A Technical Introduction to USB 2.0

This document introduces the features and benefits of USB 2.0 and describes its impact to users, PC manufacturers and PC peripheral manufacturers. Following a recap of USB 1.1, this paper overviews the technical aspects of USB 2.0 whose details are in the specification draft released in October.

USB 2.0 Executive Summary

A core team from Compaq, Hewlett Packard, Intel, Lucent, Microsoft, NEC and Philips is leading the development of the USB Specification, version 2.0, that will increase data throughput by a factor of 40. This backwards-compatible extension of the USB 1.1 specification uses the same cables, connectors and software interfaces so the user will see no change in the usage model. They will, however, benefit from an additional range of higher performance peripherals, such as video-conferencing cameras, next-generation scanners and printers, and fast storage devices, with the same ease-of-use features as today's USB peripherals.

Impact to User

From a user's perspective, USB 2.0 is just like USB, but with much higher bandwidth. It will look the same and behave the same, but with a larger choice of more interesting, higher performance devices available. Also, all of the USB peripherals the user has already purchased will work in a USB 2.0-capable system.

Impact to PC Manufacturer

USB 2.0 will provide system manufacturers the ability to connect to high performance peripherals in the least expensive way. The additional performance capabilities of USB 2.0 can be added with little impact to overall system cost. Indeed, high-bandwidth interfaces such as SCSI adapters may no longer be required in some systems, leading to a net saving of system cost. Simpler construction will result since only USB connectors will be needed on many future PCs. Today's ubiquitous USB connectors will become USB 2.0, superceding USB 1.1.

Impact to Peripheral Manufacturer

Today's USB devices will operate with full compatibility in a USB 2.0 system. The added capabilities of USB 2.0 will expand the market segment for USB peripherals, while enabling retail products to transition with the installed base. Support of USB 2.0 is recommended for hubs and higher bandwidth peripherals. Designing a USB 2.0 peripheral will be a similar engineering effort to that of designing a USB 1.1 peripheral. Some low-speed peripherals, such as HID

devices, may never be redesigned to support the USB 2.0 high-speed capability in order to maintain the absolute lowest cost.

Historical Perspective – Universal Serial Bus
The Universal Serial Bus was originally developed in 1995 by many of the same industry leading companies currently working on USB 2.0. The major goal of USB was to define an external expansion bus which makes adding peripherals to a PC as easy as hooking up a telephone to a wall-jack. The program's driving goals were ease-of-use and low cost.   These were enabled with an external expansion architecture, as shown in Figure 1, which highlights:

- PC host controller hardware and software,
- robust connectors and cable assemblies,
- peripheral friendly master-slave protocols,
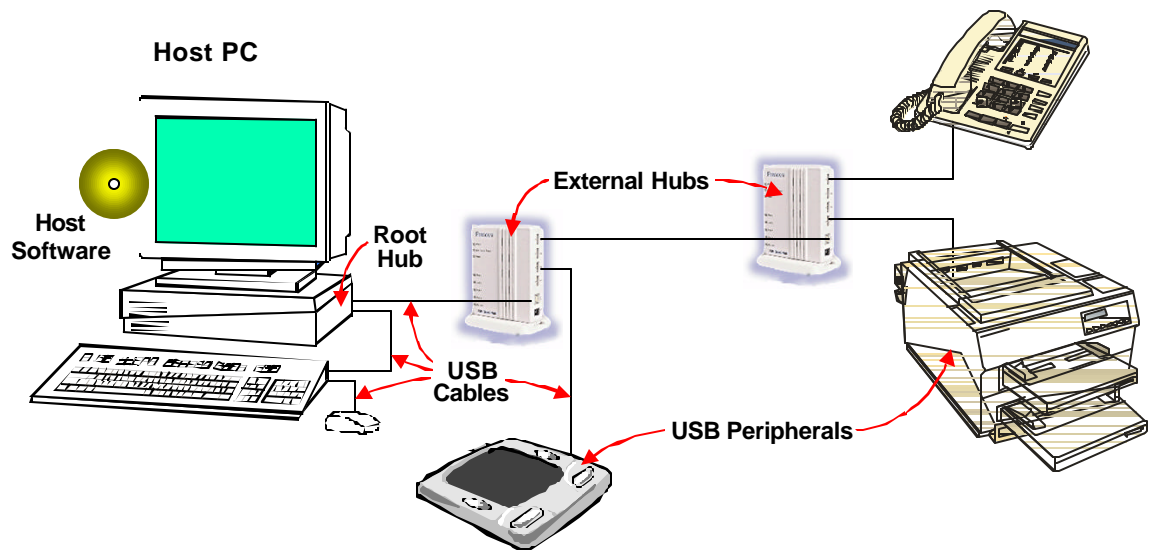- expandable through multi-port hubs.

Figure 1. Example USB 1.1 System Configuration

Today, USB is enjoying tremendous success in the marketplace, with most peripheral vendors around the globe developing products to this specification. Virtually all new PCs come with one or more USB ports on the box. In fact, USB has become a key enabler of the Easy PC Initiative, an industry initiative led by Intel and Microsoft to make PCs easier to use.   This effort sprung from the recognition that users need simpler, easier to use PCs that don't sacrifice connectivity or expandability. USB is one of the key technologies used to provide this.

Recap of USB 1.1 Operation

An understanding of the roles of each of the major elements within a USB 1.1 system will better show the evolutionary step that USB 2.0 provides.

Role of Host PC hardware and software.

The role of the system software is to provide a uniform view of IO system for all applications software. It hides hardware implementation details so that application software is more portable. For the USB IO subsystem in particular, it manages the dynamic attach and detach of peripherals. This phase, called enumeration, involves communicating with the peripheral to discover the identity of a device driver that it should load, if not already loaded. A unique address is assigned to each peripheral during enumeration to be used for run-time data transfers. During run-time the host PC initiates transactions to specific peripherals, and each peripheral accepts it's transactions and responds accordingly. Additionally the host PC software incorporates the peripheral into the system power management scheme and can manage overall system power without user interaction.

Role of the hub.

Besides the obvious role of providing additional connectivity for USB peripherals, a hub provides managed power to attached peripherals. It recognizes dynamic attachment of a peripheral and provides at least 0.5W of power per peripheral during initialization. Under control of the host PC software, the hub may provide more device power, up to a maximum of 2.5W, for peripheral operation. A newly attached hub will be assigned its unique address, and hubs may be cascaded up to five levels deep. During run-time a hub operates as a bi-directional repeater and will repeat USB signals as required on upstream (towards the host) and downstream (towards the device) cables. The hub also monitors these signals and handles transactions addressed to itself. All other transactions are repeated to attached devices. A hub supports both 12Mb/s (full-speed) and 1.5Mbs (low-speed) peripherals.

Role of the peripheral.

All USB peripherals are slaves that obey a defined protocol. They must react to request transactions sent from the host PC. The peripheral responds to control transactions that, for example, request detailed information about the device and it's configuration. The peripheral sends and receives data to/from the host using a standard USB data format. This standardized data movement to/from the PC host and interpretation by the peripheral gives USB it's enormous flexibility with little PC host software changes. USB 1.1 peripherals can operate at 12Mb/s or 1.5Mb/s.

What does USB 2.0 add?

USB 2.0 is an evolution of the USB 1.1 specification, providing a higher performance interface. Today's USB 1.1 connectors and full-speed cables will

support the higher speeds of USB 2.0 without any changes. Characterization that has already been done on these cables confirms this compatibility. Analysis that has been done by the electrical team suggests that a target of 480Mbs is achievable on USB 2.0. USB 2.0 will specify a microframe, which will be 1/8th of a 1msec frame. This will allow USB 2.0 devices to have small buffers even at high data rates.

Support of higher speed USB 2.0 peripherals connected to a hub assumes USB 2.0 hubs as shown in Figure 2. The higher transmission speed is negotiated on a device-by-device basis and if the higher speed is not supported by a peripheral, then the link operates at a lower speed of 12Mb/s or 1.5Mb/s as determined by the peripheral.
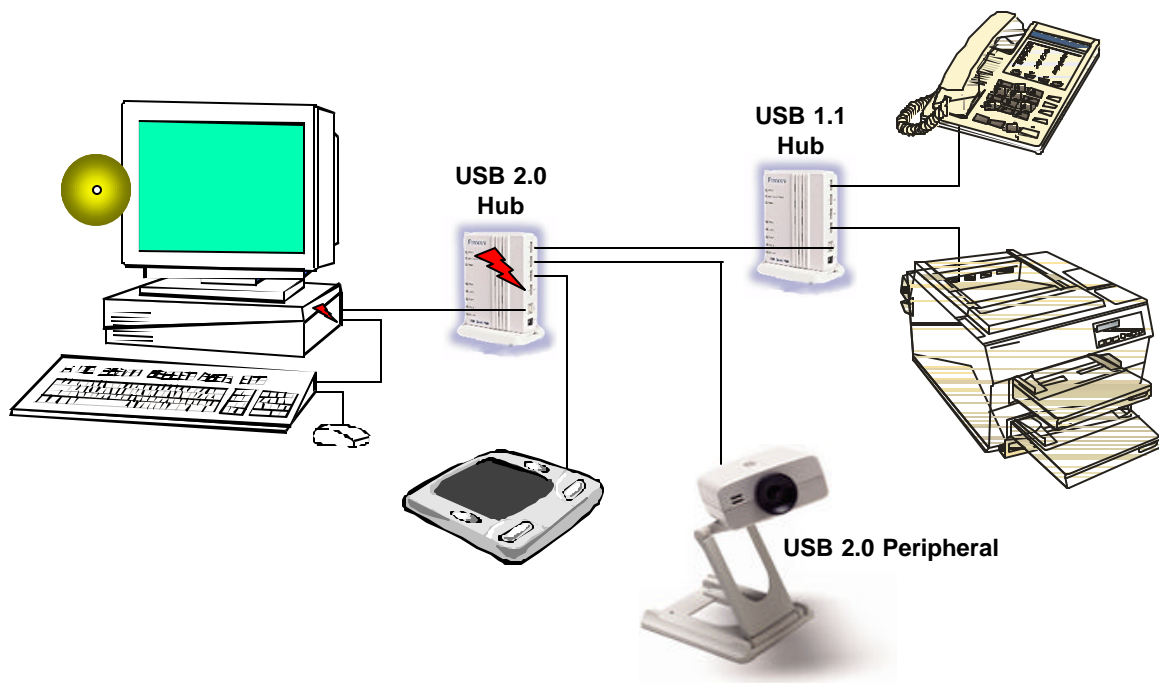
USB 1.1
Hub

USB 2.0
Hub

USB 2.0 Peripheral

Figure 2. Example Future USB 2.0 System Configuration

As shown in Figure 2, high-speed connections were negotiated between the root hub and the external USB 2.0 hub and between the external USB 2.0 hub and the video-conferencing camera (a USB 2.0 peripheral). All other connections are at USB 1.1 data rates, i.e. 12Mb/s automatically downshifting to 1.5Mb/s for low-speed peripherals. Note that the external USB 2.0 hub has different signaling rates on its ports. Using a 40x multiplier for USB 2.0, the USB 2.0 hub example in Figure 2 has an input rate of 480Mb/s and output rates of 480Mb/s for attached high speed USB 2.0 peripherals, and 12Mb/s or 1.5Mb/s for attached USB 1.1 peripherals. Any downstream port of a USB 2.0 hub can support attachment of any speed USB device. The USB 2.0 hub must match the data rates sent out of

its downstream ports to the data rate appropriate to the attached device. This increases the hub's role in a USB 2.0 system as outlined below.

Overview of USB 2.0 Operation
The external view of a USB 2.0 system looks no different from a USB 1.1 system as evidenced by comparing Figures 1 and 2. A casual observer will not be able to discriminate between the two system versions – which is exactly the view the user should have. However, the user will have to be able to distinguish between USB 2.0 hubs and USB 1.1 hubs in order to optimize the placement of USB 2.0 high-speed devices. The roles of the components of the 2.0 system have minor changes from the roles in a USB 1.1 system.

Role of Host PC software.
Current applications software on the PC continues to operate with USB 1.1 peripherals and is unchanged. The system software will comprehend the increased capabilities of USB 2.0 peripherals so that it can optimize performance. The system software will also detect sub-optimal configurations, i.e. a USB 2.0 peripheral attached to a USB 1.1 hub, and will alert the user and recommend a better configuration for attaching the peripherals. New applications will be written to take advantage of the higher speed capabilities and ease-of-use of USB 2.0 peripherals and drivers.

Role of the hub.
A USB 2.0 hub accepts high-speed transactions at the faster frame rate and must deliver them to high-speed USB 2.0 peripherals **and** USB 1.1 peripherals. This data rate matching responsibility will require some increased hub complexity and temporary buffering of the incoming high-speed data. In the simplest case of communicating with an attached USB 2.0 peripheral, the hub repeats the high-speed signals on appropriate USB 2.0 upstream and downstream cables just as a USB 1.1 hub repeats full and low-speed signals today on USB 1.1 devices. This allows USB 2.0 peripherals to utilize the majority of USB 2.0 bandwidth.
To communicate with USB 1.1 peripherals, a USB 2.0 hub contains a mechanism that supports the concept of matching the data rate with the capabilities of the downstream device. In other words, the hub manages the transition of the data rate from the high speed of the host controller to the lower speed of a USB 1.1 device. This feature of USB 2.0 hubs means that USB 1.1 devices can operate along with USB 2.0 devices and not consume disproportionate amounts of USB 2.0 bandwidth. This new hub architecture is intended to be as simple and cost effective as possible, and yet deliver the full capabilities of 1.1 connections.
The new USB 2.0 hub will be completely defined in the USB 2.0 specification providing clear implementation guidelines for hub vendors and allowing a single software driver to service USB 2.0 hub products from multiple vendors.

Role of the peripheral.

Current peripheral products do not require any changes to operate in a USB 2.0 system. Many Human Interface Devices, such as mice, keyboards and game pads will not require the additional performance that USB 2.0 offers and will remain as full or low speed peripherals as defined by USB 1.1.

The higher data rate of USB 2.0 will, however, open up the possibilities of exciting new peripherals. Video-conferencing cameras will perform better with access to higher bandwidth. Next-generation, higher-speed and higher resolution printer and scanner devices will be enabled at the high-end. High density storage devices such as R/W DVD, and high capacity CDROM jukeboxes will also be enabled by USB 2.0. These devices require minor changes to the peripheral interface, as defined in the USB 2.0 specification. Overall, the additional cost to support USB 2.0 is expected to be minimal to the peripheral.

Both USB1.1 and USB 2.0 devices will inter-operate in a USB 2.0 system.

Summary

The USB Specification is currently at Version 1.1 and supports a wide range of products. Many vendors are moving towards USB, drawn by its inclusion on virtually all PC platforms and its ease-of-use. More and more types of innovative new peripherals are taking advantage of USB, which further enhance the available USB product portfolio.

The version 2.0 specification that is under development is an evolutionary step that increases performance capabilities at low cost for USB peripherals in a backwards compatible fashion. It is expected to broaden the market for new and higher performance PC peripherals, and supercede USB 1.1 on future PCs.