

**The Definitive Reference to
the Universal Serial Bus.**

USB

Hardware & Software

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Foreword

The birth of the Universal Serial Bus (USB) represented a huge step forward in the computer's evolution. The dream of peripheral plug-and-play without rebooting the PC, and nearly limitless expansion became a reality. Now dip switches, jumper cables, IRQs, DMAs, and I/O addresses are replaced by dynamic insertion and removal, automatic configuration, and virtually unlimited peripheral connectivity.

Originally developed in 1994 by Compaq, Digital, IBM, Intel, Microsoft, NEC, and Northern Telecom, the Universal Serial Bus has grown into an industry-wide specification backed by a collection of over 450 technology companies. USB represents one of the best examples of industry-wide cooperation.

In the design of USB we implemented two bandwidth options, thus allowing devices like keyboards, mice, and game controllers to communicate at 1.5 Mbps at extremely low cost points, while providing a 12 Mbps rate for applications like audio, telephony, and digital imaging. Up to 127 devices can now be attached to a single PC, allowing virtually limitless expansion. By the year 2000, serial, parallel, and analog game ports will no longer be necessary, and the plug-in card will virtually disappear. PC's will come equipped with USB, and IEEE 1394 allowing the attachment of almost any class of external device.

To further simplify the ease of use of the PC, USB can automatically recognize the power needed by any given device, up to 500 milliamps, and can then provide that power through the cable. Many new peripherals can now be attached to the PC without the requirement for power adapter bricks, providing better power management abilities for both the system and its peripherals.

Developers no longer need to design drivers from scratch. The base USB driver, with some device class specifics, can be built upon to provide maximum support with a minimum of effort.

USB Hardware and Software is your magic ticket to accessing USB design and development. The authors have been key members in the development of USB and its specification. Whether you are just starting your design or are well into the development cycle, this is the reference you shouldn't be without. Its detailed examination of every aspect of USB makes it the best source of information available. USB's time has come, so "Hop on the Bus".

Jim Pappas
Director of Technology Initiatives
Intel Corporation

1. Introduction

- 1.1 Background
- 1.2 Universal Serial Bus Approach
- 1.3 Solution
- 1.4 Overview of this Book

This book was written in the interest of expanding on the information provided in the Universal Serial Bus Specification version 1.0. The USB specification describes the basics of what is required according to the standard, but it sometimes leaves out important background or explanatory information. Since most of us have been intimately involved in the creation of the original specification, we wanted to take the opportunity to provide the "rest of the story" to help the USB development community at large. It turned out to take a lot longer to write than any of us expected, but hopefully it will fill the need intended.

1.1 Background

Universal Serial Bus was created out of a desire to provide solutions for many problems associated with low to medium data rate, cable connected, external peripherals for the Personal Computer (PC) market. The back panel of a PC has been cluttered with too many different I/O port connectors for a variety of specific devices. There's usually an RS232 port for a modem, printer, or mouse, a Centronics-style parallel port for printers, plotters, and scanners, and a SCSI port for disk, tape, and scanners. The list of peripherals and connectors has continued to grow.

Peripheral vendors wanting to create a new peripheral have been faced with several problems. If they used a standard I/O port connector, it was likely that the end user already had something attached to that connector. If they used their own I/O port connector, they had to develop an add-in card in the "hostile" internal electrical environment of the PC. In addition, the development of an add-on card usually requires a significantly different set of skills than those required for the peripheral itself. Another consideration, even if a vendor wanted to use a standard connector, was that the data rate available might not be sufficient for the peripheral. Many of the PC connectors had been unchanged for almost the lifetime of the PC industry, and the data rates of modern peripherals are generally increasing.

Also, each I/O port connector has required its own special cable. The poor end user was constantly confused about what to connect and where. Some I/O port connectors looked almost the same, but weren't. Further, some I/O port connectors could be changed with the PC running and some couldn't. In general, end users were not always successful in connecting a peripheral without a lot of effort.

The bottom line was that the ability to attach new and innovative PC peripherals was fraught with problems; consequently few interesting or exciting PC peripherals were being developed. Something had to be done.

1.2 Universal Serial Bus Approach

A group of companies started discussions with each other to determine whether a better I/O port connector could be designed that would be easier for the developer to create and also easier for the end user to understand. This better I/O port connector should allow a large number of peripherals to be attached at any time. Also, there was a desire to try to create one bus that would do everything for everyone for any particular peripheral. Therefore, the scope of devices that USB would deal with was intentionally limited to provide a greater chance of "getting it right" and to focus the engineering team.

It was recognized at the time that there was a significant amount of energy in the PC industry working to connect the PC and the telephone in various ways. Also, there was a lot of interest in enabling the PC to do a better job of enabling human interactive devices: joysticks, tablets, pens, steering wheels, pedals, etc. Most of these devices require modest bandwidth and latency compared to devices like hard disks and video monitors. Therefore, it was arbitrarily decided to focus the USB solution on the former types of devices, in the 10 Mbit/second and below bandwidth range. In addition, USB bus would focus on desktop area connectivity as opposed to wide area or local area networks of devices and interconnects.

With attention directed at these areas, the selection of technologies was simplified.

1.3 Solution

There were a number of alternatives in progress at the time, such as access.bus, Geoport, and Apple Desktop Bus. Each had different advantages and disadvantages. None of the other buses had the combined focus of relatively high data rates, large number of possible simultaneous devices, and interactive/telephony type devices.

The USB bus originally was targeted at a 5 Mbps data rate, but it was soon determined that for the same cost, a 12 Mbps bus could be developed. The companies developing the USB bus consciously chose to make the bus definition asymmetric, *i.e.*, the cost/complexity of the host controller would be greater than that of a device. This was done so devices would be easier to create. Even though the host controller was slightly more complicated and expensive, it was expected that it could easily be incorporated in the standard silicon included on every PC.

These factors made the deployment of the USB bus easy compared to many other technology developments. People were not asking why they should be interested. The key question was "Why isn't it available yet"? Everyone involved knew it was simply a matter of time before the "bus" was on its way. End users liked