SuperSpeed USB and beyond

Introduction

Universal Serial Bus (USB) technology has been popular since its introduction in 1996, thanks largely to the low cost of the technology, its ease of adoption, and the convenience it offers to consumers for transferring data, connecting accessory devices to personal computing products and charging mobile devices. The USB Implementers Forum (USB-IF) and USB 3.0 Promoter Group continue to advance the technology to deliver more power, speed and convenience to users. The latest innovations include a new, higher-performance SuperSpeed USB, more user-friendly connector and cable designs, more flexible power and data delivery options, and greater energy efficiency. These innovations have enabled USB to realize its potential to enable single-connector platforms, which promise to deliver even more convenience and flexibility to consumers.

SuperSpeed USB (USB 3.x): More speed, greater efficiency

Boosting performance: From 480Mbps to 10 Gbps and beyond

In the decade after USB 2.0 was introduced in 2000, users required an increasing amount of storage and bandwidth to view, transfer and store high-definition images and video. Transferring large media files requires a storage medium that's capable of data transfer rates greater than 100MB/sec, but USB 2.0 topped out at roughly 32MB/sec.

"There was a push for a higher data rate, and at the same time vendors were saying 'gee, if we only had a little more power'," says Bob Dunstan, an Intel Architect. To address consumers' need for both higher performance and power, SuperSpeed USB (USB 3.0) was released in November 2008.[1] It delivered a data rate of 5 Gbps—ten times faster than USB 2.0 and 4.5W – nearly twice the power available from USB 2.0.

The next generation of the technology, USB 3.1 (SuperSpeed Gen 2), introduced in July 2013, doubled the speed again, from 5 to 10 Gbps—up to 20 times faster than USB 2.0. These dramatic performance improvements radically reduced the time it takes to complete common data transfer tasks, such as backups to external drives and downloading of songs, photos and videos. For instance, downloading a 25-gigabyte high-definition movie would take more than nine hours using USB 1.0 but only 25 seconds using USB 3.1.

Operating at 10Gbps, USB 3.1 enables users to attach much higher performance peripherals to their devices, including multiple displays and audio/video players that can drive Ultra-HD (4K) displays. The revised spec also offers high-speed data synchronization and enables multi-function, single-port connections.

> Downloading a 25-gigabyte high-definition movie would take more than nine hours using USB 1.0 but only 25 seconds using USB 3.1.

SuperSpeed USB 3.1 requires vendors to certify that their cables and connectors can operate at 10 Gbps. SuperSpeed USB 3.1

Ad touting SuperSpeed USB as "the most widely accepted, reliable form of connectivity out there."

[1] The spec was developed by the USB 3.0 Promoter Group, which consists of Hewlett-Packard Company, Intel Corporation, Microsoft, Renesas Electronics, STMicroelectronics and Texas Instruments.

requires vendors to certify that their cables and connectors can operate at 10 Gbps. The USB 3.1 connectors retain the same shape and pin count as earlier versions of the technology, some vendors have had to upgrade their cables to accommodate the higher speed. SuperSpeed USB 3.1 also requires changes to the silicon inside platforms, according to Brad Saunders, the Intel engineer who is Chairman of the Board of the USB-IF. "To run 10 gigabits per second requires changing the clock data rate, which existing platforms are not capable of doing. So there will be changes to silicon, both on the host side and the device side."

USB Versions – Performance		
USB version	**Date introduced**	**Data clock speed**
1.0	January 1996	• 1.5 Mbps (Low Speed) and 12 Mbps (Full Speed)
1.1	September 1998	• 1.5 Mbps (Low Speed) and 12 Mbps (Full Speed)
2.0	April 2000	• 1.5 Mbps (Low Speed), 12 Mbps (Full Speed) and 480 Mbps (Hi-Speed) • Hi-Speed is up to 40x faster than Full Speed
3.0	November 2008	• 5 Gbps (SuperSpeed Gen1) • Up to 10x faster than USB 2.0 Hi-Speed
3.1	July 2013	• 10 Gbps (SuperSpeed Gen2) • Up to 20x faster than USB 2.0 Hi-Speed

USB Comparative Performance for Common Data Transfer Tasks						
USB version	**Song / Picture** *(4MB)*	**256 Flash** *(256 MB)*	**USB Flash** *(1 GB)*	**SD-Movie** *(6 GB)*	**USB Flash** *(16 GB)*	**HD Movie** *(25 GB)*
1.1	5.3 sec	5.7 min	22 min	2.2 hr	5.9 hr	9.3 hr
2.0	0.1 sec	8.5 sec	33 sec	3.3 min	8.9 min	13.9 min
3.0	0.01 sec	0.6 sec	2.2 sec	13 sec	36 sec	56 sec
3.1	0.004 sec	0.26 sec	1 sec	6 sec	16 sec	25 sec

SuperSpeed USB delivers effortless audio/video streaming, music and photos to the home, office, and anywhere in between, across TVs, set-top boxes, PCs, smart phones and cars.

Increased power efficiency

To meet the need for higher data transfer rates to move data between PCs and storage devices, the team developing USB 2.0 took advantage of the "high power" defined in the USB 1.1 spec to power devices up to 2.5 watts of power. "They decided this was probably sufficient, as most storage devices would be powered from the wall," says Dunstan.

In an attempt to squeeze more power out of USB 2.0, some vendors had developed 'Y' connectors, with two plugs to insert into USB ports. But this approach was not endorsed by the USB-IF, as it is electrically unsound.

SuperSpeed USB 3.0 addressed the need for more power, by redefining the low and high power limits (defined by earlier USB versions as 0.5W and 2.5W, respectively) to 0.75W and 4.5W. The spec enables more devices (storage in particular) to operate without 'Y' cables or wall warts. And like all versions of the spec, SuperSpeed USB was designed to be backwards compatible, so it works with devices that support previous versions of the technology.

IEC collaborates with the USB-IF to support next-generation high-speed data delivery and device charging applications

In December 2014, the USB-IF and the IEC (International Electrotechnical Commission) announced they had expanded their cooperation on international standards to include the latest USB-IF specifications for high-speed data delivery and enhanced usages for device charging. These specs include USB Power Delivery (Rev. 2.0, v1.0), USB 3.1 (SuperSpeed USB 10 Gbps), and USB Type-C Cable and Connector specifications.*

The IEC's endorsement formally recognizes USB's widespread adoption throughout the world. The endorsement will drive further adoption of USB globally, as IEC's standards are recognized and accepted throughout the world.

* Source: USB-IF press release, December 8, 2014

Improved power management

To improve power management, SuperSpeed USB dropped device polling, a feature of USB 2.0 that used power unnecessarily by constantly checking the bus to see if devices were attached and in use. By contrast, SuperSpeed uses an interrupt-driven architecture that ignores connected devices until they actually do something. This significantly lowers power consumption by allowing attached devices to go into a virtual sleep mode. (This can be particularly useful, for instance, when using a laptop under battery power, as it helps to extend battery life when USB peripherals are attached.)

> *Thanks to improved power management, transferring data via 5 Gbps SuperSpeed USB requires only about a third of the power needed to complete the same task using USB 2.0.*

SuperSpeed USB on the road to ubiquity

4

SuperSpeed USB has been widely promoted at industry events.

The first SuperSpeed USB products reached the market in 2010, and Intel began supporting the spec natively in its products in 2012. A broad range of consumer devices take advantage of SuperSpeed USB, from digital cameras, thumb drives and E-readers to streaming media players, tablets and smart phones. In addition to consumer products, SuperSpeed USB enables many commercial applications that require moving large amounts of data, such as image acquisition, machine vision, medical and control applications.

By 2014, virtually every notebook shipped had USB 3.0 embedded, and Windows 8.1, the latest version of Microsoft's operating system, also supports the specification. The first SuperSpeed 3.1 products—both platforms and devices—were introduced to the market in 2015.

Power Delivery Specification: USB up to 100 watts

Offering more power delivery applications

At 4.5 watts, SuperSpeed USB supplies enough power to charge small, low-power devices such as cell phones and MP3 players. The addition of the USB Power Delivery specification radically increases the power that USB can deliver. It enables higher voltage and current in order to deliver power up to 100 watts over certified cables. Power management can be optimized across multiple peripherals such that each device uses only the power it requires. The power delivered is matched to cable capabilities, with the upper limited bounded by international safety requirements. The first version of the spec was announced in July 2012 and version 2.0 was released in September 2014.

The Power Delivery spec enables charging of higher-power devices that today are plugged into the wall, such as notebooks, PCs, monitors and printers. The spec enables voltage, current values and direction to be negotiated over the USB power pins. It optimizes power management, allowing power to be delivered only when and where it's needed. The spec is compatible with existing USB 2.0 and USB 3.1 cables and connectors, and it coexists with the USB Battery Charging 1.2 specification.

> **USB Power Delivery Spec, v1.0**
> *Key characteristics*
>
> - Tool to negotiate voltage, current and direction
>
> - Enables power delivery up to 100 watts

Enabling devices to supply power to connected hosts

One of the most powerful innovations of the Power Delivery spec is the ability to reverse the direction of current flow over USB cables, to negotiate power intelligently among devices. "Originally USB was developed with a very strong notion of upstream and downstream," says Dunstan. "You had an 'A' connector on the host and a 'B' connector on the device, and 'A' delivered power to 'B'. But if a monitor is plugged into the wall, why can't it power the notebook or PC? Why does power always have to go from the notebook or PC to the monitor instead of the other direction? We wanted to be able to reverse the power roles so that we could push power back into the A connector."

> *The ability to reverse the direction of current flow has transformed the traditional relationship between host and device. Leveraging USB Power Delivery, PCs and notebooks can receive power as well as deliver it.*

Beyond upstream vs. downstream

Being able to reverse the direction of current flow changes the traditional power relationship between host and device. Normally the PC or notebook serves as host, delivering power to peripherals, but under the Power Delivery spec, that role can be reversed. "A monitor that's plugged into the wall and with a built-in USB hub could deliver power across the USB cable in the direction that's opposite of the normal host-to-device flow," says Dunstan. "That

would allow a monitor to charge the notebook at the same time it is being used along with a keyboard, mouse, hard drive and whatever other peripherals I have on my desk.

Enabling interoperability of power supplies

The USB Power Delivery spec enables systems with a standard USB connector to source or sink power at a negotiated level. This eliminates the inconvenience of dealing with multiple types of connectors that are used to supply different voltages and current. "I foresee that in the future we'll have outlet strips with a series of USB connectors," says Dunstan. "You will plug in your device to the strip and your device will negotiate the appropriate voltage and current."

As USB enables more interoperability of external power supplies, consumers will need fewer chargers/cables to operate all of their computing and electronics devices. They will no longer require drawers full of disparate adapters lying around the house, and the days of packing a dozen chargers when traveling will end. "The eventual vision is that you won't have to carry any charger when you travel because devices and public facilities like airports will support the same USB technology," says Dunstan. "Your hotel room will have a USB-enabled power source and USB cables that will charge your phone and other devices you bring with you."

> *As USB enables more interoperability of external power supplies, consumers will need fewer chargers/cables to operate all of their computing and electronics devices.*

Extending USB to more applications

As USB has evolved, several specifications have been developed to improve the computing experience and expand the technology to new platforms. Five key specs are designed to improve the mobile experience, bring USB to new platforms, and eliminate the need for multiple audio and video cables.

Mobile Broadband Interface Model (MBIM) Specification

The Mobile Broadband Interface Model (MBIM) specification, announced in November 2011, defines a standard control/data plane for 3G and 4G wireless data modules and enables low-power, high-efficiency device implementations. The spec provides support for basic connectivity everywhere, and it enables simultaneous transfer of multiple IP streams via a single USB interface. The MBIM spec also reduces overhead and boosts performance when communicating over USB to GSM radios and GSMA radios inside mobile devices.

The USB Audio/Video Device Class Specification

The USB Audio/Video (A/V) Device Class Specification, announced in May 2012, supports the transfer of A/V data over USB for smart phones, cameras, webcams, large HD displays and TVs. It enables manufacturers to develop single-cable devices, providing A/V, data and power over a single USB cable. And it gives consumers a solution that supplies data transfer, A/V capabilities, power, mass storage and more through a single connection, eliminating the need for multiple audio and video connectors and cables.

SuperSpeed USB Inter-Chip (SSIC) Specification

The SuperSpeed USB Inter-Chip (SSIC) specification, announced in May 2012, enables chip-to-chip connections inside devices. "Because USB has been so highly successful as an external interface to connect devices to the PC, it has migrated to the inside of the box," says Saunders. "USB is used quite a bit inside platforms to connect devices such as modems and Bluetooth radios, which are now a chip on a motherboard connected directly to the host chipset."

The SSIC spec marries the SuperSpeed protocol with the MIPI M-PHY standard that mobile phone manufacturers already use. Combining the two creates a low-power, high-data-rate (5 Gbps) interconnect inside devices. Vendors are now developing products based on the spec.

Embedded USB 2.0 (eUSB2) Specification

The Embedded USB 2.0 (eUSB2) specification, announced in July 2014, is designed to enable communication and optimize power among inter-chip components. The eUSB2 spec also addresses the challenge of device reliability, as component sizes shrink and more of them can be packed onto a single chip. In addition, the spec provides for a low-voltage solution that supports process scalability.

Media-Agnostic USB Specification

The Media-Agnostic USB specification, announced in September 2013, is designed to allow wireless devices and docking stations to communicate over the USB protocol, without the need for a physical USB connection. The MA-USB spec enables the use of USB technology over a range of networking technologies, including Wi-Fi, WiGig, Ethernet, and even IP links. It also provides support for interoperability of devices from different vendors while leveraging existing USB infrastructure. The spec focuses on USB device management and transfers, and it targets wireless USB applications (docking, peripherals) and remote apps.

USB Type-C Cable and Connector Specification

USB has been evolving ever since its introduction, which helps to support its sustained success. In that spirit of evolution, in December 2013 the USB 3.0 Promoter Group announced the development of the USB Type-C^{TM} connector and cable specification, a component of USB 3.1. The spec defines a new USB plug, cables and receptacles as well as the requirements for detecting and managing USB connections in a wired architecture. It also provides support for Alternate Modes, such as using a USB Type-C connector in docking applications. The spec is robust enough to support a wide range of products, including tablets, notebooks and PCs.

The USB Type-C spec is designed to accommodate emerging devices and platforms, ever higher performance demands, and users' need for greater convenience. It is a key spec needed to enable the vision of the single connector platform. "We're looking well out into the future to envision a time when every device has a single connector, and it's USB," says Ravencraft. "And that device could be very large – it could be a workstation or an HDTV with a USB hub built into it. And the surrounding equipment plugs into the TV, which becomes the source of your power and charging, as well as the other functions you want it to perform." The spec was completed in August 2014, and products with the USB Type-C connector were introduced to the market in 2015.

Leveraging USB to Enable the Single Connector Platform

Typical Platform Connection Needs	Single Connector Platform Model
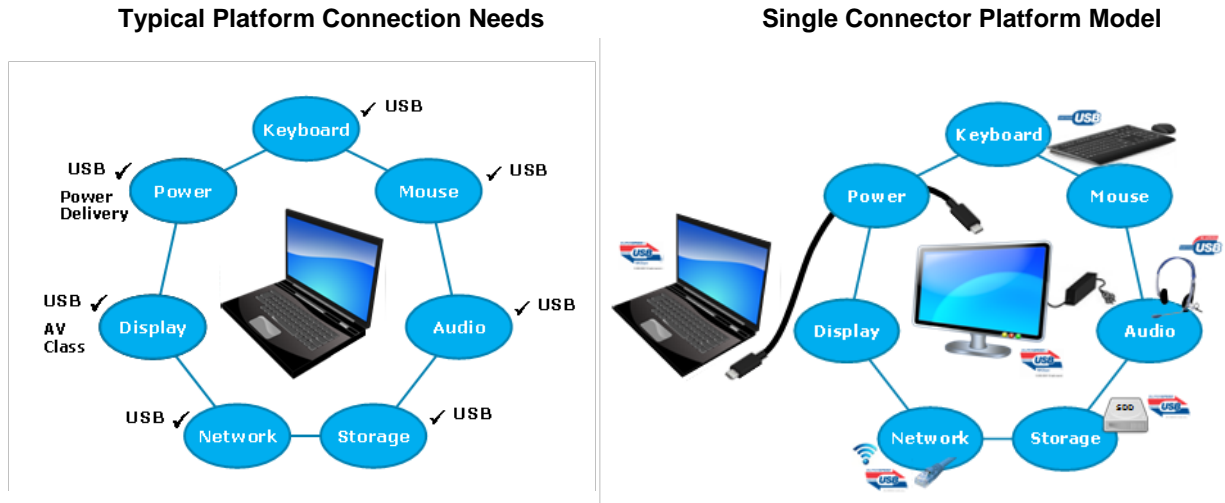
Along with the new USB Type-C cable and connector, USB 3.1 and USB Power Delivery 2.0 will bring enhanced applications, enabling a single-cable solution for data and power delivery.

Enabling new form factors

The USB Type-C spec is tailored for emerging thinner, sleeker product designs, such as ultra-thin notebooks and mobile phones. The USB Standard-A host connector is too large for mobile form factors, and USB 3.0 Micro-AB is too big to meet the design requirements of new mobile phone designs. The new USB Type-C plug is similar in size to the USB 2.0 Micro-B plug, and the USB Type-C receptacle is low profile and narrower.

Enhancing the user experience

Existing USB connector types are often inconvenient to use. There's confusion over the plug orientation and cable direction, and it's difficult to plug in a USB cable under "blind mating" or low-light conditions.

The USB Type-C plug was designed with ease of use in mind. The plug is reversible; it can be used upside down or upside up. It has rounded corners, a tactile feeling, and is more aesthetically pleasing than the current designs. The cable direction is reversible as well; users can plug either end of a USB Type-C cable into a supported host or device.

Designed for scalability and device compatibility

The USB Type-C spec is designed to accommodate performance enhancements in future versions of USB, and to support scalable power charging using USB Power Delivery. The plug, receptacle and cable designs were built to enable future USB functional extensions as well.

The spec also will enable consumers to continue using their existing USB devices and platforms. It defines USB Type-C legacy cable assemblies and allows two USB Type-C-to-legacy adapters—one for legacy "thumb drive" use with new host platforms and the other, for adapting existing Micro-B chargers to new devices. The spec also defines functional extensions, including an Audio Adapter Accessory Mode—an alternative to a standard 3.5 mm audio jack.

Leveraging USB Power Delivery

In conjunction with the development of the USB Type-C spec, the USB Power Delivery spec was updated. The new version (2.0) is designed to enable enhanced power delivery implementations with USB Type-C. The first products based on USB Power Delivery rev 2.0 started shipping early in 2015.
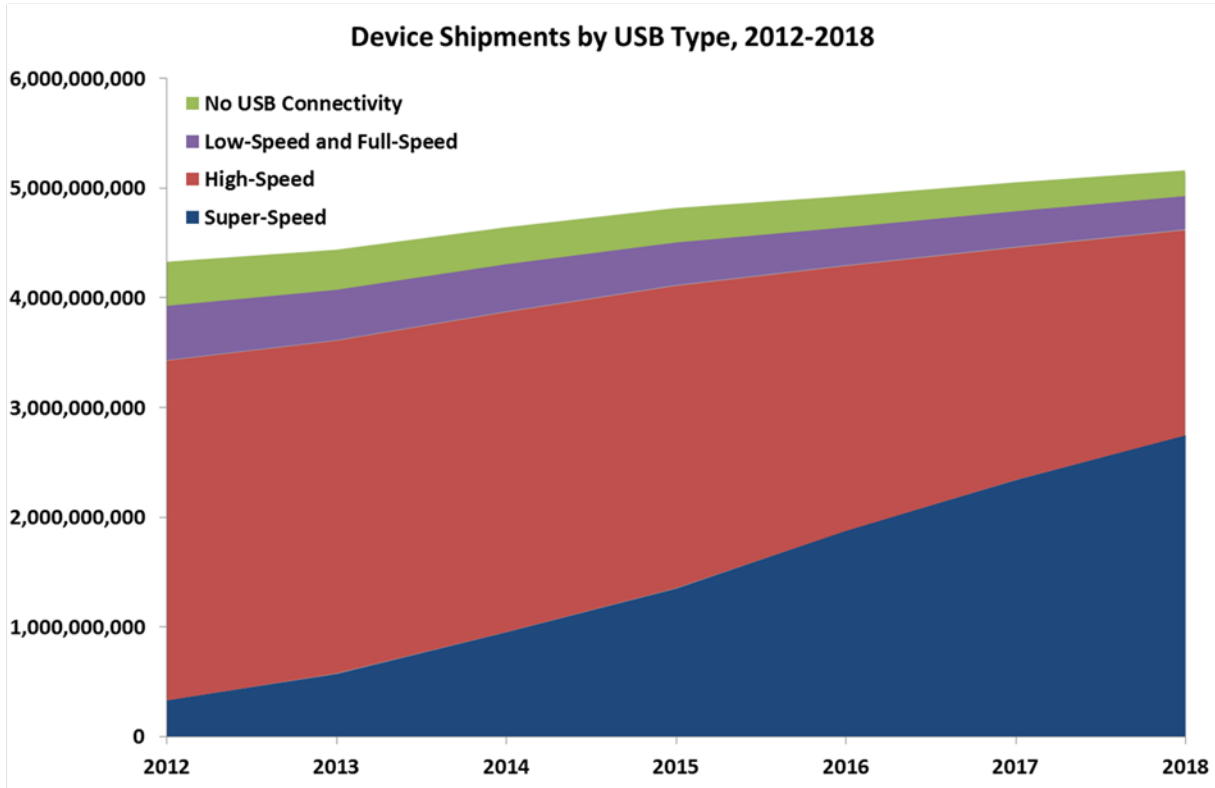
A bright future for USB

As of November 2014, there were more than 1,360 certified SuperSpeed USB product types on the market, providing consumers worldwide with end-to-end solutions. Each certified product type corresponds to thousands of units shipped. The industry estimates that 684 million SuperSpeed USB devices were shipped in 2014. That figure is expected to double in 2015, to 1.7 billion devices, and more than 2.1 billion SuperSpeed products are projected to be shipped in 2016, as the popularity of USB continues to grow.

In total, there were more than 20 billion USB devices on the market at the end of 2014, and the number continues to climb. By 2018, annual shipments of all USB devices are projected to reach roughly 5.1 billion, an increase of more than 19% over 2012.[2]

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[2] SNL Kagan Multimedia Research Group, February 2014.

Device Shipments by USB Type, 2012-2018

- No USB Connectivity
- Low-Speed and Full-Speed
- High-Speed
- Super-Speed

Source: SNL Kagan Multimedia Research Group, February 2014.

The ongoing commitment of the USB-IF and USB 3.0 Promoter Group will help to ensure the sustained success of the technology. "We are always looking to extend USB capabilities over time, trying to get ahead of the need," says Saunders. "When we built SuperSpeed USB, we architected it with future scalability in mind. We've already boosted speeds from 5 to 10 Gbps to set the roadmap and enable solutions into 2015 and beyond, to support high-performance, state-of-the-art storage and high-def video."

With the introduction of reversible cables and plugs; superior power delivery and performance; and the evolution toward the single connector platform, USB is poised to remain the leading choice for connecting peripheral devices and charging applications for years to come. The USB-IF and USB promoter groups will continue to expand the global, interoperable USB ecosystem to include a broader set of existing and emerging applications, helping to make use of the technology even more ubiquitous.

Learn more

Read about the history of USB's development, how the technology evolved to become widely adopted by consumers and businesses worldwide, and the collaborative efforts that led to USB's endorsement by international standards bodies:

www.intel.com/content/www/us/en/standards/usb-two-decades-of-plug-and-play-article.html

Explore more information about evolving USB standards: www.intel.com/standards

Learn more about USB on Intel's website: www.intel.com/technology/usb/index.htm

Visit the USB Implementers Forum: www.usb.org