An Introduction to USB 2.0 - Draft 0.8, 3/15/99

This white paper introduces the features of USB 2.0 and describes it's benefits for 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 being worked into a specification that is planned to be available in Q3'99.

A core team from Compaq, Hewlett Packard, Intel, Lucent, Microsoft, NEC and Philips is working on version 2.0 of the USB specification that will increase data throughput by at least a factor of ten. This backwards-compatible addition 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, available with the same ease-of-use features as today's USB peripherals.

Benefit to User
From a user's perspective, USB 2.0 is USB. Looks the same, operates the same, but with a larger choice of more interesting devices available. Sounds great. Is great. No confusion.

Benefit to PC Manufacturer
The additional performance capabilities of USB 2.0 can be added with almost no impact to system cost. Indeed, high-bandwidth interfaces such as SCSI adapters may be removed at a net saving of system cost. Simpler construction will result since only USB connectors will be needed on a PC 2000. The ubiquitous USB connectors will become USB 2.0, superceding USB 1.1.

Benefit to Peripheral Manufacturer
Today's USB devices will operate with full backward compatibility in a USB 2.0 system. The added capabilities of USB 2.0 expands the market segment for new types of USB peripherals, while enabling existing retail products to transition transparently. Support of USB 2.0 is recommended for hubs and offers a new horizon for higher bandwidth peripherals. Designing a USB 2.0 peripheral will be a similar engineering effort to that of designing a USB 1.1 peripheral.

Historical Perspective

Intel and other PC industry leaders developed the Universal Serial Bus. 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,
- transparent connectivity based on repeater hubs.

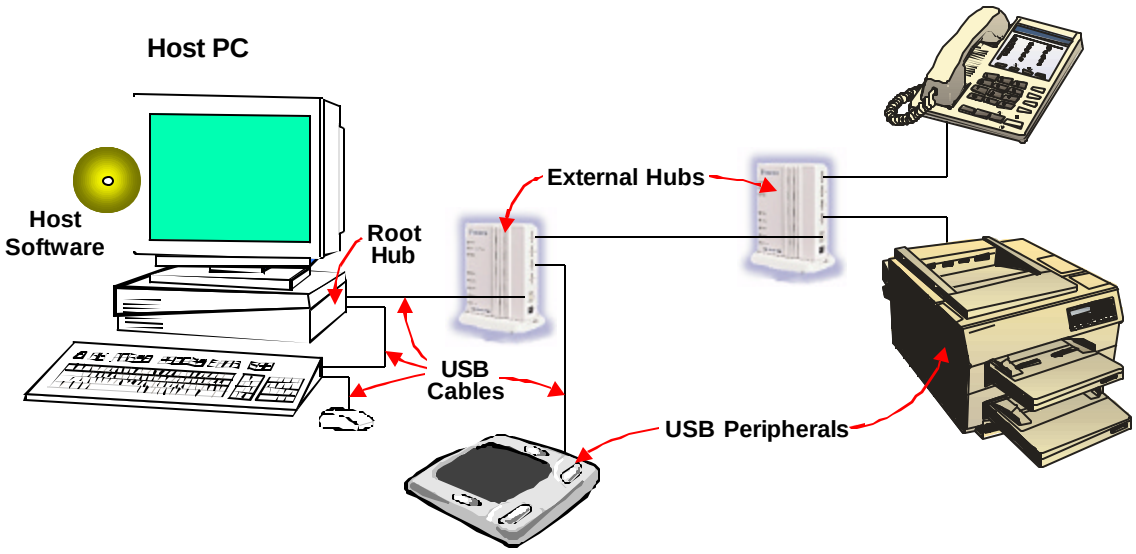

Figure 1. USB 1.1 System Configuration

To build on the successful enabling of PCI and USB as standard PC interfaces, Intel and Microsoft have defined an expanded PC Ease-Of-Use Initiative. Attracted by the versatility of the PC platform, many industries, both new and traditional, were adding technologies to the personal computer platform but none were being taken away. This unstructured technology infusion was actually making PC's more difficult to use and deploy as well as more costly to build. Consumer and business users alike mandated more reliable, easier to use PCs without having to sacrifice performance or expandability. With this in mind, the PC Ease of Use Initiative was introduced, with the goal of working with PC manufacturers and all industry suppliers to build better, simpler and more effective PC platforms. USB 2.0 is a good example of the output of this Initiative.

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 USB controller and 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 in a 1msec frames 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 connectivity for USB peripherals, a hub provides managed power to attached peripherals. It recognizes dynamic attachment of a peripheral and guarantees minimum power of 0.5W 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 and downstream cables. The hub also monitors these signals and reacts to transactions addressed to itself. All other transactions are simply repeated to attached devices. A hub supports 12Mb/s peripherals directly and automatically downshifts to support 1.5Mb/s peripherals.

Role of the peripheral.
All USB peripherals are intelligent 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 accepts standard formatted data from the PC host and disperses this data to its real world interfaces. Similarly the peripheral creates standard formatted data from its real world interfaces and provides it to the PC host on request. 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. Peripherals can operate at 12Mb/s or 1.5Mb/s.

What does USB 2.0 add?
USB 2.0 is an evolution to the USB 1.1 specification, providing a higher performance interface. The USB 2.0 host implementation will enumerate the bus using the USB 1.1 protocol. During enumeration a peripheral can identify itself as supporting the USB 2.0 capability. If the peripheral is attached to a USB 2.0 capable port, the port switches from classic USB 12Mb/s speed to high speed. Support of higher speed USB 2.0 peripherals 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 then the requesting peripheral operates at 12Mb/s. Today's USB 1.1 connectors and full-speed cables have been characterized from an EMI perspective and won't need to change for USB 2.0. Intel has prototyped USB 2.0 interface silicon with a parallel-terminated driver and receiver and initial tests show that 120Mb/s operation is easily achievable. Final speed selection for USB 2.0 is being determined. Working together with other silicon suppliers, interface components of higher frequencies are being planned. The USB 2.0 proposal includes a faster frame rate so that peripherals can have smaller buffers even for higher data throughput. The USB 1.1 1msec frame time would have required larger buffers for higher data throughput devices. A core working group is analyzing the engineering trade-offs of 8 or 10 micro-frames within the current 1msec frame.

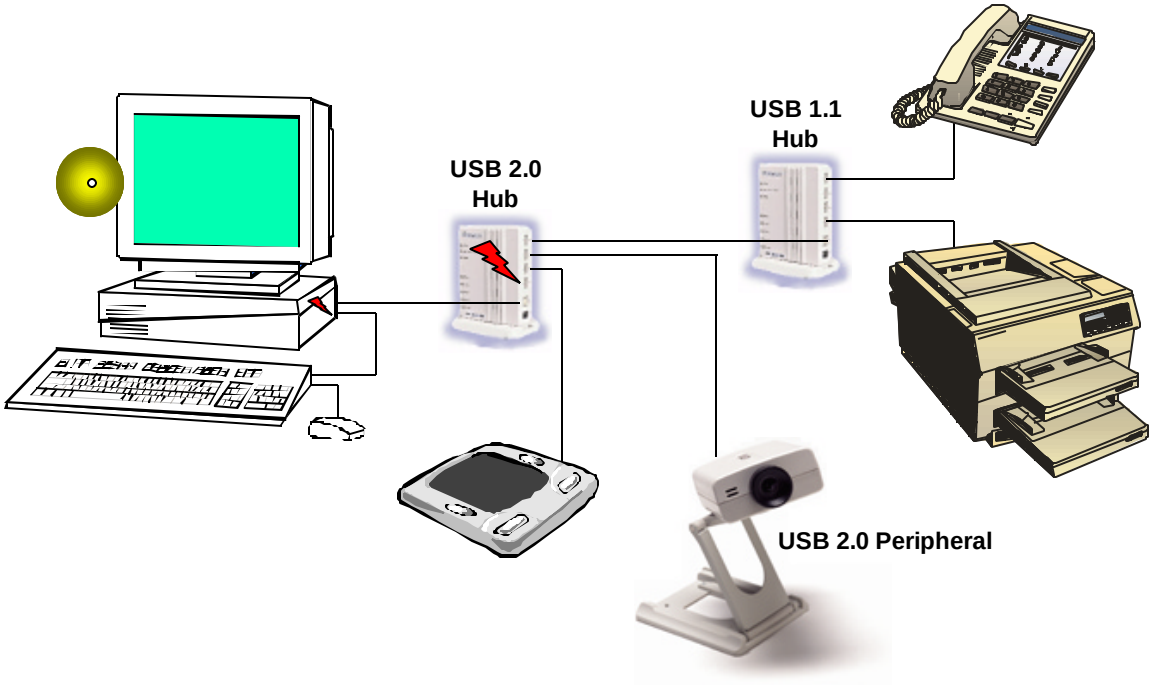

Figure 2. Future USB 2.0 System Configuration

As shown in Figure 2, during enumeration 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 USB 1.1, 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 it's ports. Using the 10x multiplier for USB 2.0, the USB 2.0 hub example in Figure 2 has an input rate of 120Mb/s and output rates of 120Mb/s (for attached high speed USB 2.0 peripherals), 12Mb/s and 1.5Mb/s (for attached classic USB 1.1 peripherals). Any downstream port of a USB 2.0 hub can support attachment of any speed USB device. Rate matching will be required and 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; there is no difference! 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 and device drivers 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 a faster frame rate and must deliver them to high-speed USB 2.0 peripherals **and** USB 1.1 peripherals. This rate matching responsibility will require some increased hub complexity and buffering of the incoming high-speed data. In the simplest case of communicating with a USB 2.0 peripheral, the hub simply repeats the signals on appropriate USB 2.0 upstream and downstream cables just as a USB 1.1 hub repeats signals. 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 'mini Host Controller' (miniHC) which provides 1.1 USB connections. Software on the host PC communicates directly with this miniHC, sending the miniHC data to be delivered to USB 1.1 devices, and receiving from the miniHC data that came from USB 1.1 devices. The architecture for the miniHC is defined to be as simple and cost effective as possible, and yet deliver the full capabilities of USB 1.1 connections. The interface to USB 2.0 hub miniHCs 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. This rate-matching 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.

Role of the peripheral.
Current peripheral products operate with no change 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 USB 1.1 peripherals.
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.
Both USB1.1 and USB 2.0 devices will inter-operate in a USB 2.0 system.

USB Specification Evolution
The USB Specification is currently at Version 1.1 and supports an excellent range of products. Many new vendors are moving towards USB, drawn by it's inclusion on all PC platforms and it's ease-of-use. Their fresh perspectives are adding capabilities which further enhance the available USB product portfolio.
Proven compliance with the USB Specification is a key element of USB's success and the industry's continued attention to these details will further broaden the acceptance of the Universal Serial Bus. . This version 2.0 proposal is an evolutionary step that increases performance capabilities at low cost for new USB peripherals in a backwards compatible fashion.