SuperSpeed USB 3.0: Ubiquitous Interconnect for Next Generation Consumer Applications

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Arasan
The Bus Stops Here

Overview

The Universal Serial Bus (USB) continues to be the dominant interface in PC, mobile, consumer electronics and communication markets. In 2008, more than 2.7 billion USB-enabled devices were shipped. According to forecasts from market research companies, USB shipments are expected to grow to approximately 4 billion units in 2012, representing an annual shipment growth of 8.3% over the next few years.

Figure 1. Sample applications that use USB

USB 2.0 has been firmly entrenched as a de-facto standard in the PC world for many years. USB 2.0 provides sufficient bandwidth for a variety of application devices connected directly or by hubs to a host computer. However, with today's increasing demands for data transfers of high-definition video content, terra-byte storage devices, high resolution digital images, and multimedia rich mobile phones, the bandwidth provided by USB 2.0 (480Mbps peak) is insufficient.

To address the bandwidth limitations of the USB 2.0 interface, the USB Implementers Forum (USB-IF) released the SuperSpeed USB 3.0 specifications in November 2008. The USB 3.0 specification provides a maximum bandwidth of up to 5Gbps while limiting power consumption. The specification maintains backward compatibility with the USB 2.0 standard which is an important requirement in the consumer electronics world. USB 3.0 is architected to appear to an end-user the same as a USB 2.0 interface but with significantly higher bandwidth. USB 3.0 utilizes a dual bus architecture consisting of a USB 2.0 and a newly developed SuperSpeed component.

In this white paper we present the features of the USB 3.0 protocol, discuss the new usage models it enables and compare it with some of the existing interface standards popular in the market today.

USB 3.0 Protocol

USB 3.0 also referred to as SuperSpeed is a layered communication protocol that is compromised of a Host, Device and SuperSpeed interconnect. The figure below describes the system overview of the SuperSpeed USB.

The USB 3.0 permits devices from different vendors to interoperate, while maintaining backward compatibility and leveraging the existing USB infrastructure (device drivers, software interfaces, etc.). The specification is intended as an enhancement to the PC architecture, spanning portable computers, business desktop, home environment, as well as simple device to device communications.

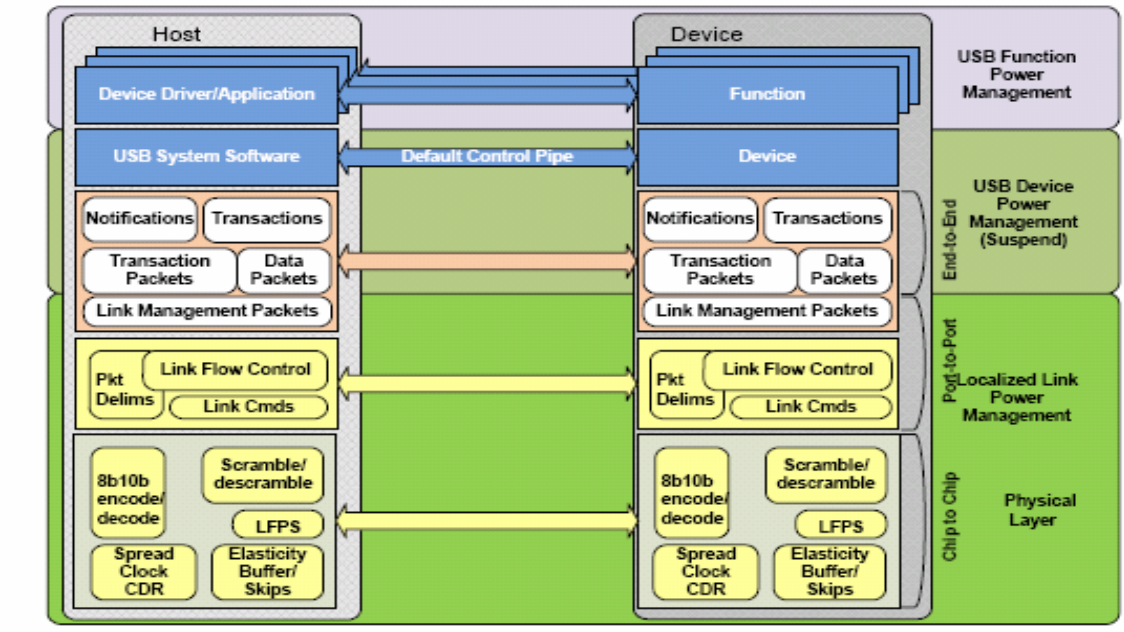

Figure 2. USB 3.0 protocol

Key aspects of SuperSpeed USB 3.0 protocol are:

- Increased bandwidth up to 5Gbps
- Dual-Simplex data transfers
- Backwards compatible
- Increased maximum bus current draw
- Enhanced Bus Power Management

- Improved Power Management

USB 3.0 achieves its higher performance due to a number of technical enhancements. Perhaps the most obvious enhancement is an additional differential pair that is added in parallel with the existing USB 2.0 data bus. This means that whereas USB 2.0 has 4 wires (power, ground, and a pair for differential data), USB 3.0 adds four more wires and a ground signal so as to have an additional two pairs of differential signals (receive and transmit) to form a total of nine wires in the cabling and connectors. These extra two pairs are necessary to support the SuperSpeed USB 3.0 bandwidth requirements. Furthermore, the signaling method, while still host-directed, is now asynchronous instead of continuous polling. USB 3.0 utilizes a bi-directional data interface rather than USB 2.0's half-duplex arrangement, where data can only flow in one direction at a time. The combination of these improvements results in a ten-fold increase in theoretical bandwidth enabling real-time transfer of bulk data.

USB 3.0 has a variety of new features that improve its power efficiency. This includes Link-level power management, which means either the host or the device can initiate a power saving state during idle, the ability for the link layer to enter progressively lower power management states when the link partners are idle, elimination of continuous device polling, elimination of broadcast packet transmission through hubs and device and individual function level suspend capabilities which allow devices to save power from those portions of their circuitry that is not in use.

Compared with USB 2.0, SuperSpeed USB provides 50% more power for devices that are not configured or in suspend mode (150 mA up from 100 mA), and 80% more power for configured devices (900 mA up from 500 mA). This means that newer power-hungry devices could be powered directly from the bus, and earlier generation of battery powered devices could potentially charge more quickly. Additionally, a new Powered-B receptable is defined with two extra contacts that enable a device to provide up to 1000 mA to another device, such as a Wireless USB adapter. This eliminates the need for a separate power supply for the wireless adapter.

Other performance enhancements include

- Streaming of bulk transfers for higher performance
- Isochronous transfers with the provision for devices to enter low power link states between service intervals
- Exchange information such as their latency tolerance with the host so as to optimize the USB interface

Enhanced Usage Enabled by USB 3.0

The ubiquity of USB is a result of the following three factors: ease of use by the end-user, proliferation of USB hardware amongst PCs and other consumer electronics and most

importantly the extensive software support due to the integration of USB drivers in all leading PC operating systems in the market today. USB 3.0 builds upon this base of USB 2.0 deployments and further improves the performance for a variety of high-bandwidth applications that were previously limited by USB 2.0.

In particular the dual-simplex transfer capability of USB 3.0 will vastly improve two way data transfers compared to using USB2.0 for applications such as sync operations in consumer electronics and data access to mass storage solid state devices whose capacity is continuously increasing. The increase in port output current to 900mA in USB 3.0 will be able to supply power to the growing array of USB-powered devices such as cell phones, media players, digital cameras and other personal electronics. The table below summarizes some of the key benefits of the new SuperSpeed USB 3.0 interface.

USB 3.0 Feature	Enables
5.0 Gbps peak bandwidth	Quickly transfer bulk files for e.g., 20GB HD movie can be transferred in less than a minute
Dual simplex connectivity	Faster sync and two-way communication
Current delivery increased to 900mA	Quickly charge larger variety of USB connected phones, personal electronic devices
Interrupt driven protocol	Reduce power consumption and increase battery life

Table 1. Overview of new features in USB 3.0 and their advantages

Another trend that will accelerate USB 3.0's adoption is the roll out of "always on", high bandwidth wireless connectivity offered by technologies such as WiMax and 3G cellular networks. Combined with the increasing resolution and storage capability of consumer electronics devices, users will want to capture, edit, download, store and share large amounts of multi-media content in a convenient and trouble free manner. USB 3.0 will play a key role in providing simple connectivity between such components.

Other examples of applications that USB 3.0 can target include the new class of solid state mass storage devices, video streaming and transfer, PC docking stations, multi-channel audio interfaces, high resolution webcams and surveillance cameras, video display solutions such as DisplayLink USB graphics technology, digital video cameras and digital still cameras with USB interface, external media such as Blu-Ray players and external hard drives and many more. With the rising popularity of home media PCs and high capacity external drivers, connecting the two with a USB 3.0 interface greatly simplifies the consumer experience of transferring large media files.

Additionally, USB 3.0's higher bandwidth provides more headroom for devices to deliver a better overall user experience. Video carried over USB 2.0 is barely tolerable (both from a maximum resolution, latency, and video compression perspective). It is now easy to imagine that with 5-10 times USB 2.0 bandwidth, SuperSpeed USB 3.0 based video solutions will offer a better end-user experience. Single-link DVI requires almost 2Gbps throughput and USB 2.0's 480Mbps was unable to keep up with it. Now, with 5Gbps of peak bandwidth, USB 3.0 can provide much better video quality.

It is expected that the higher speed and overall better performance of SuperSpeed USB 3.0 will help USB to find its way into many products and applications that previously could not be served by USB 2.0.

Competitive Landscape for USB 3.0

USB 3.0's high bandwidth, power efficient, lower noise envelope is making it attractive not only for PC applications but also to a variety of markets which had its own de-facto standard interface. The figure below shows some of the competing standards which will be discussed in this section.

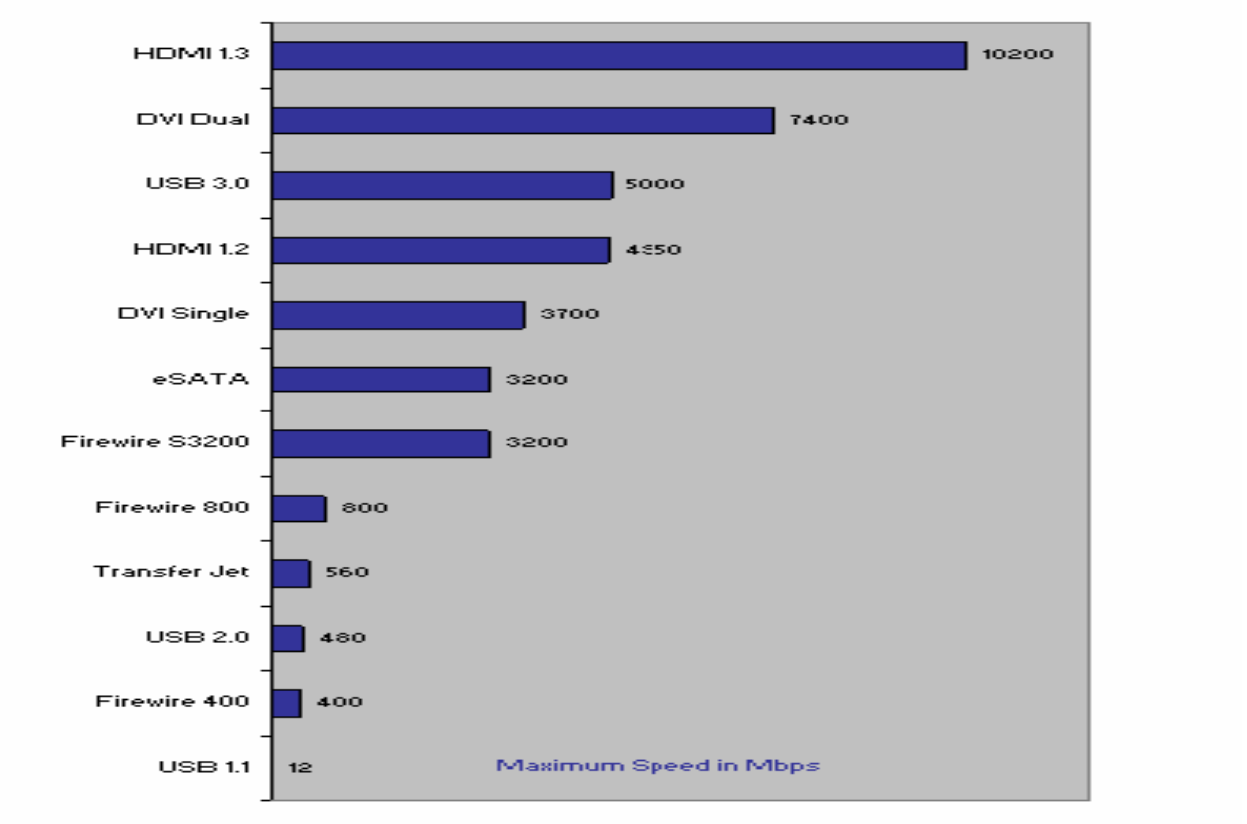

Figure 3. Peak bandwidth of popular consumer electronics interfaces

The IEEE 1394 interface also known as FireWire was invented by Apple and was positioned as the high-speed interface of choice for the mass market. The initial FireWire offerings namely 400 and 800 however, lost out due to the popularity to USB 2.0. In late 2007, the IEEE 1394 Trade Association announced FireWire 3200, called "S3200" which offered a speed of 3200 Mbps. To date, S3200 has still not gained much traction, even in traditional FireWire markets such as digital video.

Firewire's main claim was that it is highly efficient for peer-to-peer, full-duplex, non-polling data communications and has a very low overhead. Firewire delivers much higher actual throughput than USB 2.0, and can achieve close to its theoretical 800Mbps data rate. Where Firewire 800 can deliver sustained data transfers of around 90MB/s, USB 2.0 hovers more around 40MB/s.

The release of the USB 3.0 is likely to signal the death of Firewire as it offers much higher speed, dual-simplex data transfer and better power management.

External SATA or eSATA was introduced in the market in 2004 as a consumer interface targeted directly at the external storage market dominated by USB 2.0 and FireWire solutions. It successfully addresses the issue of the interface bottleneck, and allowed fast hard drives to fully realize their performance potential when located external to a server or PC. The eSATA interface supports a data rate up to 3.2Gbps, which is more than enough for the fastest hard drives, which can transfer data at about 120MB/s. However, cable length is limited to a mere 2 meters (200cm) and more over there is no provision to supply power to devices connected on the eSATA bus. Over the last several years, eSATA has steadily eroded the share of both USB 2.0 and FireWire in the data storage space. However, eSATA’s applications are limited to the storage market and it is not well-suited for the portable device market.

USB 3.0 is likely to regain USB 2.0’s lost market share in the data storage space as it offers transfer speeds up to 5Gbps, a longer cable length, and power for connected devices while maintaining a smaller connector footprint.

TransferJet is a new very short range (1-inch) interoperable UWB wireless transfer technology that enables rapid transfer of high resolution video, music and images with a target speed of 560Mbps. It is promoted by the TransferJet Consortium. The consortium promotes a wide range of products and services incorporating TransferJet technology with the aim of accelerating its adoption throughout the consumer electronics industry. The current generation of TransferJet supports a peak bandwidth of 560Mbps which is almost an order of magnitude less than USB 3.0.

HDMI (High-Definition Multimedia Interface) is an uncompressed, audio/video interface that is designed to deliver crystal-clear, all-digital audio and video via a single cable. HDMI provides an interface between any audio/video source, such as a set-top box, DVD player, or A/V receiver and an audio and/or video monitor, such as a digital television (DTV), over a single cable. HDMI standards group has continuously updated the standards and adjusted to the new

requirements of their respective target market. The latest version of HDMI (version 1.3) offers a maximum speed up to 10.2Gbps and is popular in the very high-end audio/video applications - particularly in applications where highest quality, ease of use and "HD Content-Ready" is a requirement.

The Digital Visual Interface (DVI) is a video interface standard designed to maximize the visual quality of digital display devices such as flat panel LCD computer displays and digital projectors. It was developed by an industry consortium, the Digital Display Working Group (DDWG). It is designed for carrying uncompressed digital video data to a display. It is partially compatible with the High-Definition Multimedia Interface (HDMI) standard in digital mode (DVI-D), and VGA in analog mode (DVI-A). DVI Single offers a speed up to 3700 Mbps and DVI Dual a speed up to 7400 Mbps.

It is unlikely that USB 3.0 will displace the HDMI and DVI connectors. However with the increasing share of media being accessed and downloaded from the internet, USB 3.0 interfaces are sure to exist alongside HDMI, DVI connectors to complement these higher performance interfaces.

Arasan's USB IP Portfolio

Arasan Chip Systems, Inc has been a leading developer of USB IP dating back to its first release of USB 1.0 in 1996. Arasan's USB cores have been used in diverse applications ranging from the World's first PDA to mission critical defense applications. Arasan has a complete portfolio if USB IP including host, device, hub and embedded controllers and supports the latest USB 3.0 standard. With a sizeable group of engineers dedicated to USB IP development, Arasan is committed to being the highest quality provider of USB IP in the market.

Summary

SuperSpeed USB 3.0 is the newest specification released by the USB-IF group and is over 10 times faster than USB 2.0. It enables many new bandwidth intensive applications which were not feasible with USB 2.0, yet maintains a similar footprint and backward compatibility with the familiar USB 2.0 protocol. The migration towards USB 3.0 is expected to be led by devices requiring high data transfer bandwidth such as solid state drives, HD video cameras, high resolution digital still cameras and other media players.

USB 3.0's interrupt driven protocol optimizes power management and offers greater power efficiency. It's higher power output permits devices to be charged faster and can handle newer power hungry consumer devices.

Mainstream adoption of SuperSpeed USB 3.0 is expected in mid to late 2010. With its enhanced performance, SuperSpeed USB is sure to bring a new level of performance to end-users already familiar with the existing USB interface.

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