INCREASES MINIMUM PERFORMANCE REQUIREMENTS

EXPANDS END-TO-END SOLUTION CAPABILITIES

USB4 SPECIFICATION COMPLIANT

Thunderbolt™ 3

| USB 2.0 | USB 3.2 | USB4 compatible | DisplayPort | PCIe |

Mandatory Certification for All Shipping Computers, Accessories and Cables to Offer a Consistent User Experience Across a Wide Range of Product Types and Manufacturers

Technology Analysis

Applications

■ Apple devices

- ■ MacBook Pro (14-inch, 2021)
- ■ MacBook Pro (16-inch, 2021)
- ■ Mac Studio (2022)

SDXC   Thunderbolt 4   HDMI

MagSafe 3   耳機插孔

Thunderbolt 4

■ Laptops

- ■ all Intel® Evo™ laptops

Technology Analysis

Applications

■ **Accessories**

THUNDERBOLT 4

Two Port Docks

Two Port Monitors

Portable Storage, Enclosures

Four Port Compact Docks NEW

Power Supply Docks

Adapters

Desktop Storage

Four Port Docks NEW

Audio Interfaces

Video Interfaces

External Graphics

Multi-Port Monitors NEW

Technology Analysis

Applications

- **Accessories**
  - Four ports dock

Thunderbolt™ 4 Dock

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Comparison

Thunderbolt 4 & Thunderbolt 3

	Thunderbolt™ 4 Technology	Thunderbolt™ 3 Technology
Connector type	USB-C	USB-C
Total bandwidth	40 Gbps	40 Gbps
Minimum bandwidth available for data transfer	32 Gbps	16 Gbps
Display	Up to two 4K monitors or one 8K monitor	One 4K monitor
Thunderbolt™ ports per accessory	Up to four ports	Up to two ports

Comparison

Thunderbolt 4 & Thunderbolt 3

	Thunderbolt™ 4 Technology	Thunderbolt™ 3 Technology
Laptop charging	Up to 100W on at least one computer port	Supported, but not required
System wake from sleep from connected accessory	Required	Supported, but not required
Intel® VT-d-based direct memory access (DMA) protection	Required	Supported, but not required
USB4 specification	Compliant	Compatible

Comparison

- **Thunderbolt 4 & USB 4**

	Thunderbolt™ 4	USB4
Interface	USB-C	USB-C
Minimum Supported Bandwidth	40Gbps	20Gbps
Maximum Supported Bandwidth	40Gbps	40Gbps
Minimum Display Output Requirements	Double 4K Display Output	Single Display Output
DisplayPort Tunneling	DisplayPort 1.4a	DisplayPort 1.4a
DisplayPort Alt Mode	DisplayPort 2.0	DisplayPort 2.0
Minimum Data Transfer Speed	PCIe – 32Gbps USB 3.2 – 10Gbps	USB 3.2 – 10Gbps
PCIe	PCIe Gen3x4	Optional
Wake Function Support	Yes	Optional
Minimum Power Supply	15W	7.5W
Maximum Power Supply	240W	240W
Intel VT-d DMA Protection	Yes	No
USB4 Specification	In Compliance	In Compliance

Comparison

■ Thunderbolt 4 & others

		Thunderbolt™ 4	Thunderbolt™ 3	USB4	USB3/DP
Unrivaled Simplicity	One universal computer port	●	●		
	Universal 40Gb/s cables up to 2 meters in length	●			
	Accessories with four Thunderbolt ports	●			
Maximum Performance	Minimum PC speed requirements	40Gb/s	40Gb/s	20Gb/s	10Gb/s
	Minimum PC video requirements	Two 4K displays	One 4K display	One display (No Minimum)	One display (No Minimum)
	Minimum PC data requirements	PCIe 32 Gb/s USB 3.2 - 10Gb/s	PCIe 16 Gb/s USB 3.2 - 10Gb/s	USB 3.2 - 10Gb/s	USB 3.2 - 5Gb/s
	Required PC charging on at least one computer port[1]	●			
	Required PC wake from sleep when computer is connected to a Thunderbolt dock	●			
	Minimum PC port power for accessories	15W	15W	7.5W	4.5W
	Thunderbolt Networking	●	●		
Reliable Connectivity	Mandatory certification for all shipping computers, accessories and cables	●	●		
	Cable testing and cable quality audits for Thunderbolt cable manufacturers	●	●		
	Required Intel VT-d based DMA protection	●			
	USB4 Specification	Compliant	Compatible	Compliant	Compatible

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Industrial Analysis

Market analysis

- **Based on Intel internal research and projections in March, 2020**
  - Thunderbolt dock expected to grow from ~25-40% over next few years

- **Thunderbolt Devices Manufacturer**
  - Apple
  - Belkin
  - Dell
  - HP
  - OWC
  - Anker
  - Plugable
  - And so on

Industrial Analysis

SWOT

- **Strengths**
  - High performance
  - Compatibility
  - Simplicity
- **Weaknesses**
  - Small product ecosystem
  - Expensive
- **Opportunities**
  - Develop the market of high performance devices
- **Threats**
  - USB products
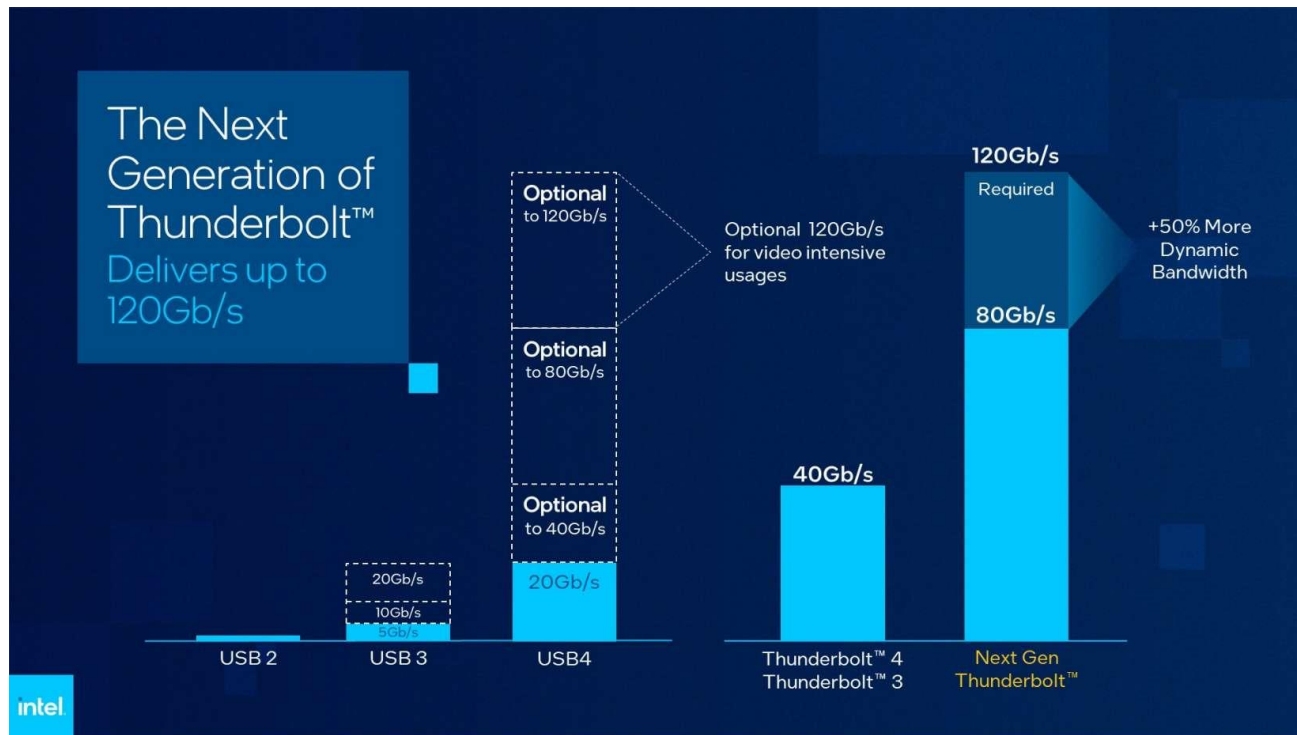
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Conclusion

Future

■ Thunderbolt 5

- ■ On October 19, 2022, Intel previewed Thunderbolt 5, aligned to the USB Implementers Forum's (USB-IF) release of the USB4 2.0 specification.

Conclusion

- **Thunderbolt 4 technology brings simplicity and flexibility to end users and product designers alike. Thunderbolt 4 ports are compatible with many connection standards. It delivers high-speed data transfer, outputs a video signal, and can deliver power. As the most complete and highest standard of USB-C connections available on the market, Thunderbolt 4 technology is backwards compatible with its prior generation as well as millions of USB 3 and USB4 products.**

Reference

- https://www.thunderbolttechnology.net/sites/default/files/intel-thunderbolt4-announcement-press-deck.pdf

- https://www.thunderbolttechnology.net/sites/default/files/18-241_Thunder7000Controller_Brief_FIN_HI.pdf

- https://www.intel.com/content/dam/doc/technology-brief/thunderbolt-technology-brief.pdf

- https://en.wikipedia.org/wiki/Thunderbolt_(interface)#Cables

- https://tripplite.eaton.com/products/thunderbolt-4

- https://www.intel.com/content/www/us/en/gaming/resources/upgrade-gaming-accessories-thunderbolt-4.html

- https://www.intel.com/content/www/us/en/architecture-and-technology/thunderbolt/thunderbolt-4-vs-usb-c.html

Reference

- https://www.intel.com/content/www/us/en/architecture-and-technology/thunderbolt/thunderbolt-3-vs-4.html

- https://www.intel.com/content/www/us/en/architecture-and-technology/thunderbolt/overview.html

- https://www.ithome.com.tw/news/153725