# TECHNOLOGY BRIEF

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Compaq Computer Corporation

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# USB and the Differences Between OHCI and UHCI

## EXECUTIVE SUMMARY

The personal computer (PC) market grew dramatically over the last few years. This surging growth results in part from advances in microprocessors, graphics subsystems, and new buses such as the Peripheral Component Interface (PCI). As PCs grow more pervasive throughout society, the ability for the computer and its peripherals to be configured easily and quickly proves increasingly important. Advances in bus architecture and plug-and-play operating systems already simplify the setup and use of the computer to some degree. However, previous advances deal only with internal Industry Standard Architecture and PCI add-in cards and fail to address setup challenges for external peripherals. The Universal Serial Bus (USB) dramatically eases the installation and use of external peripherals.

The USB specification, developed by leading computer industry companies including Compaq Computer Corp., Digital Equipment Corp. (DEC), International Business Machines (IBM) PC Co., Intel Corp., Microsoft Corp., NEC Corp., and Northern Telecom (Nortel), and supported by over 250 companies, now receives support from more than 250 companies. USB simplifies the installation of peripherals, and will open a market for a variety of new peripherals.

Please direct comments regarding this communication to the ECG Technology Communications Group at this Internet address: TechCom@compaq.com

## NOTICE



# USB and the Differences between OHCI and UHCI

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# USB DEFINITION

## Overview of USB

USB design offers a flexible, medium bandwidth connection for common peripherals (keyboards, mice, tablets, modems, telephones, CD-ROM drives, printers) and other low to moderate speed external peripherals in a tiered-star topology. In comparison to previous serial bus standards, USB offers unprecedented peripheral expandability and ease of use for computer users at minimal cost.

The USB specification offers several features and benefits:

- 12 Megabits-per-second (Mbps) data transfer rate is significantly higher than previous serial buses.
- Isochronous transfers allow audio, video, and telephony placement on the USB.
- Industry-wide plug-and-play specification simplifies installation of new peripherals.
- Multiple-tiered hubs allow virtually unlimited expansion outside the box.
- Hot-plug capabilities allow attach/detach on a powered computer.
- Power management functionality provided for system hibernation/sleep modes.
- Standard socket/connector prevents concerns with matching cables and expansion ports.

USB devices can take advantage of special bus features to deliver additional functionality. USB supports natural data type delivery for continuous data streams such as audio, video, and telephony. Using USB's support for isochronous data transfers, devices transmit and receive data in a guaranteed and predictable fashion. USB also allows non-isochronous devices to coexist in the isochronous environment. For example, USB easily supports simultaneous use of a pair of digital USB audio speakers and a USB joystick, while the USB printer prints in the background. The bus architecture allows the audio data stream to proceed at the highest priority (as an isochronous device) while still providing bus time for the joystick device. The printer consumes any time remaining on the bus. USB design provides balanced bus architecture while hiding the complexity of the operation from the devices connected to the bus. Devices focus on their specific functionality and the USB host controller, as well as the system software, handle bandwidth management and control.

USB technology redefines the manner in which computer users relate to peripheral products. Capabilities such as plug-and-play, hot-plug, and auto-configuration make attaching a new peripheral as easy as plugging in the device. In addition, USB's single connector and hub-based tiered-star topology make it easy for users to manage peripherals.

## Physical USB Connection

USB employs a four-wire cable for peripheral connectivity. Two wires (twisted pair) provide differential data (D+ and D-) signaling. One wire serves as a 5-volt power rail (Vbus) and the other wire serves as a ground conductor (GND) (see Figure 1). The 5-volt power rail powers connected peripherals.

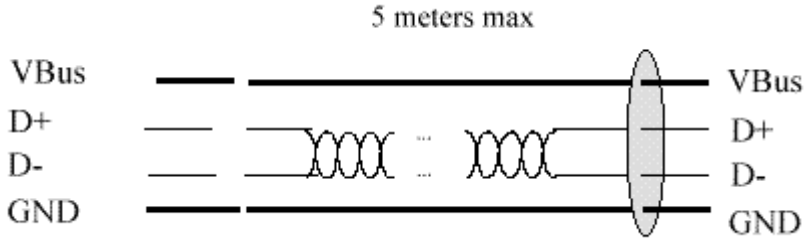


*Figure 1: USB Cable*

The four wires are bound together in a single cable. Each serial bus can be up to 5 meters (approximately 14 feet) in length.

The data transfer rate is limited to 12 Mbps, with a 1.5 Mbps subchannel available for low data-rate devices, such as mice. The data transfer rate of 12 Mbps supports a wide variety of desktop peripherals from modems, printers, microphones, and speakers to graphics tablets, game controls, joysticks, scanners, monitors, and digital cameras.

The purpose of the low-speed subchannel is to minimize chip costs and meet electromagnetic interference requirements.

## USB Hubs

The USB hub is central to the USB's architecture since it provides additional connection points to the bus. Figure 2 illustrates how a tiered-star topology hub works. The host, or root tier, is the computer from which the USB bus expands. Tier 1 shows a hub with two USB peripherals are connected. The tier 2 hub, in turn, has additional hubs and peripherals connected. By using hubs, expansion can take place outside of the computer's own USB ports.

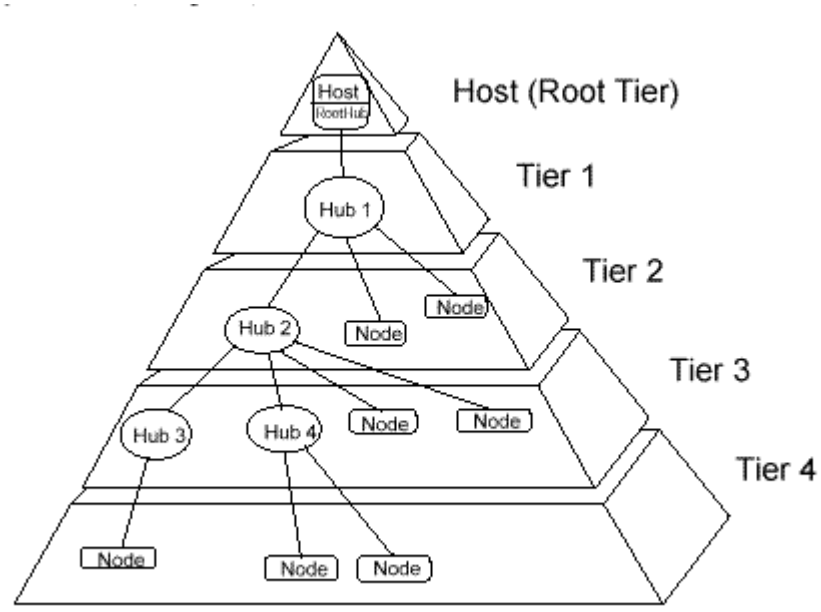


*Figure 2: USB Bus Topology*

With USB, one peripheral device, such as the keyboard or monitor, plugs directly into the PC. Other peripherals simply connect into either an expansion hub built into the keyboard, a monitor, or a stand-alone box. Each peripheral can extend up to 5 meters from each hub connection. In all, USB can connect up to 127 different devices to a single PC.

## Data Transfers Types

USB optimizes large data transfers and real-time data transfers. This allows for two distinct kinds of devices on the USB bus.

#### Bulk Transfer Devices

Most devices require a varying amount of data to be transferred over time. For instance, a joystick only transfers data when the joystick moves. When this occurs, the joystick will transfer some amount of data at the peak rate of 12Mbps, allowing the data to arrive quickly at the host computer for further processing and freeing up the USB bus for other devices.

#### Isochronous Transfer Devices

Some devices require data to transfer at a constant rate. One example includes music audio. If audio is not continuously transferred, a brief stop in the music may occur, which annoys the listener. To accommodate the need for continuous data transfers, USB supports a real-time transfer type called isochronous. Isochronous transfers guarantee bandwidth on the USB bus and typically, only consume a portion of the 12Mbps allowed by USB, leaving the remainder of the bandwidth available for other peripherals. By guaranteeing bandwidth, isochronous peripherals (such as audio) can avoid interruptions in data transfer.

## Software Architecture

One of the major benefits of USB includes its support for hot attachment and detachment of devices (i.e., users can plug in and use a new USB device without having to shut off the system). USB derives its intelligence from the processor on the host computer, which enables the bus to sense when peripheral devices attach or detach. When the USB hub detects a new device connection, the host system is notified, and system software interrogates the device, determines its capabilities, and configures the device – all without user intervention. In addition, system software loads the appropriate device driver so that the applications on the system can begin using the new device immediately.

Microsoft added support for USB in Windows 95 and promises support for USB in NT 5.0.

# USB SYSTEM IMPLEMENTATIONS

Two primary implementation standards exist for USB: the Open Host Controller Interface (OHCI) and the Universal Host Controller Interface (UHCI). Both give full compliance with the USB specification and all USB peripherals. The differences between these two implementations center primarily on the performance of the USB and the system, along with implementation costs.

Compaq offers systems implementing both OHCI and UHCI. The first computers from Compaq's Enterprise Computing Group offering include the Professional Workstation 6000 and Professional Workstation 8000 which both implement the OHCI standard.

## OHCI

OHCI, jointly developed by Compaq, Microsoft, and National Semiconductor Corporation and backed by more than 25 companies, defines the register level interface that enables the USB

controller to "talk" to the host computer and its operating system. OHCI defines an industry-standard hardware interface for operating systems, device drivers, and the basic input output system (BIOS) to manage the USB. OHCI optimizes performance of the USB bus while minimizing central processing unit (CPU) overhead to control the USB.

Key features and benefits of OHCI include:

- Scatter/Gather bus master hardware support reduces CPU overhead to handle multiple data transfers across the USB.
- Efficient isochronous data transfers allow for high USB bandwidth without slowing down the host CPU.
- Assurance of full compatibility with all USB devices.

### UHCI

UHCI, Intel's proprietary interface, defines how the USB controller talks to the host computer and its operating system. UHCI is optimized to minimize host computer design complexity and uses the host CPU to control the USB bus.

Key features and benefits of UHCI include:

- Simple design reduces the transistor count requirement to implement the USB interface on the host computer, thus reducing system cost.
- Assurance of full compatibility with all USB devices.

## COMPARISON OF USB TO OTHER SERIAL BUSES

There are several other common serial buses in the computer industry. Similarities and differences between these buses and USB are highlighted here.

### IEEE 1394-1995

IEEE standard 1394-1995 Serial Bus (also known as Firewire) is a high-speed serial bus for desktop peripheral devices, most notably video. Supporting bit rates of 400 Mbps, IEEE 1394-1995 is more expensive than USB to implement for both the host computer and peripherals.

Features of IEEE 1394-1995 include:

- 100/200/400 Mbps bit rate
- Point-to-point interconnect with a tree topology (1K buses with 64 nodes on each => 64K nodes)
- Automatic configuration (plug-and-play) and hot-plugging
- Isochronous data streams - a fixed slice of data bandwidth can be dedicated to a particular peripheral, e.g., video
- Cable length up to 4.5 meters (13.6 feet)

IEEE 1394-1995 proves ideal for high-speed peripherals but too expensive to implement for low-speed peripherals such as joysticks. Consequently, USB and IEEE 1394-1995 are complementary technologies; USB interfaces will be found in virtually every computer, whereas IEEE 1394-1995 will be used in computers and consumer electronic equipment requiring high bandwidth.

## RS-232

RS-232 remains the most common standard serial interface in the computer industry. Most PCs come with 1 or 2 RS-232 serial (COM) ports. RS-232 is a low-speed serial bus designed to work with low-speed peripherals such as mice. It uses either a 25-pin or 9-pin connector and can support cable lengths up to 50 feet. Compared to USB, RS-232 contains a much lower bandwidth and lacks many features such as hubbing, hot-attach, and plug-and-play support. Consequently, RS-232 expects to primarily support legacy devices, while new devices will be designed for USB.

## PS-2 STYLE KEYBOARD AND MOUSE PORTS

All Compaq computers come with two PS-2 style serial ports – one for the keyboard and one for the mouse. These are dedicated serial interfaces that are designed specifically for the low cost and low bandwidth of the keyboard and mouse. This interface costs less than the USB interface, so will likely be used for both the keyboard and the mouse for some time. Both keyboards and mice may convert to a USB interface when a specific benefit for doing so arises or when the cost differential between USB and the PS-2 port interface drops.

## USB PERIPHERALS

USB adoption will result in many legacy peripherals changing their older interfaces to USB, and will also drive new peripherals that currently do not have a standard bus. Examples of devices that will connect to the Universal Serial Bus include but are not limited to those previously listed and

- Digital speakers
- Writing stylus
- Joysticks
- Scanners
- Game pads
- Fixed and motorized digital videoconferencing cameras
- Musical synthesizers with MIDI and digital audio capabilities
- Digital distribution of multiple audio signals to self-powered speakers for high-end home theater systems
- Wired microphones

All Compaq USB systems undergo rigorous compatibility testing with USB peripherals. Further, USB conferences (a.k.a. PlugFests) are held regularly. An industry-supported USB consortium (of which Compaq is an active participant) ensures compatibility of USB peripherals and systems.

A significant number of leading PC, chipset, software, BIOS, and peripheral companies, including DEC, Fujitsu ICL Computers Ltd., IBM, Microsoft, Phoenix Technologies Ltd., Texas Instruments, Inc., and many others support Compaq's OHCI initiative.

## CONCLUSION

USB offers many compelling features that will make it the serial bus of choice for low to moderate speed external peripherals. It offers features such as hot-attach and isochronous transfers that offer clear user benefits in terms of flexibility and ease of use. Compaq now includes USB in selected systems to allow for the support of future USB peripherals.

## REFERENCES/URLS

The following are Internet URLs for topics relating to this white paper:

- USB Implementers Forum Web site: http://www.teleport.com/~usb (The USB Implementers Forum)
- Intel Web site for USB developers: http://developer.intel.com/ design/usb/
- Universal Host Controller Interface (UHCI) from http://developer.intel.com/design/USB/designex/ UHCI11D.HTM
- Open HCI at http://www.compaq.com/productinfo/development/openhci.html