Thunderbolt™ 5
The Next Generation
The best solution for creators and gamers
A Timeline of Thunderbolt™ Innovation

Simplify the connectivity experience to one connector & cable that can do it all with Thunderbolt & USB-C

- **2011**: Combined high-speed video and data onto a single connector (10Gb/s)
- **2013**: Speed increase (20Gb/s)
- **2015**: Data, video, & power over USB-C connector. Doubling of speed (40Gb/s)
- **2019**: Thunderbolt protocol specification contributed for use in USB4
  - 10th Gen Intel® Core™ with integrated Thunderbolt 4
- **2020**: 11th Gen Intel® Core™ with integrated Thunderbolt 4
  - First Thunderbolt 4 Hubs and multi-port docks
- **2023**: Announcing Thunderbolt™ 5
  - Up to 3X more bandwidth (120Gb/s)
Thunderbolt™ Delivering on USB-C Vision

One connector that does it all

<table>
<thead>
<tr>
<th>UX: Evo™ &amp; vPro®</th>
<th>Thunderbolt™ 4</th>
<th>USB4*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thunderbolt™ Certification</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Intel Platform Validation</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>CPU &amp; OS integration</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Required Features</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Baseline USB-C/USB4 specifications</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

Thunderbolt™ is the best-in-class end-to-end solution

<table>
<thead>
<tr>
<th>Feature</th>
<th>Thunderbolt™ 4</th>
<th>USB4*</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB Type-C</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>40 Gbps bandwidth</td>
<td>✔️</td>
<td>Optional</td>
</tr>
<tr>
<td>15W power to run accessories</td>
<td>✔️</td>
<td>Optional</td>
</tr>
<tr>
<td>Mandatory testing and certification</td>
<td>✔️</td>
<td>Optional</td>
</tr>
<tr>
<td>2 x 4K/60Hz monitors</td>
<td>✔️</td>
<td>Optional</td>
</tr>
<tr>
<td>Required PC charging on at least one computer port</td>
<td>✔️</td>
<td>Optional</td>
</tr>
<tr>
<td>Universal 40 Gbps cables up to 2m</td>
<td>✔️</td>
<td>Optional</td>
</tr>
<tr>
<td>Up to 4 Thunderbolt™ ports on accessories</td>
<td>✔️</td>
<td>Optional</td>
</tr>
<tr>
<td>System wake from sleep</td>
<td>✔️</td>
<td>Optional</td>
</tr>
<tr>
<td>Intel® VT-d based DMA protection</td>
<td>✔️</td>
<td>Optional</td>
</tr>
</tbody>
</table>
Thunderbolt™ Momentum Continues

Broad adoption, support, and availability

**OS support**
- Broad OS support

**Platform alignment**
- Thunderbolt 4 is required in all Intel® Evo™ and Intel® vPro® Enterprise based laptops

**Rapid Growth**
- Thunderbolt designs on PCs and accessories are accelerating\(^1\),\(^2\)
  - Thunderbolt 3 & Thunderbolt 4
  - PCs: >1500
  - Accessories: >1000

**Broadly Available**
- Thunderbolt 4 based PCs & accessories are widely available
  - Attach rate to 13th Gen Intel® Core™ SKUs\(^3\)
  - PC price points <$399 with Thunderbolt 4\(^4\)
  - More docks, monitors, & storage than ever before

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\(^1\) Based on sales of Thunderbolt controllers to computer and accessory vendors.
\(^2\) Based on number of accessories to complete Thunderbolt certification.
\(^3\) Estimates and Projection based on Intel internal data.
\(^4\) Based on Asus TP470EA-AS34T listed at $379.99 on Amazon.com 8.29.23
Thunderbolt™ 5
Satisfies the increasing needs of creators and gamers

Less time waiting, more time creating
- 8K HDR monitors to see every detail
- Quickly backup and archive projects
- Accelerate workflows and collaboration

Connect with community without friction
- The fastest refresh rate monitors
- Next-level SSDs for portable gaming
- Studio quality capture & streaming

Up to 3x today’s best bandwidth to keep pace with the needs of creators and gamers
New Capabilities Powered by Thunderbolt™ 5

**Today**
- Two 4K monitors
- Resolution vs. refresh rate tradeoffs
- Two 4K limited to 60Hz
- 32Gb/s of data bandwidth
- Dual 4K video limits bandwidth for data
- Second cable for charging gamer, creator PCs and workstations

**Tomorrow**
- Multiple 8K for Creators
- Up to 540Hz for Gamers
- Three 4K @ 144Hz
- 2x more bandwidth for external SSDs, eGFX, Creator tools, and more
- Bandwidth flexibility for better use
- A single cable for more notebooks
Thunderbolt™ 5 Provides Industry Leading Experience

**More accessories**
- DisplayPort™ v2.1
- USB4* v2
- USB3 20G
- PCIe 4.0

**Standards Based, Royalty Free**

**More speed**
- 80G Bi-directional
- 120G Transmit

**Up to 3x faster connection**

**More video**
- 120G Transmit

**Bandwidth Boost: the best display experience**

**More power**
- 240W PC charging
- 15W device

**Up to 2x more PC charging**

Simplicity, reliability, and maximum performance

*Other names and brands may be claimed as the property of others*
Thunderbolt™ 5 Delivers Up to 120 Gbps

The performance creators and gamers need

Optional 120 Gbps for video intensive usages
Optional to 120 Gbps
Optional to 80 Gbps
Optional to 40 Gbps

Bandwidth Boost Provides +50% more dynamic bandwidth

USB 2
USB 3
USB4*

20 Gbps
10 Gbps
5 Gbps
20 Gbps

40 Gbps
Thunderbolt™ 4
Thunderbolt™ 3
Thunderbolt™ 5

80 Gbps
Required

120 Gbps

*Other names and brands may be claimed as the property of others
True-to-Life Creation, Ultra-Fast Gaming

- Ultimate display experience
- The fastest data connection
- Outstanding docking solutions

The most data bandwidth
- 2x more than today’s solutions

Thunderbolt™ Networking
2x the speed of Thunderbolt 4

More power
Up to 240W

Outstanding docking solutions

- 3x more bandwidth for video
- 6x more bandwidth for data
Thunderbolt™ 5 Delivers Up to 120 Gbps

Bandwidth Boost for the best display experience

Evenly distributed
80 Gbps of bandwidth in each direction

Connection provides:
- Transmit: Up to 80 Gbps
- Receive: Up to 80 Gbps

Bandwidth Boost
120 Gbps for higher display bandwidth needs

Connection provides:
- Transmit: Up to 120 Gbps
- Receive: Up to 40 Gbps
New Signaling Technology
Delivers more speed with today’s PCBs, connectors, & cables

Thunderbolt™ 5 & USB4* v2 incorporates advanced signaling technology: Pulse Amplitude Modulation with 3 Levels (PAM-3)

• Key Benefits:
  • Significant performance benefits through enabling more data per clock cycle
  • Utilize existing PCB technology, connectors, & passive cables up to 1m

*Other names and brands may be claimed as the property of others
Thunderbolt™ 5 Will Be Broadly Compatible

Compatibility

- ✔ Thunderbolt 4
- ✔ Thunderbolt 3
- ✔ USB4*
- ✔ USB 3
- ✔ DisplayPort* 2.1

*Other names and brands may be claimed as the property of others
Thunderbolt™ Family of Accessories
Thunderbolt™ accessories to meet your needs

- Consumer and Commercial Docks
- Portable Docks
- Hubs & Compact Docks
- External Graphics
- External AI Accelerator
- Video Interfaces
- Portable Storage, Enclosures
- Desktop Storage
- Audio Interfaces
- Adapters
- Docking Monitors
- Monitor Stand Docks

Thunderbolt enables powerful solutions for all your productivity, creation, and gaming needs
Extending System Architecture with Thunderbolt™
Plug and Play connection for performance boost

External Graphics
• Graphics performance boost
• Faster frame rates for Gamers
• Reduced encode, export time for Creators

External AI Accelerators
• Elevated video collaboration & audio effects
• Creator/Gaming effects
• Local AI Inferencing reduces need to reach into the cloud

More Creative, Superior Gaming, Higher Productivity, Personalized Experience
Thunderbolt™ 5 Will Be Easy To Find
Thunderbolt brand continues to be simple

<table>
<thead>
<tr>
<th>Name</th>
<th>Logo</th>
<th>Icon</th>
<th>Port</th>
<th>Cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thunderbolt™ 5</td>
<td>![Thunderbolt Logo]</td>
<td>![Lightning Bolt Icon]</td>
<td>![Thunderbolt Port Icon]</td>
<td>![Thunderbolt Cable]</td>
</tr>
</tbody>
</table>
Thunderbolt™ 5 Product Update

• Thunderbolt™ 5 will be brought to market through Intel’s upcoming discrete silicon
  • Code-named “Barlow Ridge”
  • Includes controllers for computers and accessories
• Thunderbolt 5 Computers and accessories are expected to launch starting in ’24
  • Prototype dock and laptop demonstrated today
• Technical collateral and development resources will be released to the Thunderbolt developers worldwide in Q4 ‘23
Thunderbolt™ 5 & Thunderbolt™ 4

Deliver a scalable roadmap for all users

- Thunderbolt™ 5 provides the industry’s highest performance wired connectivity solution
- Thunderbolt™ 4 delivers the simplicity, reliability, and performance that mainstream consumer & business users require
Thunderbolt™ 5 Leaps Ahead

<table>
<thead>
<tr>
<th>Unrivaled Simplicity</th>
<th>Thunderbolt™ 5</th>
<th>Thunderbolt™4</th>
<th>USB4*</th>
<th>USB 3/DP</th>
</tr>
</thead>
<tbody>
<tr>
<td>One universal computer port</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Required speed for Universal cables up to 2 meters in length</td>
<td>120 Gbps</td>
<td>40 Gbps</td>
<td>20 Gbps</td>
<td>-</td>
</tr>
<tr>
<td>Accessories with four Thunderbolt ports</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exceptional Performance</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PC speed requirements</td>
<td>80Gbps &amp; 120 Gbps</td>
<td>40 Gbps</td>
<td>20 Gbps</td>
<td>10 Gbps</td>
</tr>
<tr>
<td>PC video requirements</td>
<td>Dual 6K</td>
<td>Dual 4K</td>
<td>One monitor (No Minimum BW)</td>
<td>One monitor (No Minimum BW)</td>
</tr>
<tr>
<td>PC data requirements</td>
<td>PCIe 64 Gbps USB3 – 10 Gbps</td>
<td>PCIe 32 Gbps USB3 –10 Gbps</td>
<td>USB3 –10 Gbps</td>
<td>USB3 –5 Gbps</td>
</tr>
<tr>
<td>Required PC charging on at least one computer port</td>
<td>Required up to 140W available up to 240W</td>
<td>Required up to 100W available up to 140W</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Required PC wake from sleep when computer is connected to a Thunderbolt dock</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Minimum PC port power for accessories</td>
<td>15W</td>
<td>15W</td>
<td>7.5W</td>
<td>4.5W</td>
</tr>
<tr>
<td>Thunderbolt Networking</td>
<td>64 Gbps</td>
<td>32 Gbps</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reliable Connectivity</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Mandatory certification for all shipping computers, accessories and cables</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cable testing and cable quality audits for Thunderbolt cable manufacturers</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Required Intel® VT-d-based DMA protection</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>USB4 specification</td>
<td>Compliant</td>
<td>Compliant</td>
<td>Compliant</td>
<td>Compatible</td>
</tr>
</tbody>
</table>

1 Maximum theoretical bandwidth, realized performance dependent on specific HW and SW configuration
2 Available with support for up to 200Gbps
* Other names and brands may be claimed as the property of others
• Intel continues to lead the industry in wired connectivity with Thunderbolt™ 5 based solutions launching in ‘24

• Thunderbolt™ 5 delivers 80Gbps of bi-directional bandwidth, and with Bandwidth Boost provides up to 120Gbps, 3x the capability of today’s fastest solutions, for the best display and data experiences

• Built on the USB4 v2, DisplayPort 2.1, & PCI Express Gen 4 specifications, Thunderbolt™ 5 provides a standards-based solution compatible with previous versions

• Thunderbolt™ the best-in-class end-to-end solution, has achieved wide adoption in the industry
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